AE 497G / AE 897G

[Submitted: 04/07/2010]

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[Rydal Park Medical Center Addition]
[Jenkintown, Pennsylvania]

[FINAL REPORT: IMPROVING EFFICIENCY WITHIN THE AEC INDUSTRY]

[The following report presents conclusions discovered after performing research in three architectural engineering breadths. Rydal Park's Medical Center Addition was utilized as the case study to perform this research both on the building design and the project team carrying out this venture. The three analyses conducted examined efficiency within this case study through observing the project team collaboration, researching the designed mechanical system and performing a photovoltaic array feasibility study.]

Rydal Park

Medical Center Addition

Project Information:

Function : Institutional Care
Building Cost : $26.590,000
Size : 142,862 Square Feet
Dates of Construction : Sept 09' - March 11'
Delivery Method : CM @ Risk, Design-Bid-Build w/ Negociated GMP

Project Team:

Owner : Presby's Inspired Life
Developers : Greenbrier Developers, Inc.
Architect : Stewart-Conners PLLC
Construction Manager : The Whiting-Turner Contracting Co.
Structural Engineer : WK Dickson & Co.
MEP Engineer : Moore Engineering

Architecture:

- Aesthetics intended to invoke sense of residential community living at a location where seniors may receive skilled elderly nursing care.
- 5 story structure will include:
  - two floors of parking garage space
  - two floors of skilled nursing care
  - one floor of critical memory support
- Façade will implement a stone veneer system and spray applied stucco as well as curtain window wall & Pella windows to match the existing medical facility

Structural:

Foundation :

- Helical geo-pier stone column foundation system will provide support under spread footers

Superstructure :

- Post-tension two-way concrete system
- Reinforced concrete columns
- Reinforced masonry mass shear Walls (gravity system), located mainly at stairtowers, utilized as the lateral system

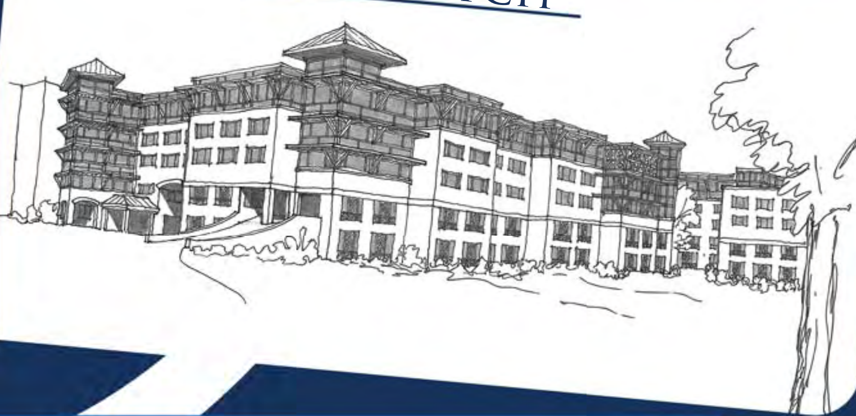
Roof Sturcutre :

- Non-composite roof deck mainly supported by K-series joists and severl intermediate wide flange beams between columns

MEP Systems:

- Four pipe air/water HVAC system:
  - Three fan coil units (400 - 1200 CFM)
  - Eight AHU's (630 - 3770 CFM)
  - Four energy recovery units (first floor)
- Building power supplied by PECO:
  - 15 KW Switchgear to stepdown power
  - 208/120V 3 Phase 4 wire wire System
  - 350 KW Emergency Generator (first floor)
- Combination dry and wet pipe fire supression system

Conceptual Sketch



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2.0 Table of Contents

1.0 Thesis Abstract 2

2.0 Table of Contents 3

3.0 Executive Summary 6

4.0 Project Overview 7

- 4.1 Project Introduction 7
- 4.2 Client Information 7
- 4.3 Building Location 8
- 4.4 Project Delivery Method 9
- 4.5 Project Team Organizational Structure 10
- 4.6 Construction Management Staffing Plan 11

5.0 Building Design and Construction Overview 12

- 5.1 Building Systems 12
- 5.2 Site Layout Plan 14
- 5.3 Detailed Project Schedule 16
- 5.4 Project Cost Estimate 17
- 5.5 General Conditions Estimate 18
- 5.6 Structural Systems Estimate 21

6.0 Integrated Project Delivery: Enhancing Team Collaboration 23

- 6.1 Problem Introduction – Critical Industry Issue and MAE Requirement (AE 572) 23
- 6.2 Background Information 23
- 6.3 Research Goal 24
- 6.4 Project Team Overview 25
- 6.5 Integrated Project Delivery 29
- 6.6 Case Studies and their Success 31
- 6.7 Detailed Preconstruction Timeline 35
- 6.8 IPD Execution and the Rydal Park Medical Center Addition 37
- 6.9 Conclusion and Final Thoughts 39

7.0 HVAC Energy Consumption and Life Cycle Analysis 41

- 7.1 Problem Introduction– Mechanical Breadth Study 41
- 7.2 Background 41
- 7.3 Research Goal 42

7.4 Research Process 42
7.5 Research Results 46
7.6 Cost and Schedule Impacts 51
7.7 Conclusion and Final Thoughts 53
8.0 Photovoltaic Array Powering Parking Garage Lighting 54
8.1 Problem Introduction – Structural Breadth and MAE Requirement (AE 597D) 54
8.2 Background 54
8.3 Research Goal 55
8.4 Photovoltaic Research Process 55
8.5 Shading Design 57
8.6 Structural Support System of the PV Array 59
8.7 Structural Calculations 60
8.8 Life Cycle Cost Feasibility 66
8.9 Schedule Impacts 68
8.10 Conclusion and Final Thoughts 69
9.0 Final Senior Thesis Report Conclusions 70
10.0 Breadth Studies and MAE Requirements 71
11.0 Primary Research References 72
11.1 M.A.E. Research References 73
AE 572: Project Development and Delivery Planning 73
AE 597D: Sustainable Building Methods 73
12.0 Personal Acknowledgements 74
13.0 Appendix A: Project Schedule 75
14.0 Appendix B: Site Layout Plans 87
15.0 Appendix C: Energy 10 Life Cycle Cost Reports 91
16.0 Appendix D: Amana PTAC DigiSmart Product Information 95
17.0 Appendix E: Photovoltaic Array Layout 99
18.0 Appendix F: Photovoltaic Module Product Data 101
19.0 Appendix G: Structural K-Series Loading Charts 103
20.0 Appendix H: UniRac Large Array Roof Mount Support System (Quotation and Engineering Reports) 106
21.0 Appendix I: USGBC LEED V 3.0 Scorecard 113

Albert Park *– Director of Facilities Planning at ThedaCare*

"I don't mind paying for labor and the cost of materials. What I don't want to do is pay for ***risk*** (contingency) so that all [this] money is sitting out there which I can't quantify, ***when it could go toward the project***."

3.0 Executive Summary

The following summary outlines three analyses that have been performed using the Rydal Park Medical Center Addition as a case study. The focused theme for this research revolves around improving efficiency both within the project team and the building design. This research will cover several aspects of the design and construction process including project delivery, energy usage, and sustainable performance. During the spring 2010 semester this research was performed, analyzed, critiqued and compiled for a presentation to the Penn State Architectural Engineering Construction Management Faculty.

Analysis #1: Utilizing Integrated Project Delivery with the Rydal Park OAC Project Team

The inspiration to research this topic developed through the personal observation of the disconnected OAC (**O**wner, **A**rchitect, **C**ontractor) project team during the 2009 summer and 09-10' winter break. Analyzing this project team and comparing it to that of a collaborative project team will pinpoint elements where successful collaboration must occur. Whiting-Turner is contracted as the construction manager at risk with a negotiated GMP. The implemented CM at risk delivery method will be compared to an alternate method known as integrated project delivery (IPD). The final result of this research will be an IPD execution outline that will assist project teams in the future by isolating successful IPD elements and explaining how they must be used as everyday common practices.

Analysis #2: Mechanical System Energy Consumption

Buildings within the United State consume approximately 40% of the energy generated nationally. Of this energy, buildings consume 68% of America's electricity generated. One of the primary methods that energy is utilized within a building is through maintaining a comfortable temperate interior environment. Far too often mechanical systems are chosen on the basis of low upfront costs while the amount of energy consumed they is somewhat neglected. An energy model of this building will be developed in order to assist with the selection of an alternate mechanical system that will reduce energy consumption. The alternate mechanical system selected will be analyzed on the basis of reducing the life cycle energy costs of this building. Along with the HVAC system analysis, enhancing the building envelope will also be analyzed to determine if there are significant added benefits of implementing improved R-Value materials and Low-E glazing.

Analysis #3: Photovoltaic Array Feasibility

Solar panels are becoming an extremely cost effective method of mitigating electrical utility costs. Over the next ten years, one of the goals of the PV industry is to drop the cost of materials below $1.50 per watt. Innovative leaders need to strive to incorporate photovoltaics into buildings if the PV industry is to reach this goal. Utilizing photovoltaics for this medical center addition is a perfect opportunity for Presby's Inspired Life. The results of this analysis will indicate a recommendation of to pursue the use of a PV array. Research results have illustrated that over a 50 year building life span this photovoltaic system will easily pay for itself. Within this final research section the following items can be found backing up this feasibility; a basic solar 3D model, five step process sizing the array, additional k-series joist and w-flange member sizing required and a 25 year life cycle analysis indicating a quick payback period for a photovoltaic system.

4.0 Project Overview

4.1 Project Introduction

Presby's Inspired Life's Rydal Park Medical Center Addition will be a facility specially designed for elderly residents with dementia and other memory impairing conditions. Each of the 115 resident rooms will comfortably house residents in a setting that will accommodate these conditions. Outside each resident room are large glass boxes where they are able place memorabilia items to help jog their memory if they become lost. Along with that, the floor plans are designed without any dead ends. Dead ends in hallways can cause elderly residents to panic thinking that they have become lost. In addition to those previously mentioned amenities are multiple dining rooms, living rooms, parlors, and a beauty salon/barber.

This facility will be a five story structure, which also addresses the need for additional parking at this retirement campus. The lower two stories are parking decks, while the upper three floors will be where the resident's rooms are located. Provided that the connecting building, the primary medical center, was built with relatively low floor-to-floor heights, this structure will be a post-tensioned concrete structure which can accommodate this design challenge.

4.2 Client Information

Presby's Inspired Life develops and manages continuing care communities that provide an opportunity for senior citizens to live their lives within a relaxing residential surrounding while retaining peace of mind that if any health emergency were to arise, assistance would be immediately available. This location, Rydal Park, is a continuing care retirement community where seniors begin living at homes that are cozy cottages and as their conditions progress (if any exist), they will eventually move into the medical facility at the center of the campus. This medical addition has finishes that closely resemble would be found within a luxury hotel, but with the added necessity of being equipped for medical emergencies.

Stewart-Conners Architects was contracted for the design of this medical addition in January 2008. From 2008 until financial closing in October 2009 the project was placed on hold twice hindering the commencement of the project. During the 2009 summer, OAC project team inefficiencies were personally observed which will be addressed within the following research sections.

Presby's Inspired Life's main mission is to provide 'exceptional communities and care for individuals representing a broad range of backgrounds, physical abilities and economic circumstances'. Currently, Presby's has more than 2,600 senior residents as well as 25 communities located within or around the greater Philadelphia region. Due to the close proximity to a metropolitan region, most seniors are able to stay well connected with the rest of their families. One of the primary goals of Presby's is to recognize 'Life in All Its Fullness'. In order to meet this mission and goal, the communities have been designed around scenic locations near ponds, lakes, brooks and woodland environments. This goal extends into the architecture as most of the homes that residents live in, are woodland cottages surrounded with rich landscaping.

Rydal Park is one of Presby's largest campuses at approximately 20 acres. It is located within a woodland suburban region containing cottages, luxury apartments, and assisted-living quarters accompanied with many amenities such as indoor pools, a woodworking center, nearby train stations, and many other services. At the heart of the campus is the Primary Medical Center which houses the assisted-living quarters. This medical center is where residents with the most critical conditions are located, allowing for the most immediate response to patients in the event that a medical emergency would arise. Patients with Alzheimer's and dementia related conditions have been increasingly admitted to this facility, but the current medical center does not have a design layout that positively addresses these conditions. In an effort to address this matter, as well as increase the skilled nursing staff, Presby's Inspired Life has decided to work with Stewart-Conners Architects to develop a design solely based at tackling this issue.

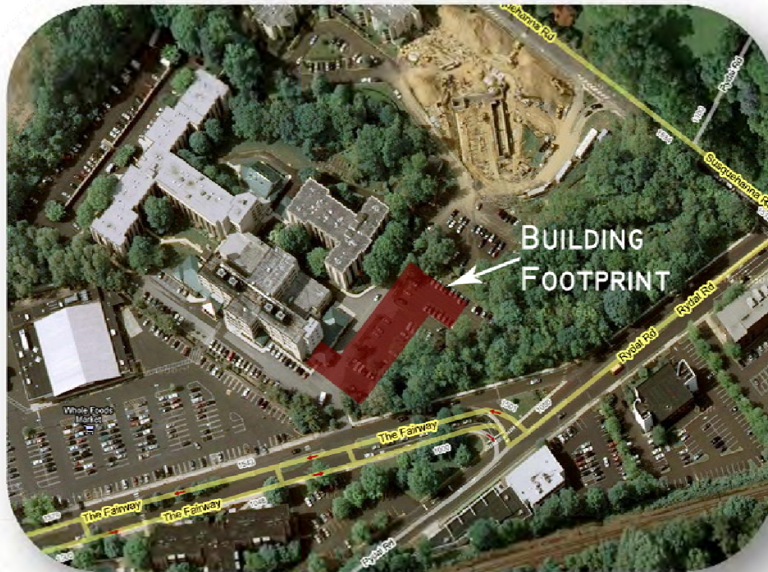
The resulting solution was a Medical Center Addition which at the same time addressed the owners concern of insufficient campus parking. Stewart-Conners had the task of eliminating the typical 'institutional' aesthetic appearance, while providing a fresh, welcoming design. A secondary target with the design was to create an attractive billboard for the continuing care community, given its location directly next to a major road with relatively constant traffic.

Mr. Garry Hennis, the Chief Operating Officer and Executive Vice President for Presby's, is relatively unfamiliar with the building design / construction process and therefore hired Greenbrier Development. Greenbrier is one of the leading national development firms when it comes to continuing care retirement communities. Garry Hennis gave a significant amount of his decision power to Greenbrier development expecting that this would streamline the process in order to have a rapid delivery. On top of an expedited schedule, Mr. Hennis has focused his efforts on keeping the project under budget and ensuring that the campus residents do not experience compromised safety and security during the construction process. The primary decisions that Mr. Hennis approves is regarding any finish materials affecting both minimal and overall aesthetics of the facility.

The general owner concerns (cost, schedule, quality and safety) are all issues that Whiting-Turner must properly address to ensure a successful project delivery and maintain a satisfied customer. During the last quarter in 2009, the architect and CM have processed the building in search of value engineering ideas and any elements that could be eliminated from the scope. Of the four general owner concerns, Mr. Hennis has placed a high level of importance on campus safety and building budget. Upon project completion, Mr. Hennis expects the project to be completed under budget due awarding the CM contract early in the design process.

4.3 Building Location

Rydal Park is located approximately 10 miles directly north of Philadelphia within a woodland suburban region. The construction site will be relatively tight but will not be restricted by buildings on all sides. To ensure the safety of the campus residents, the entire west end of the campus will be enclosed within screened panelized fencing for the duration of construction. Entrance gates will only permit authorized personnel in an effort to mitigate wandering traffic from non-construction pedestrians. The earliest trade, demolition, will require closing several resident rooms at the west end of the existing primary medical facility. A large number of utilities currently run through the southern end of the site and will require extensive relocation efforts. Please note that larger, more detailed site plans can be located within **Appendix B**. Within the detailed site plan the existing utilities, pedestrian access regions, equipment paths and construction limits can be located.



[*Figure 01*. Satellite View of Project Location]

During construction, two primary gates will be utilized for site entry. A gate on the northern end of the side will be located extremely close to the trailers and construction personnel parking lot. Entry to this northern region will be via Susquehanna Road, which runs along the northern side of the Rydal Park Campus. Another gate will be located at the south end of the site which will be primarily utilized for deliveries coming off of The Fairway street. The close proximity of this street to the southern gate will promote faster deliveries and reduce driver confusion. A third, gate will be located at the middle of the west side which will allow construction personnel to utilize Rydal Park's cafeteria and other amenities that the owner has made available to them.

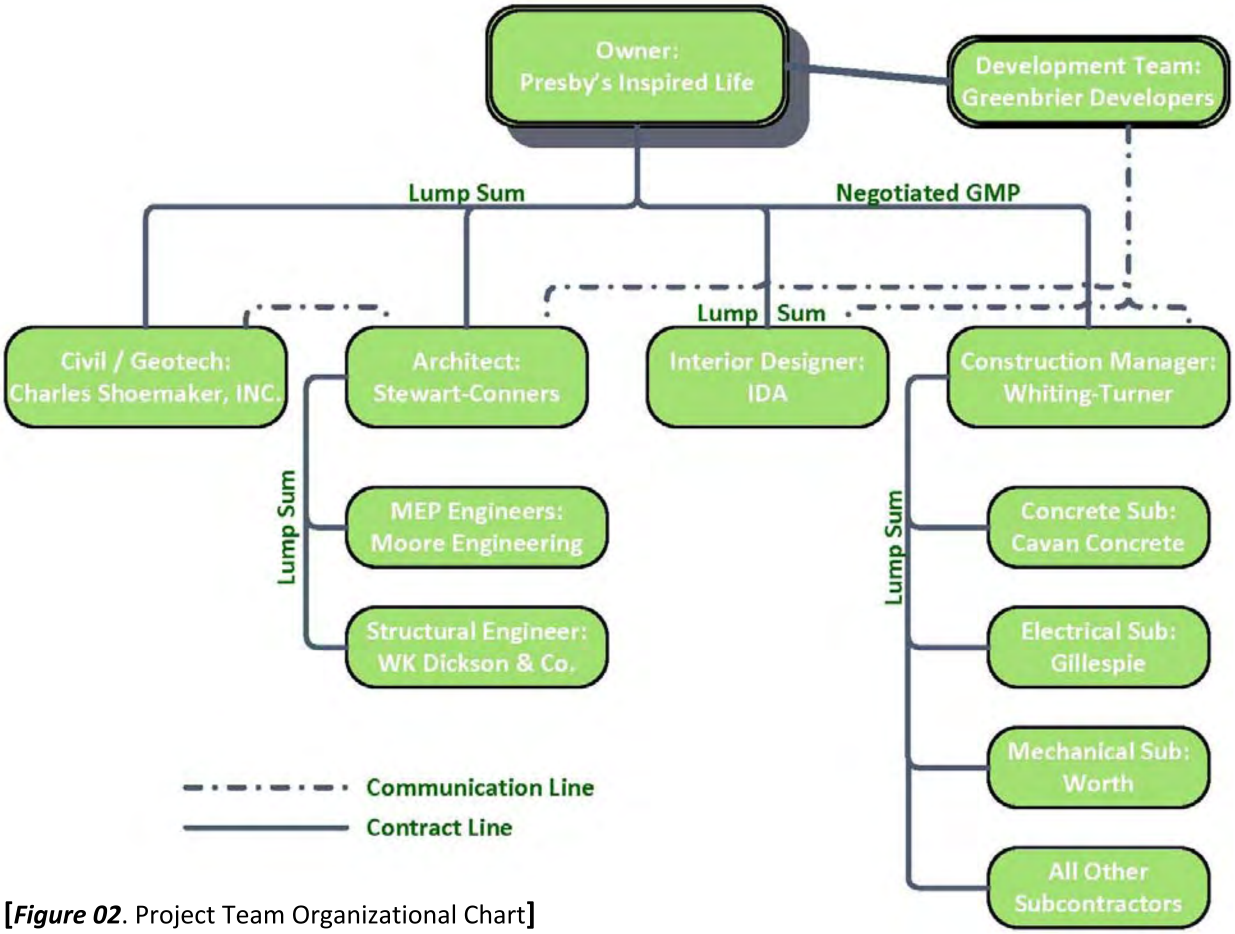
JJ Earth Engineering Incorporated, the geotechnical engineer, performed the site soil analysis which indicated that the water table was between 4.5' and 9'. The resulting data collected within the building footprint, revealed that the soil is comprised of 'variable fill materials, loose to medium dense residual soils and decomposed to highly weathered rock'. Due to this soil type, shallow foundations cannot be utilized unless the soil is reinforced with some form of caisson or pile. The recommended foundation system, by JJ Earth Engineering, is rammed aggregate piers (GeoPier) which are stone columns that support high capacity spread and strip footings.

4.4 Project Delivery Method

For this project Presby's Inspired Life has hired a development team from Texas, Greenbrier Developers. Greenbrier Developers has suggested that Presby's Inspired Life utilize the Design-Bid-Build method for the project delivery, which is the most common in the United States. This development team has helped Presby's create their preliminary budgets and schedules. Greenbrier has also guided Presby's through the preconstruction process when selecting and hiring the architecture and construction management team. Ultimately, the construction manager, Whiting-Turner, has been contracted to Presby's Inspired Life through a negotiated guaranteed maximum price (GMP) contract utilizing a construction management at risk delivery method. The following sections outline the project team organizational structure and the construction management staffing plan.

The project delivery method will discussed further within the Integrated Project Delivery Analysis One Section. Two seperate research methods were utilized to analyze the delivery method at length.

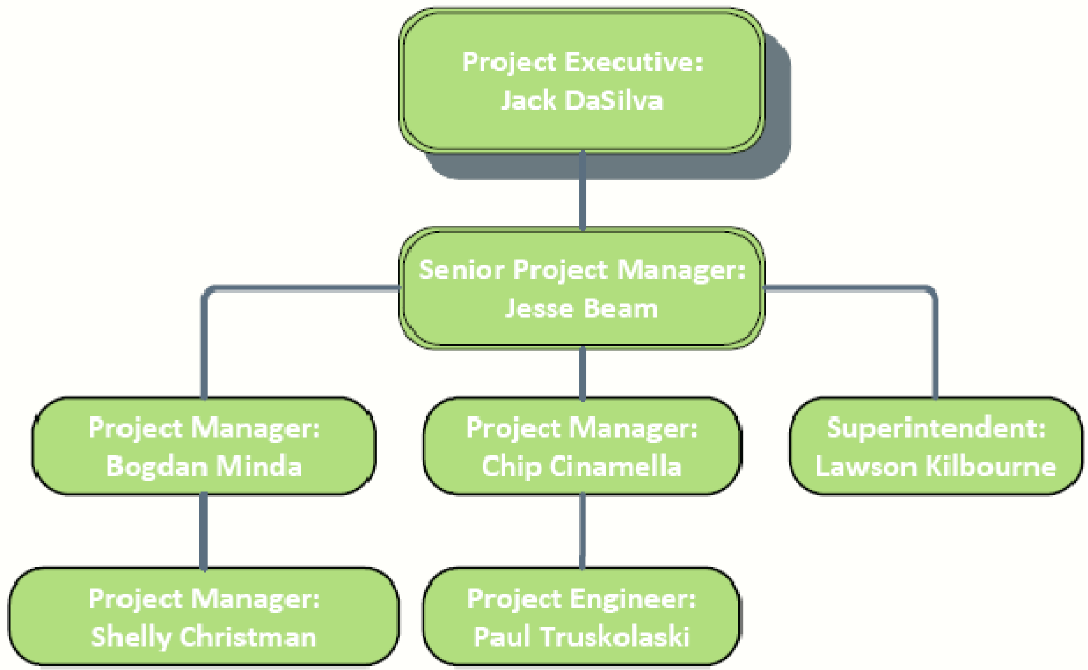
4.5 Project Team Organizational Structure



[***Figure 02***. Project Team Organizational Chart]

Due to Presby's relative inexperience with the design and construction process, Greenbrier development was hired as the agent and representative to manage this process, resulting with the delivery method seen above. Stewart-Conners is the preferred architect for Presby's and was immediately brought on board following the developer. The owner received most of their input with how to proceed from the developer and eventually the architect. It was decided to bring the construction manger on at the design development stage to assist with constructability issues and to initiate early preconstruction services. Under this delivery method, the owner holds the major consultant contracts, while architect holds most of the design consultant contracts (MEP, structural, landscape, food service). One unique item to point out is that the interior designer (Interior Design Associates, IDA) is contracted directly to the owner and not to the architect. Both the architect and owner have declined to comment as to why this was done, but speculation from discussions held in meetings suggests that Presby's was utilizing IDA to verify WT's Division 9 (finishes) materials cost estimate. Market conditions created an extremely costly finishes package for this project which shocked the owner, creating skepticism. This delivery method seen here is classified as construction manager at risk. Subcontractors were invited to bid the project as 'Merit Shop' (both union and non-union) and selection was based on a 'Best Value' system, not necessarily lowest price.

4.6 Construction Management Staffing Plan



[***Figure 03***. Whiting-Turner Staffing Plan]

Whiting-Turner Contracting Company is a large national firm with approximately 29 remote offices acting as individual business groups. The Allentown Pennsylvania office is the business group spearheading this project along with Jack DaSilva as the divisional vice president of this group. At any given moment, Mr. DaSilva may be managing between 3-10 projects as well as dealing with numerous clients, depending on the state of the economy and AEC industry. Mr. DaSilva is involved with about 5-10% of the discussions and meetings regarding this project, and has appointed Jesse Beam as the Senior PM for this project. Mr. Beam has been the individual responsible for the successful forward progress with this project as he communicates with the head architect and developer on a daily basis. Upon Whiting-Turner's mobilization to the Rydal Campus, Mr. Beam will be assigned to the project as part-time and will hand over the primary day-to-day project management duties to Chip Cinamella.

Mr. Cinamella's field team will consist of Bogdan Minda, Lawson Kilbourne, Shelly Christman and Paul Truskolaski. Now that the project has begun gearing up (GeoPier substructure began early February 2010) it has been determined by Mr. Beam than an additional project engineer was necessary and Paul Truskolaski was brought on board. It will be the responsibility of Bogdan Minda and Shelly Christman to ensure the project is staying on budget, and that all of the necessary subcontractors have been purchased. Lawson Kilbourne and Paul Truskolaski will be sharing the responsibility of site safety/security, subcontractor coordination, and that the day to day activities remain on schedule.

The Whiting-Turner Contracting Company is the construction manager who will oversee construction of this medical center addition. The project team mobilized on November 16th 2009 and has begun the substructure construction around mid-February. The building will be built during an 18 month period and cost approximately $26,590,000. Given the financial constraints of Presby's Inspired Life, LEED was not incorporated into this building. Several green elements such as a rooftop garden and generous amounts of low-e glazing for improved day lighting are included in the building's design.

Whiting-Turner has just recently completed the difficult task of coordinating underground utility relocation through the winter season. Now that the underground site utilities are wrapping up, the GeoPier foundation construction will be the primary field effort for approximately five weeks. The concrete structure is planned to begin towards the mid-March / early April.

5.0 Building Design and Construction Overview

5.1 Building Systems

Demolition

This medical center will be built on at the site of an previous asphalt parking lot. One of the benefits of this demolition is that the stone and asphalt can be recycled for the helical stone column foundation system (GeoPiers). This recycling effort will help the demolition and foundation subcontractors save money due to reduced aggregate purchasing and delivery fees.

In order to attach this addition to the existing medical center, a small portion of the eastern-most façade will be removed. The demolition will affect five floors, penetrating into approximately three rooms on each floor, ultimately disturbing a total of 3325 square feet of building space. There are no known hazardous materials located within this space. The bulk of the demolition involves the removal of masonry block wall, several steel columns, interior framing, the exterior stone veneer, and multiple windows. A seven inch expansion joint will be utilized on the second through fourth floors to join the addition with the existing structure. The expansion joint will not be utilized at the ground and first floors but rather the exterior walls (of the new facility) will be built about a foot away from the existing facility. To accommodate this design, new exterior doors will be simply added to the existing facility.

Structural Steel Frame

The roof structure will be the only building component utilizing structural steel. Intermediate wide flange beams will be placed between the concrete columns and K-series joists will span between the WF beams. While pricing and bidding this project, it was discovered that the fireproofing in the existing building (where the two buildings meet), must be reapplied to bring the existing fireproofing up to current code standards.

Cast-in-Place Concrete

Due to the low floor-to-floor heights as well as the parking garage requirement, the best option for this structure was post-tension concrete. The existing medical facility has two levels with floors-to-floor heights as low as 11'-4" which makes utilizing structural steel extremely difficult and expensive. With the proposed post tensioned concrete structure, 8" slab thicknesses have been achieved. The tendons used to place compression into the slabs range from 2" to 9" with a designed load capacity between 18 KLF to 34 KLF. As seen in *Figure 2 (pg. 5)*, concrete pours will follow a three phase pattern per floor. Cast-in-place concrete will be used for the spread footings, columns, floor slabs, and to fill the CMU foundation walls. Given that the superstructure is almost entirely comprised of concrete, it will be critical to select a concrete subcontractor that has a high level of experience with the different concrete applications being employed within this addition.

Mechanical System

Three mechanical rooms have been located on both the second and third floors, with each room spread out in an effort to reduce long duct runs. One air handling unit will be located within each region of the phasing sequence (Figure 2, pg. 5) enabling a less complex MEP coordination effort between phases. An efficient HVAC design has been developed to ensure that each mechanical room only serves the adjacent regions of that wing. The fourth floor does not house any HVAC equipment and is consequently served from the equipment in the floors below. Moore Engineering has designed a four-pipe air/water system which allows for improved temperature control and adjustment for each individual resident room as well as general public or office regions. Three fan coil units, eight air handling units, and four energy recovery units are some of the types of mechanical components that have placed throughout this building's design.

Due to the dual nature of this building, a combination dry and wet pipe fire suppression system will be installed. The lower two floors will utilize a dry pipe suppression system given that these regions are parking garage space exposed to exterior temperatures. The upper three floors will utilize an instant wet pipe system due to the nature of the residents living within this facility requiring immediate protection if an emergency were to arise.

Electrical System

PECO Power, an electric and natural gas utility subsidiary of Exelon Corporation, will be the main provider of electrical energy for the Medical Center Addition. Three new PECO 1000KCM conductors will be brought into this facility and combined with campus' spare electrical feeds; three 500KCM conductors (plus one #3/0 ground) as well as three #2 conductors (plus one #2 ground), respectively. Each of these three power service feeds will be enclosed within five inch conduits. The new PECO service will be brought into a 1200A breaker which will then combine with the other two services at a 15KV Fused Switchgear. The primary transformer, located within the unit substation, has been sized to 1000KVA. A three phase, four wire system will be utilized at a 208/120V primary/secondary power setup. Located on the first floor is a 350KW emergency generator which will support the medical utilities in the event of a power outage.

Masonry

Concrete masonry units will be utilized primarily at the ground level and at the mass shear walls (primarily stairwells). Eight inch CMU shear walls, designed as both the gravity and lateral systems, will provide most of the resistance to lateral forces and movement. In order to provide the residential aesthetics, while keeping costs down, a manufactured stone veneer system was selected for the exterior walls at the ground and first floor levels. Openings within the first two levels of parking garage space will utilize manufactured stone caps and sills that will match the selected stone veneer system. Two manufacturers of stone veneer systems currently being considered by the architect and owner include Quality Stone® and El Dorado Stone®.

Curtain Wall

The glazing system will utilize a combination of Oldcastle Glass®, YKK AP America® and Pella® Windows. The aluminum framed storefront glazing will be the Vistawall system from Oldcastle Glass®. YKK AP America's® YWW system will be used for the glazed window wall system. Both of these large glazing systems occur in grand public areas providing fantastic views of the campus' rich landscaping. Given that Pella® windows are normally utilized within residential applications, Pella® fiberglass sliding windows will be utilized within all of the resident rooms, in order to promote the desired aesthetic appearance. It is the intent of the designers to introduce as much sunlight into the facility as possible, which has been proven to aid in the prevention of illnesses and recovery of severe medical operations. The upper three floors have exterior walls enclosed with a stucco finished EFIS system.

5.2 Site Layout Plan

Due to the "addition" nature of this project, the building footprint is sitting on a site that was not originally designed or intended to accept a building. The original site was a parking lot which was bounded by a grove of trees, Rydal Road, and The Fairway to the east. Along the south and west sides of the site are parking lots and existing buildings which may not be impacted by the construction in any way. Located at the north end of the site is a parking lot which will house parking for authorized construction personnel and the site trailers. For the safety of the community residents, the owner has decided to close all pedestrian walkways within the tree groves. The only nearby walkway that is to remain open is the sidewalk along The Fairway and Rydal road. The only period that this walkway was an issue was during the tree clearing phase. Since this is a retirement community, strict working hours of 7-5pm must be adhered to as to not disturb the patients in the medical facility or residents living in the apartments. For the duration of construction, overflow parking for authorized community residents will be relocated to the Whole Foods Lot, located directly in front of the south face of the existing medical facility.

General Conditions and Temporary Facilities

Most of the general conditions components that have been located on site will stay within in the same general region for the duration of the project. The delivery gate has been located at the south end of the site which will allow for quick and easy access to the loading dock and man hoist. Two regions have been selected for dumpsters, both of which are located with road access for ease of dumpster pickup. The main construction parking lot will provide space for a maximum of four contractor trailers. Trailers on site must be properly coordinated to ensure that each contractor has the required space to manage their specific work. If more space is required, interior-focused subcontractors will be allowed to set up within the completed parking garage space on the ground level. Toilets have been located within the parking lot, within close proximity to the site trailers. A temporary power shed, located at the southeast corner of the construction parking lot, will power the trailers.

Excavation Phase

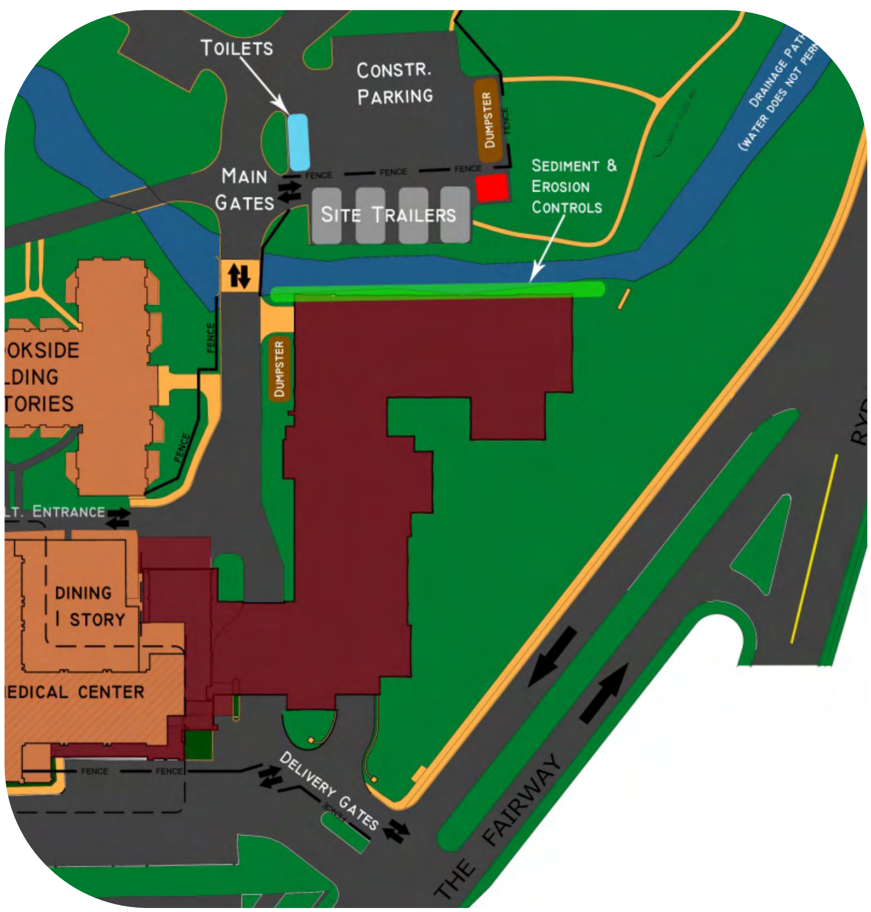
After the geotechnical reports indicated that the site soil mainly consisted of variable fill materials, as well as loose to medium dense residual soils, it was decided to utilize the suggested GeoPier foundations type. As an added benefit, this foundation system requires a minimal amount of soil removal minimizing site excavation. Due to the fact that there is relatively no space on this campus to store excavated soil, this foundation type was a perfect match for the project needs. The excavation phase of this project will mainly consist of the asphalt parking lot demolition, GeoPier drilling, sediment and erosion control set-up, tree removal, and site grading. The region to the east of the site will provide the required space for the tower crane, soil storage, and as a lay down region after the tree grove has been cleared and graded. During this phase of construction, sediment and erosion controls will be extremely critical to ensure proper storm water pollution management.

Erection Phase

During the first week of February 2010, the tower crane will be delivered and assembled on site and will begin placing concrete by the beginning of March. In order to properly reach each corner of the building, a swing radius of 180 feet is required. During this phase of construction, the newly cleared tree grove will provide a region for formwork lay down, staging, and storage trailers. The delivery gate has been located at an ideal position for the crane to easily fill the concrete bucket while maintaining operator visibility. The delivery gate location also provides an excellent queuing region for concrete trucks, given its location off of a main road. The crane will begin to wrap up its time on site as the window wall system, stone veneer, and EFIS are installed resulting with a watertight building by the end of November 2010.

Interiors Phase:

Once the crane is disassembled and removed, a man / material hoist will be built aiding in the movement of materials throughout the building. This hoist has been located directly next to the loading dock, allowing for quick and easy access to delivered items at the loading dock. Delivery trucks will be able to enter the site through the south entrance, drive through the parking garage, unload any materials, and exit through the north end of the site. This traffic route will eliminate time wasted through redirection and delivery driver confusion. The plan found within the appendix provides a clear description of the flow of work and where storage will be permitted.



[*Figure 04*. General Conditions and Temporary Facilities Plan]

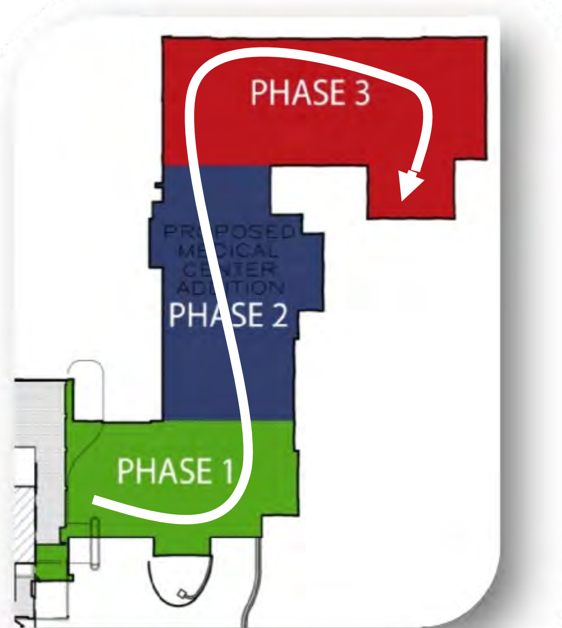
5.3 Detailed Project Schedule

Stewart-Conners Architects, who also designs many of Presby's Inpsired Life's retirement communities, began designing this Medical Center Addition in February and March of 2008. As the schematic design phase started wrapping up, The Whiting-Turner Contracting Co. was hired in April 2008 for full preconstruction and construction management services. Due to the private nature of this project, the construction management services (at risk) were not put out for public bidding. From June 2008 to July 2009 it was unsure whether or not this project would see life as it went on hold twice, each time for several months. During July 2009, Whiting-Turner began increasing its effort to improve the success of the project eventually leading to the acceptance of a negotiated GMP on October 21st, 2009. Notice to proceed was given on this date and Whiting-Turner has since then mobilized on November 16th, 2010. Currently, Whiting-Turner has bought-out site work, GeoPier foundations, concrete and MEP contractors. Achieving a watertight building is planned for the end of November '10 and substantial completion by the end of July '11. Meeting this deadline is crucial due to occupancy phasing requirements that have been dictated by the owner.

In order to properly interpret the detailed project schedule, several key features must be addressed. The construction phase of the schedule has been broken down into four major portions; substructure/subgrade, concrete structure, building enclosure, and interiors. In an attempt to remove confusion with relationships, most but not all, activities have been linked in a finish-start fashion. Within each major portion of construction, the work has been broken down by floors. This presented challenges when developing appropriate durations for specific activities. Electrical equipment within the interiors phase is shown as being set during the structural phase. Since most mechanical and electrical equipment is bulky, large and expensive, it must be set while the floor above is open and easily accessible. Finally, one key feature to note regarding this schedule is that the MEP trades will be on site for the duration of the project. Between utility relocation, utility feeds and service, major equipment placement, MEP rough-in, and fixtures, the electrical and mechanical subcontractors will be performing work during each major construction phase.

Project Sequencing

In order to properly sequence this project, this construction flow diagramed was developed. This flow was originally created for the concrete pour schedule, but was later decided that it also provides clear direction and general breakdown for each floor. Phase 1 was located because of its proximity to the existing medical facility. Once Phase 1 is completed on each floor, the rooms in the existing facility which have been closed due to the construction can be utilized once again. The owner has placed less emphasis on phases 2 and 3 since they don't impose the same issue or threat on the existing facility. Utilizing a three phased breakdown per floor will allow for high detailing when scheduling the concrete and building envelope subcontractors. Within each one of the four major construction phases, the schedule is broken down by floor. Breaking down the schedule into these four major



[*Figure 05*. Construction Flow]

construction phases will allow Whiting-Turner to improve their understanding of each activity through keeping related tasks grouped.

The Detailed Project Schedule is located within **Appendix A.**

5.4 Project Cost Estimate

The following estimate values are based on the work and research performed by The Whiting-Turner Contracting Company. Per request of Whiting-Turner, some of the figures have been altered or rounded and are not completely indicative of the actual cost of the systems.

Floor	Area (Square Feet)	Regional Area (Square Feet)	Notes / Comments
Ground	23750	-	Parking Garage
First	30628	54378	Parking Garage
Second	31600	-	Livable Area
Third	31600	-	Livable Area
Fourth	25284	88484	Livable Area
Total	**142,862**		

[**Table *01***. Building Area Summary]

Building System	Actual Cost	Cost / SF	% of Building
Concrete	$4,690,000	32.83 $/SF	20.52
Thermal & Moisture	$1,480,000	10.36 $/SF	6.47
Openings	$1,100,000	7.70 $/SF	4.81
Finishes	$4,560,000	31.92 $/SF	19.95
Conveying System	230,000	1.62 $/SF	1.01
Plumbing	$1,680,000	11.76 $/SF	7.35
Mechanical	$1,950,000	13.65 $/SF	8.53
Electrical	$2,880,000	20.16 $/SF	12.60
Earthwork	$960,000	6.72 $/SF	4.20

[**Table *03***. Building Systems Cost Estimate (Selective Systems – Bid Package Value]

Breakdown Type	Actual Cost	Cost / SF
Building Cost (without general requirements)	$22,210,000	155.00 $/SF
Construction Cost (with general requirements)	$22,860,000	160.00 $/SF
Total Project Cost	$26,590,000	186.00 $/SF

[**Table *03***. Actual Project Cost Breakdown]

5.5 General Conditions Estimate

Whiting-Turner has broken up the general conditions estimate into nine sections: mobilization and temporary field office, small tools and equipment, project management and supervision, travel and lodging, plans / permits / postage, special requirements, testing and inspections, site requirements, and building access. The value submitted within the GMP for Division 01 came to $2,666,500 or approximately $31,370.60 in weekly costs. In comparison to the entire GMP, the general conditions equate to approximately 10% of the total project cost. This general conditions estimate was designed for approximately 18-20 months worth of on-site, at risk, construction management services.

One positive outcome of the negotiated GMP between Whiting-Turner and Presby's Inspired Life was that the owner decided to pick up several general condition items. By doing this, WT was able to slightly reduce their general conditions estimate. Items that a medical setting would usually need during construction such as HEPA-VACS and ventilation machines, Presby's agreed to supply. Other items such a temporary utility services to all trailers, testing & inspections, building permits, and basic office supplies will also all be purchased and managed by the owner.

After further inspection of the general conditions estimate, it was discovered that the majority of the costs come from the project management and supervision staff. This project will require a CM staff of seven people to run efficiently, which is about 65% of the total general conditions value. Of these seven people, the senior project manager will be billed as part-time, due to his multiple active projects.

General Conditions Estimate Value	
Description	Value
Mobilization and Temporary Field Office	$ 45,075.00
Small Tools and Equipment	$ 4,150.00
Project Management and Supervision	$ 1,733,800.00
Travel and Lodging	$ 45,050.00
Plans, Permits, and Postage	$ 42,000.00
Special Requirements	$ 47,050.00
Testing and Inspections	$ 12,500.00
Site Requiements	$ 631,870.00
Building Access	$ 105,000.00
Grand Total General Conditions	**$ 2,666,495.00**

[***Table 04***. General Conditions Summary]

DIVISION. 01 - GENERAL CONDITIONS		MEDICAL CENTER ADDITION ESTIMATE			
DESCRIPTION		QTY.	UNIT	UNIT COST	TOTAL COSTS
MOBILIZATION AND TEMPORARY FIELD OFFICES/EXPENSES					
WT SUPERINTENDENT FIELD OFFICE		1	LS	$25,000.00	$25,000
WT FIELD OFFICE CONSTRUCTION / DEMO		1	LS	$0.00	BY OWNER
TRAILER ELECTRICAL / TELEPHONE CONNECTION		1	ALLOW	$5,000.00	$5,000
TRAILER TELEPHONE SERVICE - FAX LINE		18	MO	$0.00	BY OWNER
TRAILER TELEPHONE EQUIPMENT		1	LS	$0.00	BY OWNER
TRAILER ELECTRIC SERVICE		0	MO	$0.00	BY OWNER
TRAILER WATER / SANITARY CONNECTION / TANK		1	ALLOW	$0.00	BY OWNER
TRAILER WATER SERVICE		0	MO	$0.00	BY OWNER
TRAILER ACCESS PLATFORMS AND MISC CARPENTRY - SUPPLY AND REMOVE		1	LS	$2,500.00	$2,500
OFFICE FURNITURE		1	LS	$1,000.00	$1,000
OFFICE SUPPLIES		17	MO	$150.00	$2,550
OFFICE POSTAGE & SHIPPING		17	MO	$100.00	$1,700
COMPUTER INTERNET SERVICE		18	MO	$0.00	BY OWNER
OFFICE FAX MACHINE		1	EA	$300.00	$300
OFFICE PRINTER		2	EA	$300.00	$600
COLOR PRINTER		1	EA	$500.00	$500
SCANNER		1	EA	$200.00	$200
OFFICE COPIER (RENT-W/SERVICE AGREEMENT)		18	MO	$0.00	BY OWNER
PRINTER CONSUMABLES (TONER, PRINTER CARTRIDGES, ETC...)		17	MO	$50.00	$850
PLOTTER		0	EA		$0
FILE SERVER		1	EA	$0.00	BY OWNER
OFFICE TRAILER CLEANING SERVICE		18	MO	$0.00	BY OWNER
OFFICE TRAILER DUMPSTER/TRASH REMOVAL		18	MO	$250.00	$4,500
FIELD OFFICE TRAILER INSURANCE		1.5	YRS	$250.00	$375
				SUBTOTAL:	**$45,075**
SMALL TOOLS AND EQUIPMENT					
MISCELLANEOUS MILEAGE		17	MO	$100.00	$1,700
MISC. SMALL TOOLS-BROOMS, GARBAGE CANS, MOPS ETC...		1	LS	$750.00	$750
MISC. SUPPLIES		17	MO	$100.00	$1,700
				SUBTOTAL:	**$4,150**
PROJECT MANAGEMENT AND SUPERVISION					
JESSE BEAM - SENIOR PROJECT MANAGER		1440	HRS	$120.00	$172,800
LAWSON KILBOURNE - SUPERINTENDENT		2960	HRS	$95.00	$281,200
CHIP CINAMELLA - PROJECT MANAGER		3240	HRS	$95.00	$307,800
BOGDAN MINDA - PROJECT MANAGER		3240	HRS	$95.00	$307,800
SHELLY CHRISTMAN - ASSISTANT PROJECT MANAGER		1800	HRS	$80.00	$144,000
KEN FONDE - PROJECT ENGINEER		3240	HRS	$70.00	$226,800
FIELD ENGINEER		2500	HRS	$70.00	$175,000
PROJECT ACCOUNTANT/CLERICAL		2960	HRS	$40.00	$118,400
				SUBTOTAL:	**$1,733,800**
TRAVEL AND LODGING					
JESSE BEAM - SENIOR PROJECT MANAGER		17	MO	$400.00	$6,800
DAILY COMMUTES		17	MO	$2,000.00	$34,000
MISC. MILEAGE / TRAVEL COSTS		17	MO	$250.00	$4,250
				SUBTOTAL:	**$45,050**
PLANS, PERMITS AND POSTAGE					
DRAWINGS AND SPECIFICATIONS-BID SETS		150	SETS	$200.00	$30,000
DRAWINGS AND SPECIFICATIONS-ROUTINE UPDATES/BULLETINS		17	MO	$250.00	$4,250
BUILDING / SPECIAL PERMITS			N/A		BY OWNER
OVERNIGHT EXPRESS CHARGES / FEDEX / UPS		17	MO	$250.00	$4,250
POSTAGE AND SHIPPING-BID PERIOD		2	MO	$750.00	$1,500
SHOP DRAWINGS AND SAMPLES		1	ALLOW	$1,000.00	$1,000
RED-LINE AS-BUILT DRAWING COPIES		1	ALLOW	$1,000.00	$1,000
				SUBTOTAL:	**$42,000**

[***Table 05a***. General Conditions Detailed Breakdown]

SPECIAL REQUIREMENTS					
PROGRESS PHOTOS-MONTHLY UPDATES		17	MO	$50.00	$850
FINAL PHOTOS		1	LS	$2,000.00	$2,000
PROGRESS PHOTOS-DIGITAL CAMERA		1	EA	$400.00	$400
AERIAL PHOTOS (MONTHLY)		17	MO	$300.00	$5,100
PROGRESS MEETINGS		17	MO	$100.00	$1,700
MONTHLY REPORTS		17	MO	$100.00	$1,700
CPM SCHEDULE-SET UP / INDEPENDENT CONSULTANT		1	LS	$7,500.00	$7,500
CPM SCHEDULE UPDATES		17	MO	$500.00	$8,500
ARCHITECT AND ENGINEERING FEES			N/A		BY OWNER
PUNCHLIST/CLOSEOUT		1	ALLOW	$2,500.00	$2,500
QUALITY CONTROL PROGRAM		1	EA	$500.00	$500
QUALITY CONTROL AWARDS		17	MO	$50.00	$850
LOSS PREVENTION PROGRAM		1	EA	$500.00	$500
SAFETY PROGRAM		1	EA	$500.00	$500
SAFETY AWARDS		17	MO	$100.00	$1,700
MISC JOB STORAGE TRAILERS		17	MO	$500.00	$8,500
JOB DRINKING WATER		17	MO	$250.00	$4,250
				SUBTOTAL:	**$47,050**
TESTING & INSPECTIONS					
EXTERIOR SKIN WATER/LEAK TEST		5	DAYS	$2,500.00	$12,500
INDEPENDENT TESTING & INSPECTION			LS		BY OWNER
				SUBTOTAL:	**$12,500**
SITE REQUIREMENTS					
TEMPORARY FENCES / PEDESTRIAN PROTECTION (~ 1,000 LF)		1	LS	$15,000.00	$15,000
GATES		3	EA	$750.00	$2,250
TEMPORARY ACCESS ROADS		0	LS	$0.00	$0
TEMPORARY PARKING / LAYDOWN		1	LS	$15,000.00	$15,000
MAINTAIN ACCESS ROADS & PARKING		17	MO	$500.00	$8,500
SURVEY AND ESTABLISH BENCHMARKS		1	ALW	$5,000.00	$5,000
SAFETY MAINTENANCE		17	MO	$1,000.00	$17,000
BARRICADES & SAFETY		1	ALW	$25,000.00	$25,000
FLOOR OPENING PROTECTIONS		1	ALW	$7,500.00	$7,500
ELEVATOR SHAFTS OPENING PROTECTION		10	EA	$500.00	$5,000
WEATHER & DUST PROTECTION		1	ALW	$10,000.00	$10,000
TEMPORARY FIRE PROTECTION-EXTINGUISHERS (1 EVERY 3,000 SF)		50	EA	$75.00	$3,750
FLOOR PROTECTION			SF		BY SUB
DAILY CLEANUP - LABORERS		12	MO	$7,500.00	$90,000
FINAL CLEANING		90000	SF	$2.34	$210,600
FINAL WINDOW CLEANING		1	LS	$15,000.00	$15,000
DUMPSTER SERVICE		17	MO	$5,000.00	$85,000
STREET CLEANING		12	MO	$2,000.00	$24,000
SNOW REMOVAL (INSIDE JOB FENCE ONLY)		1	ALW	$10,000.00	$10,000
TEMPORARY SANITARY FACILITIES (PORTA TOILETS)		17	MO	$1,000.00	$17,000
TEMPORARY POWER / WATER CONSUMPTION			MO		BY OWNER
SELECT TEMPORARY HEAT		4	MO	$10,000.00	$40,000
PROJECT SIGN		2	EA	$750.00	$1,500
CONSTRUCTION SIGNAGE		1	LS	$2,500.00	$2,500
MAINTAIN SEDIMENT AND EROSION CONTROL		17	MO	$500.00	$8,500
STABILIZED CONSTRUCTION ENTRANCE		2	EA	$5,000.00	$10,000
CRANE USAGE WITH OPERATORS		1	LS	$9,520.00	$9,520
ELEVATOR OPERATOR (BY ELEVATOR CONTRACTOR)		2	MO	$20,000.00	$40,000
VENTILATION / NEGATIVE AIR MACHINE - TO BE SUPPLIED AS DICTATED			ALW		BY OWNER
HEPA-VACS / CLEANING SUPPLIES - TO BE SUPPLIED AS DICTATED			ALW		BY OWNER
				SUBTOTAL:	**$631,870**
BUILDING ACCESS					
MATERIAL HOIST		6	MO	$15,000.00	$90,000
SET-UP / BREAKDOWN OF MATERIAL HOIST		1	LS	$15,000.00	$15,000
TRASH CHUTE			LS		NOT USED
				SUBTOTAL:	**$105,000**
GRAND TOTAL GENERAL CONDITIONS =					$2,666,495
				WEEKLY COSTS:	$34,185.83

[*Table 05b*. General Conditions Detailed Breakdown**]**

5.6 Structural Systems Estimate

Provided that this structure is concrete, it was decided to perform a volume analysis through utilizing the structural schedules. Since this structure has unique bays with varying slab thicknesses and column dimensions, utilizing the single bay method would contain a level of inconsistency and inaccuracy. The components that were taken off for this portion of the assignment included footers, grade beams, slabs on grade, columns, elevated slabs, elevated beams, shear walls, and stairwells. All five levels of this building are above ground, therefore no foundation or subgrade walls are found within this analysis. Basic measurements and quantity take offs were transferred into Excel spreadsheets and applied to the appropriate building component. These spreadsheets immediately calculated the cubic yards, tonnages, and formwork contact area for each major structural element. Without the use of an electronic spreadsheet tool, this estimate would not have been a viable option and would have required an extensive amount of work to complete.

Cavan Concrete® was the selected subcontractor for this project, winning the bid with a submitted lump sum value of $4.61 million (this amount has been slightly rounded per request of WT and Cavan). This value equates to roughly $28.97 per square foot. A total of eight contractors submitted bids for this contract with a price range varying from $4.4 million to $7.2 million.

The following table summarizes the quantities of concrete, rebar, formwork required to build this concrete structure.

Structural Component Summary			
Item Description	Concrete (CY)	Rebar (Tons)	Formwork (SFCA)
Footing	1408	59	6,431
Slab on Grade	566	N / A	638
Structural PT Slab	3525	159	134,457
Column	337	41	25,619
Grade Beam	143	5	2,142
Beam	63	4	3,018
Shear Walls / Stair Towers	672	60	15,280
	6714 CY	**328 Tons**	**187,585 Tons**

[***Table 06***. Structural System Quantity Take-Off Summary]

After applying these quantities to RS Mean's 2009 data, an estimated value of $3,774,382 ($23.72 per sf) was derived. The table found on the next page provides a complete summary of this calculated estimate. Comparing this value to the actual lump sum value reveals that this analysis has a percentage of error of 18%. One potential source of this error could be Cavan's knowledge of pricing post-tension projects. From this estimates point of view, many of the components were priced as just cast-in-place. Extra labor associated with constructing a post tension structure would be captured due to Cavan's specialty insight and knowledge.

Another factor that could have resulted in high bids from contractors to Whiting-Turner was that the architect and structural engineer released two significant drawing addenda during the bid period. Due to this, several contractors may have felt uneasy and unsure as to what new features would be added in future addenda. Contractors may have utilized higher contingencies in order to properly protect themselves.

Finally, it was felt that the discovered ratio of tons of steel to cubic yards of concrete was relatively low. Averaged throughout the entire building, this ratio was found to be approximately .0488. The component that raised the most concern was the structural slab. The post tension slabs had a ratio of 0.0198 compared to the columns at 0.122. Due to this, when estimating the total tonnage of steel within the slabs, a ratio of 0.04 was utilized in an effort to account for any reinforcing that was possibly missed during multiple slab takeoffs.

The following table summarizes the estimated cost for the materials, labor, and equipment required to erect this structure. RS Means Cost Works 2009 data was utilized for this estimate. These cost units have been adjusted for Philadelphia. Ten percent waste factors where applied to the concrete and rebar value, and fifteen percent was applied to formwork. Waste factors have only been applied to material pricing only, labor or equipment has not been altered.

Detailed Estimate for Cost of the Post Tension Concrete System								
Item Description	**Quantity**	**Unit**	**Bare Material**	**Bare Labor**	**Bare Equipment**	**Subtotal**	**Total O & P**	**Calculated O & P**
Concrete								
Spread Footings (3000 psi)	1,408	CY	$ 111.10	$ 33.86	$ 12.15	$ 157.11	$ 204.24	$ 287,582.81
Grade Beams (5000 psi)	143	CY	$ 122.10	$ 12.41	$ 4.56	$ 139.07	$ 180.78	$ 25,911.76
Elevated Beams (5000 psi)	63	CY	$ 122.10	$ 36.36	$ 13.15	$ 171.61	$ 223.09	$ 14,004.85
Slab on Grade(4000 psi)	566	CY	$ 116.60	$ 17.36	$ 8.25	$ 142.21	$ 184.87	$ 104,701.21
Columns (5000 psi)	337	CY	$ 122.10	$ 45.36	$ 22.00	$ 189.46	$ 246.30	$ 83,002.43
Shear Walls / Stair Towers (5000 psi)	672	CY	$ 122.10	$ 27.86	$ 13.75	$ 163.71	$ 212.82	$ 143,068.92
Elevated Structural Slabs (5000 psi)	3,525	CY	$ 122.10	$ 22.86	$ 10.90	$ 155.86	$ 202.62	$ 714,314.53
							Subtotal Concrete:	**$ 1,372,586.52**
Rebar								
Spread Footings	59	Tons	$ 1,540.00	$ 395.00	$ -	$ 1,935.00	$ 2,175.00	$ 128,325.00
Grade Beams / Elevated Beams	10	Tons	$ 1,705.00	$ 890.00	$ -	$ 2,595.00	$ 3,150.00	$ 31,500.00
Slab on Grade(WWF)	303	CSF	$ 0.55	$ 20.50	$ -	$ 21.05	$ 31.58	$ 9,562.51
Columns	42	Tons	$ 1,705.00	$ 950.00	$ -	$ 2,655.00	$ 3,250.00	$ 136,500.00
Shear Walls / Stair Towers	60	Tons	$ 1,622.50	$ 1,340.00	$ -	$ 2,962.50	$ 3,400.00	$ 204,000.00
Elevated Structural Slabs	159	Tons	$ 1,815.00	$ 490.00	$ -	$ 2,305.00	$ 2,605.00	$ 414,195.00
							Subtotal Rebar:	**$ 924,082.51**
Formwork								
Spread Footings	6,431	SFCA	$ 0.17	$ 0.70	$ 5.35	$ 6.22	$ 9.08	$ 58,426.76
Grade Beams / Elevated Beams	5,161	SFCA	$ 0.14	$ 0.90	$ 4.75	$ 5.79	$ 8.45	$ 43,612.15
Slab on Grade	638	SFCA	$ 0.13	$ 1.35	$ 3.25	$ 4.73	$ 6.90	$ 4,405.35
Columns	25,619	SFCA	$ 0.17	$ 0.79	$ 5.65	$ 6.61	$ 9.65	$ 247,336.64
Shear Walls / Stair Towers	15,280	SFCA	$ 0.14	$ 0.78	$ 4.73	$ 5.65	$ 8.25	$ 126,001.37
Elevated Structural Slabs	134,457	SFCA	$ 0.10	$ 1.55	$ 3.43	$ 5.08	$ 7.42	$ 997,930.16
							Subtotal Formwork:	**$ 1,477,712.42**
							Grand Total Estimate:	**$ 3,774,381.46**

[*Table 07*. Detailed Structural Systems Cost Estimate**]**

6.0 Integrated Project Delivery: Enhancing Team Collaboration

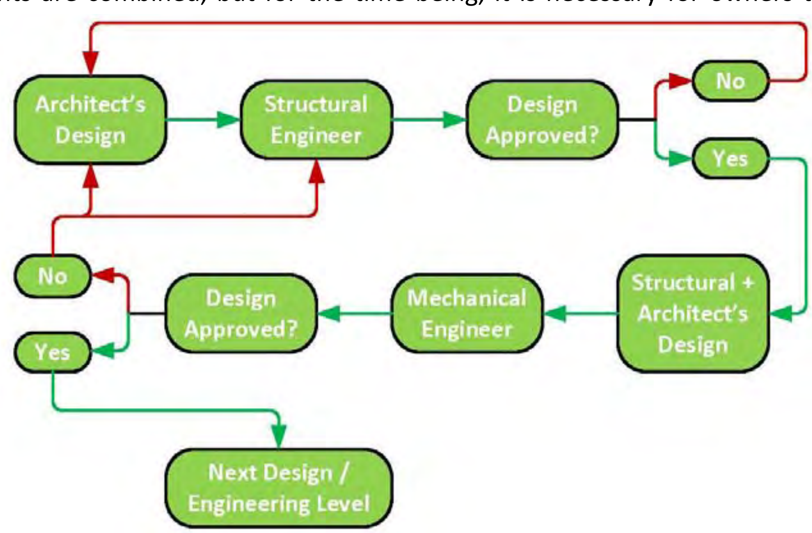
6.1 Problem Introduction – Critical Industry Issue and MAE Requirement (AE 572)

During the fall 2009 PACE Conference IPD was discussed at the Business Networking: Expanding Circles and Creating Opportunities breakout session. This discussion covered how the entry and implementation of Integrated Project Delivery (IPD) should occur. The time of professionals within the AEC industry is extremely valuable and should be utilized with careful thought and planning. Within today's industry there exist many inefficiencies within the design development and construction of buildings. These inefficiencies need to be pinpointed, addressed, explored and corrective means need to be properly implemented. Each consulting firm within the design and construction process must understand their specific roles and when they overstep their intended professional boundaries. Given the disconnected relationship between each professional group (OAC project team) for this medical addition, the impact of enhanced collaboration techniques and improved goal alignment will tackle this critical industry issue.

6.2 Background Information

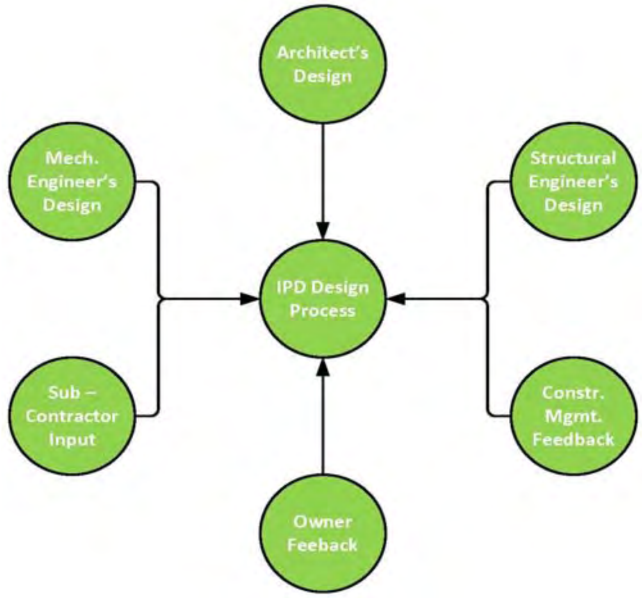
The United States Bureau of Labor Statistics performed a study which indicated that construction, out of all non-farm industries, has been decreasing in productivity since 1964. On the other hand, during that same period, all other non-farm industries have increased their productivity by over 200%. Along with that, The National Institute of Standards and Technology released a study in 2004 which estimated that the lack of software interoperability has cost the AEC industry over $15.8 billion annually.

Integrated Project Delivery is a new delivery method that has been gaining popularity during the past decade. Primarily this method tries to improve the level of collaboration between all parties involved with designing and constructing a building. Design-Bid-Build, the most common delivery method today, inherently fragments all of the parties, as seen in the figure below. Each phase of the project is clearly outlined in the title of the delivery style. The DBB method has worked for a while, but it is time to update the methods and procedures used in the construction industry. IPD can be applied to several aspects of the delivery process including the contractual language, project team arrangements and the use of new technologies. Clearly, IPD works best when all of these elements are combined, but for the time being, it is necessary for owners to become more familiar with this style before 100% integration of these elements can occur. Several design and construction firms have realized the need for this new style and have decided to only work on projects where IPD can be implemented. Owners are starting to learn that there exist many benefits in utilizing this method which include a higher quality delivery, reduced schedule time, minimal RFIs, and almost zero change orders (except those that are owner initiated).



[Figure 06. Traditional Linear Design Process**]**

Another benefit resulting with the growth of this style change is the potential to update the fee structures within the construction industry. Usually a construction manager or general contractor receives their fee based on a percentage of work, which means they want as must work as possible (even if this extra work doesn't exist) in order to maximize their profits. If these fees and potential profits are distributed on an alternate method where architects and construction managers receive their profits based on the project's success, then improved collaboration becomes inherent.



[**Figure 07**. Radial Input Method – Standard IPD Process]

The figure to the left represents how the Integrated Project Delivery Design process receives inputs from all of the professionals during the entire design and construction process. This method allows all of the consultants to be in constant communication with each other. Whenever one participant alters or changes an aspect of the design, all of the other parties are notified allowing for all other updates to be quickly implemented. This process helps prevent field clashes down the line, after construction has begun. Again one of the biggest benefits of this delivery method is that the subcontractors become extremely knowledgeable regarding the design which requires more effort upfront, but less during the construction phase.

6.3 Research Goal

The final building design and commencement of construction for the Medical Center Addition has been placed on hold twice between February 2008 and November 2009. The primary objective of this research was to pinpoint inefficiencies within this OAC project team and determine as to how it came to standstill during this period. A project specific Integrated Project Delivery Execution Guide has been created using this project team as a lessons learned case study. This guide will outline successful IPD elements that will improve the current level of team collaboration and goal alignment.

This research section of the report will begin with a detailed profile of the project team followed by several IPD case studies. Analysis one will conclude with a project specific IPD guide. Following the case study reviews, an in depth timeline of the two years of major preconstruction events leading up the start of construction in November 2009 will be presented. This timeline was developed from information gathered from during an interview with the lead project manager.

Please Note: Many of the things mentioned within this section are personal opinions and thoughts which have not been validated with years of experience but rather only four summers of internships (which accounts for some experience development). Most of the items mentioned are not just elements that should be present in IPD but should be expected within traditional project methods. These opinions may also contain personal biases that have been created from a construction management or Whiting-Turner employee point of view.

6.4 Project Team Overview

After having a firsthand experience with a project that is encountering communication and goal issues, it has become clear how much of an impact such problems will have on team collaboration and project success. This issue is slowly being brought into the spotlight and addressed with the development of new contract strategies which suggest that project stakeholders improve their collaboration and communication methods. The first major step towards a solution was design-build, which essentially took the entire design and construction team and put them into one company. A design-build (DB) project team can quickly accommodate and adapt to unforeseen conditions as well as deliver a project in a very short period of time. The issue with this project delivery type is that is almost 100% of the owner decision making power and involvement is given to this DB single entity. Upon studying the success within a design-build company, The American Institute of Architects (AIA) has begun research, development and implementation of a new contract type called Integrated Project Delivery (IPD). The IPD approach is a step forward towards allowing an owner to retain their decision making power while attempting to improve the collaboration within project participants while using a more traditional construction manager (CM) delivery system.

In order to properly discuss the implementation of IPD with this project, a well defined and detailed overview of the owner, designer and constructor must be established. Through the research of T. Vesay and V. Sanvido with their Project Delivery Selection System (PDSS), several basic factors have been identified which help profile the project at hand.

Time (Schedule): During an initial overview of this project, it has been identified that there are multiple phases that have created crucial completion dates. This would lead one to conclude that time is extremely critical. Yet, this detail is only one of several that must be considered when deciding on the level of importance for time. One personal method to gage time importance is by performing a quick time to budget ratio. Utilizing this tool will give a concept of how much work is being performed during a single month. For this phase of the project roughly 1.45 million dollars per month will be ongoing for 18 months. Comparing this ratio to a data center project (summer 2008 internship) where a $285 million project could be designed and built over 13 months reveals a ratio of 22 million dollars per month of work. For this example the cash flow for one month is almost equal to the cash flow for the entire medical center addition project. Therefore time is not critical, but schedule growth must be closely monitored, which should be done on any project perusing a successful and timely completion.

Owner Experience (Presby's Inspired Life): Interacting with this owner during two internship periods has indicated that the owner does not have the knowledge necessary or required to make proper design or construction related decisions. For this reason, Greenbrier Developers were hired to assist the owner with making the proper decisions when design and construction information was presented to them. One problematic feature that has been amplified with this development company is that they have assumed the role of a Project Manager Agent, even though a PM Agent project delivery strategy was never established. This issue will be further discussed within the later sections of this analysis.

Team Experience (Developer, Architect, Construction Manager, etc.): Greenbrier Developers (GD) is a company that specializes in the development and budget management of senior living projects. They have an excellent reputation, but have the disadvantage of working remotely from Texas and only visit the construction site, at most, once a month. Stewart-Conners Architects (SCA) is a relatively young company that operates out of a small firm in North Carolina. Their market sectors mainly include senior living and hotels which makes them a good fit for this medical center addition. Whiting-Tuner Contracting Company (WT) is a well established national construction management company. The Allentown business group (Pennsylvania) is spearheading this project for WT. This group has been established within the Lehigh Valley and Greater Philadelphia Regions making them a good fit for understanding the local subcontractor market. Overall this project team is has good experience, but is facing communication and collaboration barriers.

Quality (Craftsmanship, Difficulty in Constructing Planned Details, etc.): This project quality is relatable to that of a hotel such as a Best Western or Holiday Inn which would put the quality level in the industry standard category. In comparison, a Ritz Carlton or a well funded private preparatory high school would be considered to have design elements that are above industry standard rating. The only element of this project that will be above standard quality are specific woodworking or carpentry components such as executive meeting tables and elevator interiors.

Cost (Budget Constraints, Cash Flow): This project has been held up several times mainly due to the rejection of estimates and budgets from the bank for which the primary loan was being pursued. Cost and budget issues have also become one of the major problematic features of this project. Due to this reason, cost has become a critical factor determining the success of this project.

Scope Definition (Building Program, Engineered System Designs, etc.): Whiting-Turner was awarded the project prior to the 35% schematic design phase. This means that WT would become the critical participant with the preconstruction effort for this project. As construction began (Nov. 2009) many field issues were discovered within the drawings that were either under-designed (retaining wall) or just missing (existing steel columns, not to be removed) that have hindered the critical path of the schedule. Due to these reasons, it would be considered that the scope for this project is not well defined. In this case, it is critical to select a project team with experience that can fill in the undefined portions of the design.

Building upon this project profile with research performed by S. Anderson and A. Oyetunji at Texas A&M University reveals 20 additional factors that influence the success of a project. This research titled “Selection Procedure for Project Delivery and Contract Strategy” (PDCS, taught in AE572) is an upgraded version of the PDSS developed by T. Vesay and V. Sanvido. Within this more detailed selection system, 12 detailed delivery strategies and 20 project factors are related to one another through a specific rating system.

Upon review of the 12 delivery strategies four have been selected as most fitting for this project:

1. Traditional DBB with early Procurement
2. Traditional DBB with early Procurement and Agent
3. Construction Manager at Risk
4. Design-Build

*1. and 2. are considered to have similar phase sequencing

Other strategies not fitting of this project include Traditional Design-Bid-Build, Engineer-Procure-Construct (EPC), Parallel Primes, Traditional with Staged Development, Turnkey and Fast Track. Traditional Design-Bid-Build was not considered for this project given its clear-cut nature consisting of separated design and construct phases. This medical center’s design, estimate, bid negotiation, procurement and build phases overlap in a very complex manner not fitting of a typical traditional design bid build strategy.

For this analysis, the PDCS was not utilized to output a specific delivery style, but rather to analyze the differences within the four selected delivery strategies. Upon review of a personalized matrix with the factor ratings used from the PDCS, it is clear that the rankings are: 1. Design Build, 2. Traditional DBB with Early Procurement, 3. Construction Manager at Risk, 4. Traditional DBB with Early Procurement and Agent.

The following factors indicate that the design-build (IPD alternative) delivery strategy would have been an excellent method for this owner but three factors point out why it was not implemented. First, design-build does not work well when an above normal level of changes are expected, second the owner desires significant project involvement (to help grow their experience) and finally there was poor scope definition at the early phases of this project. The next best fit would be the Traditional Design Bid Build with Early Procurement which would have been an excellent alternative, but the owner insisted that they would not deal with suppliers. Therefore the best fit for Presby's Inspired Life, which they are most familiar and comfortable with, is construction manager at risk.

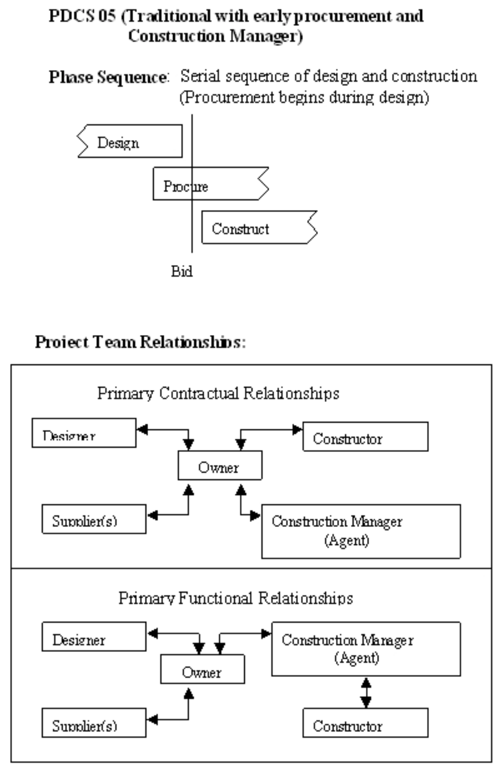
Selected PDCS Alternatives with respect to Selection Factors Maxtrix

Factor Action Statement	Trad. DBB with Early Procurement	Trad. DBB with Early Procur. and Agent	Construction Manager at Risk	Design-Build (Best IPD Alternative)
Control Cost Growth	50	50	**60**	**90**
Ensure Lowest Cost	**100**	60	40	**80**
Facilitate Early Cost Estimates	20	20	**70**	**90**
Reduce / Transfer Risk	50	20	**70**	**90**
Control Time Growth	50	50	**70**	**90**
Ensure Shortest Schedule	50	40	**80**	**100**
Promote Early Procurement	**90**	**90**	**100**	**100**
Ease Change Incorporation	**80**	**70**	60	10
Capitalize on Familiar Project Conditions	50	40	**70**	**100**
Maximize Owner's Control	**100**	**80**	60	10
Maximize Owner's Involvement	**90**	**80**	40	10
Efficiently Utilize Poorly Defined Scope	**80**	**70**	60	0

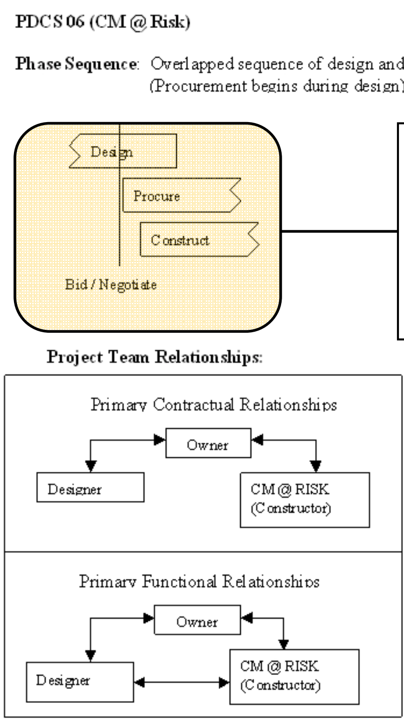
[**Table 08**. Factors with Point Values Associated with Delivery Methods]

This table clearly displays that CM at Risk took second place in many factors, which indicates a relatively average delivery system. This table could be analyzed by summing each column but weighting factors must be considered which are primarily developed by the owner. Considering the stance of this owner, a comfortable and average delivery system is most preferred over one with large swinging pros and cons. Even though these other delivery systems are accompanied with disadvantages, if Presby's Inspired Life wants to deliver successful projects in the future, they must learn to properly address and manage these risk factors.

As seen within these diagrams, the top three delivery styles where selected base on the phase sequencing and project team relationships. The benefit for Construction Manager at Risk is that the suppliers are tied to the CM and primary subcontractors rather than the owner. Typically within a Traditional DBB with Early Procurement (Fig. 07) suppliers must be tied to the owner, which creates the natural conduit for the early procurement to occur. Presby's Inspired Life does not have the desire or experience to deal with suppliers directly. Finally within the design-build style total control is given to the DB contractor almost eliminating the need for the owner. DB contractors can also be more expensive to contract not fitting for a relatively small project estimated at $28 million dollars. DB becomes very useful when projects have extremely critical schedule dates. A $300 million data center that needs to open in less than a year or university dorms that have been pre-booked have extreme time constraints. This project has about 18 months to complete which is more than should be allotted considering the preconstruction period.

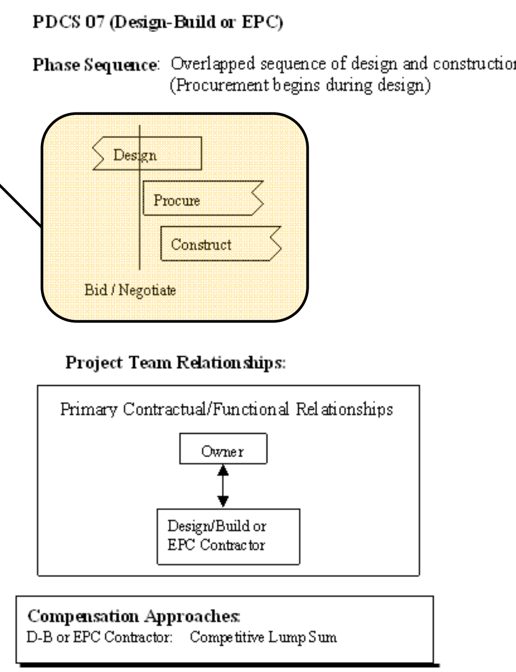


[Figure 07. Trad DBB w/ Early Procurement**]**



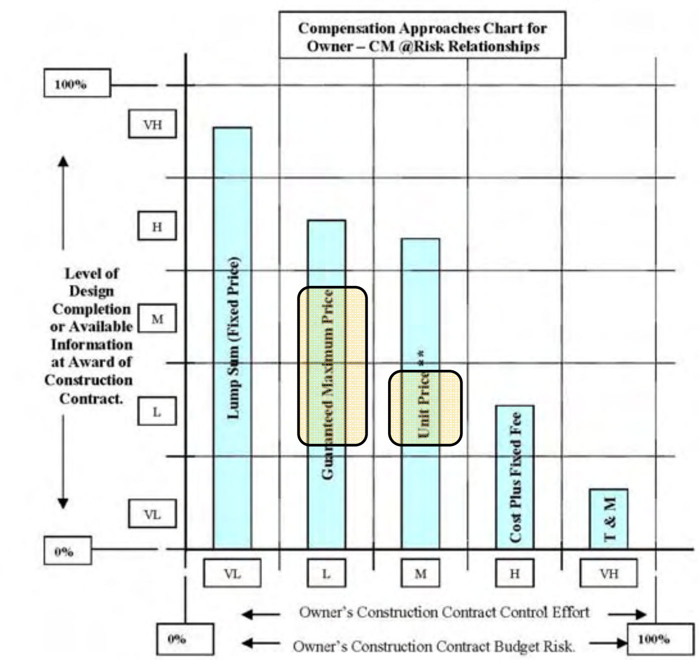
*Note the overlap in Phase Sequencing. This is a key element to this project being delivered on schedule.

[Figure 08. Design Build Contractor**]**



[Figure 09. Design Build Contractor**]**

The last element that the PDCS will assist with pinpointing, is the Compensation Approach, also known as the contract type. The figure to the right utilizes a qualitative ranking system from very low to very high on the x and y-axis's. The X-axis is the owner's construction contract control effort and the construction contract budget risk. On the Y-axis is the level of design completion or information available during the time of awarding the construction contract. From personal observation with the construction management team, the highlighted regions indicate where the owner's contract control effort and budget risk would fall in comparison to the level of design completion.



Frequency of Usage, based on Research Data*** N = 69.

Relationship	Contract Strategy	Relative Frequency of Usage***
Owner – CM @ Risk (Constructor)	GMP	0.51
	Cost Reimbursable + Fee	0.25
	Negotiated Lump Sum	0.08
	Competitive Lump Sum	0.08
	Firm Price	0.08

} 1.0

** Unit Price contract type is not usually used for main contract in capital industrial projects.

[Figure 10. CM @ Risk Compensation Approaches**]**

6.5 Integrated Project Delivery

Integrated Project Delivery has been under research and refinement process since its first introduction around 2005. Since then several studies have been conducted to examine its level of success. Several characteristics have been developed by the American Institute of Architects (AIA) which are utilized to define IPD:

- Early Involvement of Key Participants
- Shared Risk and Reward
- Multi-Party Contracting
- Collaborative Decision Making and Control
- Liability Waivers Among Key Participants
- Jointly Developed and Validated Project Goals and Targets

(Characteristics from the Integrated Project Delivery: Case Studies, AIA California Council 2010)

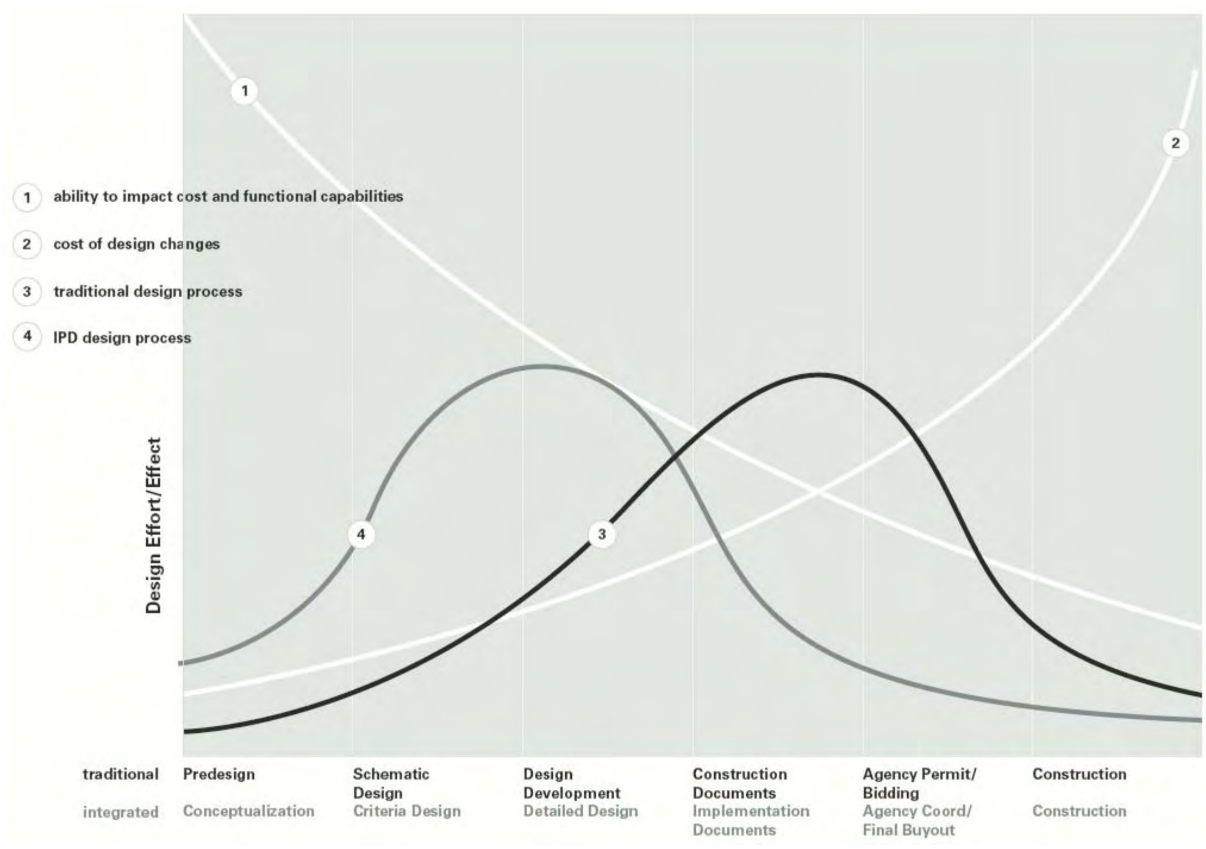
After obtaining and reviewing standard AIA IPD contracts (195 Family of Documents), it became clear that there was not a significant difference compared to the AIA CMc (Construction Manager – Constructor) contract documents. Where the documents primarily differ is that the IPD contract suggests enhanced collaboration, improving goal alignment, using BIM and there is a final section which attaches the whole project team together to the accepted GMP. Tom Krajewski, a project executive with DPR Construction which specializes in IPD projects, had this to say regarding the contractual language in the IPD contract:

> "I actually call these 195 documents, CMc with a hug. The contractor [becomes] the hook to make sure the development of design stays within the GMP even thought the CM and Architect are tied directly to the owner with their own separate contracts. The common General Conditions are

supposed to be the IPD element that binds everyone. It's not as good as a common document would be, because it allows people to revert to their traditional ways of pointing fingers at the other parties to blame for mistakes. That is where [the contract] falls short in what IPD is really all about."

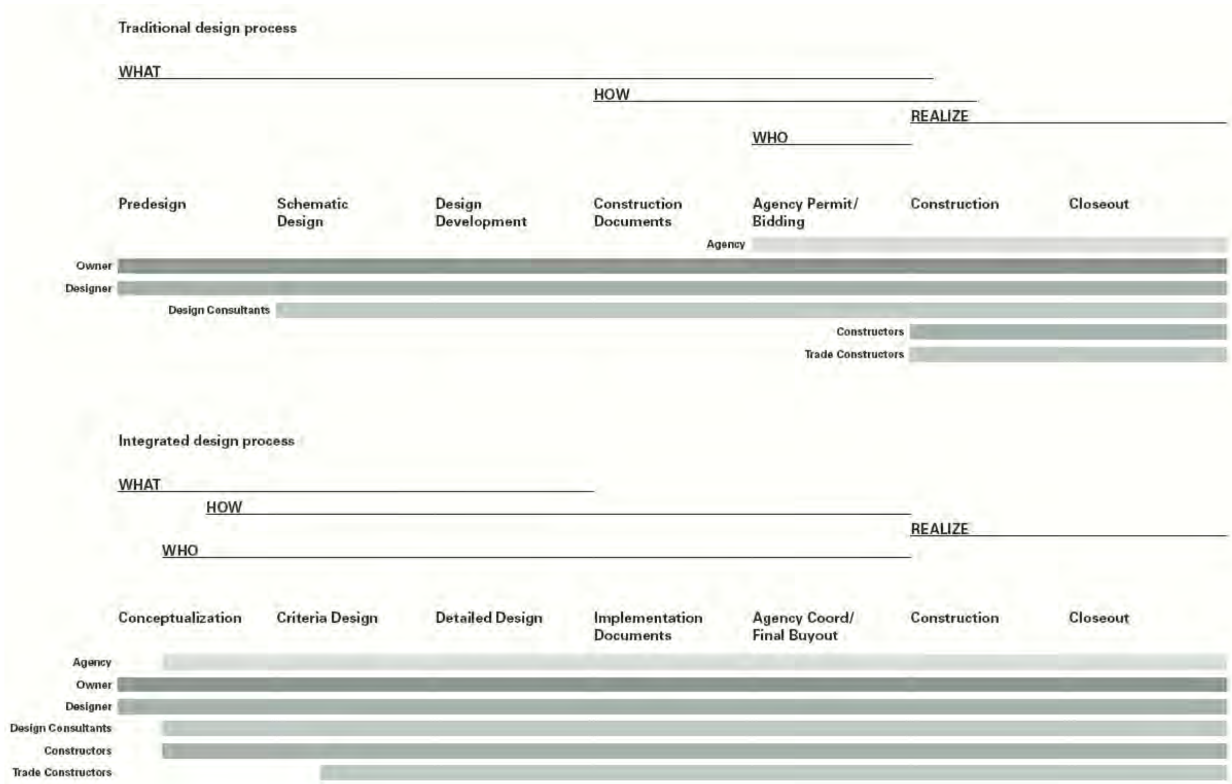
It is clear that the contractual language still has some refinement to go through, but in the mean time, significant success is being observed with the techniques developed thus far within the industry. Even though the contractual language falls short, the reallocation of effort during the entire design and construction phase indicates positive outcomes.

When the IPD process (curve 4) is compared to the traditional construction process (curve 3, design-bid-build) on the MacLeamy Curve (curves 1 and 2), it is clear that most of the design effort is completed prior to construction documents. On the other hand, during the traditional process, more effort is required during the construction documents and bidding period. An equal amount of effort is performed in each process but within the IPD method, issues and roadblocks are eliminated prior to construction facilitating an extremely smooth building delivery. It is also important to note that the IPD curve always stays under the MacLeamy Curve, mainly the line (curve 1) indicating the ability to impact cost and functional capabilities. In doing this, efficiency is maximized and wasteful redundancies are eliminated. Conversely, the traditional style exceeds both line (curves 1 and 2) defined by the MacLeamy Curve, indicating areas where inefficiencies will occur.



[Figure 11. MacLeamy Curve**]**

The following graph shows how the major stakeholders within the project delivery are affected and when their consulting skills are required. One key difference between the traditional process and IPD is where the WHO is positioned. Normally the owner will decide what is it they need, hire an architect and engineers who will figure out how the facility will operate. Only then is the project put out to bid and the people who are most familiar with construction brought on board for the project. Integrated Project Delivery alters this sequence by bringing the people most familiar with construction (CMs, GCs and Subs) onboard during conceptualization. This allows professionals with key construction experience to critique the design and explain methods to improve the quality and construction schedule of the facility. Another added benefit of bringing the CM and subcontractors onboard early is that by the time the project physically begins in the field, they are well versed on the project details. This allows the construction managers to better anticipate potential project holdups and plan rational solutions.



[**Figure 12**. Traditional Design Process vs. IPD Design Process]

6.6 Case Studies and their Success

Autodesk Inc. Solutions Division Headquarters

- Designed and Built between May 2008-January 2009
- Final Design Cost: $1,221,000 (-0.9% change from initial budget)
- Final Construction Cost: $12,117,000 (-0.9% change from initial budget)
- Procurement Phase RFIs: 76
- Construction Phase RFIs 49
- LEED Platinum

Key Elements of the Case Study:

- First IPD for the entire project team – hesitation with the IPD contract with architect and construction manager, three way contract implemented (owner, architect, builder)
- Design and build team constrained to a primary budget, but allowed to move money among line items
- Shared risk for profit between architect and builder with project goals (all or nothing scenario)
- Each party waived liability claims against each other – except for fraud, willful misconduct and gross negligence

Major Lessons Learned:

- Compatibility issues between all of the different 3D modeling softwares utilized
- Construction Manager capitalized on early procurement availability
- The final BIM delivered should have displayed information more quickly for facilities management
- Close collaboration made redundant detailing unnecessary
- Architect could be on site more with reduced time reviewing RFIs and Submittals
- Elimination of many shop drawings due to architects time spent on site

Sutter Health Fairfield Medical Office Building

- Designed and Built between July 2005 and November 2007
- Final Design Cost: Cost information not supplied
- Final Construction Cost: $19,462,103 (+2.33% change from initial budget)
- Procurement and Construction RFIs: 123
- No LEED / Sustainability Goals

Key Elements of the Case Study:

- Three way contract between owner, architect, and builder, no financial incentives were implemented
- Implemented a "No-Sue" clause which is supplemented with alternative dispute resolution clause
- Owner, architect and builder agreed to indemnify each other

Major Lessons Learned:

- Subcontractors discovered that the up-front work significantly increased, but later revision and review of documents is almost 100% eliminated
- All subcontractor's foremen must attend group scheduling meetings
- The owner must be kept engaged for the entire duration of the project
- Not only should MEP subcontractors be involved in early preconstruction design, but so should glazing and exterior building envelope subcontractors
- Developing upfront IPD standards and protocols still consumes a great deal of upfront time

St. Clare Health Center

- Designed and Built between 2005 and 2009
- Final Design Cost: $8,947,000 (+1.12% change from initial budget)
- Final Construction Cost: $148,300,000 (+5.18% change from initial budget)
- Procurement and Construction RFIs: 278
- No LEED / Sustainability Goals

Key Elements of the Case Study:

- Core team consisting of the owner, architect, engineers and builder was already established prior to the start of the project
- Owner's program manager attempted to establish a GMP at the beginning of the project but was overruled by the architect and builder
- No GMP was ever established, but books were keep 100% open and audited
- Implemented a "No-Sue" clause

Major Lessons Learned:

- Owner must work together with the architect and constructor to develop budgets. Budgets created by the owner will encounter resistance when they are attempted to be implemented for actual GMP estimates.
- Intense efforts required by designers upfront but the time spent reviewing submittals and answering RFIs is almost eliminated
- No defined bidding or negotiating phase which allows this time to be spent pushing the project forward

Encircle Health Ambulatory Care Center

- Designed and constructed between 2006 and 2009
- Final Design Cost: $3,185,917 (+19.87% from initial budget)
- Final Construction Cost: $35,408,131 (+3.85% from initial budget)
- Procurement and Construction RFIs: 0
- LEED Gold Achieved (Initially designed for LEED Silver)

Key Elements of the Case Study:

- Core team established early. Selection based on fee proposals and experience of committed personnel within the architect, engineering and construction firms.
- Architect and constructor contracted on a time-and-materials system. Anticipated profits would be distributed based on project results.
- Overall budget fixed, but allowed to move money between subcontractor trades
- Unit costs given to the architect early which allowed for improved design decisions when adding or eliminating certain materials or finishes

Major Lessons Learned:

- Integrate more major field foremen into the entire process
- Extremely blurry line between design refinement, scope change, and contingency item. Better definitions are needed for future projects
- When discrepancies arose regarding who should pay for certain elements, they were resolved with simple discussion and never escalated to major conflict.
- Certain building components where being constructed at such an expedited pace that most stakeholders could not keep up with. Some elements were still being sketched while other parts were being constructed in the field.
- Trent Jezwinski (Boldt Construction's Project Manager, 23 years of experience) – "I've never had a job run this smooth. The interactive scheduling process showed you the logic of where everything had to go. If you have partners who are willing to ***change culturally*** then this process could work anywhere."

Cardinal Glennon Children's Hospital Expansion

- Designed and constructed between October 2004 and August 2007
- Final Design Cost: Cost information not supplied
- Final Construction Cost: $45,572,449 (-3.04% from initial budget)
- Procurement and Construction RFIs: 0
- No LEED / Sustainability Goals

Key Elements of the Case Study:

- First IPD experience for the owner, architect, MEP engineer and construction manager – a four way contract was implemented, each party held accountable for the other parties as equal partners
- The IPD contract was established after a traditional contract was established. The IPD contract was in effect at about the 50% design development phase.
- An Integrated Form of Agreement (IFOA) was established based on the model developed from the Sutter Health Fairfield Medical Office Building project
- Financial incentives were utilized which resulted in approximately $400,000 of savings dispersed to the owner, design team and constructor
- All books were 100% open
- A "No-Sue" clause was not implemented
- BIM was not utilized, coordination was done using experienced field personnel and light tables

Major Lessons Learned:

- The owner felt that IPD contracts dictate behavior to much through its "relational" verbiage
- Challenges were address with effective open, transparent and cooperative management
- The architect and engineers were more involved during the construction process allowing for quick responses when field clashes occurred, the building was occupied six weeks week earlier than planned
- The owner has decided to mandate the use of BIM for every future project

6.7 Detailed Preconstruction Timeline

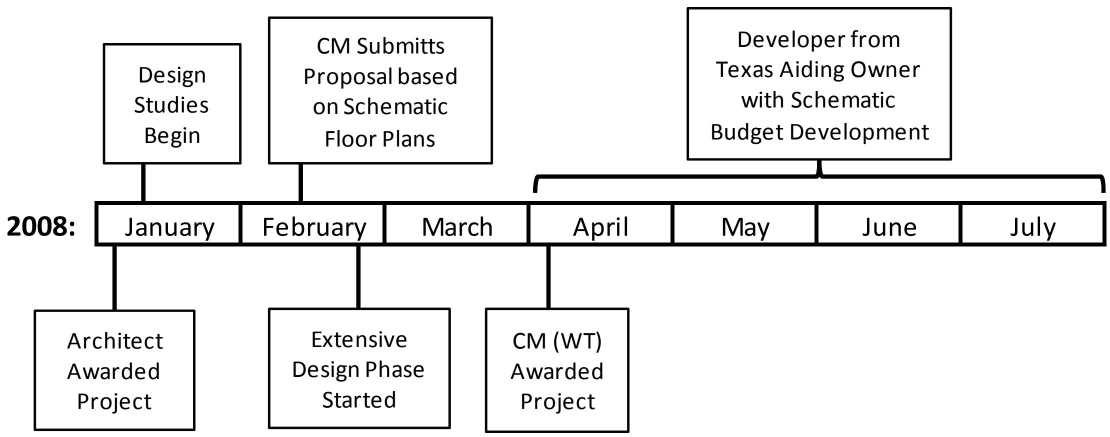
January –December 2008

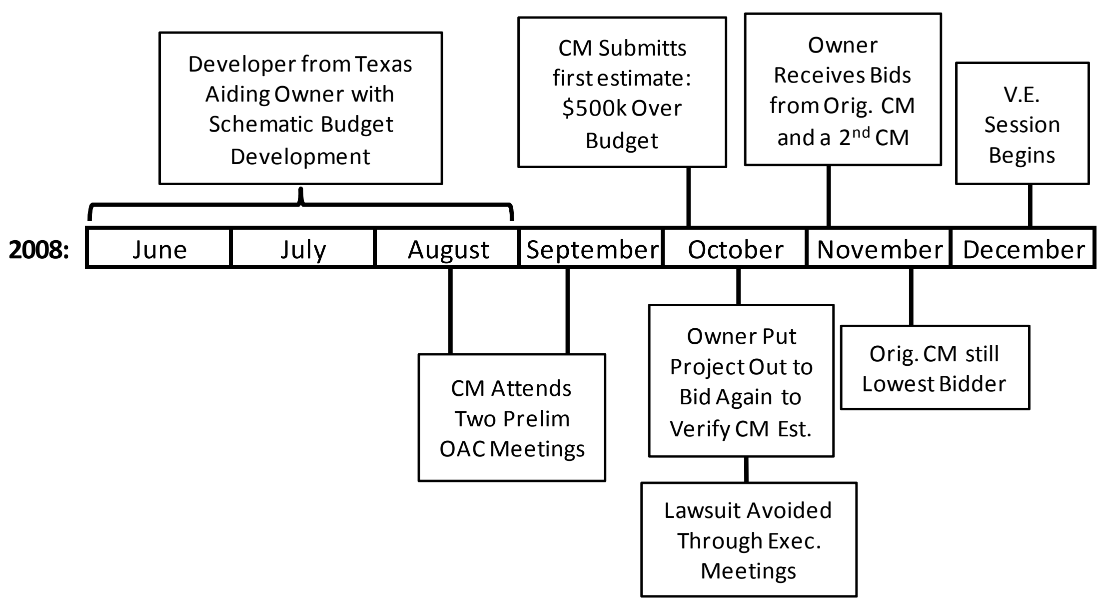
Year:

2000: Rydal Park Established Need for Campus Improvements

2001: Rydal Park Begins to assess needs for a new medical facility

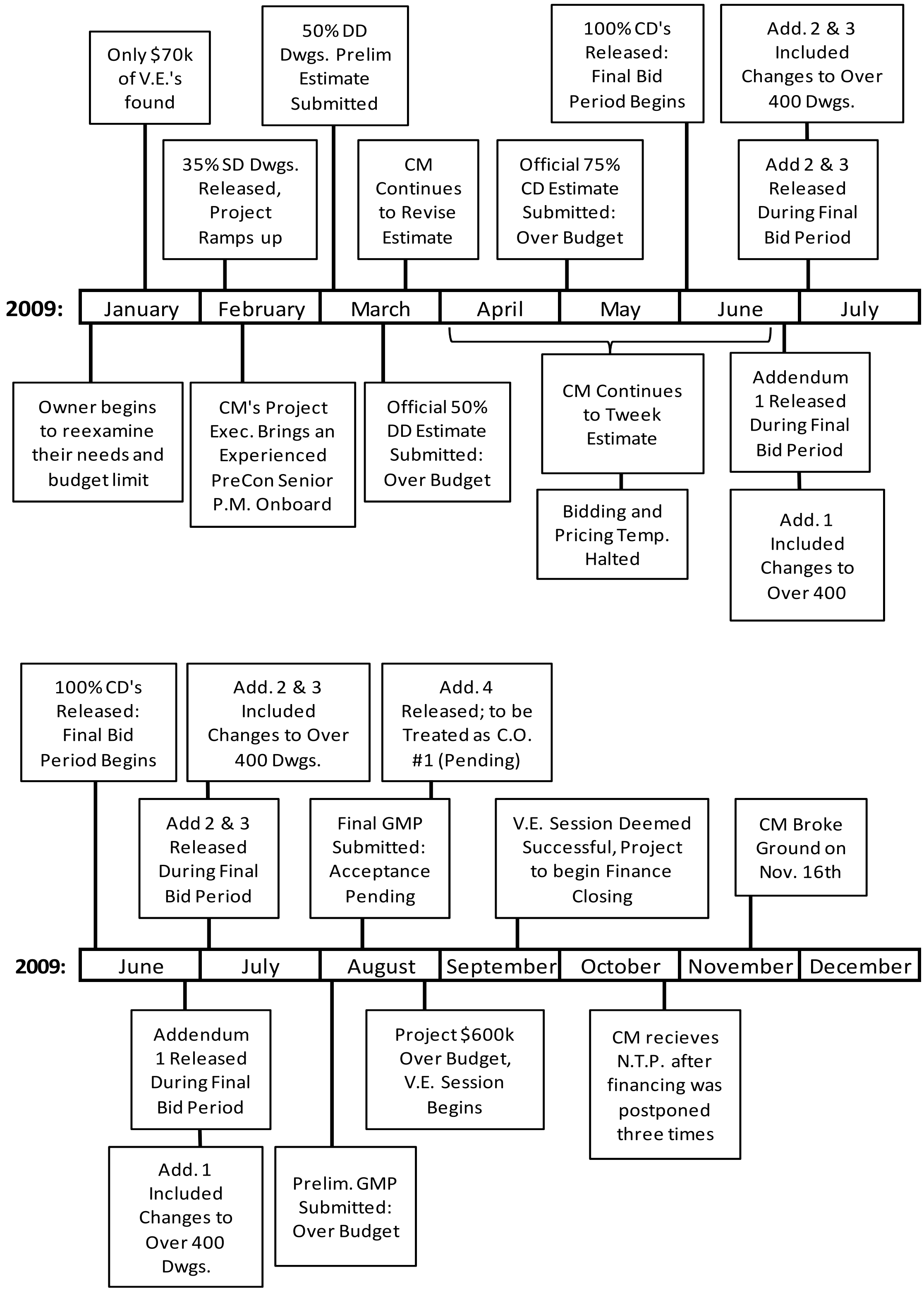
2007: Owner initiates discussions with the Architect





[Figure 13. January – December 2008 Preconstruction Timeline**]**

January – December 2009



[Figure 14. January – December 2009 Preconstruction Timeline**]**

6.8 IPD Execution and the Rydal Park Medical Center Addition

Successful Elements (seen in the case studies)	Comments Regarding the Medical Center Addition Project Team
Early development of conservative budget	Presby's Inspired Life should have purchased an extensive and in depth feasibility study from Greenbrier Development. Final financing was hanging on items that were .002% of the overall cost of the entire project.
Early selection of project team	Presby's brought a core group together early, but they never worked together until the 6 months prior to construction, subs were not contracted until that specific trade was needed.
Core team working together to establish the GMP	Between the architect and construction manager, contingencies were increasing due to the decreasing level of trust between all parties
Addressing challenges with effective, open, transparent and cooperative management	Finger pointing was widespread at all levels of this project, individual parties were not taking responsibility issues generated by their firm and were not offering solutions
100% open books	Only after the CM received a subs bid and reviewed it was a lump sum value shown to the owner. If the owner wanted to see the exact number submitted, an alternate fee structure would be required.
Distance vs. face to face communication	The core team only met/meets face to face once a month. People are more likely to lie or avoid questions when they are in their office and on the phone.
Utilizing BIM	BIM was not used on this project. This must start with the core team deciding to utilize. 2D coordination was the primary method
Implement "No-Sue" Clause / Indemnification Clause	This would have fostered a more open forum during meetings since litigation would be almost eliminated. Each party should be responsible for all other parties within the core team.
Bring subcontractors on early	The CM could not commit to subcontractors because the owners cash flow was not confirmed until the start of construction.
Mutual respect within the core team	Stigma still exists today where the owner, architect or developer still view a Construction Manager as just a builder or contractor, trying to cheat the owner out money.
Owner Involvement	Presby's Inspired Life wanted to be kept in the loop, but didn't want to make important decisions. Owner needs to decide whether to be involved (decision making) or not (give power to an agent).
Risk Allocation	All parties must take part in accepting risk. If 100% open books are used, the CM cannot and should not be the only party accepting risk. Each participant should is responsible for the project success.
Trust Building	Presby's Inspired Life lost WT's trust when they attempted to put the project out to bid a second time after they already contractually committed to WT as the CM.

[**Table 09**. Successful IPD Elements with Commentary Regarding the Rydal Park OAC Project

IPD Execution Guide - Steps to be taken for future projects:

1. **Owner Involvement:** Owner must determine their level of involvement. They must assses, manage and adhere to this decision appropriately. Decide if it is appropriate to hire an agent or developer.

2. **Budget Estimate:** Owner must establish a conservative budget. Purchase a feasibility study if necessary. Determine if this project is viable, if this project cannot commence because of an increase of 3-5% of the project cost, then it may be prudent to wait until more funds can be accumulated.

3. **Core Team**: The owner must assemble the architect, construction manager, engineers and agent or developer (if needed). Build a team that can easily meet location-wise. Building a team where everyone has to fly just to have a meeting will result in slow and delayed communication lines. The construction manager must introduce the superintendent to the project earlier than in a traditional delivery. The superintendent is the key element in fostering construction progress in the field.

4. **Contracting:** Establish “No-Sue” and indemnification elements within the contract. Clarify how project savings will be distributed and determine how risk will be allocated. The architect will only receive their portion of savings or profit when the CM is successful and vice versa. New fee structures should be utilized for payment methods for the participants in the core team (i.e. not just a percentage of the work).

5. **Establish Project Team Norms:** Allow challenges to be discussed in an open, transparent and cooperative environment. Mutual respect must be established within the core team. Do not permit finger pointing to occur, determine the underlying cause of an issue and resolve it immediately. Both new and experienced personnel must remain rational when something does not go as expected; this delivery style is new territory for all participating professionals. Communication methodology is well established and defined.

6. **100% Open Books:** The core team will develop the GMP, not just the construction manager. The construction manager will vocalize their experience and explain their knowledge regarding the interaction with bidders. After a GMP is established allow for reallocation of funds to other trades if savings are realized within another trade. If these saving do not need to be put back into the project, then they can be added to the shared savings among core team. This step inherently creates the need for implementing an alternate fee structure (as seen with step 4. Contracting).

7. **Designers and Prime Constructor (During design phases):** Design must be continually kept up to date, and the constructor must continually provide cost feedback and schedule impacts. Constructor must begin introducing the project to potential subcontractors, especially major system trades. Bringing the subcontractors onboard early will allow for early prefabrication.

8. **BIM Execution:** A software platform should be agreed upon and utilized for use with BIM. BIM must extend beyond a 3D model and include cost, schedule, specification details, supplier information, etc. BIM should also be a key element during the coordination process considering its visualization effectiveness.

9. **Meetings:** Face-to-face weekly meetings are essential to a well informed project team. All parties must know what progress the team has made. These meetings must continue during every phase of the project. Face-to-face meetings will help reinforce the established project team norms. Integrate key field foremen into scheduling meetings. They can provide quick answers and are the best people at gauging schedule and cost impacts.

10. **Drawing and Specification Addenda:** Properly manage the release of new and/or updated drawings/specifications. Clearly outline where the changes or updated occurred. Manage cost and schedule impacts with the information available, the core team must agree with decisions made. Keep subcontractors aware when addenda are released, don't keep it from them until the last minute.

11. **Designers and Prime Constructor (During construction phase):** Construction manager must keep the core team up to date with construction progress. The design team must be ready to clarify issues that arise in the field. Since IPD contracting language minimizes the potential for litigation, the use of RFIs should be minimized to difficult clarifications.

12. **Closeout:** Project success is determined by how close the final delivery is to the schedule and budget. All project participants should feel ready to work with each other again and on excellent business terms. The BIM model should be delivered to the owner which contains more information then they will ever need and it accurately reflects the as-built nature of the facility.

6.9 Conclusion and Final Thoughts

During the 2009 Pace roundtable event, the question was asked, "what exactly is integrated project delivery?" All the industry participants present really did not know how to give a specific answer. The one answer that will always be remembered was, "I thought IPD was just another name for a successful design-build project." This answer was were a personal interest in IPD began because after thinking about it, why can't the elements that enhance collaboration in design-built projects be applied to traditional methods of delivery? This research has broadened my personal understanding of integrated project delivery, and hopefully will allow others interested in IPD to learn about it.

Ideally many of the characteristics that define integrated project delivery should be implemented regardless of the contract type with clauses dictating how to manage. The traditional method of design-bid-built worked extremely well during the early to mid 20th century, when considering the norms of that period. Today, architects and engineers are creating more and more complex building designs which requires the people managing the construction to update their norms, procedures, and delivery methods. Considering the increasing complexity of these building designs, the experience and input of all project participants is required earlier within the design phase, and not just during the construction phase. Most of the case studies presented within this section, have indicated that RFIs and change orders are significantly reduced because subcontractors are able to become more familiar with the project during the design development.

Today, all of the professionals within the AEC industry must learn to work together during each phase and end the individual fragmentized linear design process. A large amount of time and effort is wasted with redesigning when using the linear process. It is my personal recommendation that all of the parties involved in the Medical Center Addition OAC project team achieving an environment where many of the suggestions noted above become inherent. For some of the participants this goal may require increased effort considering their business models. Both Presby's Inspired Life and Greenbrier Development have a model where maximizing profit is idealized. Understandably this is what U.S. business and capitalism encompasses, but maximizing profit can still be achieved when transparent management and cooperation incorporated is into business models.

Final Recommendation

Presby's Inspired Life should reassess their business model and what originally generated the need for a new medical center. Far too often, this project was hanging on design elements that where a tiny fraction of the overall cost of the project. When this occurs, time is wasted at all project levels with subcontractors who are constantly resubmitting pricing as designers are readjusting their designs. Presby's Inspired Life does not have the extensive experience required to fully participate in the design and construction process. Greenbrier Developers, even though they are the premier retirement community development company, is located in Texas which is too far to deliver the required management input. Presby's Inspired Life must also learn to bring everyone together on the project. Too much time was spent with each project participant off in their own corner when collaboration was the necessary element. When each project firm is off working alone, the development of OAC project team trust is extremely hinders. On that note of trust, Presby's compromised their trust when they attempted to put the project out to bid a second time, after they contractually committed to Whiting-Turner as the construction manager.

In the future, Presby's Inspired Life must learn to make the tough decisions, properly communicate the plan and adhere to what they've committed to. Presby's should also begin to educate themselves on IPD if they wish to stay a part of the project team, otherwise they should hire an properly identified construction agent. Finally, Presby's needs to acknowledge that generating capitol cannot be the only goal in mind. Profits should be one of the primary goals, but to effectively manage, there are other key elements that need to be bundled into the overall goal.

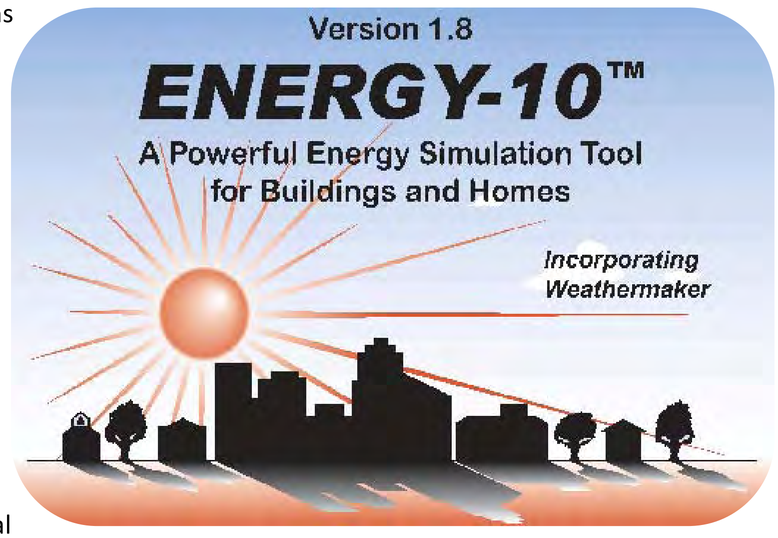
Whiting-Turner was placed in a very strange position with this project. Whiting-Turner is always striving to build their client base and this project was the first time that WT worked together with Presby's Inspired Life. Jack DaSilva, WT's project executive, saw this project as an opportunity to grow that client base. Several members within the Whiting-Turner staff did a good job at maintaining positive relationships with the entire project team, while others could have displayed more professionalism. With that said, it was difficult for WT to maintain a positive relationship with Presby's given the amount of times that trust was compromised. In the future WT should begin implementing successful relational elements of integrated project delivery practices into their standard methods. At the same time, they should be attempting to persuade potential clients to contract utilizing IPD. The biggest effort here is for WT's executive to educate owners regarding integrated project delivery and how it can improve the outcome of a building delivery. IPD is going to become the most commonly utilized delivery style if the AEC industry has any hope of closing that efficiency gap that exists in today's market.

7.0 HVAC Energy Consumption and Life Cycle Analysis

7.1 Problem Introduction– Mechanical Breadth Study

This medical center addition will be part of a large campus and is a building that the owner will be occupying for an indefinite period of time. Considering this, it is important to implement systems that are efficient over the lifetime of the building. Mechanical systems should not be simply selected due to low upfront costs, but should be properly researched so that they last and return the best savings over the 50+ years of the building's existence. This research focuses on examining how efficient the selected four pipe air/water HVAC system is within the Medical Center Addition. Once an alternate HVAC system is selected, the life cycle benefits of this system will be outlined and discussed.

7.2 Background



More than often, major building systems are selected solely on upfront cost without even considering the lifecycle costs. This can result with a building that was initially relatively inexpensive to build but becomes a maintenance nightmare requiring the installation of new and expensive components to keep the building operating. Energy-10 is a conceptual design tool which helps designers uncover methods to create low-energy buildings. The software analyzes a building by performing hour by hour simulation for an entire typical year for a given regional location. Going beyond just temperature, Energy-10 can also analyze day lighting, passive solar effects and low-energy cooling strategies within the simulations.

The Department of Energy released a report in 2002 titled, "Energy Consumption Characteristics of Commercial Building HVAC Systems Volume III: Energy Savings Potential". The following table, pulled from this report, presents some important information regarding the energy consumption of certain mechanical components.

Component	Total Energy Use (Quads)	Percent
Rotary Screw Chillers	0.037	2.7%
Reciprocating Chillers	0.17	12.4%
Absorption Chillers	0.022	1.7%
Centrifugal Chillers	0.19	13.7%
Heat Pump	0.092	6.8%
PTAC	0.038	2.8%
Unitary A/C (Rooftops)	0.74	55.%
RACs	0.074	5.5%
Totals	1.4	100%

[**Table *10***. Commercial Building Cooling Primary Energy Consumption Breakdown]

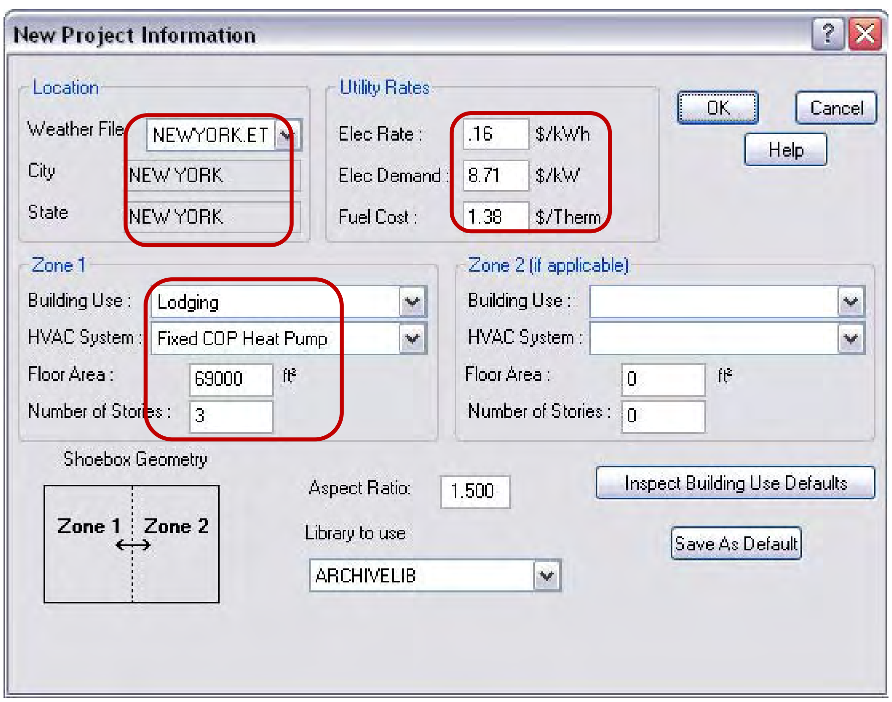
7.3 Research Goal

This research will explore alternate mechanical systems through energy efficiency and life cycle costs. The alternate mechanical system will be selected at an efficiency basis; therefore research will uncover which mechanical system will be most efficient for this building type within the Philadelphia region. This section will conclude with a life cycle cost investigation. A LEED v 3.0 scorecard can be found within the appendix.

Through this analysis, it is expected to discover an HVAC system that will provide a better life cycle solution to the cooling, heating and air handing demands of this facility. The main criteria for this selection is to increase building efficiency, which means the upfront cost may increase but may improve the overall life cycle expenditures. The life cycle cost analysis should demonstrate that the purchase of an efficient system, possibly with a higher upfront cost, will ultimately result in lower bills and maintenance fees during a 50 year period. It is also expected that with the development of a sip schedule, that schedule acceleration can easily occur as the resident rooms are built.

7.4 Research Process

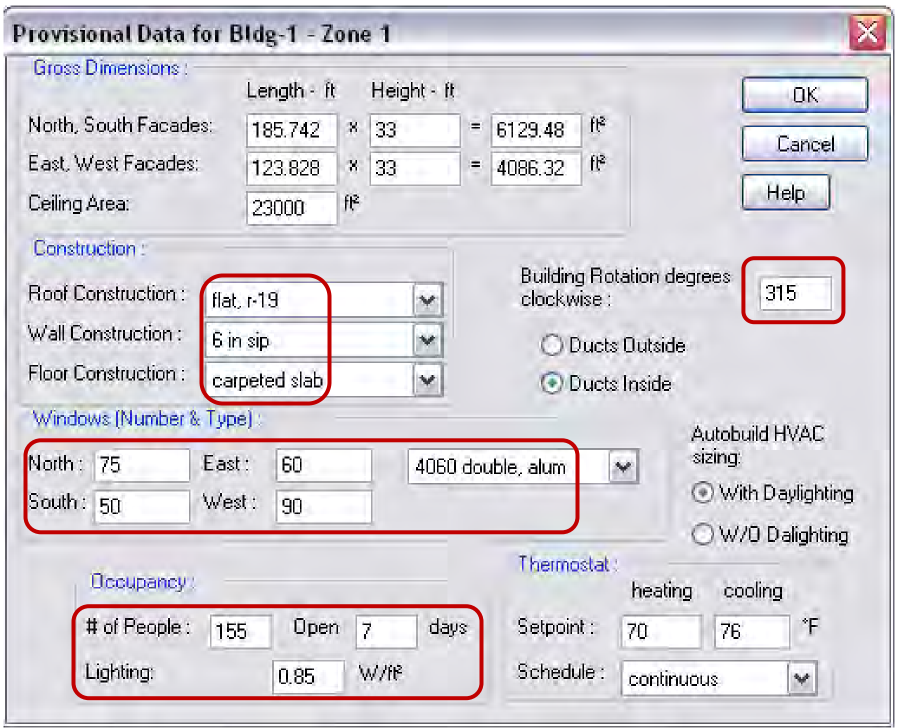
In order to create a baseline for which to analyze an alternate mechanical system, Energy 10 was used to model the building as it has been currently designed. The following images show the information that was utilized to create this benchmark model. After this baseline model was created all other heating and cooling HVAC systems that were available to selected were analyzed within this building.



[*Figure 15*. Energy 10 Input Box #1, Baseline Model]

The closest location to Philadelphia that Energy 10 had information for was New York City, which for purposes of a rough order magnitude model is close enough that the error will be minimal. The three highlighted utility rates were obtained by from PECO's (Philadelphia Electric Company) recently released Energy Rates Memorandum which came out in January 2010. The fuel cost will not be utilized for this research since the fixed COP heat pump and the selected alternate HVAC system do not directly use natural gas for heating. For Building Use, this medical center addition is best described as a lodging facility rather than a hospital. Regardless, building use is limited to assembly, education, grocery, lodging, mercantile, office residential, restaurant and warehouse. The HVAC system selection was also limited to certain combinations of direct-expansion (DX), baseboard heating, furnaces, packaged terminal air conditioner (PTAC), variable air volume (VAV) and fixed coefficient of performance (COP) heat pump. The Fixed COP heat pump best matched the air-water system that has been designed for this medical center addition. Energy 10 defines the Fixed COP system as a "system that approximates a water-to-air heat pump with a reversing valve for either heating or cooling. The electric resistance (ER) backup operates when the compressor cannot meet the load. This implementation fixes the heating and cooling COP to a constant value and disables the defrost submodel of the underlying air-to-air heat pump." The floor area and number of stories is limited to the top three floors of the building which is where the conditioned space is located, the bottom two (parking garage) were neglected for this model.

The second dialog box narrows the building specifications even further by collecting more information regarding the walls, roof, floor and glazing. The façades areas are approximated in a rectangular fashion. Some error will be introduced into this model due to this modeling limitation, given that the actual building footprint is shaped like a Z. A standard flat built-up roof was selected with an R-Value of 19. The closest matching wall type was a six inch structurally insulated panel which contains stucco EFIS and steel studs. Since this building is a post-tensioned concrete structure, all the floors will be carpeted concrete slabs. The listed window numbers are roughly estimated provided that only one window type can be selected. Any large areas of storefront glazing was taken off as a large area and converted into multiples of 4060 double hung aluminum windows. The double hung aluminum window, rather than storefront, was selected because it was the most prevalent window type located around the building. An occupancy of 115 was assumed considering the 115 room facility (only one person per resident room) and an additional 40 people included representing staff, nurses and visitors. The building project north is orientated 315 degrees counterclockwise from magnetic north, which allows the software to properly implement passive solar simulations. After this base case model was established, all other applicable HVAC systems offered by this program were analyzed. This resulted with nine scenarios, where the only variable item was the HVAC system.

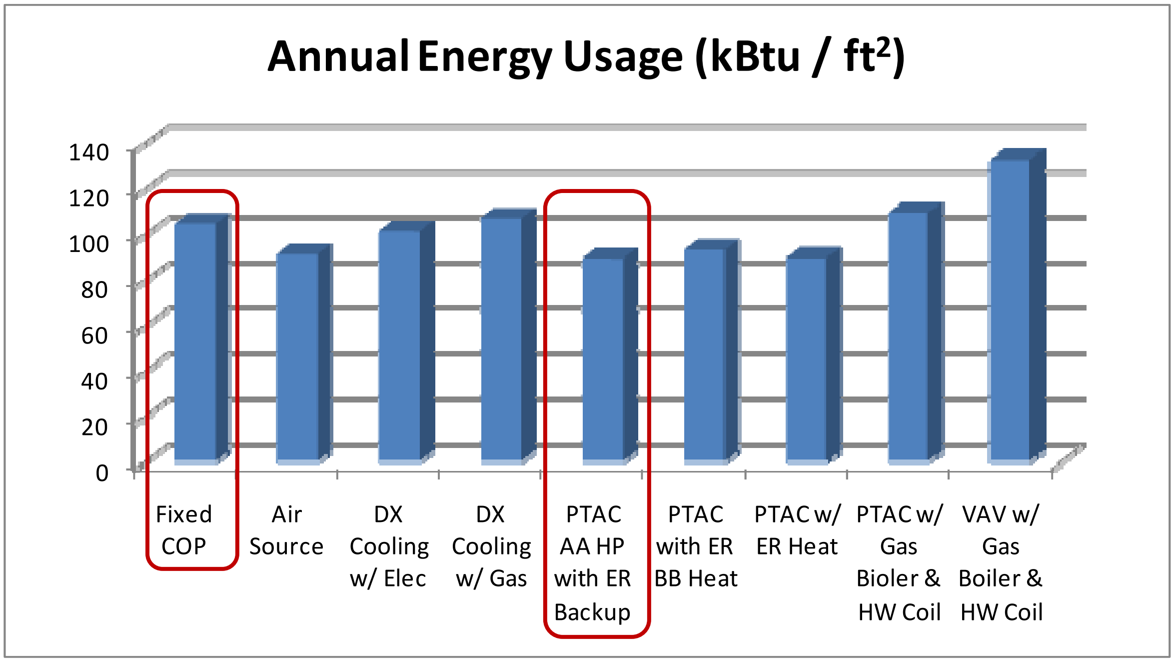


[*Figure 16*. Energy 10 Input Box #2, Baseline Model]

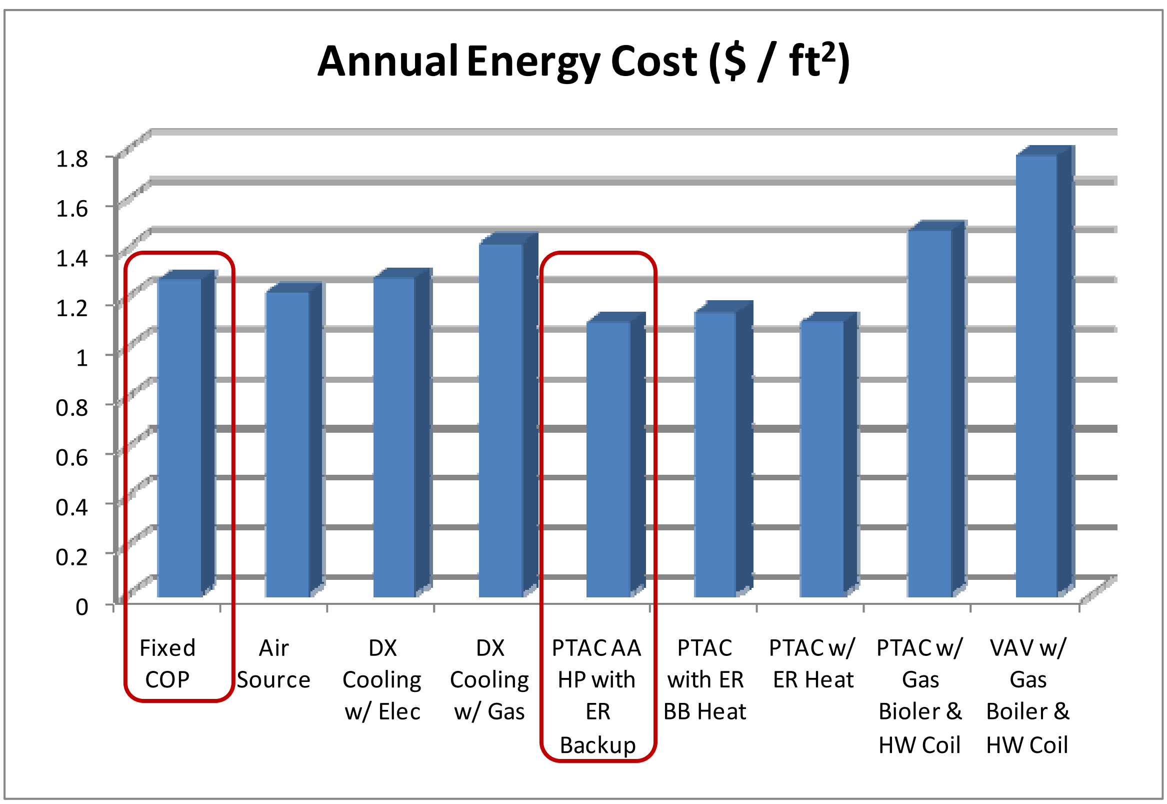
The table and charts on the following two pages shows the data recovered during this process. Upon review of this data, the most cost effective and least energy consuming system was selected. The column listed as Fixed COP represents the HVAC system currently utilized in this building. The system labeled as PTAC AA HP with ER Backup (Packaged Terminal Air Conditioner with an Air-Air Heat Pump with Electric Resistance Heating Backup) was the alternate system that was revealed to be energy efficient and cost effective.

Energy 10 HVAC Systems									
HVAC System:	Fixed COP	Air Source	DX Cooling w/ Elec	DX Cooling w/ Gas	PTAC AA HP with ER Backup	PTAC with ER BB Heat	PTAC w/ ER Heat	PTAC w/ Gas Bioler & HW Coil	VAV w/ Gas Boiler & HW Coil
Annual Energy Usage (kBtu / ft^2)									
Heating	4.2	6.1	10.4	17.3	0.7	0.7	0.8	24.6	39.6
Cooling	21	11	11	10.4	16	19	16	12	11.1
Lights	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
Other	66.3	66.8	66.7	66.3	59.5	30.1	59.5	59.6	68.8
Total	104.7	91.1	101.4	107.2	89.4	93.1	89.6	109.5	132.8
Annual Electric Use Breakdown (kWh / ft^2)									
Int Lights	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ext Lights	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Hot Water	10.3	10.3	10.3	N/A	10.3	10.3	10.3	N/A	N/A
Other	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Heating	1.2	1.8	3.1	N/A	0.2	0.2	0.2	N/A	N/A
Cooling	6.1	3.2	3.2	3	4.7	5.6	4.7	3.5	3.3
Fan	2.5	2.6	2.6	2.5	0.5	0.7	0.5	0.5	3.2
Total	30.6	28.4	29.7	16	26.2	27.3	26.2	14.5	17
Annual Energy Cost ($ / ft^2) - Utility Cost									
Fuel	N/A	N/A	N/A	0.725	N/A	N/A	N/A	0.826	1.033
kWh	0.828	0.768	0.802	0.432	0.708	0.737	0.709	0.393	0.458
Demand	0.44	0.448	0.474	0.259	0.392	0.403	0.392	0.247	0.278
Total	1.269	1.216	1.276	1.416	1.10	1.14	1.101	1.465	1.77
Annual Energy Cost Breakdown ($ / ft^2)									
Int Lights	0.129	0.133	0.134	0.135	0.131	0.13	0.131	0.137	0.135
Ext Lights	0.032	0.033	0.033	0.033	0.032	0.032	0.032	0.034	0.033
Hot Water	0.427	0.442	0.444	0.487	0.434	0.432	0.434	0.487	0.487
Other	0.273	0.283	0.284	0.285	0.277	0.276	0.277	0.291	0.287
Heating	0.051	0.076	0.131	0.238	0.008	0.009	0.01	0.339	0.547
Cooling	0.254	0.138	0.139	0.131	0.197	0.232	0.197	0.155	0.141
Fan	0.102	0.112	0.112	0.106	0.02	0.028	0.2	0.023	0.14
Total	1.268	1.217	1.277	1.415	1.099	1.139	1.281	1.466	1.77
HVAC Rated Capacities (kBtu / hr)									
Heating	1493	1402	1402	1496	795	674	798	1537	2846
Cooling	1823	1912	1912	1872	1321	2070	1321	1782	2070
Fan	50872	53796	53796	50872	49956	69000	49956	49946	69000
Total	54188	57110	57110	54240	52072	71744	52075	53265	73916
Performance Summary - Annual Energy Loads (kBtu / ft^2)									
Heating	1.9	1.2	1.2	1.9	1.3	1.4	1.3	1.9	1.9
Cooling	38.8	41.6	41.6	38.8	33.9	337	33.9	39.2	38.9
Lighting	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
Other	66.3	66.8	66.7	66.3	59.5	60.1	59.5	59.5	66.3
Total	120.3	122.9	122.8	120.3	108	411.8	108	113.9	120.4

[***Table 11***. Selective Energy 10 HVAC Systems Efficiencies, within the baseline model parameters]



[**Graph *01***. Energy 10 HVAC Systems (Annual Energy Usages), within the baseline model parameters]



[***Graph 02***. Energy 10 HVAC System (Annual Energy Costs), within the baseline model parameters]

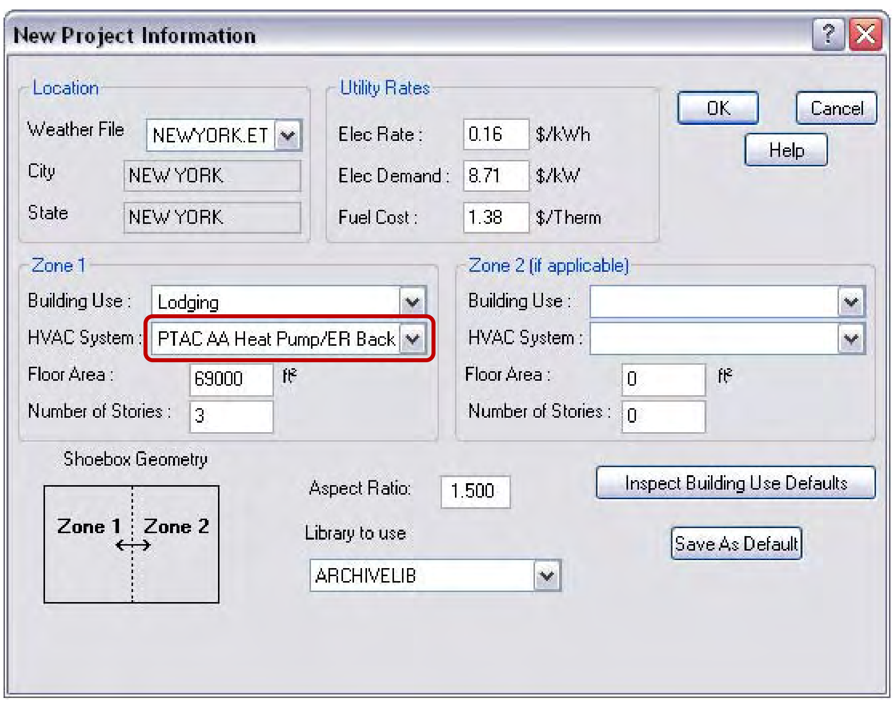
The results from the data collected coincides with information presented within the DOE report, motioned at the beginning of this section.

Application	Motor Size (HP)	Energy Consumed (Quads)	Energy Savings (%)	Energy Savings (Quads)	Simple Payback (Years)
Room Air Conditioner Blower	1/10 – 1/3	0.017	20%	0.0033	7.7
Packaged Terminal Air Conditioner Blower	1/10 – 1/4	0.010	33%	0.0033	2.6
Small Unitary Blowers	1/4 – 3/4	0.066	33%	0.022	N/A
Small Unitary Condenser Fan	1/4 - 1/2	0.026	33%	0.0088	N/A
Medium Unitary Blower	1 - 5	0.091	11%	0.01	N/A

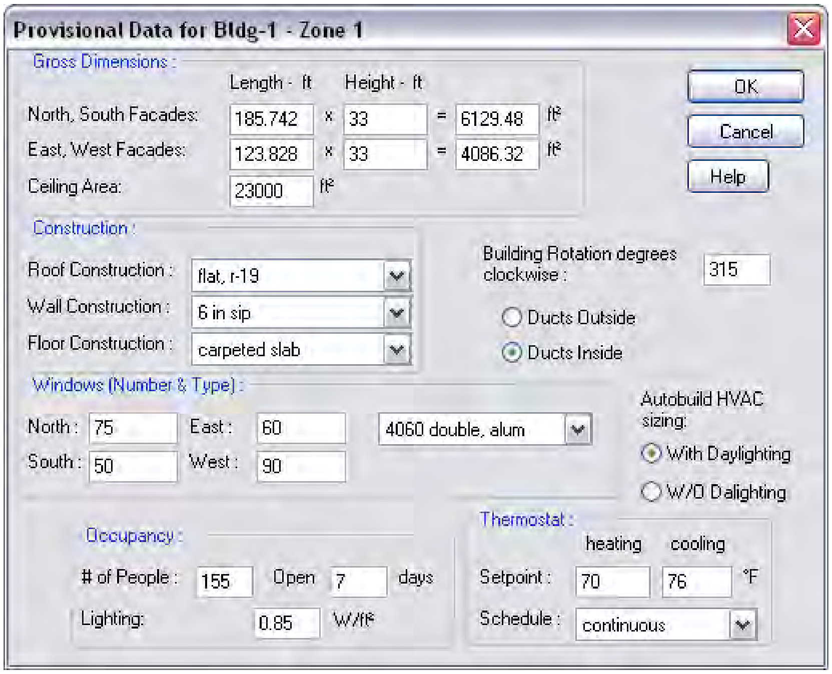
[*Table 12*. Fractional Horsepower DC Motor Energy Savings Potential in Commercial Buildings]

7.5 Research Results

Now that an alternative HVAC system has been pinpointed for use within this building, more specific data can be analyzed within those specific parameters. As highlighted below, the pinpointed alternate HVAC system type was updated for this scenario.

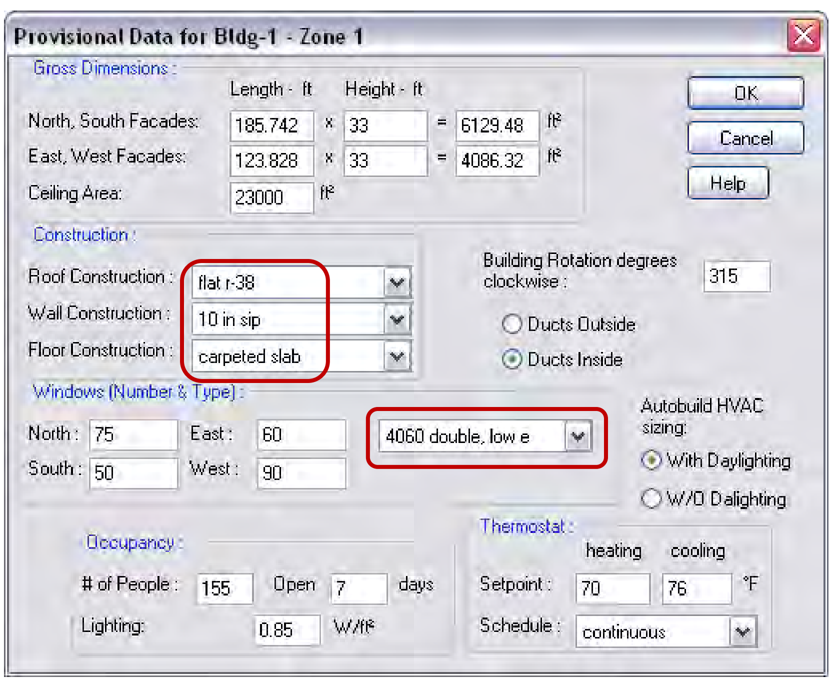


[*Figure 17*. Energy 10 Input Box #1, Alternate HVAC System Model]

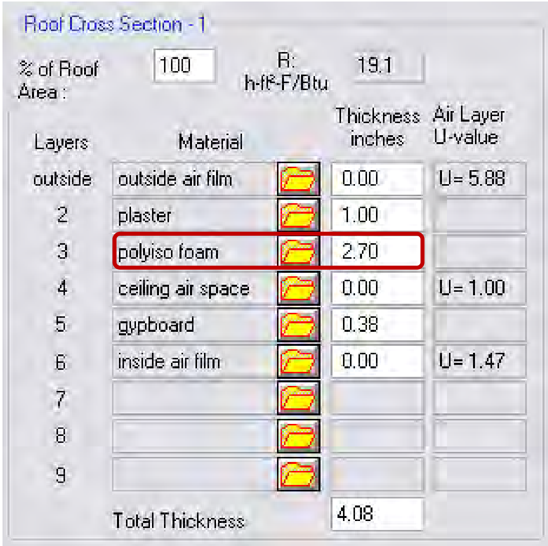


[*Figure 18*. Energy 10 Input Box #2, Alternate HVAC System Model]

In addition to just running an alternate HVAC system analysis, a low energy scenario was developed where the building utilized better roof and wall construction (improved R-Values) as well as low-e glazing. The updates can be seen below where the flat roof has an R-Value of 38, and the wall was increased from a six inch SIP to a ten inch SIP.



[*Figure 19*. Energy 10 Input Box #2, Alt. HVAC Sys. + Improved Constr. Model]

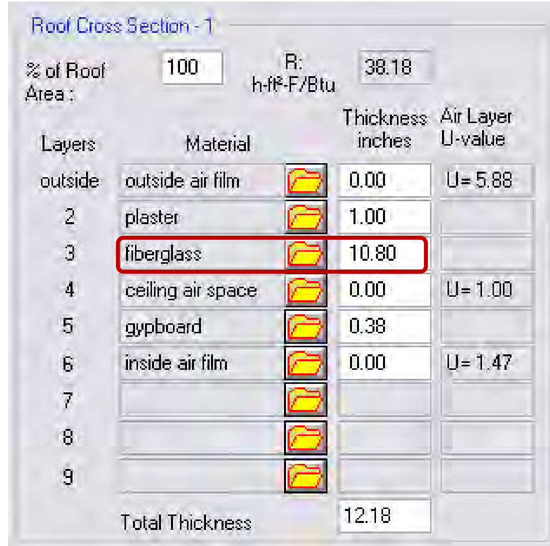


Roof Cross Section - 1

% of Roof Area: 100 R: h-ft²-F/Btu 19.1

Layers	Material	Thickness inches	Air Layer U-value
outside	outside air film	0.00	U= 5.88
2	plaster	1.00	
3	polyiso foam	2.70	
4	ceiling air space	0.00	U= 1.00
5	gypboard	0.38	
6	inside air film	0.00	U= 1.47
7			
8			
9			
	Total Thickness	4.08	

[*Figure 20*. Flat Roof (R19) Cross Section Info]



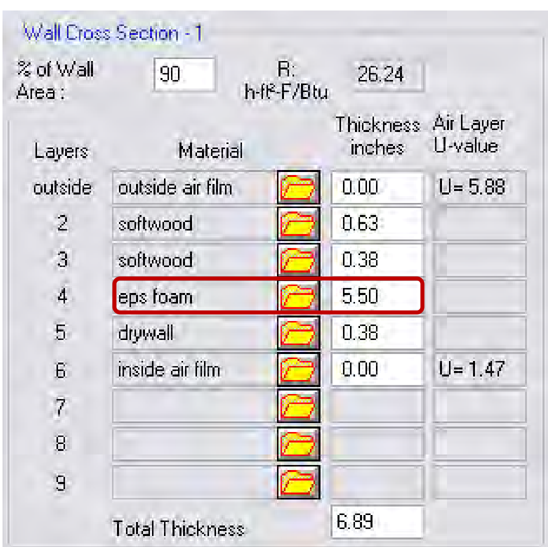
Roof Cross Section - 1

% of Roof Area: 100 R: h-ft²-F/Btu 38.18

Layers	Material	Thickness inches	Air Layer U-value
outside	outside air film	0.00	U= 5.88
2	plaster	1.00	
3	fiberglass	10.80	
4	ceiling air space	0.00	U= 1.00
5	gypboard	0.38	
6	inside air film	0.00	U= 1.47
7			
8			
9			
	Total Thickness	12.18	

[*Figure 21*. Flat Roof (R38) Cross Section Info]

The figures above show the materials used to develop the cross section of the roof type. The primary difference between these two roof types is the use of polyisocyanurate foam (rigid insulation) vs. the use of fiberglass. The R38 flat built-up roof utilizes an additional eight inches over the R19 roof which only utilizes four inches of thickness. With this additional space, the R38 roof can utilize batt fiberglass insulation rather than rigid insulation. The figures below show the cross sectional differences between the six inch SIP and the ten inch SIP. The primary difference between the two walls types is the thickness of the extruded polystyrene (eps) foam. The four inches of extra foam provides additional 17.4 (h ft^2 F°)/Btu to the overall R-value of the ten inch wall system.

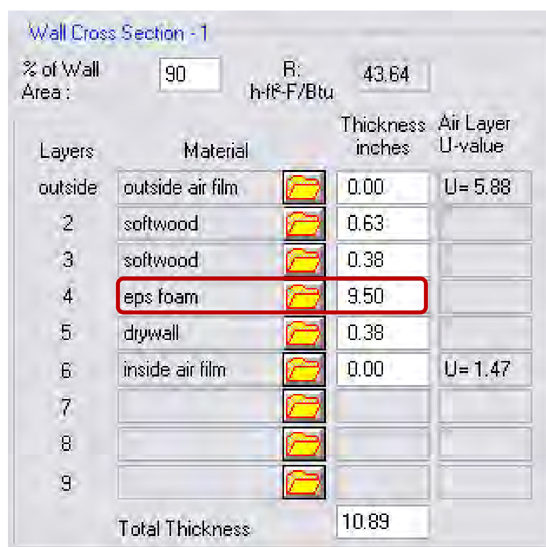


Wall Cross Section - 1

% of Wall Area: 90 R: h-ft²-F/Btu 26.24

Layers	Material	Thickness inches	Air Layer U-value
outside	outside air film	0.00	U= 5.88
2	softwood	0.63	
3	softwood	0.38	
4	eps foam	5.50	
5	drywall	0.38	
6	inside air film	0.00	U= 1.47
7			
8			
9			
	Total Thickness	6.89	

[*Figure 22*. 6 in SIP Cross Section Information]



Wall Cross Section - 1

% of Wall Area: 90 R: h-ft²-F/Btu 43.64

Layers	Material	Thickness inches	Air Layer U-value
outside	outside air film	0.00	U= 5.88
2	softwood	0.63	
3	softwood	0.38	
4	eps foam	9.50	
5	drywall	0.38	
6	inside air film	0.00	U= 1.47
7			
8			
9			
	Total Thickness	10.89	

[*Figure 23*. 10 in SIP Cross Section Information]

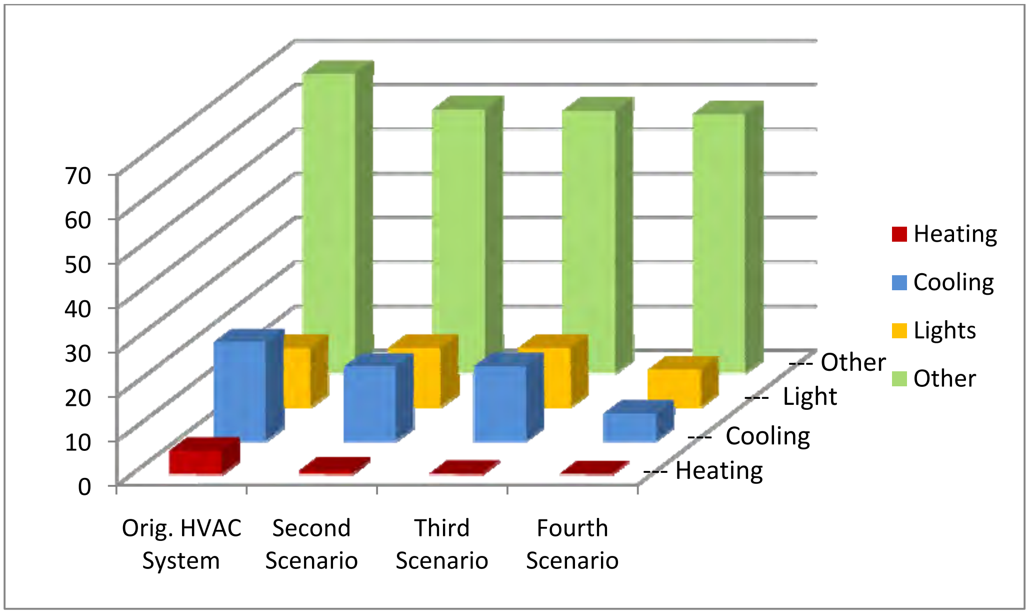
After all of the required simulations were developed and calculated, the data was processed and reviewed. Four total scenarios were developed during this entire process; 1. The Baseline Model (original HVAC system), 2. The Alternate HVAC System Scenario, 3. The Alternate HVAC System + Improved Envelope, and 4. The Alternate HVAC System + Energy 10's built in Low Energy Scenario. The following table presents a summary of the results found for these four different scenarios.

	Orig. HVAC System	Second Scenario	Third Scenario	Fourth Scenario
Annual Energy Use	kBTU / ft2			
Heating	5.3	0.8	0.1	0
Cooling	22.2	16.7	16.8	6.1
Lights	13.3	13.3	13.3	8.43
Other	67.6	59.6	59.3	58.5
Total	**108.4**	**90.4**	**89.5**	**73**
Utility Costs	$/ft2			
kWh	5.082	4.237	4.194	3.424
Demand	0.574	0.504	0.486	0.412
Total	**5.656**	**4.742**	**4.68**	**3.835**
Cost Breakdown	$/ft2			
Int Lights	0.555	0.558	0.557	0.336
Ext Lights	0.137	0.138	0.138	0.104
Hot Water	1.841	1.851	1.845	1.852
Other	1.177	1.184	1.18	1.85
Heating	0.278	0.04	0.005	0
Cooling	1.157	0.877	0.88	0.322
Fan	0.511	0.094	0.074	0.036
Total	**5.656**	**4.742**	**4.679**	**4.5**
Elec. Use Breakdown	kWh/ft2			
Int Lights	3.1	3.1	3.1	1.9
Ext Lights	0.8	0.8	0.8	0.6
Hot Water	10.3	10.3	10.3	10.3
Other	6.6	6.6	6.6	6.6
Heating	1.6	0.2	0.01	0
Cooling	6.5	4.9	4.9	1.8
Fan	2.9	0.5	0.4	0.2
Total	**31.8**	**26.4**	**26.11**	**21.4**

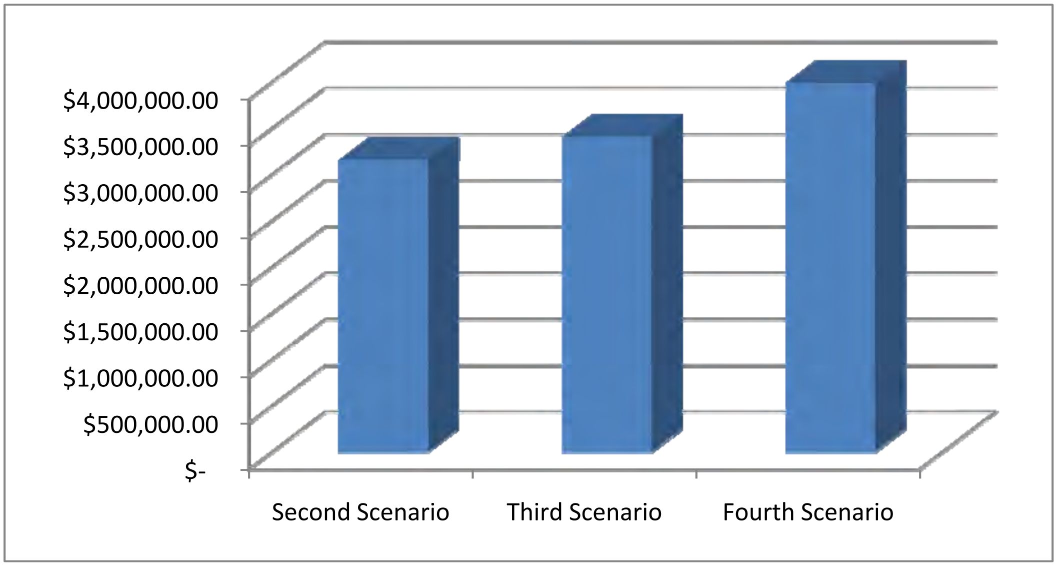
[***Table 13***. Summary of HVAC Scenarios in Energy 10]

The table above illustrates that there exist significant benefits when going from the original HVAC system to scenario two. On the other hand, going from the scenario two to scenario three, the benefits from improving the building envelopes (increased R-values) are minimal. Finally, significant benefits are seen when going to scenario four, which involves the incorporation of a photovoltaic façade, implementing natural ventilation techniques and many other sustainable methods that are beyond the scope of this analysis. The fourth scenario was included to illustrate the benefits of incorporating sustainable methods into the schematic design of the building. These sustainable alterations to the building design are also far too extensive to properly quantify. Information collected from the fourth scenario simply reinforces the concept that energy efficient building designs must utilize passive solar, natural ventilation and other sustainable techniques to truly cut back on energy consumption and utility costs.

One of the primary areas where energy is conserved with the PTAC system is the method for heating. Heat is produced within the room that needs to be heated rather than running loops of heated water where energy has to potential to dissipate. There is also a significant benefit with the reduction of energy consumed for cooling as well. The fourth scenario illustrates how much cooling can be eliminated when the proper building orientation, glazing materials, passive solar, and natural ventilation techniques are utilized within a building's design.



[***Graph 03***. Consumption of kBTUs / square foot]



[***Graph 04***. Potential Savings (dollars) Over Fifty Years Period]

7.6 Cost and Schedule Impacts

Cost Impacts

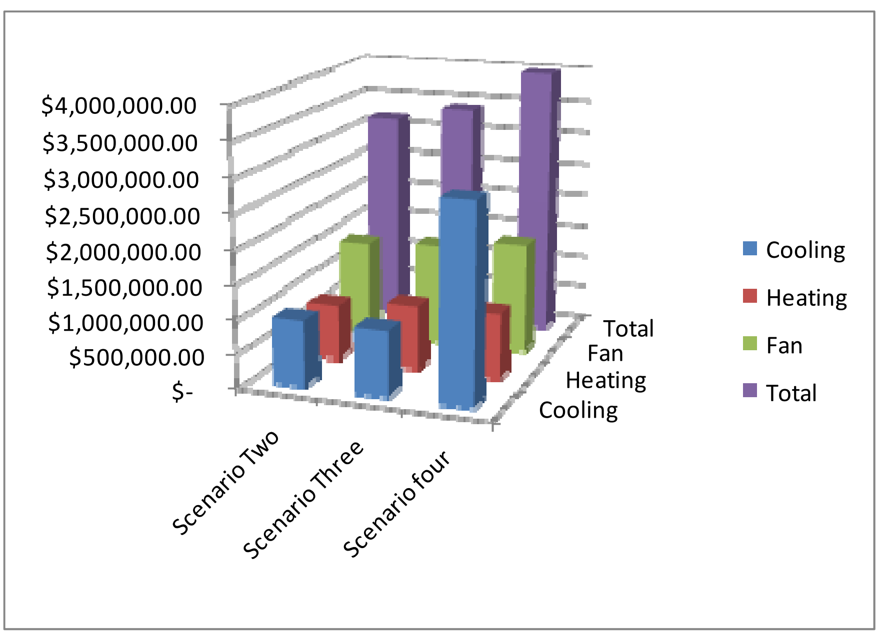
Along with the potential energy savings that exist with switching to the PTAC system, there are also upfront costs benefits. If the four pipe air-water system was changed to a 300 unit PTAC system, a difference of $7.57 per square foot or $529,900 savings could be achieved for the upfront estimate. Along with the upfront cost savings, a simple fifty year estimate shows a present worth of $3,153,300 in savings resulting from reducing energy consumption from cooling, heating and ventilation sources. **Note:** the total value in the last row of Table 15 does not include the electrical cost savings resulting from altering the interior/exterior lighting, hot water pumps, and other items that were previously included in the Energy 10 data results, as these elements are not involved in this research scope.

Original HVAC System		
Installation	$16.35/sf	$ 1,144,500.00
Materials	$11.50/sf	$ 805,000.00
Total	$27.85/sf	$ 1,949,500.00
PTAC with ER Heat Backup		
Installation	$15.85/sf	$ 1,109,500.00
Materials	$4.43/sf	$ 310,100.00
Total	$20.28/sf	$ 1,419,600.00
Difference		
Installation	$0.50/sf	$ 35,000.00
Materials	$7.07/sf	$ 494,900.00
Total	$7.57/sf	$ 529,900.00

[*Table 14*. Summary of HVAC Material and Installation Costs]

Equipment Cost Breakdown			
	Scenario Two	Scenario Three	Scenario four
Cooling	$ 966,000.00	$ 955,650.00	$ 2,880,750.00
Heating	$ 821,100.00	$ 941,850.00	$ 959,100.00
Fan	$ 1,438,650.00	$ 1,507,650.00	$ 1,638,750.00
Total	$ 3,153,300.00	$ 3,370,650.00	$ 3,988,200.00

[*Table 15*. Electricity Cost Savings by Scenario over a Fifty Years Period]



[*Graph 05*. Electricity Cost Savings Compared to Scenario One, over a Fifty Year Period]

Cost Impacts (Continued)

Along with the benefits mentioned above, there will be savings when the amount mechanical equipment is reduced. Currently most of the primary mechanical equipment is located on the second and third floors taking up valuable space. At least one of the two mechanical rooms could be eliminated on the second and third floor which would open up space for an additional resident room, or enlarged office space for the nurses and management staff. If two additional resident rooms were added to this facility, where the average cost of living at this facility is $2500 a month, Presby's Inspired Life could see approximately three million dollars in additional revenue over a fifty year period.

Schedule Impacts

Installing a packaged terminal air conditioning system would allow the elimination of most of the ductwork within the building. On the detailed schedule, ductwork on every floor is a critical element lasting approximately 22 days. Eliminating ductwork could save the project roughly two months if the interior schedule was rearranged, capitalizing on this alteration. If ductwork was eliminated as a critical activity, other items such as electrical, plumbing and gypsum wallboard could be installed soon after the framing completed rather than waiting for the installation of ductwork to finish.

Through the elimination of ductwork, valuable plenum space is opened up providing more space for the plumbing, electrical and sprinkler contractors. This outcome is extremely beneficial considering the extremely low floor-to-floor heights that this building must adhere to. This will reduce the difficulty of installation, provided they will not have to accommodate pipe runs around bulky ductwork. Also, considering that a majority of field classes occur with ductwork, the frequency of field classes will be decreased. If contractors capitalize on increased plenum space (reduced clashes), they will save float time that was imbedded into their construction schedules. Since this float duration is confidential to the subcontractor, it is difficult to quantify this element.

A third schedule related benefit with the use of a PTAC system is that procurement of the large air handling units (AHUs) is eliminated. Since PTAC room units are smaller and easily sized for rooms, they can be ordered and delivered in a relatively short period of time. If the large AHUs are eliminated, the complex sequencing of delivery during the concrete structure construction is also abolished. All in all, much of the difficulties associated with air handling units are removed from the schedule if PTAC units were utilized.

7.7 Conclusion and Final Thoughts

The results discovered from the Energy 10 scenarios indicate that this medical center addition would be best served if an alternate and less extensive HVAC system were implemented. Provided that this building is utilized as a "lodging" facility, similar to that of hotel where residents only occupy their rooms for a certain percentage of the day, it would be more efficient if an HVAC system was designed that accommodated for this concept. Instead of heating or cooling the environment in an attempt to maintain a steady temperature throughout the day, allow the residents to maintain their own desired temperate environments. The resulting cost differences indicate positive outcomes through savings realized from reduced utility usage, improved energy efficiency of the unit, and increasing available space through the elimination of air handling equipment rooms.

Another primary benefit is that maintenance of the PTAC units can be easily monitored from a single remote station and the complexity is significantly reduced. One of the PTAC products researched was the Amana DigiSmart PTAC Technology. This system integrates Energy Management Software with the building owners Property Management software. This system acknowledges if and when occupants are in the room, and adjusts the room temperature accordingly. The energy management software also enables maintenance personnel to monitor all of the units and are alerted when a unit is not properly working. Another important acknowledgement for this alternate system was found within the conclusions of the Department of Energy's Volume III Report where the PTAC was listed as the "Most Promising Opportunities for Technology, Location, and Application" as a smaller HVAC unit utilizing a propeller-style fan.

After performing this research analysis, it is personally recommended to peruse the alterations involved for going from the original four-pipe, air-water, fixed coefficient of performance HVAC system to the packaged terminal air conditioning unit (scenario two). Scenario three which implemented additional changes to the wall and roof construction did not indicate enough of a change to recommend the additional cost of rigid foam and batt insulation. Finally, the fourth scenario implemented too many sustainable elements that began to alter the conceptual design of the building. Altering the schematic design would have cost impacts far beyond the scope of simply altering the heating and cooling system within the building.

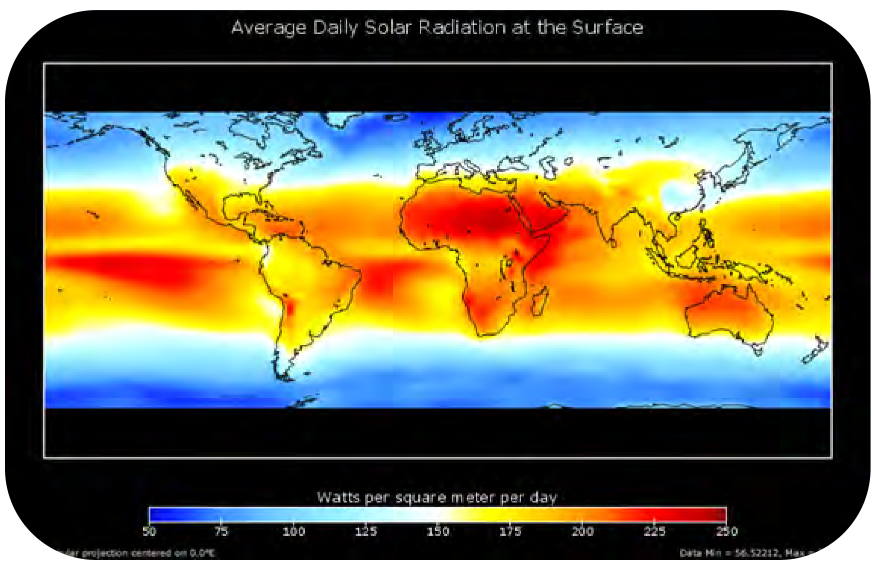
8.0 Photovoltaic Array Powering Parking Garage Lighting

8.1 Problem Introduction – Structural Breadth and MAE Requirement (AE 597D)

This analysis builds upon the topic of energy efficiency within buildings by expanding upon the knowledge gained in the AE 597D: Sustainable Building Methods graduate course. A photovoltaic array will be designed to power the two levels of parking garage space located within this addition. The current building design has not incorporated the placement of any mechanical equipment on the roof. This was done per request of the owner in an attempt to eliminate undesirable aesthetic views. After interning at the Rydal Park continuing care campus, it was noticed that all other buildings on this campus had equipment located on the roof, hidden by fences and screening. These screens and fences were observed to be well over 15 feet high, thus creating undesirable views. After this discovery, it was decided to forgo this request of the owner and incorporate a photovoltaic system that would be located on the medical center roof. The medical center addition provides a great location for a system of this magnitude, given an almost 100% unobstructed roof with an area of over 24,000 square feet. It is also important to mention that this medical center addition will be just as tall as the rest of the buildings on this campus, maxing out at five stories high. Provided that this building will be just as tall as the other buildings, residents will not be able to easily these solar panels, reducing the chance that residents are exposed to undesirable views.

8.2 Background

A photovoltaic array is composed of many small solar cells that convert the radiation given off by the sun into direct current (DC) electricity. Over the last two decades the demand for solar photovoltaics has been rapidly increasing. In 2009 a report was released indicating that photovoltaics are currently the fastest growing energy technology, with a combined global energy production of approximately 15,000 megawatts. This increase in demand has allowed the technology to become more efficient and cost less for the average consumer. As seen in the figure to the right, from the Center for Global Development, there exists a significant amount of solar radiation than can be collected throughout the world. Harvesting renewable energies will reduce the global dependence on fossil fuels. Utilizing renewable energies, which will always be available in contrast to fossil fuels, will provide a future path towards a healthier worldwide environment. One of the best places to location photovoltaics is at the source for which the energy is to utilized, since direct current experiences large voltage drops in long wire and cable runs. This makes building integrated photovoltaics an excellent option since energy is generated and used at the same site. Most



[*Figure 24*. Solar Radiation at the Surface of the Earth] residential and commercial PV array systems are tied into the local grid providing a location for extra, unused generated electricity to spill over. Solar cells can be implemented into the building design through various methods including directly onto the façade, replacing glazing, awnings, and roofing systems. Given the large unobstructed area on the roof of this building, a roofing system will be selected for this research section.

8.3 Research Goal

The results of this analysis will indicate a recommendation of whether or not to pursue a PV array system. It is optimistic that life cycle cost data will indicate that over a 50 year building life span this photovoltaic system will easily pay itself off. The final research product will contain a basic 3D model, solar energy collected, additional joist and w-flange member sizing required and a life cycle cost analysis indicating that the system should be pursued.

8.4 Photovoltaic Research Process

In today's market it can be difficult to select a solar panel manufacturer considering that the technology is continuously updating as research with photovoltaics advances. It was decided to select a company with a significant amount of research and reputation backing this expensive system. Kyocera Solar, Inc. has been researching photovoltaics since 1975 and has been extremely successful in many market sectors including telecommunications, grid-tie systems, traffic, and many large commercial based applications. Their 35 years of research have allowed them to develop a relatively straight-forward five step program which allows designers to get a rough order magnitude of the required components for a solar panel system. The following two tables present a basic overview of the information used to determine the size of the photovoltaic array.

Initially a rough estimate of the total building load was developed by summing the total volt-amps (VA) of all of the panelboards in the medical center addition. It calculated that roughly 1500 kVA will be supplied to the panelboards, which is equivalent to 1200 kW (assuming a power factor of 0.8). Entering this value into the Kyocera five-step process, which will be explained on the following page, revealed that roughly 5,700 (quantity) 16ft^2 solar modules would be required. Attempting to place 5,700 modules (91,200sf) is just not practical for this application. Therefore it was decided to target an individual element within the building to provide power for – the lighting for the two parking decks. The load calculated for the parking garage lighting is significantly more reasonable, which was calculated at approximately 5.25% of the total building load or 63 kW (5.25% was derived for the worst case loading scenario, during the 4.5 peak solar hours of the day). Table 16 summarizes the information required prior to starting the Kyocera five step process to determine the necessary number of modules.

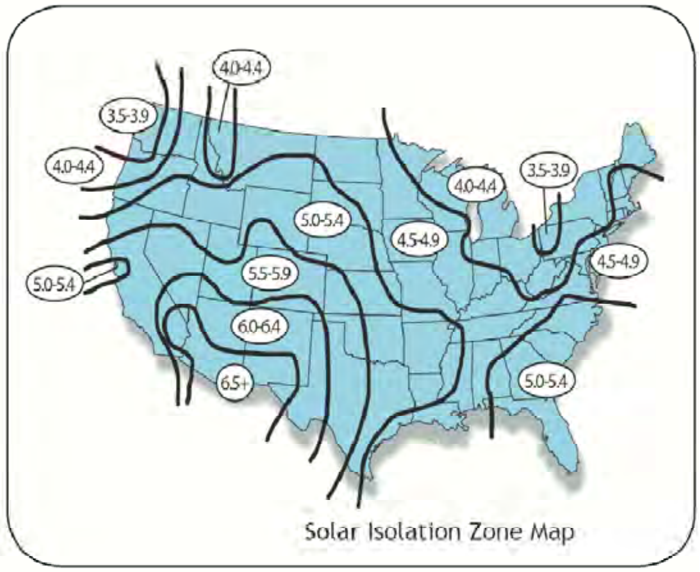
PV ARRAY PARAMETERS					
Rydal Park Medical Center Addition (1515 The Fairway, Rydal, PA 19046)					
Longitude:	-75.123	Comments			
Latitude:	40.106				
Available Roof Area:	24,000	sf			
FL G. Parking Garage Lighting	83	28W Flourescent	kWh=	69.72	(28 watts, 83 units, 2 lamps, 15 hrs)
FL. 1 Parking Garage Lighting	73	28W Flourescent	kWh=	61.32	(28 watts, 73 units, 2 lamps per unit, 15 hrs)
Slope of Roof	1/4" per 1'	Flat, Built Up Roof			
Orientation	Due South			131.04	Total kWh Needed
Optimum tilt angle	35 Degrees	Summer: 25 degrees			
		Fall/Sping: 40 degrees			
		Winter: 55 degrees			

[***Table 16***. Parameters for Array Size Based on Location and Loading]

KYOCERA - Calculation for the Parking Garage Lighting		
Step	Value	Comment / Description
1	4.5	sun hours per day (Philadelphia)
2	137592	watt-hours energy load *(5% waste factor)
3	30576	watts/hour of sunlight
4	102.7	amperage x charging voltage for model KD210GX-LP
5	297.7	# of models required
	300	Units Required

[*Table 17*. Summary of Kyocera's Five Step Process]

Step 1: Solar Isolation Zone – On the map in Figure 24, Philadelphia is located within the 4.5-4.9 solar hours a day region. This map provides a reasonable estimate for solar hours (values derived from a radiation map as seen in Figure 24). Since this system will be a grid-tied in system, if there happens to be one of those worst case scenario days, electricity can ultimately be provided to the lighting system in the parking garage space. For this study the system will be designed for a minimum of 4.5 solar hours a day (9:30am – 2:00pm).



[*Figure 24*. Kyocera's Solar Isolation Map of the USA]

Step 2: Energy Load – The parking garage lighting system uses 156 two lamp luminaire fixtures (28 watt lamps). Lighting for the parking garage has been designed to be active between the hours of 5pm and 8am. Taking these design assumption into account yields a 137,592 watt-hours per 24 hour period. A five percent waste factor has been included within this value to account for efficiency loss and to simply overdesign the required amount of watts. The required information for determining the energy load for this step is located within Table 16.

Step 3: Watts per Hours of Sunlight – Dividing the energy load (step 2) by the solar hours per day (step 1) will return a value of 30,576 watts per hour of peak sun hour.

Step 4: Determine Actual Energy Produced by Selected Panel – The KD210GX-LP solar module provides an excellent solution for this design scenario. This module can produce 7.9 amps during the peak sun hours. Multiplying this by 13 volts (typical operating volts for a 12 volt system) yields a production of 102.7 watts per module.

Step 5: Number of Modules required – Taking the result from step 3 (30,576 watts/hr) and dividing it by the actual energy produce by the specific model (102.7 watts) returns 297.7 or approximately 300 solar modules will be required to light the two stories of parking garage space.

Now that the total number of solar modules has been determined, the size of the system can be calculated. To determine the photovoltaic array size, the Rate of Power (watts) for the module product model (210W) is multiplied by the number of modules (300). This calculation yields 63kW (63,000W) which is the size of the system. The system size value will be the factor that calculates the photovoltaic watts factors for this location which determines the amount of alternating current (AC) generated for this system. Also knowing the system size will allow for the system cost to be properly estimated.

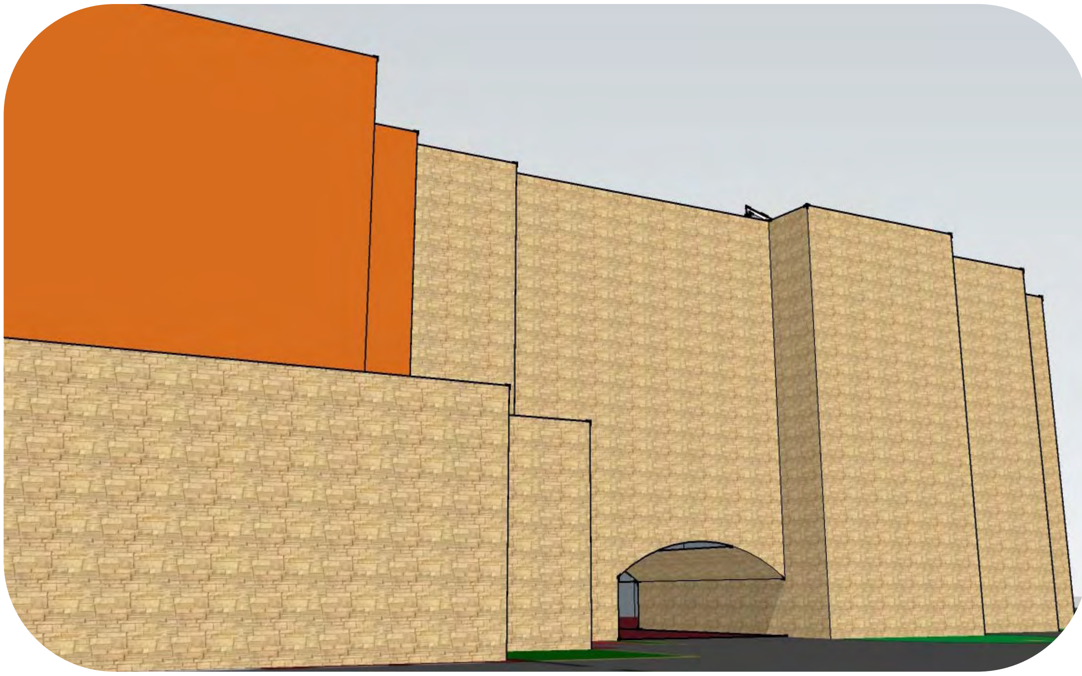
It is important to clarify at this point that this system will only provide an equivalent amount of power for the parking garage lighting; it will not be directly powering the lights. All of the electricity generated from the array will be mixed into the power company energy at the switchgears. Otherwise an expensive battery system would be required to directly power the lighting in the parking decks.

8.5 Shading Design

Now that the required number of photovoltaic modules has been determined, the layout must be created. Google SketchUp's solar shading tool was utilized to assist with the development of the photovoltaic array layout. Several different scenarios were attempted with varying array sizes starting at as small as 3 x 3 and getting as big as 5 x 10. Trying to position the smaller arrays became extremely difficult as more and more shadows were being created. It was soon realized that the most efficient size was the larger 5 x 10 array size. The shadows created by the larger arrays were much more manageable which resulted in an arrangement that easily accommodated the roof's footprint. The final arrangement can be seen here in the following figure.

There were several roof features that had to be accounted for which created additional shadows on top the shadows generated by the array structures. First, two stairwells created longer shadows since they are about 10.5 feet higher than the roof elevation. The second issue was the three and half foot parapet wall around the edge of the roof which created potential issues during the shorter days of the year. After these issues were accommodated for, an arrangement was possible which performs as intended without shading interference.

[*Figure 25*. Rydal Park Campus Overview Indicating PV Array Arrangement**]**

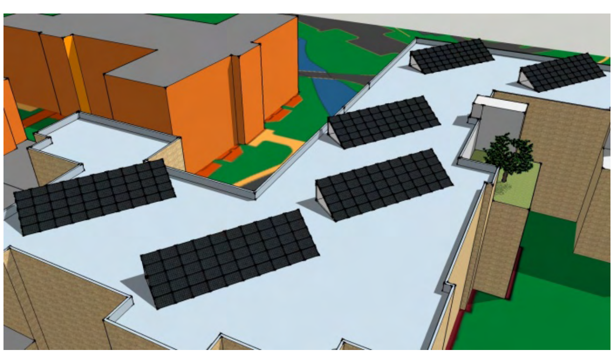


[*Figure 26*. View from the Ground Level (PV Structures not easily visible)]

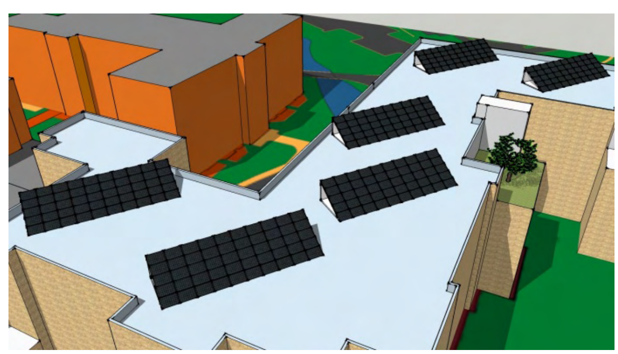
The view above represents a potential view from the ground for what a person 5’-8” tall would notice. This view is shown to indicate that adding a photovoltaic structure to the roof would not create any major architectural alterations to the building facade. Only a slight portion of the top of the structure can been seen which goes almost unnoticed unless it would be pointed out. The only residents that would see the structures would be the people on the fourth and fifth floor of the building (Hillside) directly west of the new medical center.

The next four figures represent the worst case scenarios for shadows created on the roof of this building. Shadows are shown between 9:00am and 2:30pm which is a five and a half hour window. This time window was utilized to show the smaller and necessary four and half hours of peak solar radiation, which the system was designed for, can be easily achieved.

Summer Solstice (Longest Day of the Year, June 21st)
Shadows Cast from the Array Support System angled at 35 Degrees (8ft tall)



[*Figure 27*. Shadows at 9:00am, June 21st]



[*Figure 28*. Shadows at 2:30pm, June 21st]

Winter Solstice (Shortest Day of the Year, December 21st)

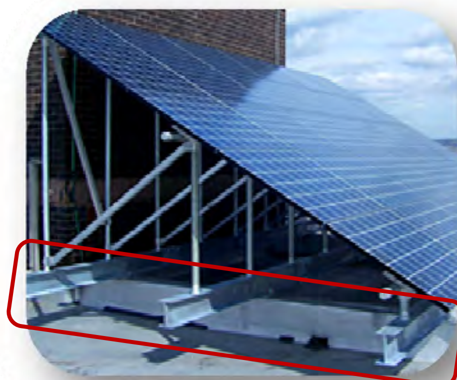
Shadows Cast from the Array Support System angled at 35 Degrees (8ft tall)

[*Figure 29*. Shadows at 9:00am, December 21st]

[*Figure 30*. Shadows at 2:30pm, December 21st]

8.6 Structural Support System of the PV Array

Considering that this building has a flat roof, an additional support structure will be required to provide the 35-degree angle that these photovoltaic modules require to perform as designed. After performing some research on support systems, it was decided to utilize a mounting system from a company called UniRac. The company's sales and engineering department was contacted and a quote and engineering report was obtained for the desired system, the Large Array Support System (Figure 31). A seen in the figure to the right, this system is mounted to the roof deck with the use of aluminum wide flange beams. The weight of the system is then distributed throughout the decking and into the joist and/or beams supporting the deck. Of the many different systems that exist to support PV arrays, this system is best suited for a flat built-up-roof. This system's angle is also adjustable which would allow maintenance personnel to increase the angle up to 45 degrees during the winter months and as low as 25 degrees during the summer months. For the system described, a structure supporting a 5 x 10 module array, it would cost approximately $12,500 for one array, or $75,000 for all six support racks systems. Analyzing this cost estimate by braking it down into a price per watt produces $1.19/watt. This value will be utilized for the life cycle cost feasibility study explained at the end of this analysis section.



[*Figure 31*. UniRac Large Array Support]

This engineering report contained a critical element required to complete this photovoltaic feasibility study – the maximum load that is created by this system. The engineering report included a detailed breakout of how this load was calculated utilizing wind and snow load combinations. The maximum (absolute) load combination created by this system was determined to be 53.21psf. This number was rounded to 55psf to ensure a little overdesign occurred when the final code load combination is calculated.

The detailed information regarding the rack system quote and engineering report can be found within the appendix.

8.7 Structural Calculations

The starting point for this section of the analysis was to obtain the live and dead load design information for the medical center addition. This information is required to properly calculate the AScE 7-05 load combination that will be used to check whether or not the roof's structural members need to be resized. The results of the combination are summarized in Table 18. It was found that adding this photovoltaic array system to the roof will place an additional 72 psf to the final design load combination resulting with 146.8 psf. This 72 psf is calculated by 1.2*[55psf (rack) + 5psf (modules)] = 1.2*60 = 72 psf.

Within the following pages, the process is outlined as to how the structural members were redesigned in order to support this additional 72 psf.

DESIGN LOAD INFORMATION

1. ROOF DESIGN LOADS:

LIVE LOAD:	LL=25 PSF
DEAD LOAD:	DL=29 PSF
SNOW LOAD:	PF=23 PSF (GROUND SNOW LOAD PG=30 PSF, CE=1.0, I=1.1, CT=1.0)
SNOW DRIFTING	MAXIMUM DRIFT =70 PSF - PF (DRIFT WIDTH = 16 FT)
UNBALANCED SNOW LOAD	NONE
RAIN-ON-SNOW SURCHARGE	NONE
RAIN LOAD	25 PSF (4.3 OF RAIN)

2. FLOOR DESIGN LOADS:

LIVE LOAD:	
TYPICAL	LL=80 PSF
Garage	LL=40 PSF
FIRST FLOOR COORIDOR	LL=100 PSF
STORAGE/Mechanical	LL=125 PSF
STAIRS	LL=100 PSF
WANDERING COURTYARD	LL=300 PSF
DEAD LOAD:	
8 CONCRETE SLAB	DL=112 PSF
10 CONCRETE SLAB	DL=136 PSF
11 CONCRETE SLAB	DL=149 psf

IF FLOOR LIVE LOAD INDICATED ABOVE EXCEEDS 50 PSF, THE OWNER SHALL PLACE A CONSPICUOUSLY POSTED SIGN INDICATING THE LIVE LOAD.

3. SPECIAL LIVE LOADS

HANDRAIL DESIGN LOAD	LL=50 PLF IN EITHER VERTICAL OR HORIZONTAL DIRECTION LL=200 LBS IN EITHER VERTICAL OR HORIZONTAL DIRECTION

4. WIND LOAD:

BASIC WIND SPEED	100 MPH
IMPORTANCE FACTOR	I=1.15
WIND EXPOSURE	EXPOSURE= B
COMPONENTS & CLADDING DESIGN PRESSURES	
WALLS/WINDOWS	26 PSF
ROOF	CORNERS=53 PSF EDGES=32 PSF CENTER=24 PSF
INTERIOR PARTITION	5 PSF (BLAST LOAD)
WIND BASE SHEARS (MWFRS)	VX=598KIPS VY=686KIPS

[***Figure 32***. Structural Design Information for the MCA]

Load Resistance Factor Design		
Live Load:	25 psf	
Dead Load:	29 psf	
PV Rack Support:	55 psf	
PV Panels:	5 psf	
Snow Load	23 psf	
Load Comb:	74.8 psf	w/out PV
Load Comb:	146.8 psf	w/ PV

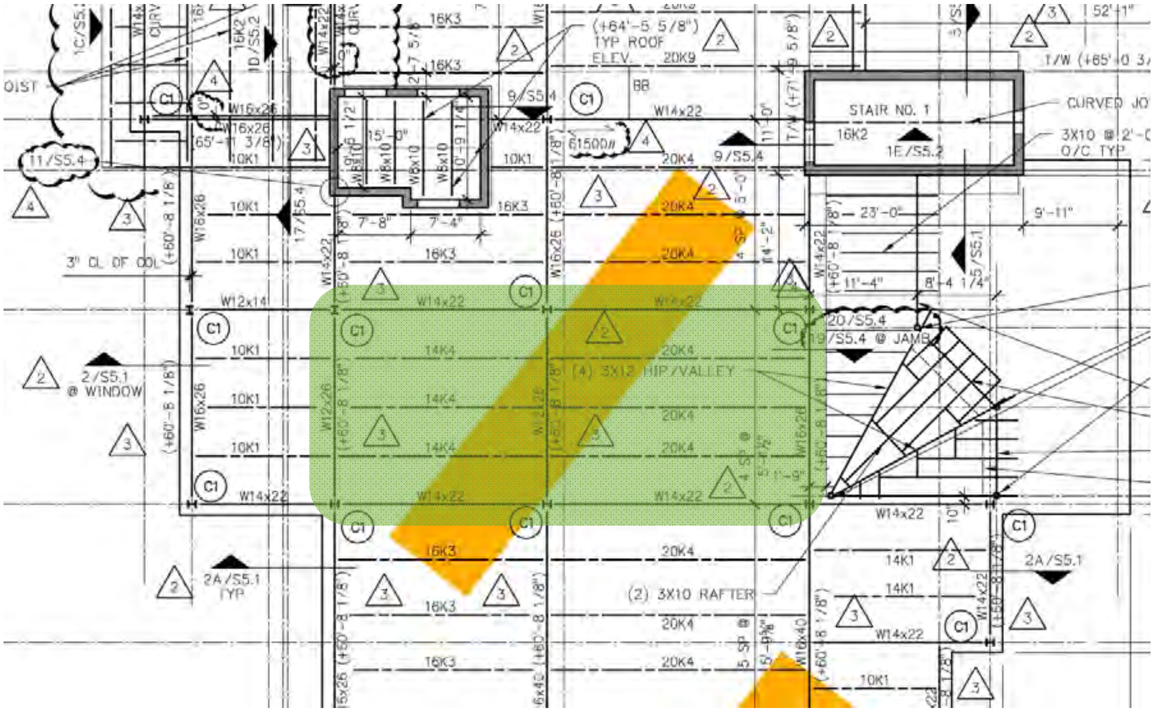
Load Combination Utilized:

$(1.2^*D) + (1.6^* L_{ROOF} \text{ or } S_L)$

Allowable Deflection: l / 180

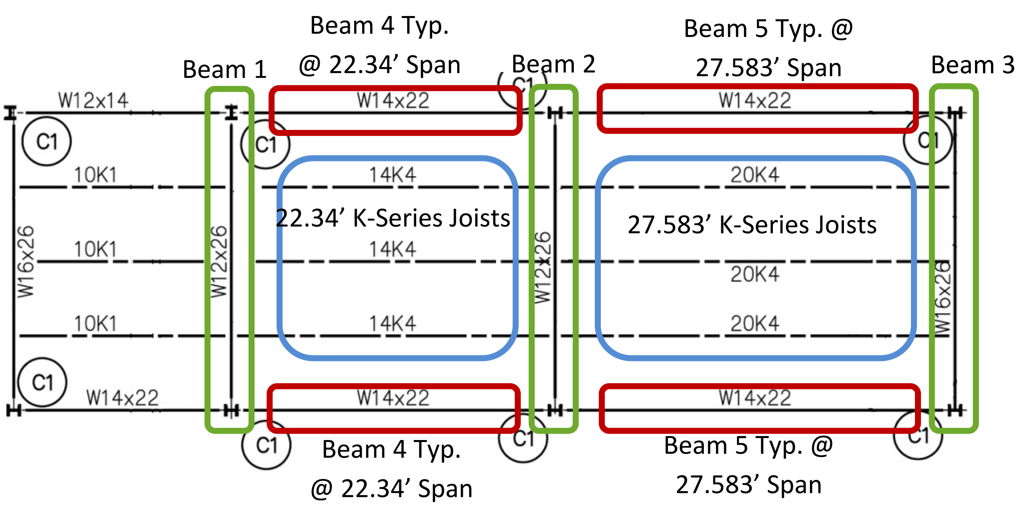
[***Table 18***. Summary of the ASCE 7-05 Load Combination]

In order to create the worst case scenario, it was assumed that the added solar panel support system's dead load (72 psf) was equally distributed over the green highlighted region. The following sketch, pulled from the solar array layout (found in the appendix), overlaid on the structural roof drawing indicates the affected bay.



[*Figure 33*. Portion of the Solar Array Layout overlaid on the Structural Roof Drawing]

The following highlighted structural members of the bay will be affected by the additional loading of the solar panel array support system. The structural analysis is broken down into three basic components joists, spandrel beams with the joist point loads and beams without the joist point loads. The spacing between joists for this bay is 5.125 feet (tributary width). Each listed member below has a table showing the step by step process involved in proving that this PV array system can be supported by the roof structure.



[*Figure 34*. Highlighted Structural Elements affects by the new Load Combination]

The following sample calculations illustrate the basics behind the following tables. The numbers shown may not necessary be the exact numbers utilized to solve member sizing. The maximum allowable deflection was found in table 1604.3 (Deflection Limits) in the IBC 2006. L/180 was selected based on a roof member supporting a nonplaster ceiling, with a load combination including both dead and live loads.

$$Deflection_{MAX} = {}^{L}/_{180}$$

$$Deflection_{MAX} = \frac{\left(20'\left({}^{12"}/_{1'}\right)\right) + 6"}{180}$$

$$Deflection_{MAX} < 1.4"$$

Deflection in a Simply Supported Beam (Solving for I_X since deflection primarily controls this design):

$$Deflection_{MAX} < 1.4" < \frac{(5)(\omega)(l)^4}{(384)(EI)}$$

$$I_x < \frac{(5)(\omega)(l)^4}{(384)(29{,}000{,}000psi)(1.4")}$$

Beam 1 (W12x26) @ 20.5 ft Span			
	Trib Width 1:	7.5 ft	
	Trib Width 2:	11.167 ft	
Step 1:	Without PV Array Loading		
	Load:	1396.292 plf	< 3540 (OK)
	Deflection:	0.938 in	< 1.4 (OK)
Step 2:	With PV Array Loading		
	New Joist Wt:	13.659 plf	
	Load:	2753.974 plf	> 2529 (Not OK)
	Deflection:	1.850 in	> 1.4 (Not OK)
	--> Upsize for both Deflection and Loading		
Step 3:	Solving Backwards for I_X		
	Solve I_X:	269.545 $in.^4$	
Step 4:	Looking Up Economical Beams		
	W14x30:	291 $in.^4$	
	W16x26	301 $in.^4$	<-- Use this Beam
Step 5:	Resize Beam 1 to (W16x26) 20.5 ft Span		
	Load:	2740.316 plf	< 3005 (OK)
	Deflection:	1.247 in	< 1.4 (OK)

[***Table 19***. Summary of Beam 1 Load Check]

Beam 2 (W12x26) @ 20.5 ft Span			
	Trib Width 1:	11.167 ft	
	Trib Width 2:	13.7915 ft	
Step 1:	Without PV Array Loading		
	Load:	1866.896 plf	< 3540 (OK)
	Deflection:	1.254 in	< 1.4 (OK)
Step 2:	With PV Array Loading		
	New Joist Wt:	18.2623 plf	
	Load:	3682.170 plf	> 2529 (Not OK)
	Deflection:	2.473 in	> 1.4 (Not OK)
	--> Upsize for both Deflection and Loading		
Step 3:	Solving Backwards for I_X		
	Solve I_X:	360.393 $in.^4$	
Step 4:	Looking Up Economical Beams		
	W18x35:	510 $in.^4$	<-- Use this Beam
	W16x31	375 $in.^4$	
Step 5:	Resize Beam 2 to (W18x35) 20.5 ft Span		
	Load:	3682.170 plf	< 4524 (OK)
	Deflection:	0.989 in	< 1.4 (OK)

[***Table 20***. Summary of Beam 2 Load Check]

Beam 3 (W16x26) @ 20.5 ft Span			
	Trib Width 1:	13.7915 ft	
Step 1:	**Without PV Array Loading**		
	Load:	1031.604 plf	< 4207 (OK)
	Deflection:	0.470 in	< 1.4 (OK)
Step 2:	**With PV Array Loading**		
	New Joist Wt:	10.0913 plf	
	Load:	2034.684 plf	< 4207 (OK)
	Deflection:	0.926 in	< 1.4 (OK)
	--> No Need to Upsize, Check Anyways		
Step 3:	**Solving Backwards for I_X**		
	Solve I_X:	199.145 in.^{4}	
Step 4:	**Looking Up Economical Beams**		
	W14x22:	199 in.^{4}	
	W12x26:	204 in.^{4}	
	W16x26:	301 in.^{4}	<-- Use this Beam
Step 5:	**Resize Beam 3 to (W16x26) 20.5 ft Span**		
	Load:	2034.684 plf	< 4207 (OK)
	Deflection:	0.926 in	< 1.4 (OK)

[***Table 21***. Summary of Beam 3 Load Check]

Beam 4 Typ. (W14x22) @ 22.34 ft Span			
	Trib Width 1:	2.5625 ft	
	Trib Width 2:	2.5625 ft	
Step 1:	**Without PV Array Loading**		
	Load:	383.350 plf	< 1883 (OK)
	Deflection:	0.264 in	< 1.49 (OK)
Step 2:	**With PV Array Loading**		
	New Joist Wt:	0.000 plf	
	Load:	752.350 plf	< 1883 (OK)
	Deflection:	0.731 in	< 1.49 (OK)
	--> No Need to Upsize (Check Anyways)		
Step 3:	**Solving Backwards for I_X**		
	Solve I_X:	69.188 in.^{4}	
Step 4:	**Looking Up Economical Beams**		
	W14x22:	199 in.^{4}	<-- Use this Beam
	W12x14	84 in.^{4}	
Step 5:	**Keep Beam 4 at (W14x22) @ 22.34 ft Span**		
	Load:	752.350 plf	< 1883 (OK)
	Deflection:	0.731 in	< 1.49 (OK)

[***Table 22***. Summary of Typ. Beam 4 Load Check]

Beam 5 Typ. (W14x22) @ 27.583 ft Span		
Trib Width 1:	2.5625 ft	
Trib Width 2:	2.5625 ft	
Step 1:	**Without PV Array Loading**	
Load:	383.350 plf	< 3540 (OK)
Deflection:	0.865 in	< 1.84 (OK)
Step 2:	**With PV Array Loading**	
New Joist Wt:	0.000 plf	
Load:	752.350 plf	< 3540 (OK)
Deflection:	1.698 in	< 1.84 (OK)
--> No Need to Upsize, Check Anyways		
Step 3:	**Solving Backwards for I_X**	
Solve I_X:	183.634 $in.^4$	
Step 4:	**Looking Up Economical Beams**	
W14x22:	199 $in.^4$	<-- Use this Beam
W12x26:	204 $in.^4$	
W16x26:	301 $in.^4$	
Step 5:	**Keep Beam 5 at (W14x22) @ 27.583 ft Span**	
Load:	752.350 plf	< 3540 (OK)
Deflection:	1.698 in	< 1.84 (OK)

[***Table 23***. Summary of Typ. Beam 5 Load Check]

		Uniform Kips @ X ft Span				PFL @ X ft Span			
Beam	I_X	15 ft	21 ft	23 ft	28 ft	15 ft	21 ft	23 ft	28 ft
W18x35	510	133	95	86.7	71.3	8867	4524	3770	2546
W16x31	375.0	108.0	77.1	70.4	57.9	7200	3671	3061	2068
W16x26	301.0	88.4	63.1	57.7	47.4	5893	3005	2509	1693
W14x22	199.0	66.4	47.4	43.3	35.6	4427	2257	1883	1271
W12x26	204.0	74.4	53.1	48.5	39.9	4960	2529	2109	1425
W12x14	88.6	34.8	24.9	22.7	18.6	2320	1186	987	664

[***Table 24***. Summary of Utilized Values pulled from the AISC Steel Manual]

Joist 1 (K-Series 14K4) @ 22.34 ft Span			
	Trib Width 1:	2.5625 ft	
	Trib Width 2:	2.5625 ft	
Step 1:	Without PV Array Loading		
	Load:	383.350 plf	< 483 (OK)
Step 2:	With PV Array Loading		
	Joist Wt:	7.000 plf	
	Load:	759.350 plf	> 483 (Not OK)
	--> Upsize for Loading		
Step 3:	Looking Up Joists		
	16K7:	760 plf	
	16K8:	825 plf	<-- Use this Beam
Step 4:	Resize Beam 1 to (W16x26) 20.5 ft Span		
	Load:	759.350 plf	< 825 (OK)

[***Table 24***. Summary of Typ. Joist 1 Load Check]

Joist 2 (K-Series 20K4) @ 27.583 ft Span			
	Trib Width 1:	2.5625 ft	
	Trib Width 2:	2.5625 ft	
Step 1:	Without PV Array Loading		
	Load:	383.350 plf	< 472 (OK)
Step 2:	With PV Array Loading		
	Joist Wt:	7.000 plf	
	Load:	759.350 plf	> 472 (Not OK)
	--> Upsize for Loading		
Step 3:	Looking Up Joists		
	20K9:	775 plf	
	20K10:	825 plf	<-- Use this Beam
Step 4:	Resize Beam 1 to (W16x26) 20.5 ft Span		
	Load:	759.350 plf	< 825 (OK)

[***Table 25***. Summary of Typ. Joist 2 Load Check]

After performing this structural breadth analysis it was determined that this structure could easily support the added load of the PV array support structure and the accompanying solar modules with minimal upsizing of structural members. The only beams significantly affected be the additional loading were the beams supporting the joists. After these beams were upsized, they were still under the max allowable depth of 20” for this roof design. Unfortunately, all of the joists located where the arrays are to be placed, will need to be resized. After performing some structural calculations, it was found that the joists had to be significantly increased to support the additional PV structure. On a positive note, the newly sized joists did not exceed the 20” depth requirement.

8.8 Life Cycle Cost Feasibility

PV Watts Factor

The last element required for the rebate and loan calculator is to determine the photovoltaic watts factor with determines the amount of AC energy created by the panels. In doing this the savings determined by comparing the amount of energy generated to the local utility rates. The following two tables reveal the amount of potential AC energy generated throughout the year. To determine the PV Watts Factor the total years energy (76,166 kWh) is divided by the DC rating (63 kW, aka the System Size). This equates to 1209 kilowatt hours per kilowatt of electricity. This number represents the number of kilowatt hours generated by the entire system from every kilowatt of DC energy.

Station Identification	
City:	Philadelphia
State:	Pennsylvania
Latitude:	39.88° N
Longitude:	75.25° W
Elevation:	9 m
PV System Specifications	
DC Rating:	63.0 kW
DC to AC Derate Factor:	0.77
AC Rating:	48.5 kW
Array Type:	Fixed Tilt
Array Tilt:	35.0°
Array Azimuth:	180.0°
Philadelphia Utility Costs	
Cost of Electricity:	0.2 ¢/kWh

[*Table 25*. Prelim Info for PVWatts Factor]

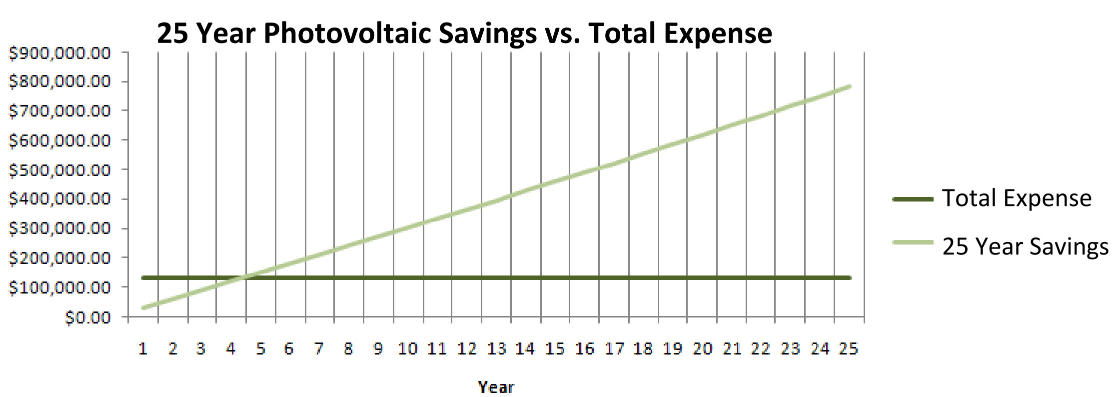
AC Energy Generated			
Month	**Solar Radiation ($kWh/m^2/day$)**	**AC Energy (kWh)**	**Energy Value ($)**
January	3.30	5197	8.16
February	4.16	5805	9.29
March	4.74	6998	11.20
April	5.06	7014	11.22
May	5.20	7176	11.48
June	5.43	7032	11.25
July	5.51	7279	11.65
August	5.67	7548	12.08
September	5.07	6690	10.70
October	4.59	6538	10.46
November	3.37	4804	7.69
December	2.67	4085	6.39
Year	4.57	76166	121.57

[*Table 26*. Total AC Energy Generated per Year]

Utilizing information and tools assembled from AE 597D (Sustainable Building Methods), a photovoltaic rebate and loan calculator (created by Andrew Mackey, M.S. Construction Management, researching photovoltaics) can predict the 25 year value of the system. This calculator will be filled out providing two scenarios; first, that 100% of the system cost is included within the GMP (bank loan) and second, that Presby's Inspired Life simply purchases the entire system themselves without a loan.

Market			Comments
Retail Cost of Electricity	0.16	$/kWh	-Avg. cost of electricity in Philadelphia (March 2010)
Elec. Rate increase	1.00%		-Increase per year of cost of electricity
AECs Value	230	$/MWh	-Alternative Energy Credits ($ Power Co. Pays Back)
Loan			
Percentage Borrowed	100.00%		-Assuming full cost of system is in the GMP
Loan Value	$91,879.64		-Total cost of system minus all of the rebates
Interest rate	3.00%	APY	
Period	25	Years	
CRF	0.004742113		-Capitol Recovery Factor: r(1+r)^n/[(1+r)^n-1]
Rebates / Incentives			
PA Solar Sunshine	16.15%		-These rebates and incentes are conservatively assumed
PA Tax Rebate	15.00%		
Federal Tax Credit	30.00%		-These Rebates/Incentives are explained in great detail at the Database of State Incentives for Renewables and Efficiency (dsireuse.org)
DCED Grant	$90,000.00		
PEDA Grant	$90,000.00		
System			
Size	63	kW DC	-Derived earlier in the PV analysis section
Cost / Watt	$8.65	$/W	-Read on further for this breakout
Total Cost	$544,950.00		-Size * Cost/Watt
PVWatts Factor	1209		-Location based solar electricity production rate
Annual AC production	76167	kWh	-Size * PVWatts Factor
Roof Area Needed	6300	sq.ft.	-Generalized requirement
Value			
Up Front Expense	$0.00		-100% of Cost is placed into the GMP
Loan Cost	$130,711.10		
Total Expense	$130,711.10		
25 yr Value	**$651,441.12**		-Savings seen after load is paid off

[*Table 27*. Rebate/Load Calculator]



[*Graph 06*. 25 Year Life Cycle Cost (100% of the Cost embedded into the GMP)]

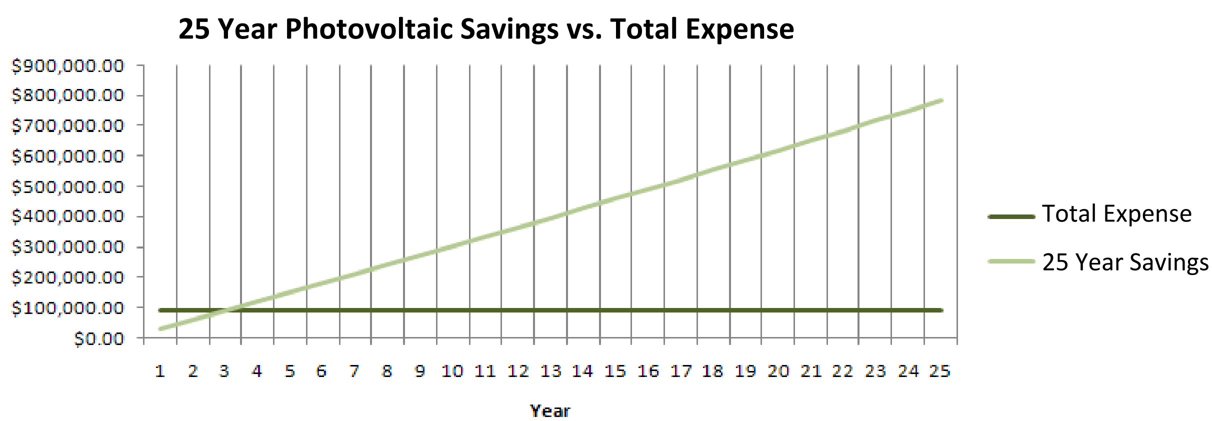
Cost per Watt:

This line item (seen under the System heading in the Rebate/Loan Calculator, Table 25) was derived with the following assumptions:

Cost per Watt	Description
$0.32	6% Tax for Pennsylvania
$1.19	Cost of UniRac Support Structure
$4.15	Cost for Solar Modules
$2.97	Installation Labor
$8.65	**Total Cost per Watt**

[*Table 28*. Breakdown of the Cost per Watt]

The results from this 25 year life cycle cost analysis reveal that this system will pay itself off in approximately 4.5 years. Over a 25 year period, potential savings could reach $651,441.12 and over 50 years potential savings could reach close to $1.42 million. One of the drawbacks with utilizing this rebate/loan calculator over such a long period (50 years) is the uncertainty and predictability of maintenance and upkeep costs.



[*Graph 07*. 25 Year Life Cycle Cost (Purchased directly by owner)]

For the second scenario, the only line item altered was the percentage borrowed under the loan heading (seen in Table 25, on the previous page). When this item is changed, the owner has to pay an upfront cost of $91,880 for the system but the system is paid off 1.25 years faster. Since the owner pays this money immediately, the owner doesn't have to pay for $40,000 of interest as seen in the first scenario.

8.9 Schedule Impacts

The benefit of a roof mounted photovoltaic system is that work can begin as soon as access to the roof is approved. This benefit prevents the installation from becoming a critical path activity. On the other hand, purchase and delivery of the components must be properly managed in order to prevent this item from becoming a critical path item. The UniRac aluminum wide flange beams providing foundation support will have to be placed prior to the construction of the built-up-roof. Ensuring proper sealing and flashing around these foundation beams will be similar to that of HVAC equipment pads and support structures. After the flashing around these foundation beams has been completed, the final installation of the support rack will occur relatively fast and can occur when there is reduced work congestion on the roof level. The only critical element that must be considered for this system is when the AC conductors are run to the switchgear on the first floor. Each array will have an inverter located within close proximity in order to avoid purchasing long lengths of expensive DC conductors. These inverters will convert the DC to AC current which will be combined and run to the switchgear where it will tie into the local electrical grid system. This additional work will require the electrical subcontractor to re-evaluate their price, but should not affect the critical path of the establish 18 month construction schedule.

8.10 Conclusion and Final Thoughts

Pursuing an addition of six fifty-module photovoltaic arrays for the Medical Center Addition should be implemented. Although this system will not directly power the parking garage lighting, an equivalent amount of power can be generated with the use of a 63 kW PV system. It would be foolish to waste the unobstructed roof space found on this project. The three and half foot parapet would conceal most of the view of the solar structures minimizing the impact on the architectural view of the building façade. Today's photovoltaic market is being flooded with rebates, grants, and incentives that innovative owners must capitalize upon. It is recommended to place the purchase of this system into the GMP which will help defray the burden of the upfront cost on the owner, which more than often is a major concern.

Structurally, only six areas would require member redesign. Each affected K-series joist would require upsizing, along with the wide flange beams supporting those joists. All in all, roughly 30 wide flange beams and 60 joists would need to be upsized or at least to be structurally checked. Ninety structural elements would equate to approximately 25% of the total amount of steel found on the roof structure. This structural alteration would not significantly impact the structure and is extremely feasible. Serviceability and maintenance have been taking into consideration when the layout of the array structures was developed.

Utilizing the Rebate / Incentive Calculator (created by Andrew Mackey / explained in AE 597D) was the final element required to confirm that this photovoltaic system should be pursued. Two scenarios revealed that regardless whether the owner pays for the system directly or imbeds it into the GMP, at worst the system will be paid off in four and a half years. After the system is paid off, the facility would save about $32,000 per year. These savings could be added to the maintenance budget, which this campus is desperately going to need as the facility increases in size of the following decades.

Beyond the physical and calculable aspects listed above are the underlying elements of efficiency and sustainability. Today, buildings need to become energy conscious and the first step towards this goal is implementing new technologies. Even though there exist inherent risks within new technologies, they must be utilized if there is any chance for researchers to improve upon them. Looking towards the future, only renewable energies are limitless, it is just a matter of time until the reserves of fossil fuels dry up. It is the responsibility of engineers and designers to educate owners of the benefits of these new technologies. Engineers need to create methods for implementing these technologies for mass use while keeping costs minimized. On the other hand, it is also the responsibility of owners to invest in these technologies because they are target audience for implementing these new techniques.

9.0 Final Senior Thesis Report Conclusions

Each analysis performed within this report indicated positive benefits from implementing the suggested modifications. On the other hand, implementing these alterations also have inherent risks, given that they are still new and emerging methods and technologies. Building owners must decide which of these risks they are willing to take and which ones are beyond their comfort zone. From a purely academic viewpoint, it can be easily suggested to implement of the options outlined in this report, but there are many political and bureaucratic elements that effect whether or not an owner will utilize such methods and technologies.

Integrated Project Delivery

Given the disconnected OAC project team, it is highly suggested to implement new and alternative methods to enhance collaboration and improve communication. One potential manner in which this could be captured is by contracting the OAC team with an integrated project delivery documents. IPD hooks the entire project team together aligning everyone towards the final delivery rather than just one participant per phase (i.e. architect = design phase, cm = construction phase). After reviewing and analyzing several IPD case studies, the many successful elements were targeted and applied to the preconstruction timeline for this Medical Center Addition project. It is recommended to the selected elements, which will create a more transparent and open team environment where collaboration becomes inherent.

Mechanical System Energy Efficiency

Energy 10 provided a route to analyze the difficult task of quantifying the efficiency of the HVAC system within the boundaries of this Medical Center Addition. Upon analyzing the effects of several HVAC systems on a model of the addition, one of the systems revealed the potential to improve energy efficiency. By implementing Packaged Terminal Air Conditioning (PTAC) units, residents will be able to individually control their personal environments. A PTAC system will eliminate the need to install costly ductwork and reduce the installation complexity. It is recommended to review this option in future building designs as new technology becomes available that integrates building management software with HVAC unit energy monitoring. Case studies have indicated savings when such hybrid management softwares are implemented.

Photovoltaic Array Feasibility

Implementing photovoltaics on building facades and roofs must become a norm with building design. These new technologies offer many potential options for offsetting electrical utility costs. Currently the primary barrier to success of these materials is the associated upfront cost. Research and mass production is pushing the price of these units down, allowing the average consumer to finally purchase them. The study performed within this report indicated that if a 63kW system were incorporated into the GMP, the system could be paid off in approximately four and half years. This system would also provide an equivalent amount of energy to power the entire parking garage lighting every day. The structural system would require several minor alterations, but nothing that would severely impact the structural budget or elongate the construction schedule.

10.0 Breadth Studies and MAE Requirements

Mechanical Breadth:

With the use of Energy 10, a model of the energy demands of the Medical Center Addition has been created. Data recovered from this model aided with the selection of an alternate mechanical system. After several scenarios were run, it was revealed that a Packaged Terminal Air Conditioner (PTAC) will provide significant benefits which include reducing the energy consumption, minimizing the amount of mechanical equipment, and eliminating major ductwork within the building. Located with the second analysis section and the appendix are life cycle cost reports indicating positive savings over the first 50 years of the building's occupancy.

Structural Breadth:

As the roof is currently designed, it will not safely support the additional load of six large PV arrays. Within the third analysis, a structural analysis was performed to check the affected structural elements and upsize any that will not support the new load combination. This analysis revealed that any K-series joists supporting a PV array and rack support system will require resizing. Also, the only wide flange beams there were required to be upsized where those supporting these joists. Any wide flange beams not supporting joists did not require any additional redesign. It was also revealed that for the wide flange beams, deflection primarily controlled the redesign, not just direct load.

Incorporation of 500-Level Architectural Engineering Courses (MAE Requirement)

AE 572: Project Development and Delivery Planning - Within the first analysis, integrated project delivery, a research tool, which was tough during AE572, was utilized to the analyze factors affecting the delivery planning method. These factors were related to elements within successful integrated project delivery case studies.

AE 597D: Sustainable Building Methods - Knowledge gained from this course was integrated in the third analysis researching the feasibility of a photovoltaic array system. Primary lessons learned went beyond calculable values to examining the aspects that progress the development of new technologies. Included within the third analysis is a Rebate / Loan Calculator that confirmed the hypothesis of a swift payback period. Finally, a LEED v3.0 scorecard has been included within the appendix reflecting the potential rating this medical center could expect if the modifications outlined in this report were implemented.

Critical Industry Issue:

The entire first analysis was developed based on the discussion held at the business networking breakout session during the 2009 fall PACE Roundtable conference. During this session many of the industry leaders were unsure of a specific definition of Integrated Project Delivery. After considering this ambiguity, it was decided to research IPD and how it could be applied to the Rydal Park project team in order to positively affect the outcome of the building delivery.

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12.0 Personal Acknowledgements

I would like to personally thank the following people and companies for providing me with assistance during both of my senior thesis semesters (Fall 2009-Spring 2010).

WT
WHITING-TURNER

· Chip Cinamella
· Jesse Beam
· Jack DaSilva
· Bogdan Minda
· Shelly Christman
· Lawson Kilbourne

PRESBY'S INSPIRED Life
At the heart of experience and vision.

· Garry Hennis

Stewart & Conners Architects, PLLC

· Jeff Mullen

PENNSTATE
1855

· Christopher Magent
· PSU AE Faculty
· 2009 PACE Conference Participants
· Andrew Mackey
· Students from AE Class of '10 that helped with breadth topics

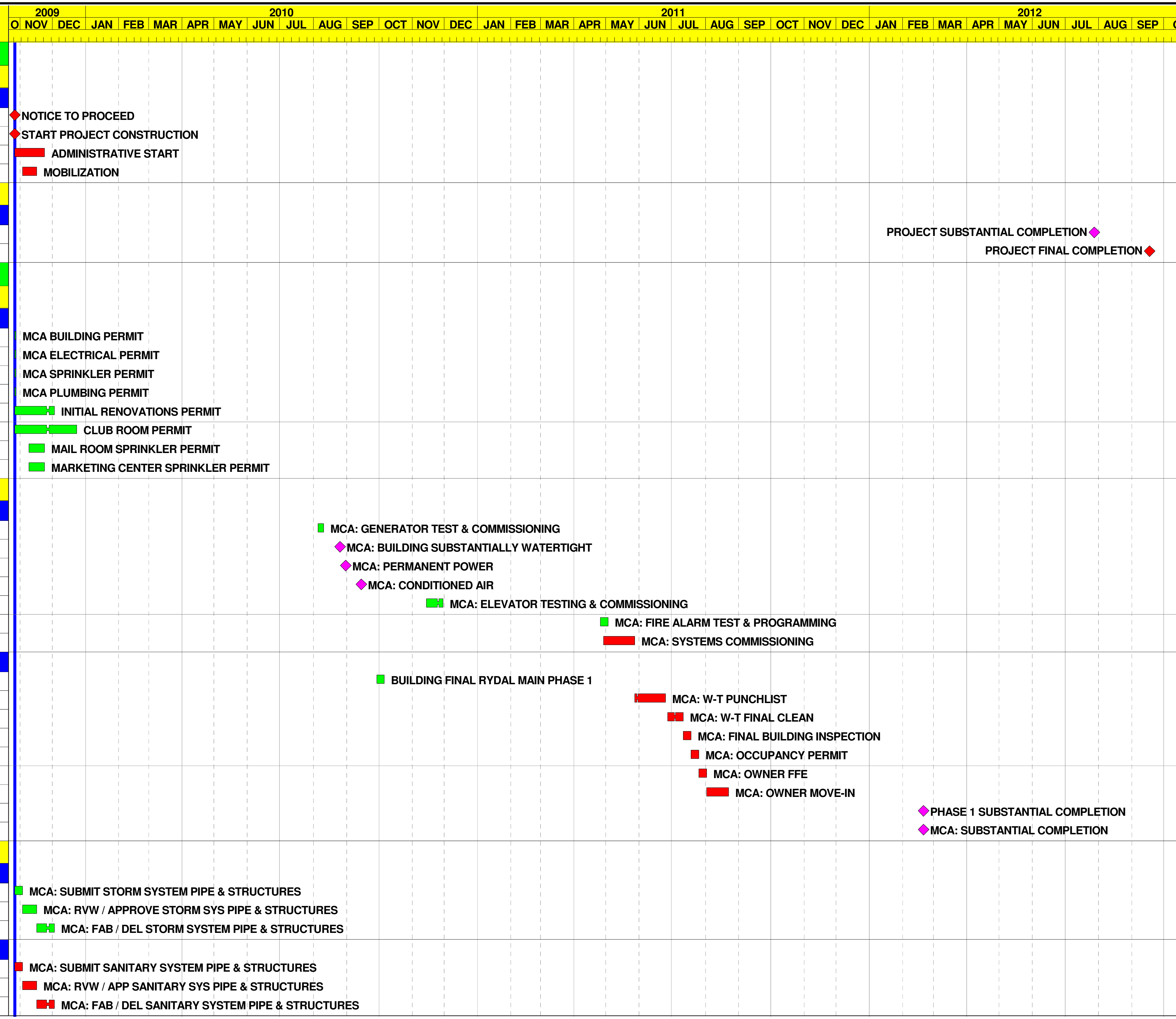
GREENBRIER

· Gene Hooton

Thank you to all my friends and family for providing support and confidence during the Spring 2010 Semester

13.0 Appendix A: Project Schedule

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
RYDAL PARK CAMPUS REPOSITIONING				
PRECONSTRUCTION				
PROJECT ADMIN & MILESTONES				
1	NOTICE TO PROCEED	0	27OCT09	
2	START PROJECT CONSTRUCTION	0	27OCT09	
3	ADMINISTRATIVE START	20	27OCT09	23NOV09
5	MOBILIZATION	10	03NOV09	16NOV09
PROJECT COMPLETION				
INSPECTIONS / COMPLETION / TURNOVER				
99999	PROJECT SUBSTANTIAL COMPLETION	0		27JUL12
100000	PROJECT FINAL COMPLETION	0		17SEP12
PHASE 1				
PRECONSTRUCTION				
PERMITS				
200	MCA BUILDING PERMIT	1	27OCT09	27OCT09
202	MCA ELECTRICAL PERMIT	1	27OCT09	27OCT09
204	MCA SPRINKLER PERMIT	1	27OCT09	27OCT09
206	MCA PLUMBING PERMIT	1	27OCT09	27OCT09
210	INITIAL RENOVATIONS PERMIT	25	27OCT09	02DEC09
290	CLUB ROOM PERMIT	40	27OCT09	23DEC09
230	MAIL ROOM SPRINKLER PERMIT	10	10NOV09	23NOV09
231	MARKETING CENTER SPRINKLER PERMIT	10	10NOV09	23NOV09
PROJECT COMPLETION				
MILESTONES / TESTING / COMMISSIONING				
130	MCA: GENERATOR TEST & COMMISSIONING	3	06AUG10	10AUG10
100	MCA: BUILDING SUBSTANTIALLY WATERTIGHT	0		25AUG10
110	MCA: PERMANENT POWER	0		30AUG10
120	MCA: CONDITIONED AIR	0		14SEP10
7610	MCA: ELEVATOR TESTING & COMMISSIONING	10	15NOV10	29NOV10
7700	MCA: FIRE ALARM TEST & PROGRAMMING	5	26APR11	02MAY11
900	MCA: SYSTEMS COMMISSIONING	20	29APR11	26MAY11
INSPECTIONS / COMPLETION / TURNOVER				
1111	BUILDING FINAL RYDAL MAIN PHASE 1	5	29SEP10	05OCT10
910	MCA: W-T PUNCHLIST	20	27MAY11	24JUN11
920	MCA: W-T FINAL CLEAN	10	27JUN11	11JUL11
930	MCA: FINAL BUILDING INSPECTION	5	12JUL11	18JUL11
11112	MCA: OCCUPANCY PERMIT	5	19JUL11	25JUL11
940	MCA: OWNER FFE	5	26JUL11	01AUG11
950	MCA: OWNER MOVE-IN	15	02AUG11	22AUG11
11111	PHASE 1 SUBSTANTIAL COMPLETION	0		20FEB12
MCA9999	MCA: SUBSTANTIAL COMPLETION	0		20FEB12
PROCUREMENT				
STORM SYSTEM PIPE & STRUCTURES				
430	MCA: SUBMIT STORM SYSTEM PIPE & STRUCTURES	5	27OCT09	02NOV09
434	MCA: RVW / APPROVE STORM SYS PIPE & STRUCTURES	10	03NOV09	16NOV09
438	MCA: FAB / DEL STORM SYSTEM PIPE & STRUCTURES	10	17NOV09	02DEC09
SANITARY SYSTEM PIPE & STRUCTURES				
440	MCA: SUBMIT SANITARY SYSTEM PIPE & STRUCTURES	5	27OCT09	02NOV09
444	MCA: RVW / APP SANITARY SYS PIPE & STRUCTURES	10	03NOV09	16NOV09
448	MCA: FAB / DEL SANITARY SYSTEM PIPE & STRUCTURES	10	17NOV09	02DEC09



Start Date	27OCT09
Finish Date	17SEP12
Data Date	27OCT09
Run Date	14DEC09 17:41

Early Bar
Progress Bar
Critical Activity

RP00

Sheet 1 of 24

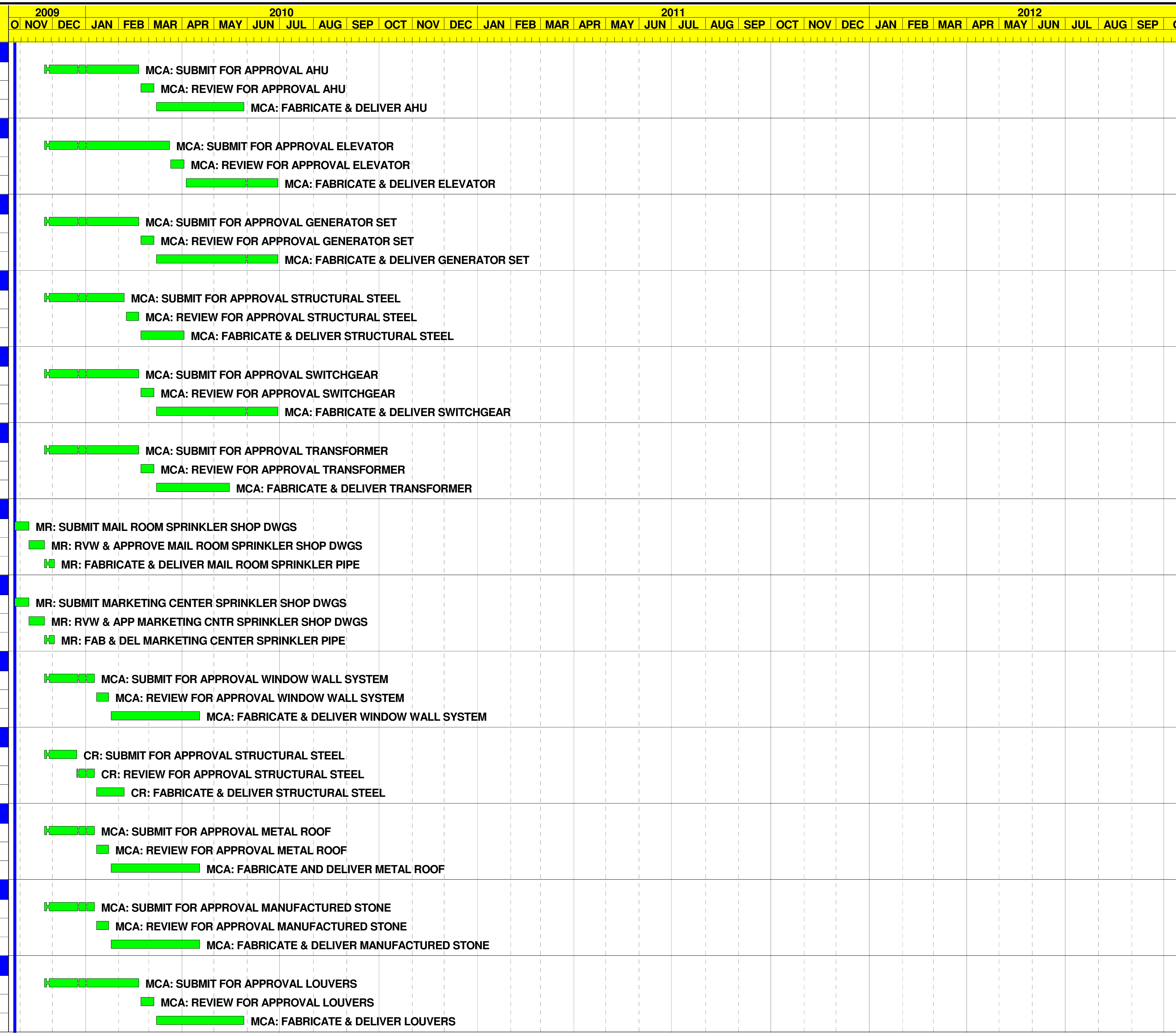
Whiting-Turner Contracting Company

Rydal Park Campus Repositioning

Classic Schedule Layout

Date	Revision	Checked	Approved

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
AIR HANDLING UNITS				
400	MCA: SUBMIT FOR APPROVAL AHU	60	24NOV09	19FEB10
404	MCA: REVIEW FOR APPROVAL AHU	10	22FEB10	05MAR10
408	MCA: FABRICATE & DELIVER AHU	60	08MAR10	28MAY10
ELEVATOR				
410	MCA: SUBMIT FOR APPROVAL ELEVATOR	80	24NOV09	19MAR10
414	MCA: REVIEW FOR APPROVAL ELEVATOR	10	22MAR10	02APR10
418	MCA: FABRICATE & DELIVER ELEVATOR	60	05APR10	28JUN10
EMERGENCY GENERATOR				
420	MCA: SUBMIT FOR APPROVAL GENERATOR SET	60	24NOV09	19FEB10
424	MCA: REVIEW FOR APPROVAL GENERATOR SET	10	22FEB10	05MAR10
428	MCA: FABRICATE & DELIVER GENERATOR SET	80	08MAR10	28JUN10
STRUCTURAL STEEL				
450	MCA: SUBMIT FOR APPROVAL STRUCTURAL STEEL	50	24NOV09	05FEB10
454	MCA: REVIEW FOR APPROVAL STRUCTURAL STEEL	10	08FEB10	19FEB10
458	MCA: FABRICATE & DELIVER STRUCTURAL STEEL	30	22FEB10	02APR10
SWITCHGEAR				
460	MCA: SUBMIT FOR APPROVAL SWITCHGEAR	60	24NOV09	19FEB10
464	MCA: REVIEW FOR APPROVAL SWITCHGEAR	10	22FEB10	05MAR10
468	MCA: FABRICATE & DELIVER SWITCHGEAR	80	08MAR10	28JUN10
TRANSFORMER				
470	MCA: SUBMIT FOR APPROVAL TRANSFORMER	60	24NOV09	19FEB10
474	MCA: REVIEW FOR APPROVAL TRANSFORMER	10	22FEB10	05MAR10
478	MCA: FABRICATE & DELIVER TRANSFORMER	50	08MAR10	14MAY10
MAIL ROOM SPRINKLER SYSTEM				
480	MR: SUBMIT MAIL ROOM SPRINKLER SHOP DWGS	10	27OCT09	09NOV09
484	MR: RVW & APPROVE MAIL ROOM SPRINKLER SHOP DWGS	10	10NOV09	23NOV09
488	MR: FABRICATE & DELIVER MAIL ROOM SPRINKLER PIPE	5	24NOV09	02DEC09
MARKETING CENTER SPRINKLER SYSTEM				
490	MR: SUBMIT MARKETING CENTER SPRINKLER SHOP DWGS	10	27OCT09	09NOV09
494	MR: RVW & APP MARKETING CNTR SPRINKLER SHOP DWGS	10	10NOV09	23NOV09
498	MR: FAB & DEL MARKETING CENTER SPRINKLER PIPE	5	24NOV09	02DEC09
WINDOW WALL SYSTEM				
4680	MCA: SUBMIT FOR APPROVAL WINDOW WALL SYSTEM	30	24NOV09	08JAN10
7890	MCA: REVIEW FOR APPROVAL WINDOW WALL SYSTEM	10	11JAN10	22JAN10
7900	MCA: FABRICATE & DELIVER WINDOW WALL SYSTEM	60	25JAN10	16APR10
CLUB ROOM STRUCTURAL STEEL				
500	CR: SUBMIT FOR APPROVAL STRUCTURAL STEEL	20	24NOV09	23DEC09
504	CR: REVIEW FOR APPROVAL STRUCTURAL STEEL	10	24DEC09	08JAN10
508	CR: FABRICATE & DELIVER STRUCTURAL STEEL	20	11JAN10	05FEB10
METAL ROOF				
4645	MCA: SUBMIT FOR APPROVAL METAL ROOF	30	24NOV09	08JAN10
7810	MCA: REVIEW FOR APPROVAL METAL ROOF	10	11JAN10	22JAN10
7820	MCA: FABRICATE AND DELIVER METAL ROOF	60	25JAN10	16APR10
MANUFACTURED STONE				
700	MCA: SUBMIT FOR APPROVAL MANUFACTURED STONE	30	24NOV09	08JAN10
704	MCA: REVIEW FOR APPROVAL MANUFACTURED STONE	10	11JAN10	22JAN10
708	MCA: FABRICATE & DELIVER MANUFACTURED STONE	60	25JAN10	16APR10
LOUVERS				
690	MCA: SUBMIT FOR APPROVAL LOUVERS	60	24NOV09	19FEB10
694	MCA: REVIEW FOR APPROVAL LOUVERS	10	22FEB10	05MAR10
698	MCA: FABRICATE & DELIVER LOUVERS	60	08MAR10	28MAY10



Start Date	27OCT09	Early Bar	RP00
Finish Date	17SEP12	Progress Bar	Sheet 2 of 24
Data Date	27OCT09	Critical Activity	
Run Date	14DEC09 17:41		

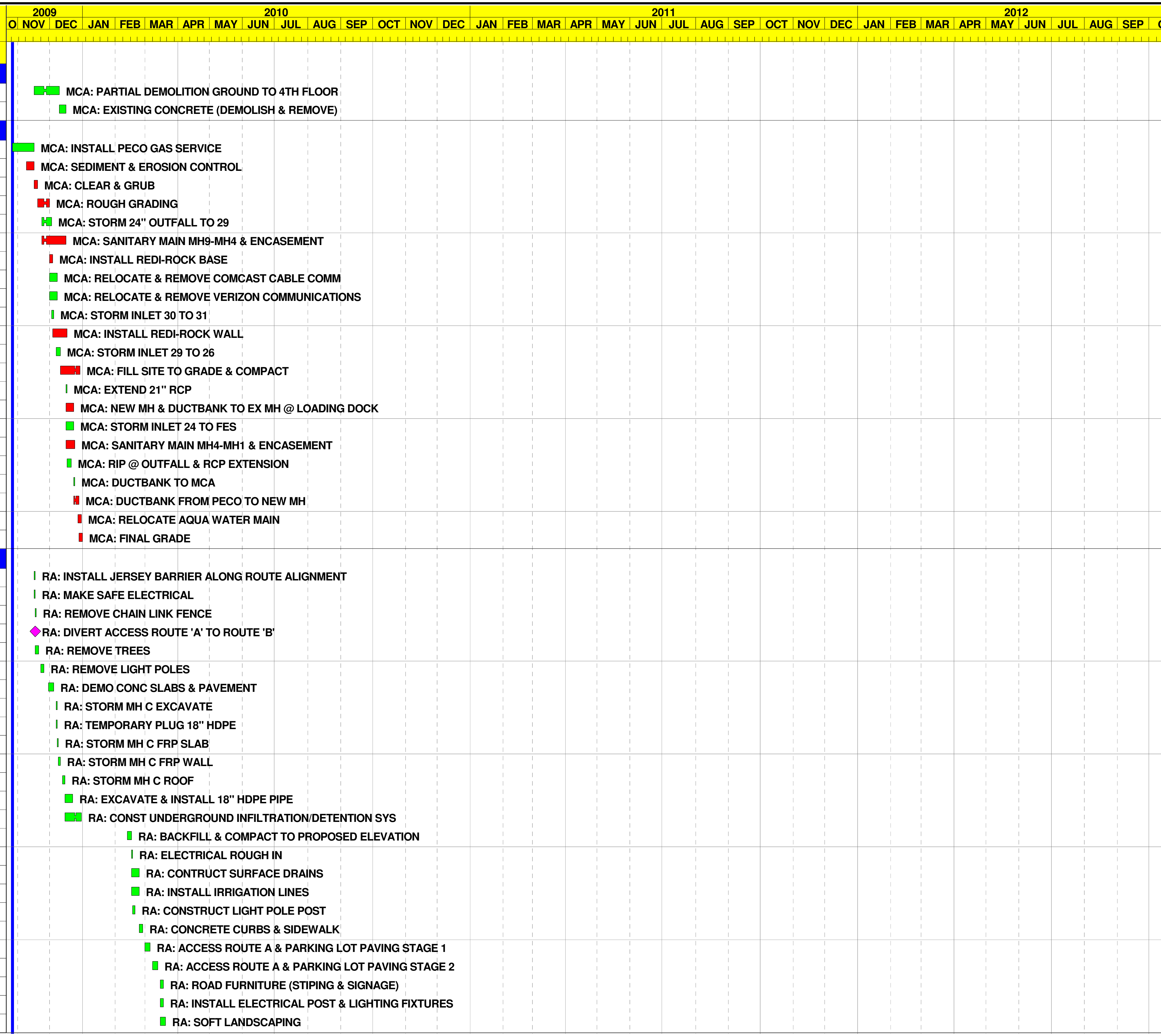
Whiting-Turner Contracting Company

Rydal Park Campus Repositioning

Classic Schedule Layout

Date	Revision	Checked	Approved

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
SITEWORK				
PARTIAL DEMO				
2000	MCA: PARTIAL DEMOLITION GROUND TO 4TH FLOOR	15	17NOV09	09DEC09
2010	MCA: EXISTING CONCRETE (DEMOLISH & REMOVE)	5	10DEC09	16DEC09
SITE UTILITIES				
2100	MCA: INSTALL PECO GAS SERVICE	15	27OCT09	16NOV09
2110	MCA: SEDIMENT & EROSION CONTROL	5	10NOV09	16NOV09
2120	MCA: CLEAR & GRUB	3	17NOV09	19NOV09
2130	MCA: ROUGH GRADING	5	20NOV09	30NOV09
2150	MCA: STORM 24" OUTFALL TO 29	5	24NOV09	02DEC09
2140	MCA: SANITARY MAIN MH9-MH4 & ENCASEMENT	15	24NOV09	16DEC09
2160	MCA: INSTALL REDI-ROCK BASE	3	01DEC09	03DEC09
2170	MCA: RELOCATE & REMOVE COMCAST CABLE COMM	5	01DEC09	07DEC09
2180	MCA: RELOCATE & REMOVE VERIZON COMMUNICATIONS	5	01DEC09	07DEC09
2200	MCA: STORM INLET 30 TO 31	2	03DEC09	04DEC09
2190	MCA: INSTALL REDI-ROCK WALL	10	04DEC09	17DEC09
2210	MCA: STORM INLET 29 TO 26	5	07DEC09	11DEC09
2220	MCA: FILL SITE TO GRADE & COMPACT	12	11DEC09	29DEC09
2260	MCA: EXTEND 21" RCP	1	17DEC09	17DEC09
2230	MCA: NEW MH & DUCTBANK TO EX MH @ LOADING DOCK	5	17DEC09	23DEC09
2250	MCA: STORM INLET 24 TO FES	5	17DEC09	23DEC09
2240	MCA: SANITARY MAIN MH4-MH1 & ENCASEMENT	6	17DEC09	24DEC09
2270	MCA: RIP @ OUTFALL & RCP EXTENSION	2	18DEC09	21DEC09
2290	MCA: DUCTBANK TO MCA	1	24DEC09	24DEC09
2280	MCA: DUCTBANK FROM PECO TO NEW MH	2	24DEC09	28DEC09
2300	MCA: RELOCATE AQUA WATER MAIN	3	28DEC09	30DEC09
2310	MCA: FINAL GRADE	3	29DEC09	31DEC09
ACCESS "A"				
2400	RA: INSTALL JERSEY BARRIER ALONG ROUTE ALIGNMENT	1	17NOV09	17NOV09
2410	RA: MAKE SAFE ELECTRICAL	1	17NOV09	17NOV09
2430	RA: REMOVE CHAIN LINK FENCE	1	18NOV09	18NOV09
2440	RA: DIVERT ACCESS ROUTE 'A' TO ROUTE 'B'	0	18NOV09	
2420	RA: REMOVE TREES	3	18NOV09	20NOV09
2450	RA: REMOVE LIGHT POLES	3	23NOV09	25NOV09
2460	RA: DEMO CONC SLABS & PAVEMENT	5	30NOV09	04DEC09
2470	RA: STORM MH C EXCAVATE	1	07DEC09	07DEC09
2480	RA: TEMPORARY PLUG 18" HDPE	1	07DEC09	07DEC09
2490	RA: STORM MH C FRP SLAB	1	08DEC09	08DEC09
2500	RA: STORM MH C FRP WALL	3	09DEC09	11DEC09
2510	RA: STORM MH C ROOF	2	14DEC09	15DEC09
2520	RA: EXCAVATE & INSTALL 18" HDPE PIPE	5	16DEC09	22DEC09
2530	RA: CONST UNDERGROUND INFILTRATION/DETENTION SYS	10	16DEC09	30DEC09
2540	RA: BACKFILL & COMPACT TO PROPOSED ELEVATION	3	12FEB10	16FEB10
2570	RA: ELECTRICAL ROUGH IN	1	17FEB10	17FEB10
2550	RA: CONTRUCT SURFACE DRAINS	5	17FEB10	23FEB10
2560	RA: INSTALL IRRIGATION LINES	5	17FEB10	23FEB10
2580	RA: CONSTRUCT LIGHT POLE POST	2	18FEB10	19FEB10
2590	RA: CONCRETE CURBS & SIDEWALK	3	24FEB10	26FEB10
2600	RA: ACCESS ROUTE A & PARKING LOT PAVING STAGE 1	5	01MAR10	05MAR10
2610	RA: ACCESS ROUTE A & PARKING LOT PAVING STAGE 2	5	08MAR10	12MAR10
2630	RA: ROAD FURNITURE (STIPING & SIGNAGE)	3	15MAR10	17MAR10
2640	RA: INSTALL ELECTRICAL POST & LIGHTING FIXTURES	3	15MAR10	17MAR10
2620	RA: SOFT LANDSCAPING	5	15MAR10	19MAR10



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Finish Date 17SEP12
Data Date 27OCT09
Run Date 14DEC09 17:41

Early Bar
Progress Bar
Critical Activity

RP00

Sheet 3 of 24

Whiting-Turner Contracting Company

Rydal Park Campus Repositioning

Classic Schedule Layout

Date	Revision	Checked	Approved

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
2650	RA: COMPLETE ACCESS ROUTE 'A'	0		19MAR10
SITE FINISHES				
MCA SITE FINISHES				
2700	MCA: CONSTRUCT SIDEWALK & CURB	5	17SEP10	23SEP10
2710	MCA: PAVEMENT MILLING & RESURFACING WORK	5	24SEP10	30SEP10
2720	MCA: HARD LANDSCAPE	10	01OCT10	14OCT10
2730	MCA: SOFT LANDSCAPE	10	08OCT10	21OCT10
PERGOLA & RETAINING WALL				
2800	PERGOLA: EXCAVATE & RETAINING WALL FOOTING	2	31DEC09	04JAN10
2801	PERGOLA: FRP PERGOLA & RETAINING WALL FOOTING	5	05JAN10	11JAN10
2802	PERGOLA: FRP PERGOLA PIERS	3	12JAN10	14JAN10
2803	PERGOLA: ELECTRICAL EMBED ROUGH IN	3	12JAN10	14JAN10
2804	PERGOLA: FRP RETAINING WALL	5	12JAN10	18JAN10
2805	PERGOLA: FRP PERGOLA RAMP WALLS	10	15JAN10	28JAN10
2806	PERGOLA: FRP PERGOLA RAMP & STAIR	3	29JAN10	02FEB10
2807	PERGOLA: ERECT PERGOLA STEEL COLUMN	2	03FEB10	04FEB10
2808	PERGOLA: ERECT PERGOLA ROOF STRUCTURE	5	05FEB10	11FEB10
2809	PERGOLA: INSTALL ROOFING & ACCESSORIES	2	12FEB10	15FEB10
2810	PERGOLA: TUBE COLUMN CONCRETE ENCASING	2	16FEB10	17FEB10
2812	PERGOLA: PAINTING	2	18FEB10	19FEB10
2811	PERGOLA: INSTALL STONE VENEER & WALL CAP	5	18FEB10	24FEB10
2813	PERGOLA: INSTALL ELECTRICAL FIXTURES & TRIM	1	22FEB10	22FEB10
2814	PERGOLA: INSTALL RET WALL GUARDRAIL & STAIR RAIL	3	25FEB10	01MAR10
2815	PERGOLA: COMPLETE PERGOLA & RETAINING WALL	0		01MAR10
MEDICAL CENTER ADDITION				
MCA FOUNDATIONS				
3000	MCA: INSTALL GEOPIERS GL - R-X/7-24	6	18DEC09	28DEC09
3005	MCA: INSTALL GEOPIERS GL - A-R/7-18	8	29DEC09	08JAN10
3010	MCA: EXCAVATE FOOTINGS GL - R-X/7-24	2	04JAN10	05JAN10
3015	MCA: CAST MUD SLAB GL - R-X/7-24	2	06JAN10	07JAN10
3020	MCA: FRP COLUMN FOOTINGS GL - R-X/7-24	10	08JAN10	21JAN10
3025	MCA: EXCAVATE FOOTINGS GL - A-R/7-18	2	11JAN10	12JAN10
3030	MCA: INSTALL GEOPIERS GL - A-K/1-7	6	11JAN10	18JAN10
3035	MCA: CAST MUD SLAB GL - A-R/7-18	2	13JAN10	14JAN10
3040	MCA: INSTALL HELICAL PILES GL - A-K/1-7	3	19JAN10	21JAN10
3050	MCA: EXCAVATE FOOTINGS GL - A-K/1-7	1	22JAN10	22JAN10
3045	MCA: FRP COLUMN FOOTINGS GL - A-R/7-18	10	22JAN10	04FEB10
3055	MCA: CAST MUD SLAB GL - A-K/1-7	1	25JAN10	25JAN10
3060	MCA: FRP COLUMN FOOTINGS/PILE CAP GL - A-K/1-7	5	05FEB10	11FEB10
3065	MCA: FRP COLUMNS & WALLS GL - A-K/1-7	10	12FEB10	25FEB10
3070	MCA: FRP COLUMNS & WALLS GL - A-R/7-18	18	26FEB10	23MAR10
3075	MCA: EXTR CMU WALLS & COLUMN GL - A-R/7-18	5	24MAR10	30MAR10
3080	MCA: FRP COLUMNS & WALLS GL - R-X/7-24	15	24MAR10	13APR10
3085	MCA: CMU COLUMNS GL - R-X/7-24	5	14APR10	20APR10
MCA GROUND LEVEL STRUCTURE				
3150	MCA: UNDERGROUND PLUMBING AREA 3	5	22JAN10	28JAN10
3120	MCA: UNDERSLAB PLUMBING AREA 2	5	05FEB10	11FEB10
3100	MCA: UNDERGROUND PLUMBING AREA 1	5	12FEB10	18FEB10
3110	MCA: FRP AREA 1 SLABS ON GRADE	7	26FEB10	08MAR10
3130	MCA: FRP SOG1,2,3 & 4 AREA 2	15	31MAR10	20APR10
3140	MCA: REMOVE SHORING GROUND-1ST FL AREA 1	1	01APR10	01APR10
3160	MCA: FRP SOG2 & 3 AREA 3	15	21APR10	11MAY10
3170	MCA: REMOVE SHORING GROUND-1ST FL AREA 2	2	20MAY10	21MAY10

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
3180	MCA: REMOVE SHORING GROUND-1ST FL AREA 3	2	09JUN10	10JUN10
MCA 1ST FLOOR STRUCTURE				
3200	MCA: FRP 1ST FLOOR SLAB POUR AREA 1	8	09MAR10	18MAR10
3205	MCA: FRP COLUMNS 1ST TO 2ND FLOOR POUR AREA 1	4	19MAR10	24MAR10
3210	MCA: CURE 1ST FLOOR SLAB POUR AREA 1	7	19MAR10	25MAR10
3215	MCA: ENGINEER APPROVE BREAK 1ST FL SLAB AREA 1	1	26MAR10	26MAR10
3220	MCA: STRESS 1ST FLOOR TENDON @ AREA 1	3	29MAR10	31MAR10
3230	MCA: REMOVE SHORING 1ST-2ND FL AREA 1	1	19APR10	19APR10
3225	MCA: FRP 1ST FLOOR SLAB POUR AREA 2	10	21APR10	04MAY10
3240	MCA: CURE 1ST FLOOR SLAB POUR AREA 2	7	05MAY10	11MAY10
3235	MCA: FRP COLUMNS 1ST TO 2ND FLOOR POUR AREA 2	6	05MAY10	12MAY10
3250	MCA: ENGINEER APPROVE BREAK 1ST FL SLAB AREA 2	1	12MAY10	12MAY10
3245	MCA: FRP 1ST FLOOR SLAB POUR AREA 3	9	12MAY10	24MAY10
3255	MCA: STRESS 1ST FLOOR TENDON @ AREA 2	5	13MAY10	19MAY10
3260	MCA: FRP SHEAR WALLS 1ST TO 2ND FLOOR	10	18MAY10	01JUN10
3270	MCA: CURE 1ST FLOOR SLAB POUR AREA 3	7	25MAY10	31MAY10
3265	MCA: COLUMNS 1ST TO 2ND FLOOR POUR AREA 3	5	25MAY10	01JUN10
3275	MCA: ENGINEER APPROVE BREAK 1ST FL SLAB AREA 3	1	01JUN10	01JUN10
3280	MCA: STRESS 1ST FLOOR TENDON @ AREA 3	5	02JUN10	08JUN10
3285	MCA: REMOVE SHORING 1ST-2ND FL AREA 2	2	11JUN10	14JUN10
3290	MCA: REMOVE SHORING 1ST-2ND FL AREA 3	2	01JUL10	02JUL10
3295	MCA: MASONRY WALLS 1ST TO 2ND FLOOR	5	06JUL10	12JUL10
MCA 2ND FLOOR STRUCTURE				
3300	MCA: FRP 2ND FLOOR SLAB POUR AREA 1	8	25MAR10	05APR10
3305	MCA: FRP COLUMNS 2ND TO 3RD FLOOR POUR AREA 1	3	06APR10	08APR10
3310	MCA: CURE 2ND FLOOR SLAB POUR AREA 1	7	06APR10	12APR10
3315	MCA: ENGINEER APPROVE BREAK 2ND FL SLAB AREA 1	1	13APR10	13APR10
3320	MCA: STRESS 2ND FLOOR SLAB TENDON @ AREA 1	3	14APR10	16APR10
3325	MCA: REMOVE SHORING 2ND-3RD FL AREA 1	1	03MAY10	03MAY10
3330	MCA: FRP 2ND FLOOR SLAB POUR AREA 2	10	13MAY10	26MAY10
3340	MCA: CURE 2ND FLOOR SLAB POUR AREA 2	7	27MAY10	02JUN10
3335	MCA: FRP COLUMNS 2ND TO 3RD FLOOR POUR AREA 2	5	27MAY10	03JUN10
3350	MCA: ENGINEER APPROVE BREAK 2ND FL SLAB AREA 2	1	03JUN10	03JUN10
3345	MCA: FRP 2ND FLOOR SLAB POUR AREA 3	9	03JUN10	15JUN10
3355	MCA: STRESS 2ND FLOOR SLAB TENDON @ AREA 2	5	04JUN10	10JUN10
3360	MCA: FRP COLUMNS 2ND TO 3RD FLOOR POUR AREA 3	5	16JUN10	22JUN10
3365	MCA: FRP SHEAR WALLS 2ND TO 3RD FLOOR	5	16JUN10	22JUN10
3370	MCA: CURE 2ND FLOOR SLAB POUR AREA 3	7	16JUN10	22JUN10
3375	MCA: ENGINEER APPROVE BREAK 2ND FL SLAB AREA 3	1	23JUN10	23JUN10
3380	MCA: STRESS 2ND FLOOR SLAB TENDON @ AREA 3	5	24JUN10	30JUN10
3385	MCA: REMOVE SHORING 2ND-3RD FL AREA 2	2	02JUL10	06JUL10
3390	MCA: REMOVE SHORING 2ND-3RD FL AREA 3	2	22JUL10	23JUL10
3395	MCA: 3RD FLOOR ROOF STRUCTURE	5	22JUL10	28JUL10
3400	MCA: 3RD FLOOR ROOFING	5	29JUL10	04AUG10
MCA 3RD FLOOR STRUCTURE				
3600	MCA: FRP 3RD FLOOR SLAB POUR AREA 1	8	09APR10	20APR10
3610	MCA: FRP COLUMNS 3RD TO 4TH FLOOR POUR AREA 1	3	21APR10	23APR10
3605	MCA: CURE 3RD FLOOR SLAB POUR AREA 1	7	21APR10	27APR10
3615	MCA: STRESS 3RD FLOOR SLAB TENDON @ AREA 1	3	28APR10	30APR10
3620	MCA: REMOVE SHORING 3RD-4TH FL AREA 1	1	18MAY10	18MAY10
3625	MCA: FRP 3RD FLOOR SLAB POUR AREA 2	10	04JUN10	17JUN10
3630	MCA: FRP COLUMNS 3RD TO 4TH FLOOR POUR AREA 2	5	18JUN10	24JUN10
3635	MCA: CURE 3RD FLOOR SLAB POUR AREA 2	7	18JUN10	24JUN10

Start Date 27OCT09
Finish Date 17SEP12
Data Date 27OCT09
Run Date 14DEC09 17:41

Early Bar
Progress Bar
Critical Activity

RP00 Sheet 5 of 24

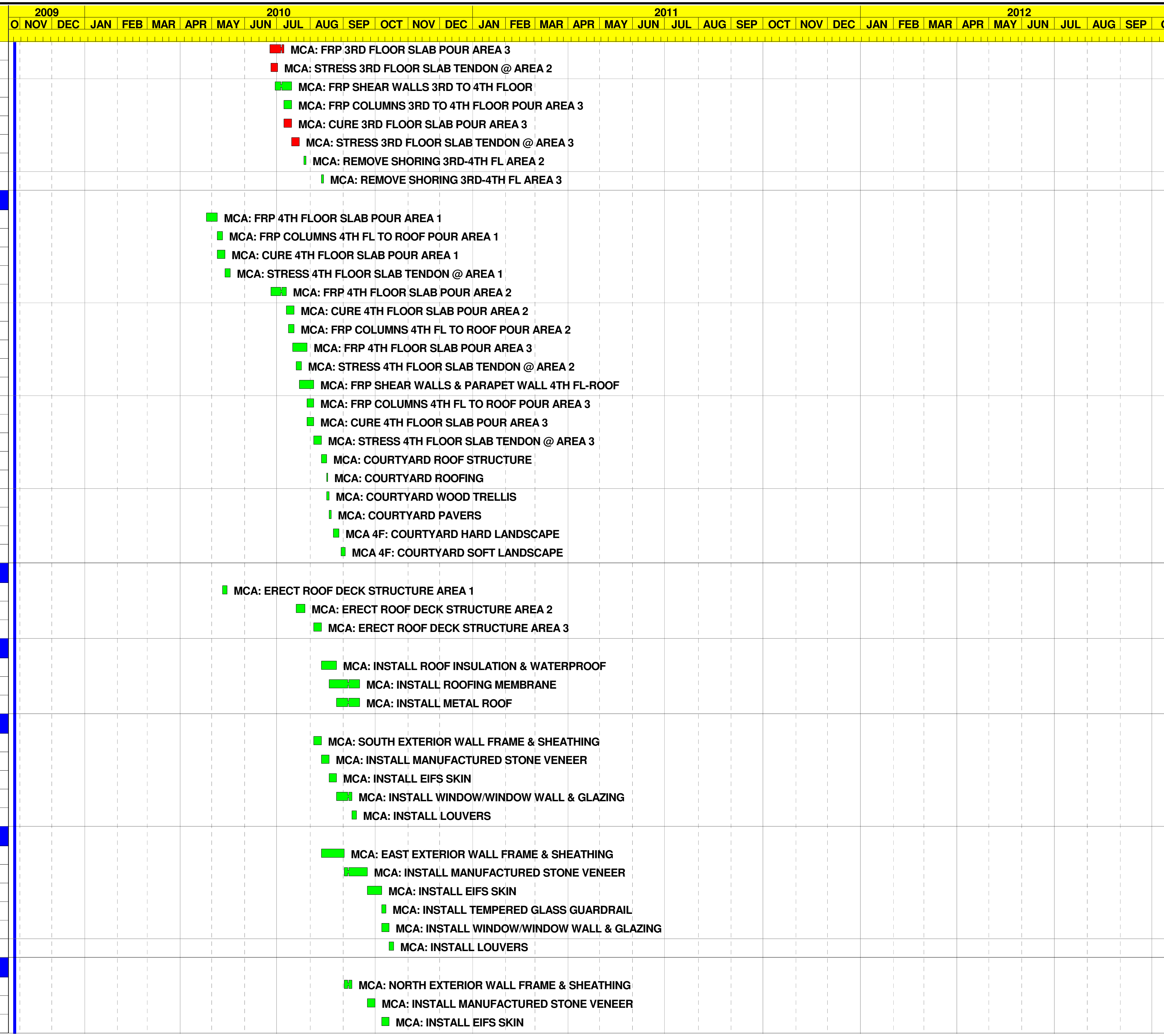
Whiting-Turner Contracting Company

Rydal Park Campus Repositioning

Classic Schedule Layout

Date	Revision	Checked	Approved

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
3640	MCA: FRP 3RD FLOOR SLAB POUR AREA 3	9	24JUN10	07JUL10
3645	MCA: STRESS 3RD FLOOR SLAB TENDON @ AREA 2	5	25JUN10	01JUL10
3650	MCA: FRP SHEAR WALLS 3RD TO 4TH FLOOR	10	30JUN10	14JUL10
3655	MCA: FRP COLUMNS 3RD TO 4TH FLOOR POUR AREA 3	5	08JUL10	14JUL10
3660	MCA: CURE 3RD FLOOR SLAB POUR AREA 3	7	08JUL10	14JUL10
3665	MCA: STRESS 3RD FLOOR SLAB TENDON @ AREA 3	5	15JUL10	21JUL10
3670	MCA: REMOVE SHORING 3RD-4TH FL AREA 2	2	26JUL10	27JUL10
3675	MCA: REMOVE SHORING 3RD-4TH FL AREA 3	2	12AUG10	13AUG10
MCA 4TH FLOOR STRUCTURE				
3700	MCA: FRP 4TH FLOOR SLAB POUR AREA 1	8	26APR10	05MAY10
3710	MCA: FRP COLUMNS 4TH FL TO ROOF POUR AREA 1	3	06MAY10	10MAY10
3705	MCA: CURE 4TH FLOOR SLAB POUR AREA 1	7	06MAY10	12MAY10
3715	MCA: STRESS 4TH FLOOR SLAB TENDON @ AREA 1	3	13MAY10	17MAY10
3720	MCA: FRP 4TH FLOOR SLAB POUR AREA 2	10	25JUN10	09JUL10
3725	MCA: CURE 4TH FLOOR SLAB POUR AREA 2	7	10JUL10	16JUL10
3730	MCA: FRP COLUMNS 4TH FL TO ROOF POUR AREA 2	5	12JUL10	16JUL10
3735	MCA: FRP 4TH FLOOR SLAB POUR AREA 3	9	16JUL10	28JUL10
3740	MCA: STRESS 4TH FLOOR SLAB TENDON @ AREA 2	5	19JUL10	23JUL10
3745	MCA: FRP SHEAR WALLS & PARAPET WALL 4TH FL-ROOF	10	22JUL10	04AUG10
3750	MCA: FRP COLUMNS 4TH FL TO ROOF POUR AREA 3	5	29JUL10	04AUG10
3755	MCA: CURE 4TH FLOOR SLAB POUR AREA 3	7	29JUL10	04AUG10
3760	MCA: STRESS 4TH FLOOR SLAB TENDON @ AREA 3	5	05AUG10	11AUG10
3765	MCA: COURTYARD ROOF STRUCTURE	3	12AUG10	16AUG10
3775	MCA: COURTYARD ROOFING	1	17AUG10	17AUG10
3770	MCA: COURTYARD WOOD TRELLIS	2	17AUG10	18AUG10
3780	MCA: COURTYARD PAVERS	2	19AUG10	20AUG10
3785	MCA 4F: COURTYARD HARD LANDSCAPE	5	23AUG10	27AUG10
3790	MCA 4F: COURTYARD SOFT LANDSCAPE	5	30AUG10	03SEP10
MCA ROOF STRUCTURE				
3800	MCA: ERECT ROOF DECK STRUCTURE AREA 1	4	11MAY10	14MAY10
3810	MCA: ERECT ROOF DECK STRUCTURE AREA 2	6	19JUL10	26JUL10
3820	MCA: ERECT ROOF DECK STRUCTURE AREA 3	5	05AUG10	11AUG10
MCA ROOFING				
3900	MCA: INSTALL ROOF INSULATION & WATERPROOF	10	12AUG10	25AUG10
3910	MCA: INSTALL ROOFING MEMBRANE	20	19AUG10	16SEP10
3920	MCA: INSTALL METAL ROOF	15	26AUG10	16SEP10
MCA ENVELOPE - SOUTH				
4000	MCA: SOUTH EXTERIOR WALL FRAME & SHEATHING	5	05AUG10	11AUG10
4010	MCA: INSTALL MANUFACTURED STONE VENEER	5	12AUG10	18AUG10
4020	MCA: INSTALL EIFS SKIN	5	19AUG10	25AUG10
4030	MCA: INSTALL WINDOW/WINDOW WALL & GLAZING	10	26AUG10	09SEP10
4040	MCA: INSTALL LOUVERS	2	10SEP10	13SEP10
MCA ENVELOPE - EAST				
4100	MCA: EAST EXTERIOR WALL FRAME & SHEATHING	15	12AUG10	01SEP10
4110	MCA: INSTALL MANUFACTURED STONE VENEER	15	02SEP10	23SEP10
4120	MCA: INSTALL EIFS SKIN	10	24SEP10	07OCT10
4140	MCA: INSTALL TEMPERED GLASS GUARDRAIL	2	08OCT10	11OCT10
4130	MCA: INSTALL WINDOW/WINDOW WALL & GLAZING	5	08OCT10	14OCT10
4150	MCA: INSTALL LOUVERS	2	15OCT10	18OCT10
MCA ENVELOPE - NORTH				
4200	MCA: NORTH EXTERIOR WALL FRAME & SHEATHING	5	02SEP10	09SEP10
4210	MCA: INSTALL MANUFACTURED STONE VENEER	5	24SEP10	30SEP10
4220	MCA: INSTALL EIFS SKIN	5	08OCT10	14OCT10



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Data Date	27OCT09
Run Date	14DEC09 17:41

Early Bar
Progress Bar
Critical Activity

RP00

Whiting-Turner Contracting Company

Rydal Park Campus Repositioning

Classic Schedule Layout

Date	Revision	Checked	Approved

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
4230	MCA: INSTALL WINDOW/WINDOW WALL & GLAZING	5	15OCT10	21OCT10
4240	MCA: INSTALL LOUVERS	1	22OCT10	22OCT10
MCA ENVELOPE - WEST				
4300	MCA: WEST EXTERIOR WALL FRAME & SHEATHING	15	10SEP10	30SEP10
4310	MCA: INSTALL MANUFACTURED STONE VENEER	15	01OCT10	21OCT10
4320	MCA: INSTALL EIFS SKIN	10	22OCT10	04NOV10
4330	MCA: INSTALL WINDOW/WINDOW WALL & GLAZING	10	05NOV10	18NOV10
4340	MCA: INSTALL LOUVERS	1	19NOV10	19NOV10
MCA RISERS GROUND TO 1ST FLOOR				
4420	MCA: INSTALL DUCTWORK RISERS GROUND TO 1ST	5	08JUL10	14JUL10
4400	MCA: INSTALL PLUMBING RISERS GROUND TO 1ST	10	08JUL10	21JUL10
4410	MCA: INSTALL MECHANICAL PIPING RISERS GND TO 1ST	10	08JUL10	21JUL10
4430	MCA: INSTALL SPRINKLER PIPE RISERS GROUND TO 1ST	4	29JUL10	03AUG10
4440	MCA: INSTALL ELECTRICAL RISERS GROUND TO 1ST	10	12AUG10	25AUG10
MCA RISERS 1ST TO 2ND FLOOR				
4500	MCA: INSTALL DUCTWORK RISERS 1ST TO 2ND FL	10	15JUL10	28JUL10
4510	MCA: INSTALL PLUMBING RISERS 1ST TO 2ND FL	10	22JUL10	04AUG10
4520	MCA: INSTALL MECHANICAL PIPING RISERS 1ST TO 2ND	10	22JUL10	04AUG10
4530	MCA: INSTALL SPRINKLER PIPE RISERS 1ST TO 2ND FL	4	04AUG10	09AUG10
4540	MCA: INSTALL ELECTRICAL RISERS 1ST TO 2ND FL	10	26AUG10	09SEP10
MCA RISERS 2ND TO 3RD FLOOR				
4600	MCA: INSTALL DUCTWORK RISERS 2ND TO 3RD FL	10	29JUL10	11AUG10
4610	MCA: INSTALL PLUMBING RISERS 2ND TO 3RD FL	10	05AUG10	18AUG10
4620	MCA: INSTALL MECHANICAL PIPING RISERS 2ND TO 3RD	10	05AUG10	18AUG10
4630	MCA: INSTALL SPRINKLER PIPE RISERS 2ND TO 3RD FL	4	10AUG10	13AUG10
4640	MCA: INSTALL ELECTRICAL RISERS 2ND TO 3RD FL	10	10SEP10	23SEP10
MCA RISERS 3RD TO 4TH FLOOR				
4710	MCA: INSTALL SPRINKLER PIPE RISERS 3RD TO 4TH FL	4	16AUG10	19AUG10
4700	MCA: INSTALL DUCTWORK RISERS 3RD TO 4TH FL	10	16AUG10	27AUG10
4720	MCA: INSTALL PLUMBING RISERS 3RD TO 4TH FL	10	19AUG10	01SEP10
4730	MCA: INSTALL MECHANICAL PIPING RISERS 3RD TO 4TH	10	19AUG10	01SEP10
4740	MCA: INSTALL ELECTRICAL RISERS 3RD TO 4TH FL	10	24SEP10	07OCT10
MCA RISERS 4TH FLOOR				
4800	MCA: INSTALL SPRINKLER PIPE RISERS 4TH FL	4	20AUG10	25AUG10
4810	MCA: INSTALL DUCTWORK RISERS 4TH FL	5	30AUG10	03SEP10
4820	MCA: INSTALL PLUMBING RISERS 4TH FL	5	02SEP10	09SEP10
4830	MCA: INSTALL MECHANICAL PIPING RISERS 4TH FL	5	02SEP10	09SEP10
4840	MCA: INSTALL ELECTRICAL RISERS 4TH FL	5	08OCT10	14OCT10
MCA GROUND LEVEL ROUGHS & FINISHES				
10020	MCA GF: ELEVATOR EQUIPMENT ROOM FITOUT	10	09JUN10	22JUN10
10010	MCA GF: TRANSFORMER ROOM FITOUT	15	09JUN10	29JUN10
10000	MCA GF: ELECTRICAL ROOM FITOUT (SUBSTATION)	20	09JUN10	07JUL10
10030	MCA GF: LAYOUT & TOP TRACK	3	11JUN10	15JUN10
10040	MCA GF: SPRINKLER ROOM FITOUT	10	11JUN10	24JUN10
10050	MCA GF: SET/CONNECT GENERATOR & FITOUT GEN ROOM	15	29JUN10	20JUL10
10060	MCA: TRANSFORMER TEST	3	03AUG10	05AUG10
10070	MCA GF: INSTALL DUCTWORK	5	26AUG10	01SEP10
10100	MCA GF: OH MECHANICAL PIPING ROUGH IN	5	02SEP10	09SEP10
10080	MCA GF: OH ELECTRICAL / LV ROUGH IN	15	02SEP10	23SEP10
10090	MCA GF: OH SPRINKLER ROUGH IN	15	02SEP10	23SEP10
10110	MCA GF: OH PLUMBING ROUGH IN	10	10SEP10	23SEP10
10130	MCA GF: INTERIOR WALL FRAMING	5	24SEP10	30SEP10
10150	MCA GF: ELECTRICAL WALL ROUGH IN	5	01OCT10	07OCT10

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Early Bar
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Whiting-Turner Contracting Company

Rydal Park Campus Repositioning

Classic Schedule Layout

Date	Revision	Checked	Approved

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
10140	MCA GF: PLUMBING WALL ROUGH IN	10	01OCT10	14OCT10
10160	MCA GF: WALL CLOSE IN INSPECTION	3	15OCT10	19OCT10
10170	MCA GF: H/T/F GWB WALLS	5	20OCT10	26OCT10
10180	MCA GF: PRIME PAINT	5	27OCT10	02NOV10
10210	MCA GF: INSTALL MILLWORK	2	03NOV10	04NOV10
10190	MCA GF: CEILING GRID	5	03NOV10	09NOV10
10200	MCA GF: INSTALL RAILING	5	03NOV10	09NOV10
10220	MCA GF: INSTALL LIGHT FIXTURES	10	10NOV10	23NOV10
10230	MCA GF: SPRINKLER DROPS	10	10NOV10	23NOV10
10240	MCA GF: OH CLOSE IN INSPECTION	1	24NOV10	24NOV10
10260	MCA GF: SPRINKLER HYDRO TEST	1	24NOV10	24NOV10
10250	MCA GF: INSTALL GARAGE WHEEL STOPS	3	24NOV10	29NOV10
10270	MCA GF: HANG CEILING	5	26NOV10	02DEC10
10280	MCA GF: GARAGE STRIPING & SIGNAGE	5	30NOV10	06DEC10
10290	MCA GF: FINAL PAINT	5	03DEC10	09DEC10
10310	MCA GF: INSTALL ELEC & FIRE ALARM FINAL TRIM	2	10DEC10	13DEC10
10300	MCA GF: FLOOR FINISHES	5	10DEC10	16DEC10
10330	MCA GF: ELECTRICAL INSPECTION	1	14DEC10	14DEC10
10320	MCA GF: FIRE MARSHAL INSPECTION	2	14DEC10	15DEC10
10340	MCA GF: BUILDING INSPECTION	2	16DEC10	17DEC10
10360	MCA GF: DELIVERY FURNITURE	1	17DEC10	17DEC10
10350	MCA GF: INSTALL DOORS & HARDWARES	2	17DEC10	20DEC10
10370	MCA GF: PUNCHLIST & CORRECTION	3	21DEC10	23DEC10
MCA 1ST FLOOR ROUGHS & FINISHES				
11000	MCA 1F: LAYOUT & TOP TRACK	3	06JUL10	08JUL10
11010	MCA 1F: ELECTRICAL ROOM FITOUT	15	13JUL10	02AUG10
11020	MCA 1F: SWITCHGEAR ROOM FITOUT	15	13JUL10	02AUG10
11030	MCA 1F: MECHANICAL ROOM FITOUT	20	13JUL10	09AUG10
11050	MCA 1F: CLEAN & TEST SWITCHGEAR	10	03AUG10	16AUG10
11040	MCA 1F: PECO PULL FEEDS & TERMINATE	15	03AUG10	23AUG10
11060	MCA 1F: TEST FEEDERS & ENERGIZE SWITCHGEAR	5	24AUG10	30AUG10
11070	MCA 1F: MECHANICAL START-UP	10	31AUG10	14SEP10
11080	MCA 1F: INSTALL DUCTWORK	15	02SEP10	23SEP10
11090	MCA 1F: OH MECHANICAL PIPING ROUGH IN	15	10SEP10	30SEP10
11120	MCA 1F: OH PLUMBING ROUGH IN	10	24SEP10	07OCT10
11100	MCA 1F: OH ELECTRICAL / LV ROUGH IN	15	24SEP10	14OCT10
11110	MCA 1F: OH SPRINKLER ROUGH IN	15	24SEP10	14OCT10
11140	MCA 1F: INTERIOR WALL FRAMING	5	15OCT10	21OCT10
11150	MCA 1F: ELECTRICAL WALL ROUGH IN	5	22OCT10	28OCT10
11160	MCA 1F: WALL CLOSE IN INSPECTION	3	29OCT10	02NOV10
11170	MCA 1F: H/T/F GWB WALLS	5	03NOV10	09NOV10
11180	MCA 1F: PRIME PAINT	5	10NOV10	16NOV10
11210	MCA 1F: INSTALL MILLWORK	2	17NOV10	18NOV10
11200	MCA 1F: INSTALL RAILING	5	17NOV10	23NOV10
11190	MCA 1F: CEILING FRAMING / GRID	10	17NOV10	01DEC10
11220	MCA 1F: INSTALL LIGHT FIXTURES	10	02DEC10	15DEC10
11230	MCA 1F: SPRINKLER DROPS	10	02DEC10	15DEC10
11240	MCA 1F: OH CLOSE IN INSPECTION	1	16DEC10	16DEC10
11250	MCA 1F: SPRINKLER HYDRO TEST	1	16DEC10	16DEC10
11260	MCA 1F: INSTALL GARAGE WHEEL STOPS	3	16DEC10	20DEC10
11270	MCA 1F: HANG CEILING	10	17DEC10	03JAN11
11280	MCA 1F: GARAGE STRIPING & SIGNAGE	3	21DEC10	23DEC10
11290	MCA 1F: FINAL PAINT	5	04JAN11	10JAN11

Start Date	27OCT09
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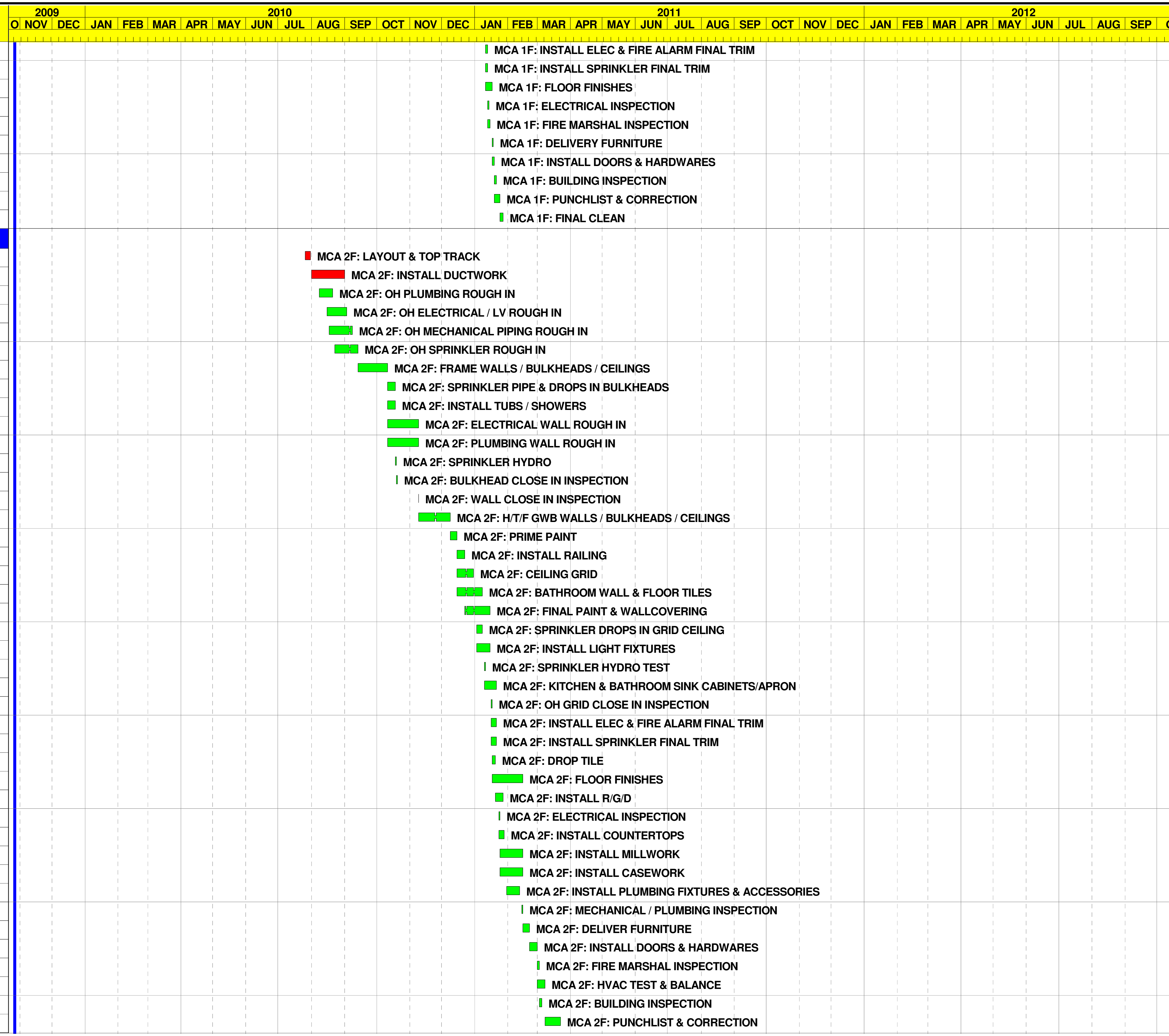
Classic Schedule Layout

Date	Revision	Checked	Approved

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
11310	MCA 1F: INSTALL ELEC & FIRE ALARM FINAL TRIM	2	11JAN11	12JAN11
11320	MCA 1F: INSTALL SPRINKLER FINAL TRIM	2	11JAN11	12JAN11
11300	MCA 1F: FLOOR FINISHES	5	11JAN11	17JAN11
11340	MCA 1F: ELECTRICAL INSPECTION	1	13JAN11	13JAN11
11330	MCA 1F: FIRE MARSHAL INSPECTION	2	13JAN11	14JAN11
11360	MCA 1F: DELIVERY FURNITURE	1	18JAN11	18JAN11
11350	MCA 1F: INSTALL DOORS & HARDWARES	2	18JAN11	19JAN11
11370	MCA 1F: BUILDING INSPECTION	2	20JAN11	21JAN11
11380	MCA 1F: PUNCHLIST & CORRECTION	3	20JAN11	24JAN11
11390	MCA 1F: FINAL CLEAN	3	25JAN11	27JAN11
MCA 2ND FLOOR ROUGHS & FINISHES				
12000	MCA 2F: LAYOUT & TOP TRACK	5	26JUL10	30JUL10
12010	MCA 2F: INSTALL DUCTWORK	22	02AUG10	31AUG10
12020	MCA 2F: OH PLUMBING ROUGH IN	10	09AUG10	20AUG10
12030	MCA 2F: OH ELECTRICAL / LV ROUGH IN	15	16AUG10	03SEP10
12040	MCA 2F: OH MECHANICAL PIPING ROUGH IN	15	18AUG10	08SEP10
12050	MCA 2F: OH SPRINKLER ROUGH IN	15	23AUG10	13SEP10
12060	MCA 2F: FRAME WALLS / BULKHEADS / CEILINGS	20	14SEP10	11OCT10
12090	MCA 2F: SPRINKLER PIPE & DROPS IN BULKHEADS	5	12OCT10	18OCT10
12100	MCA 2F: INSTALL TUBS / SHOWERS	5	12OCT10	18OCT10
12070	MCA 2F: ELECTRICAL WALL ROUGH IN	20	12OCT10	08NOV10
12080	MCA 2F: PLUMBING WALL ROUGH IN	20	12OCT10	08NOV10
12110	MCA 2F: SPRINKLER HYDRO	1	19OCT10	19OCT10
12120	MCA 2F: BULKHEAD CLOSE IN INSPECTION	1	20OCT10	20OCT10
12130	MCA 2F: WALL CLOSE IN INSPECTION	1	09NOV10	09NOV10
12140	MCA 2F: H/T/F GWB WALLS / BULKHEADS / CEILINGS	20	10NOV10	08DEC10
12150	MCA 2F: PRIME PAINT	5	09DEC10	15DEC10
12160	MCA 2F: INSTALL RAILING	5	16DEC10	22DEC10
12170	MCA 2F: CEILING GRID	10	16DEC10	30DEC10
12180	MCA 2F: BATHROOM WALL & FLOOR TILES	15	16DEC10	07JAN11
12190	MCA 2F: FINAL PAINT & WALLCOVERING	15	23DEC10	14JAN11
12210	MCA 2F: SPRINKLER DROPS IN GRID CEILING	5	03JAN11	07JAN11
12200	MCA 2F: INSTALL LIGHT FIXTURES	10	03JAN11	14JAN11
12230	MCA 2F: SPRINKLER HYDRO TEST	1	10JAN11	10JAN11
12240	MCA 2F: KITCHEN & BATHROOM SINK CABINETS/APRON	10	10JAN11	21JAN11
12270	MCA 2F: OH GRID CLOSE IN INSPECTION	1	17JAN11	17JAN11
12280	MCA 2F: INSTALL ELEC & FIRE ALARM FINAL TRIM	5	17JAN11	21JAN11
12290	MCA 2F: INSTALL SPRINKLER FINAL TRIM	5	17JAN11	21JAN11
12300	MCA 2F: DROP TILE	3	18JAN11	20JAN11
12220	MCA 2F: FLOOR FINISHES	20	18JAN11	14FEB11
12310	MCA 2F: INSTALL R/G/D	5	21JAN11	27JAN11
12330	MCA 2F: ELECTRICAL INSPECTION	1	24JAN11	24JAN11
12320	MCA 2F: INSTALL COUNTERTOPS	5	24JAN11	28JAN11
12250	MCA 2F: INSTALL MILLWORK	15	25JAN11	14FEB11
12260	MCA 2F: INSTALL CASEWORK	15	25JAN11	14FEB11
12340	MCA 2F: INSTALL PLUMBING FIXTURES & ACCESSORIES	10	31JAN11	11FEB11
12370	MCA 2F: MECHANICAL / PLUMBING INSPECTION	1	14FEB11	14FEB11
12350	MCA 2F: DELIVER FURNITURE	5	15FEB11	21FEB11
12360	MCA 2F: INSTALL DOORS & HARDWARES	5	22FEB11	28FEB11
12390	MCA 2F: FIRE MARSHAL INSPECTION	2	01MAR11	02MAR11
12380	MCA 2F: HVAC TEST & BALANCE	5	01MAR11	07MAR11
12400	MCA 2F: BUILDING INSPECTION	2	03MAR11	04MAR11
12410	MCA 2F: PUNCHLIST & CORRECTION	10	08MAR11	21MAR11



Start Date 27OCT09
Finish Date 17SEP12
Data Date 27OCT09
Run Date 14DEC09 17:41

Early Bar
Progress Bar
Critical Activity

RP00

Sheet 9 of 24

Whiting-Turner Contracting Company

Rydal Park Campus Repositioning

Classic Schedule Layout

Date	Revision	Checked	Approved

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
12420	MCA 2F: FINAL CLEAN	5	22MAR11	28MAR11
MCA 3RD FLOOR ROUGHS & FINISHES				
13000	MCA 3F: LAYOUT & TOP TRACK	5	16AUG10	20AUG10
13010	MCA 3F: INSTALL DUCTWORK	22	01SEP10	01OCT10
13020	MCA 3F: OH PLUMBING ROUGH IN	10	09SEP10	22SEP10
13030	MCA 3F: OH ELECTRICAL / LV ROUGH IN	15	16SEP10	06OCT10
13040	MCA 3F: OH MECHANICAL PIPING ROUGH IN	15	20SEP10	08OCT10
13050	MCA 3F: OH SPRINKLER ROUGH IN	15	23SEP10	13OCT10
13060	MCA 3F: FRAME WALLS / BULKHEADS / CEILINGS	20	14OCT10	10NOV10
13090	MCA 3F: SPRINKLER PIPE & DROPS IN BULKHEADS	5	11NOV10	17NOV10
13100	MCA 3F: INSTALL TUBS / SHOWERS	5	11NOV10	17NOV10
13070	MCA 3F: ELECTRICAL WALL ROUGH IN	20	11NOV10	09DEC10
13080	MCA 3F: PLUMBING WALL ROUGH IN	20	11NOV10	09DEC10
13110	MCA 3F: SPRINKLER HYDRO	1	18NOV10	18NOV10
13120	MCA 3F: BULKHEAD CLOSE IN INSPECTION	1	19NOV10	19NOV10
13130	MCA 3F: WALL CLOSE IN INSPECTION	1	10DEC10	10DEC10
13140	MCA 3F: H/T/F GWB WALLS / BULKHEADS / CEILINGS	20	13DEC10	11JAN11
13150	MCA 3F: PRIME PAINT	5	12JAN11	18JAN11
13160	MCA 3F: INSTALL RAILING	5	19JAN11	25JAN11
13170	MCA 3F: CEILING GRID	10	19JAN11	01FEB11
13180	MCA 3F: BATHROOM WALL & FLOOR TILES	15	19JAN11	08FEB11
13190	MCA 3F: FINAL PAINT & WALLCOVERING	15	26JAN11	15FEB11
13210	MCA 3F: SPRINKLER DROPS IN GRID CEILING	5	02FEB11	08FEB11
13200	MCA 3F: INSTALL LIGHT FIXTURES	10	02FEB11	15FEB11
13220	MCA 3F: FLOOR FINISHES	20	02FEB11	01MAR11
13230	MCA 3F: SPRINKLER HYDRO TEST	1	09FEB11	09FEB11
13240	MCA 3F: KITCHEN & BATHROOM SINK CABINETS/APRON	10	09FEB11	22FEB11
13250	MCA 3F: INSTALL MILLWORK	15	09FEB11	01MAR11
13270	MCA 3F: OH GRID CLOSE IN INSPECTION	1	16FEB11	16FEB11
13280	MCA 3F: INSTALL ELEC & FIRE ALARM FINAL TRIM	5	16FEB11	22FEB11
13290	MCA 3F: INSTALL SPRINKLER FINAL TRIM	5	16FEB11	22FEB11
13260	MCA 3F: INSTALL CASEWORK	15	16FEB11	08MAR11
13300	MCA 3F: DROP TILE	3	17FEB11	21FEB11
13310	MCA 3F: INSTALL R/G/D	5	22FEB11	28FEB11
13330	MCA 3F: ELECTRICAL INSPECTION	1	23FEB11	23FEB11
13320	MCA 3F: INSTALL COUNTERTOPS	5	23FEB11	01MAR11
13340	MCA 3F: INSTALL PLUMBING FIXTURES & ACCESSORIES	10	02MAR11	15MAR11
13350	MCA 3F: DELIVER FURNITURE	5	09MAR11	15MAR11
13370	MCA 3F: MECHANICAL / PLUMBING INSPECTION	1	16MAR11	16MAR11
13360	MCA 3F: INSTALL DOORS & HARDWARES	5	16MAR11	22MAR11
13390	MCA 3F: FIRE MARSHAL INSPECTION	2	23MAR11	24MAR11
13380	MCA 3F: HVAC TEST & BALANCE	5	23MAR11	29MAR11
13400	MCA 3F: BUILDING INSPECTION	2	25MAR11	28MAR11
13410	MCA 3F: PUNCHLIST & CORRECTION	10	30MAR11	12APR11
13420	MCA 3F: FINAL CLEAN	5	13APR11	19APR11
MCA 4TH FLOOR ROUGHS & FINISHES				
14000	MCA 4F: LAYOUT & TOP TRACK	5	12AUG10	18AUG10
14010	MCA 4F: INSTALL DUCTWORK	22	04OCT10	02NOV10
14020	MCA 4F: OH PLUMBING ROUGH IN	10	11OCT10	22OCT10
14030	MCA 4F: OH ELECTRICAL / LV ROUGH IN	15	18OCT10	05NOV10
14040	MCA 4F: OH MECHANICAL PIPING ROUGH IN	15	20OCT10	09NOV10
14050	MCA 4F: OH SPRINKLER ROUGH IN	15	25OCT10	12NOV10
14060	MCA 4F: FRAME WALLS / BULKHEADS / CEILINGS	20	15NOV10	13DEC10

Start Date 27OCT09
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RP00

Sheet 10 of 24

Whiting-Turner Contracting Company

Rydal Park Campus Repositioning

Classic Schedule Layout

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Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
14090	MCA 4F: SPRINKLER PIPE & DROPS IN BULKHEADS	5	14DEC10	20DEC10
14100	MCA 4F: INSTALL TUBS / SHOWERS	5	14DEC10	20DEC10
14070	MCA 4F: ELECTRICAL WALL ROUGH IN	20	14DEC10	12JAN11
14080	MCA 4F: PLUMBING WALL ROUGH IN	20	14DEC10	12JAN11
14110	MCA 4F: SPRINKLER HYDRO	1	21DEC10	21DEC10
14120	MCA 4F: BULKHEAD CLOSE IN INSPECTION	1	22DEC10	22DEC10
14130	MCA 4F: WALL CLOSE IN INSPECTION	1	13JAN11	13JAN11
14140	MCA 4F: H/T/F GWB WALLS / BULKHEADS / CEILINGS	20	14JAN11	10FEB11
14150	MCA 4F: PRIME PAINT	5	11FEB11	17FEB11
14160	MCA 4F: INSTALL RAILING	5	18FEB11	24FEB11
14170	MCA 4F: CEILING GRID	10	18FEB11	03MAR11
14180	MCA 4F: BATHROOM WALL & FLOOR TILES	15	18FEB11	10MAR11
14190	MCA 4F: FINAL PAINT & WALLCOVERING	15	25FEB11	17MAR11
14210	MCA 4F: SPRINKLER DROPS IN GRID CEILING	5	04MAR11	10MAR11
14200	MCA 4F: INSTALL LIGHT FIXTURES	10	04MAR11	17MAR11
14220	MCA 4F: FLOOR FINISHES	20	04MAR11	31MAR11
14230	MCA 4F: SPRINKLER HYDRO TEST	1	11MAR11	11MAR11
14240	MCA 4F: KITCHEN & BATHROOM SINK CABINETS/APRON	10	11MAR11	24MAR11
14250	MCA 4F: INSTALL MILLWORK	15	11MAR11	31MAR11
14270	MCA 4F: OH GRID CLOSE IN INSPECTION	1	18MAR11	18MAR11
14280	MCA 4F: INSTALL ELEC & FIRE ALARM FINAL TRIM	5	18MAR11	24MAR11
14290	MCA 4F: INSTALL SPRINKLER FINAL TRIM	5	18MAR11	24MAR11
14260	MCA 4F: INSTALL CASEWORK	15	18MAR11	07APR11
14300	MCA 4F: DROP TILE	3	21MAR11	23MAR11
14310	MCA 4F: INSTALL R/G/D	5	24MAR11	30MAR11
14330	MCA 4F: ELECTRICAL INSPECTION	1	25MAR11	25MAR11
14320	MCA 4F: INSTALL COUNTERTOPS	5	25MAR11	31MAR11
14340	MCA 4F: INSTALL PLUMBING FIXTURES & ACCESSORIES	10	01APR11	14APR11
14350	MCA 4F: DELIVER FURNITURE	5	08APR11	14APR11
14370	MCA 4F: MECHANICAL / PLUMBING INSPECTION	1	15APR11	15APR11
14360	MCA 4F: INSTALL DOORS & HARDWARE	5	15APR11	21APR11
14390	MCA 4F: FIRE MARSHAL INSPECTION	2	22APR11	25APR11
14380	MCA 4F: HVAC TEST & BALANCE	5	22APR11	28APR11
14400	MCA 4F: BUILDING INSPECTION	2	26APR11	27APR11
14410	MCA 4F: PUNCHLIST & CORRECTION	10	29APR11	12MAY11
14420	MCA 4F: FINAL CLEAN	5	13MAY11	19MAY11
ELEVATOR				
15010	MCA: HANDOVER ELEVATOR SHAFT TO ELEVATOR CONT	0	26AUG10	
15000	MCA: EMR SET & CONNECT ELEVATOR MACHINERY	25	26AUG10	30SEP10
15040	MCA: EMR MECHANICAL ROUGH IN	5	01OCT10	07OCT10
15020	MCA: INSTALL RAILS & THRESHOLDS	10	01OCT10	14OCT10
15030	MCA: EMR ELECTRICAL ROUGH IN	15	01OCT10	21OCT10
15050	MCA: INSTALL DOOR BUCKS	10	15OCT10	28OCT10
15060	MCA: EMR PULL WIRE & INSTALL LIGHTING	6	22OCT10	29OCT10
15070	MCA: CONSTRUCT ELEVATOR CAB	10	29OCT10	11NOV10
15080	MCA: EMR SEAL FLOOR	2	01NOV10	02NOV10
15090	MCA: EMR FINAL PAINT	2	03NOV10	04NOV10
15100	MCA: FINAL TRIM CAB	1	12NOV10	12NOV10
BUILDING CONNECTOR & LOBBY				
16000	CONN: MAKE SAFE AREA	1	31MAR10	31MAR10
16010	CONN: MAKE SAFE ELECTRICAL	1	31MAR10	31MAR10
16020	CONN: DEMOLITION	5	01APR10	07APR10

Start Date	27OCT09
Finish Date	17SEP12
Data Date	27OCT09
Run Date	14DEC09 17:41

Early Bar
Progress Bar
Critical Activity

RP00

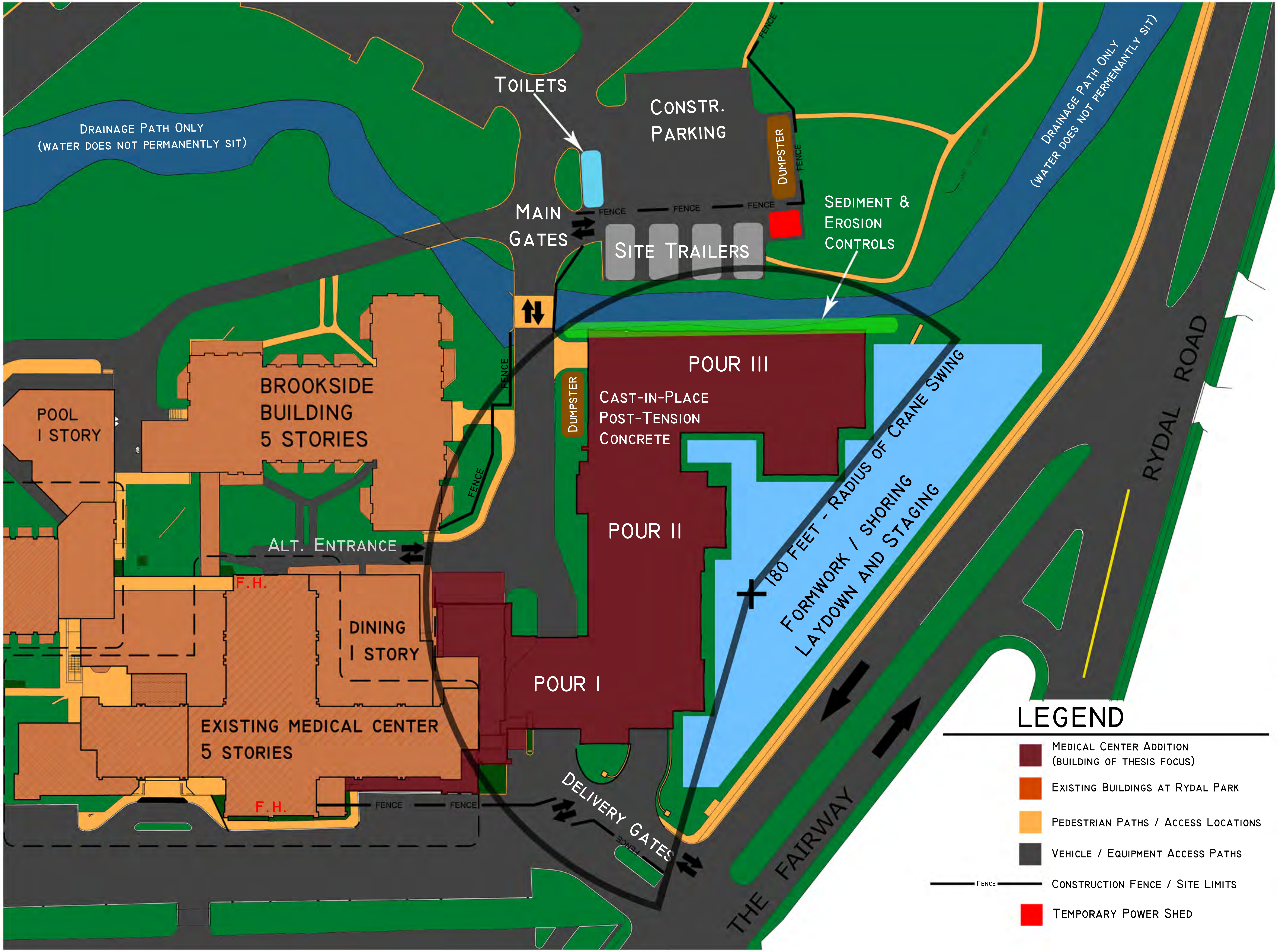
Whiting-Turner Contracting Company

Rydal Park Campus Repositioning

Classic Schedule Layout

Date	Revision	Checked	Approved

14.0 Appendix B: Site Layout Plans



RYDAL PARK CONTINUING CARE RETIREMENT COMMUNITY : MEDICAL CENTER ADDITION

RYDAL, PENNSYLVANIA

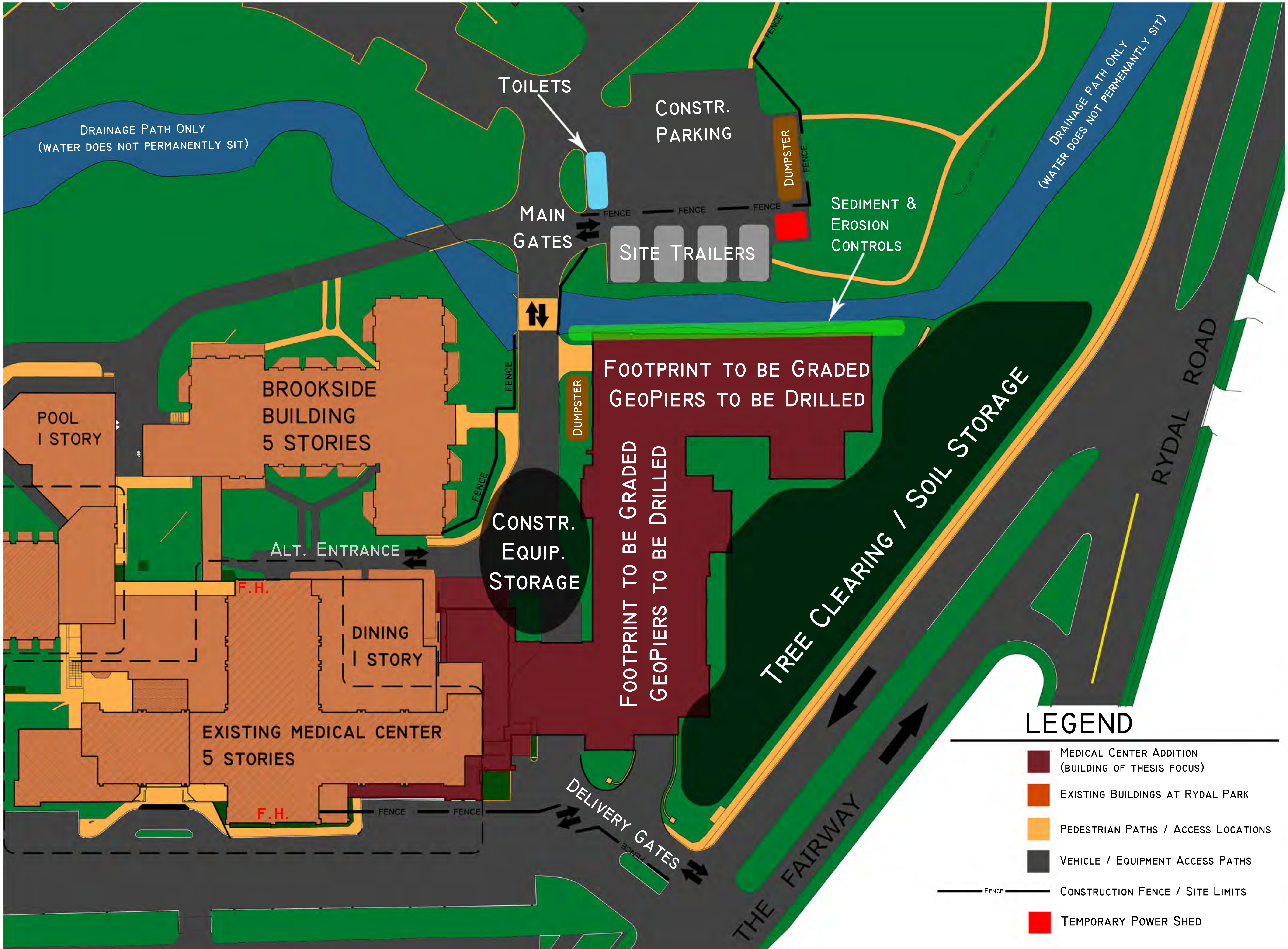
SPECIFIC CONSTRUCTION PHASE: ERECTION PLAN

DRAWN BY: MATT DABROWSKI

DATE: 10/28/2009

1 OVERALL CAMPUS PLAN
SCALE: N.T.S.

PLAN NORTH
NORTH



Rydal Park Continuing Care Retirement Community : Medical Center Addition

Rydal, Pennsylvania

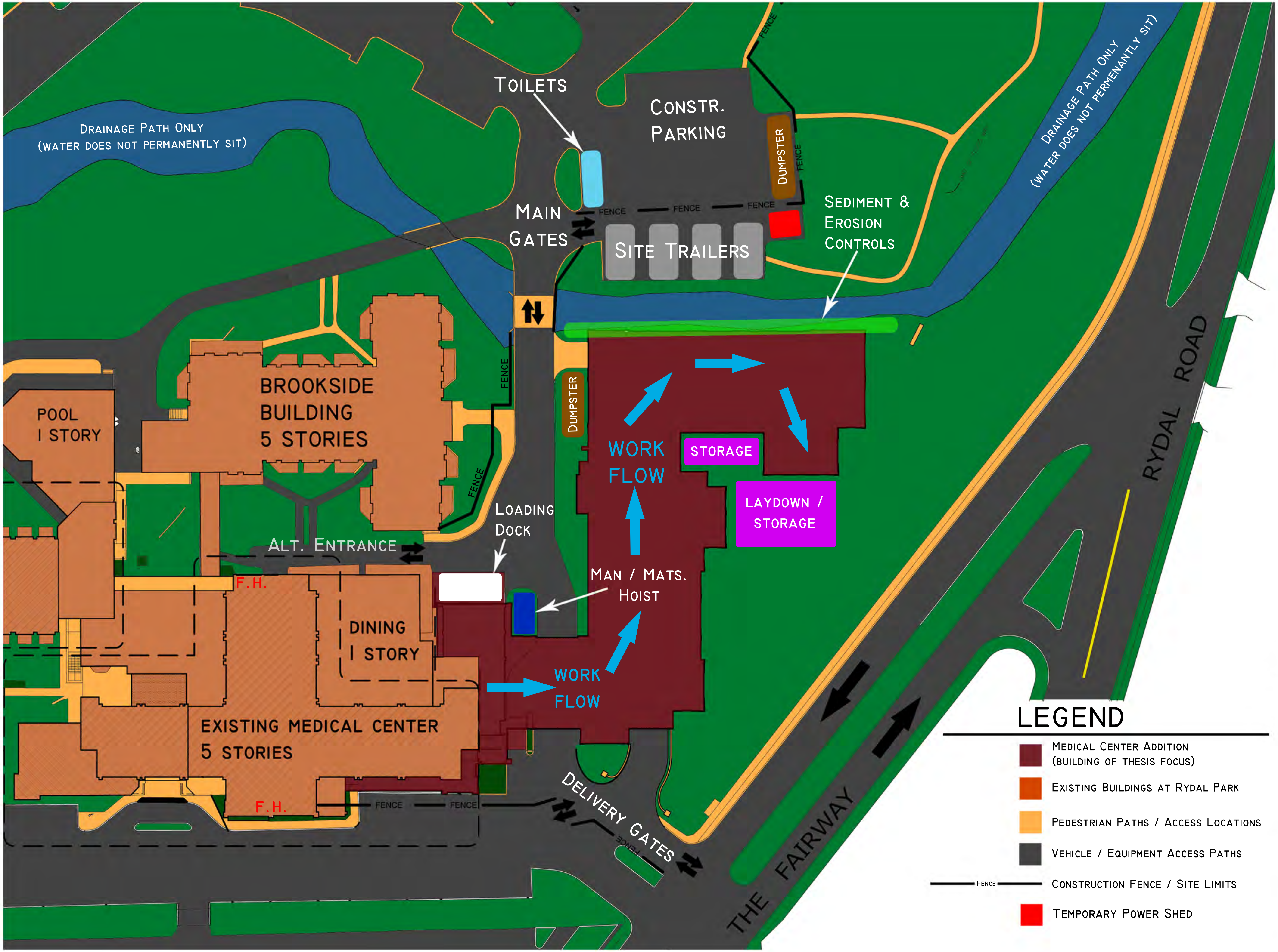
Specific Construction Phase: Excavation Plan

DRAWN BY:
MATT DABROWSKI

DATE:
10/28/2009

1 OVERALL CAMPUS PLAN
SCALE: N.T.S.

PLAN NORTH
NORTH



RYDAL PARK CONTINUING CARE RETIREMENT COMMUNITY : MEDICAL CENTER ADDITION

RYDAL, PENNSYLVANIA

SPECIFIC CONSTRUCTION PHASE: INTERIORS PLAN

DRAWN BY:
MATT DABROWSKI

DATE:
10/28/2009

1 OVERALL CAMPUS PLAN
SCALE: N.T.S.

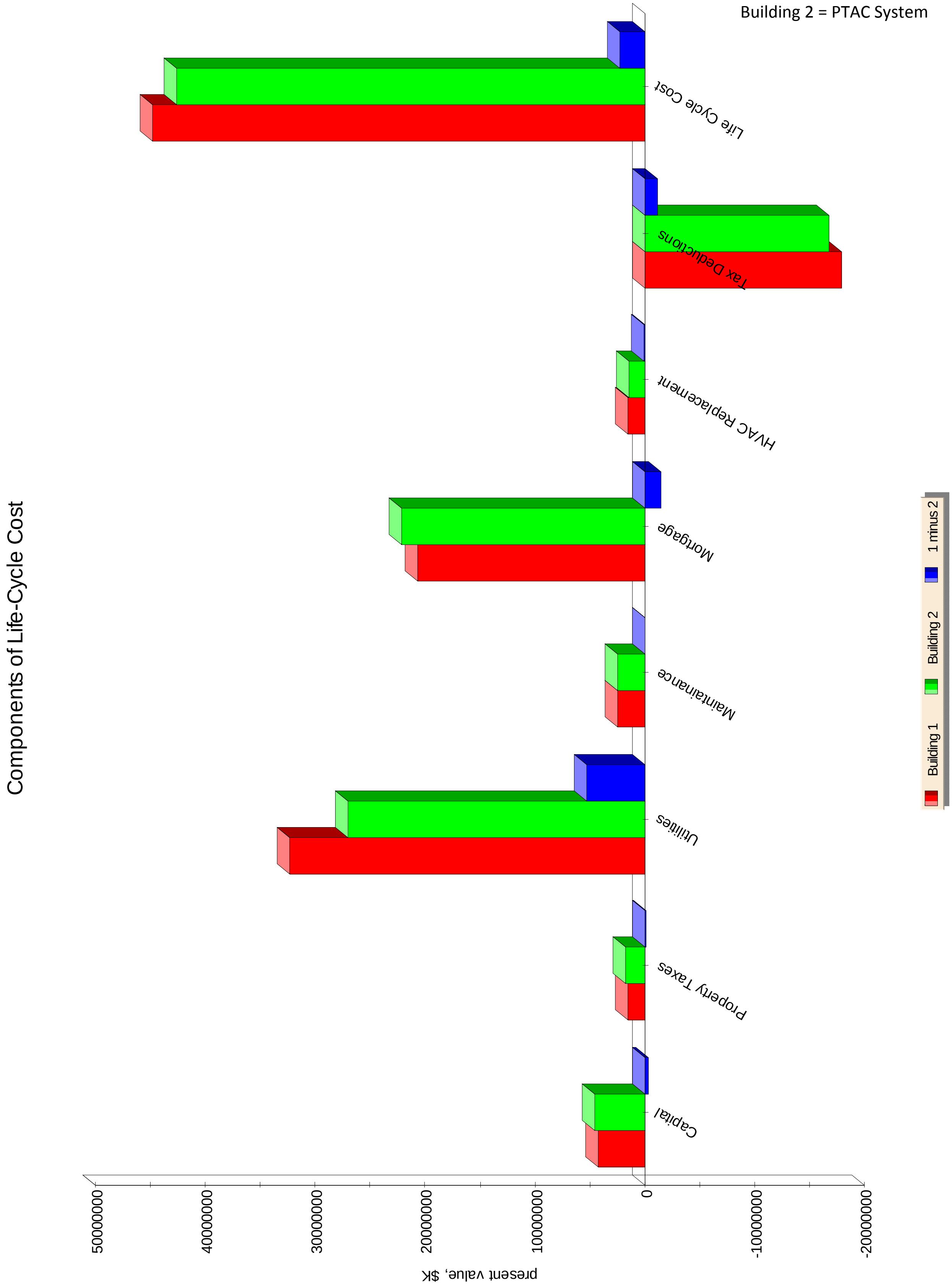
PLAN NORTH
NORTH

15.0 Appendix C: Energy 10 Life Cycle Cost Reports

NOTE

Building 1 = Original HVAC System

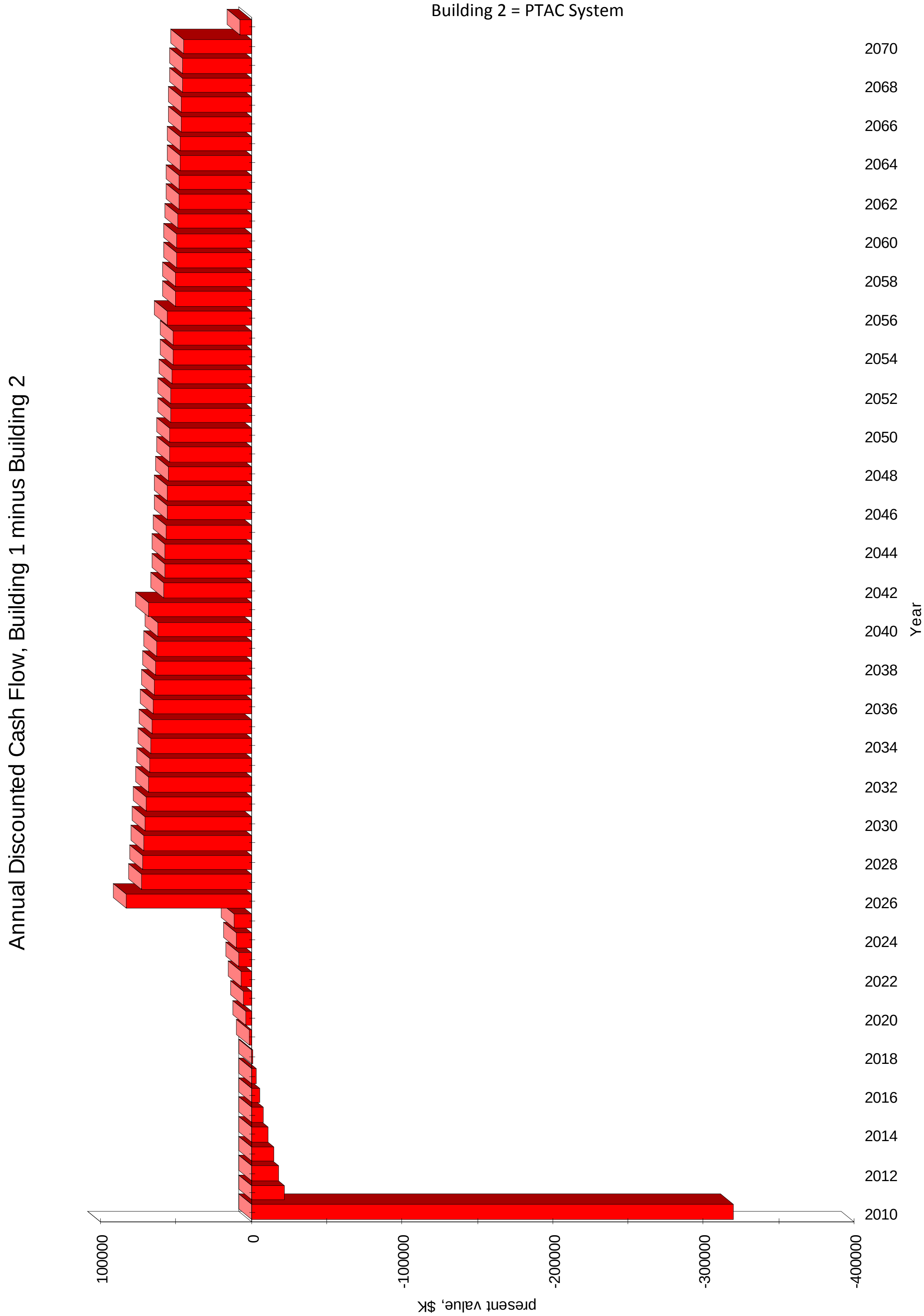
Building 2 = PTAC System



NOTE

Building 1 = Original HVAC System

Building 2 = PTAC System



NOTE

Reference Case = Original HVAC System

Low-Energy Case = PTAC System

Cost Summary Report

Scheme Name:	Reference Case	Low-Energy Case	Difference
Construction	21844829.13	23444185.35	-1599356.22
fixed	20700000.00	20700000.00	0.00
EE strategies	0.00	1621654.72	-1621654.72
HVAC installation	1144829.13	1122530.63	22298.50
Mortgage payment	2004101.00	2150831.00	-146730.00
HVAC replacement	858622.00	841897.97	16724.03
Annual fuel	0.00	0.00	0.00
Annual electric	703213.13	587828.77	115384.36
Annual maintenance	69000.00	69000.00	0.00

Life Cycle Cost Results	Reference Case	Low-Energy Case	NetPresentValue
capital	4265061	4577325	-312264
property taxes	1577133	1692602	-115469
mortgage	20632192	22142766	-1510574
utilities	32332188	27027085	5305103
maintenance	2490799	2490799	0
HVAC replacement	1494467	1465358	29109
tax deductions	-17956271	-16793050	-1163221
Life-Cycle Cost	44835569	42602885	2232684

Internal Rate of Return, IRR,	13.035%
Simple Payback, years	0.00
Benefit / Cost Ratio	1.72

Financial Parameters

Year of Construction	2010
Building life, yr	60
Salvage value, % of original	10.00
Annual property tax, % of value	0.20
Property tax escalation rate, %	4.00
Fuel cost escalation rate, %	4.50
Electric cost escalation rate, %	5.00
Maintenance cost escalation rate, %	4.00
Building resale escalation rate, %	4.00
HVAC replacement cost escalation rate, %	4.00
HVAC replacement cycle	15
Discount rate, %	6.00
Mortgage?	yes
mortgage term, yr	15
mortgage interest, %	8.00
down payment, %	20.00
Tax deductible?	
property taxes	yes
loan interest	yes
utilities	yes
maintenance	yes
HVAC upgrade	yes
depreciation	yes
straight line depreciation period, yr	31
incremental tax bracket, %	31.00

16.0 Appendix D: Amana PTAC DigiSmart Product Information

DigiSmart brings together our best PTAC ever with our best Energy Management Software and now integration with Property Management and Front Desk Management Software. Reduce PTAC energy consumption by **35% OR MORE*** through the power of the in-unit Energy Management System, programmable temperature set-back and limits combined. Reduce PTAC maintenance cost through our automated maintenance notification system. Improved maintenance sustains energy efficiency (EER) and prolongs PTAC life, keeping equipment running greener and room guests more comfortable.

Amana® Brand DigiSmart Solution

In-Room — "Self Installable" Wireless Peripherals

The DigiSmart **Wireless Remote Thermostat** can mount on the wall anywhere in the guest room. Battery powered and with its own wireless ability to communicate with the PTAC to maintain room temperature. Best of all, no wires to run. The PTAC and Thermostat connect at the press of a button and are permanently linked. The thermostat and PTAC work in-sync to display accurate temperature.

The DigiSmart **Occupancy Sensor** completes the in-room equipment. This infrared sensor can determine if the room is occupied or empty and when empty, signal the PTAC to adjust the temperature to save energy based on programmable setbacks.

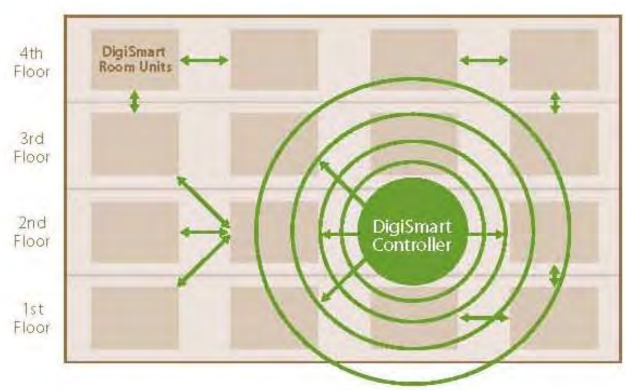
The DigiSmart **Wireless Antenna** installs inside the PTAC with a snap-in connector like a telephone jack. Installing the antenna allows the PTAC to communicate wirelessly with other devices in the room and to the DigiSmart network.

> 45,000+ rooms have had wireless installations since 2005
> Total wireless devices deployed to date – 120,000+

The Amana brand DigiSmart PTAC with antenna, combined with the self-installable, wireless Thermostat and Occupancy Sensor give the property owner complete control over the equipment settings and can reduce PTAC energy usage by **35% OR MORE***

Site-Level — Central Wireless Controller

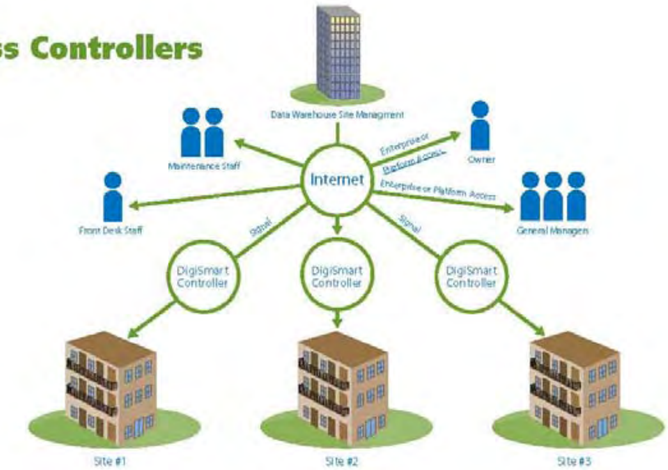
- Site-wide PTAC Configuration
- Site-wide PTAC Diagnostics
- Front Desk System Interface
- Email Reporting
- Internet Accessible Web User Interface Enterprise



Enterprise — Multiple Wireless Controllers

Central Monitoring and Control of Multiple Properties

- > Data Warehousing
- > Savings Analysis
- > Email Reporting
- > Virtual Metering
- > Load Shedding



Web Based, Real-Time Monitoring

Amana® Brand DigiSmart™ Controller:

All of the PTACs in the building can be managed through a single interface on a PC.

FEATURES INCLUDE: Full unit details for every PTAC, visible from the front desk or home office, automatic emails for PTAC maintenance, ability to change all settings on the unit, and enhanced diagnostics. Monitor up to 170 PTACs, WIRELESSLY, with one controller. Additional controllers can expand the network for additional rooms/properties.

- > System Verification
- > Global Setbacks
- > EMS Configuration
- > Site Statistics
- > Battery Notices
- > Email Reporting
- > Unit Health
- > Unit Code Alerts

Temp Limiting – Each PTAC can be configured with a heating and cooling temperature set-point limit.

Setbacks – Once a room is declared unoccupied by the occupancy sensor, the PTAC progresses through three different temperature setbacks, configured as three degree and time pairs (An example configuration is listed below).

1st: 2°, 30 mins – Setback the temp 2 degrees after 30 minutes
2nd: 4°, 1 hr – Setback the temp 2 more degrees after 30 more minutes
3rd: 8°, 3 hrs – Setback the temp 4 more degrees after 2 more hours

Unrented Set-Points – By integrating with your property's Front Desk System, the PTACs will adjust to specific set-points when no longer identified as rented in the system.

Case Studies

DigiSmart CONTROL BOARD

> EAST COAST - REGIONAL TEMPERATURE ZONES

In January 2006, a property in Maryland installed our full Amana® brand EMS suite.

– In 2005, this property used 676,320 kwh of electricity and paid $47,263.34 in utilities.

– At the end of 2006, the site had only consumed 550,320 kwh for the year and paid $38,301.68 in electrical utilities.

Assuming that PTACs make up about half of the connected load at the property, this represents a **37% SAVINGS** on their PTAC consumption.

> WEST COAST - REGIONAL TEMPERATURE ZONES

In 2008, we began logging a complete history of runtime statistics for a property in California with our full suite of EMS products – including an interface to their Front Desk.

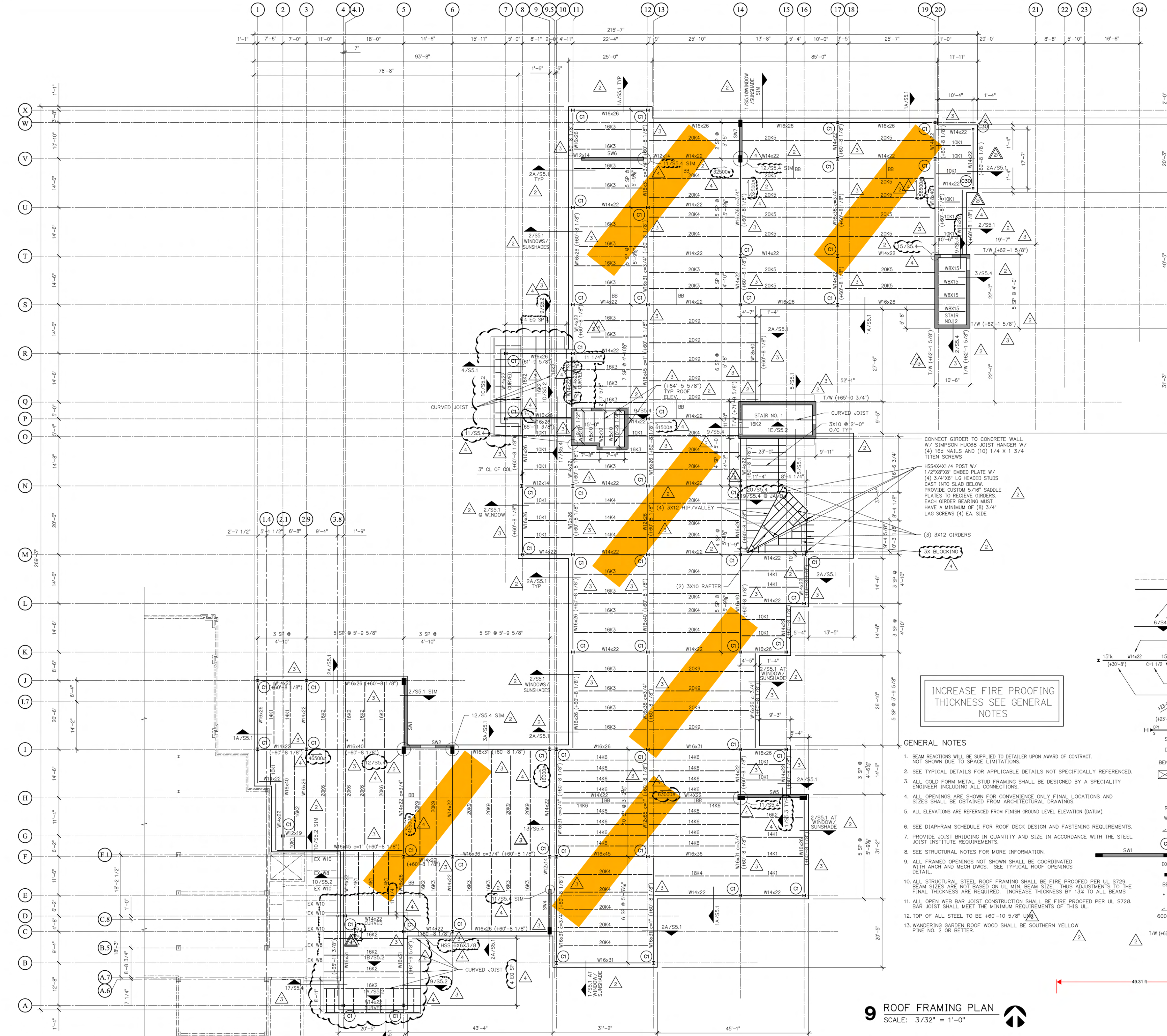
The data for a ten week period showed that guests were physically occupying the properties rooms less than 35% of the time on average.

Analysis showed that the major power drawing components of the PTACs ran almost 12% of the time when the room was occupied.

However, with the Amana brand DigiSmart™ system in place, these same components ran less than 1% of the time when unoccupied.

This resulted in an average kWH savings of over 2100 kWHs a week and **63% SAVINGS** on their PTAC electricity consumption.

17.0 Appendix E: Photovoltaic Array Layout



INCREASE FIRE PROOFING THICKNESS SEE GENERAL NOTES

EXISTING DIMENSIONS HAVE BEEN TAKEN FROM EXISTING DOCUMENTS. CONTRACTOR SHALL VERIFY ALL DIMENSIONS PRIOR TO COMMENCING HIS WORK.

CONTRACTOR SHALL FIELD VERIFY ALL EXISTING DIMENSIONS AND CONDITIONS AND IDENTIFY ANY CONFLICTS OR OBSTRUCTIONS NOT ON THE PLANS PRIOR TO SUBMITTING CONSTRUCTION BID AND FABRICATION OF ANY ITEMS.

GENERAL NOTES

1. BEAM REACTIONS WILL BE SUPPLIED TO DETAILER UPON AWARD OF CONTRACT. NOT SHOWN DUE TO SPACE LIMITATIONS.
2. SEE TYPICAL DETAILS FOR APPLICABLE DETAILS NOT SPECIFICALLY REFERENCED.
3. ALL COLD FORM METAL STUD FRAMING SHALL BE DESIGNED BY A SPECIALITY ENGINEER INCLUDING ALL CONNECTIONS.
4. ALL OPENINGS ARE SHOWN FOR CONVENIENCE ONLY FINAL LOCATIONS AND SIZES SHALL BE OBTAINED FROM ARCHITECTURAL DRAWINGS.
5. ALL ELEVATIONS ARE REFERNCED FROM FINISH GROUND LEVEL ELEVATION (DATUM).
6. SEE DIAPHRAM SCHEDULE FOR ROOF DECK DESIGN AND FASTENING REQUIREMENTS.
7. PROVIDE JOIST BRIDGING IN QUANTITY AND SIZE IN ACCORDANCE WITH THE STEEL JOIST INSTITUTE REQUIREMENTS.
8. SEE STRUCTURAL NOTES FOR MORE INFORMATION.
9. ALL FRAMED OPENINGS NOT SHOWN SHALL BE COORDINATED WITH ARCH AND MECH DWGS. SEE TYPICAL ROOF OPENINGS DETAIL.
10. ALL STRUCTURAL STEEL ROOF FRAMING SHALL BE FIRE PROOFED PER UL S729. BEAM SIZES ARE NOT BASED ON UL MIN. BEAM SIZE. THUS ADJUSTMENTS TO THE FINAL THICKNESS ARE REQUIRED. INCREASE THICKNESS BY 13% TO ALL BEAMS
11. ALL OPEN WEB BAR JOIST CONSTRUCTION SHALL BE FIRE PROOFED PER UL S728. BAR JOIST SHALL MEET THE MINIMUM REQUIREMENTS OF THIS UL.
12. TOP OF ALL STEEL TO BE +60'-10 5/8" UNO
13. WANDERING GARDEN ROOF WOOD SHALL BE SOUTHERN YELLOW PINE NO. 2 OR BETTER.

LEGEND

- = EXISTING CONSTRUCTION TO REMAIN
- = NEW CONSTRUCTION
- DETAIL NUMBER
- DRAWING NUMBER
- 6/S400 = SECTION CUT
- STRUCTURAL STEEL BEAM SIZES
- STRUCTURAL STEEL COLUMNS
- 15'k W14x22 15'k (+30'-8") C=1 1/2
- BEAM FACTORED LOAD REACTION
- AMOUNT OF CAMBER
- TOP OF STEEL RELATIVE TO FINISH 1ST FLOOR
- +23-0 = BOTTOM OF DECK ELEVATION FROM FINISHED LOWER LEVEL
- (+23'-0") = TOP OF STEEL ELEVATION FROM FINISHED LOWER LEVEL
- DP1 S = MOMENT CONNECTION, SEE TYPICAL MOMENT CONNECTION DETAIL
- S = STIFFENERS REQUIRED, SEE TYPICAL MOMENT CONNECTION
- DP1 = COLUMN WEB DOUBLER PLATE. SEE TYPICAL DOUBLER PLATE DETAIL.
- BENT = BENT BEAM. SEE TYPICAL DETAIL
- = INDICATES ROOF OPENING. GENERAL CONTRACTOR TO COORDINATE ALL DUCT SIZES, OPENINGS AND LOCATION WITH ARCHITECTURAL DWGS AND MECHANICAL CONTRACTOR BEFORE CONSTRUCTION. FRAME AROUND ALL OPENINGS PER TYPICAL DETAIL.
- RTU = ROOF TOP UNIT. SEE TYPICAL FRAMING DETAILS
- WP = INDICATES STEEL WORK POINT (ELEVATION)
- = DIRECTION OF DECK SPAN
- C1 = COLUMN SIZE, SEE COLUMN SCHEDULE
- SW1 = REINFORCED CONCRETE SHEAR WALL, SEE ELEVATIONS.
- EOS = EDGE OF CONCRETE SLAB. SEE SECTIONS
- = REINFORCED CONCRETE COLUMN
- BB = BEAM BRACE SEE TYP DETAIL
- * = BOTTOM CORD EXTENSION TO BRACE BEAM. SEE TYP DETAIL.
- 6000# = STEEL FABRICATOR SHALL DESIGN SHEAR CONNECTION FOR FACTORED LATERAL LOAD FOR THE MAGNITUDE SHOWN DISTRIBUTED ALONG ENTIRE BEAM LINE.
- T/W (+62'-0") = TOP OF CONCRETE WALL. SEE ARCH DWGS

9 ROOF FRAMING PLAN
SCALE: 3/32" = 1'-0"

Stewart & Conners Architects, PLLC
3731 Latrobe Drive
Charlotte, NC 28211
704.365.3941 phone
704.365.3942 fax

Presby's Inspired Life — At the heart of experience and vision.

title: **Rydal Park Campus Repositioning**

location: **Rydal Park**
1515 The Fairway
Jenkintown, PA 19046

MEDICAL CENTER ADDITION

Rydal Project No.:

seals: COMMONWEALTH OF PENNSYLVANIA — REGISTERED PROFESSIONAL ENGINEER — MICHAEL A. GARDINA — PE053345E
06-26-09

WK DICKSON
community infrastructure consultants
616 COLONNADE DRIVE
CHARLOTTE, NC 28205
(704) 334-5348
Office Locations:
North Carolina NC LICENSE NO. F-0374
South Carolina
Georgia

sca project number: 10-01-400 date: 05-19-2009
drawn by: checked by:

revisions:

PERMIT SET

1	GMP SET	06-09-2009
2	DOH/ COORDINATION	06-26-2009
3	ADDENDUM 3	06-29-2009
4	COUNTY COMMENTS/ CONTRACTOR CLARIFICATIONS	07-28-2009

sheet name: **ROOF FRAMING PLAN**

sheet number: **S2.5**

MCA BUILDING

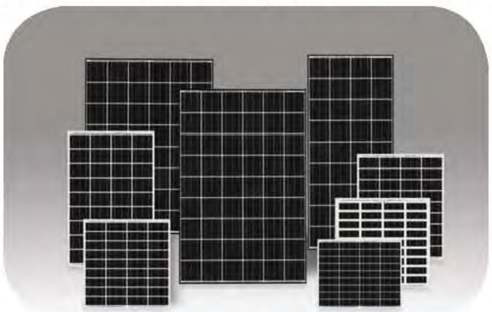
18.0 Appendix F: Photovoltaic Module Product Data

18

Kyocera Solar Modules [KC/KD]

KYOCERA

Kyocera's advanced cell processing technology and automated production facilities have produced multi-crystalline solar cells with efficiencies of over 18.5%. All modules are constructed using a tempered glass front, EVA pottant and a PVF backing to provide maximum protection from the most severe environmental conditions. The entire laminate is framed in a heavy duty anodized aluminum frame to provide structural strength and ease of installation. Because Kyocera modules are so efficient less space is required than other solar modules of equal output. This translates to both more wattage per square foot and lower mounting structure cost.



KD Module Family

KD 210GX-LP

Features

- KC65T - KC130TM modules have a +10/-5% power tolerance, KC40T-50T: +15/-5%
- KD135GX-LP - KD210GX-LP modules have a +5%/-5% tolerance
- UL listed
- Low iron, tempered glass, EVA encapsulant and anodized aluminum frame construction
- 20 year output warranty on Kyocera modules
- Weather resistant junction box (KC40T-KC130TM) or multi-contact connectors (KD130GX-LP, 180GX-LP, 205GX-LP & 210GX)

Quality Assurance

Kyocera multi-crystal photovoltaic modules exceed government specifications for the following tests:

- Thermal cycling test
- Thermal shock test
- Thermal/Freezing and high humidity cycling test
- Electrical insolation test
- Hail impact test
- Mechanical, wind and twist loading test
- Salt mist test
- Light and water exposure test
- Field exposure test

Product Name and Descriptions	KD 210GX-LP	KD 205GX-LP	KD 180GX-LP	KD 135GX-LP	KC 130TM	KC85T	KC65T	KC50T	KC40T
Part Number	**503091**	**501015**	**501014**	**501013**	**501004**	**703004**	**703005**	**703007**	**703008**
Rate of Power(Watts)	210	205	180	135	130	87	65	54	43
Series Fusing(Amps)	15.0	15.0	15.0	15.0	15.0	7.0	6.0	6.0	6.0
Current at Max. Power(Amps)	7.90	7.71	7.63	7.63	7.39	5.02	3.75	3.11	2.48
Voltage at Max Power(Volts)	26.6	26.6	23.6	17.7	17.6	17.4	17.4	17.4	17.4
Short Circuit Current(Amps)	8.58	8.36	8.35	8.37	8.02	5.34	3.99	3.31	2.65
Open Circuit Voltage(Volts)	33.2	33.2	29.5	22.1	21.9	21.7	21.7	21.7	21.7
Length (Inches)	59.1	59.1	52.8	59.1	56.0	39.6	29.6	25.2	20.7
Width (Inches)	39.0	39.0	39.0	26.3	25.7	25.7	25.7	25.7	25.7
Depth of Frame (Inches)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Depth including j-box	1.4	1.4	1.4	1.4	2.2	2.2	2.1	2.1	2.1
Shipping Weight (lbs.)	45.8	45.8	41.4	33.0	33.0	24.0	18.0	16.0	13.0

Replacement bypass diodes for Kyocera J-Box equipped modules are sold in packs of 25; part number 705070

All specification at 25°C. cell temperature, 1.5 AM and 1000W/m2. KC "T" and "TM" modules have a conduit ready junction box. "GX" modules have locking multi-contact connectors. See Appendix A for module dimensions and shipping information.

Kyocera Solar Electric Products Catalog • October 2009

SOLAR by KYOCERA

19.0 Appendix G: Structural K-Series Loading Charts

STANDARD LRFD LOAD TABLE

OPEN WEB STEEL JOISTS, K-SERIES

Based on a 50 ksi Maximum Yield Strength
Adopted by the Steel Joist Institute May 1, 2000
Revised to November 10, 2003 – Effective March 01, 2005

The black figures in the following table give the TOTAL safe factored uniformly distributed load-carrying capacities, in pounds per linear foot, of **LRFD K-Series** Steel Joists. The weight of factored DEAD loads, including the joists, must be deducted to determine the factored LIVE load-carrying capacities of the joists. Sloped parallel-chord joists shall use span as defined by the length along the slope.

The figures shown in **RED** in this load table are the unfactored nominal LIVE loads per linear foot of joist which will produce an approximate deflection of 1/360 of the span. LIVE loads which will produce a deflection of 1/240 of the span may be obtained by multiplying the figures in **RED** by 1.5. In no case shall the TOTAL load capacity of the joists be exceeded.

The approximate joist weights per linear foot shown in these tables do not include accessories.

The approximate moment of inertia of the joist, in inches^4 is;

$I_j = 26.767(W_{LL})(L^3)(10^{-6})$, where W_{LL} = **RED** figure in the Load Table and L = (Span - 0.33) in feet.

For the proper handling of concentrated and/or varying loads, see Section 6.1 in the Code of Standard Practice for Steel Joists and Joist Girders.

Where the joist span exceeds the unshaded area of the Load Table, the row of bridging nearest the mid span shall be diagonal bridging with bolted connections at the chords and intersections.

LRFD

STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown in Pounds per Linear Foot (plf)

Joist Designation	8K1	10K1	12K1	12K3	12K5	14K1	14K3	14K4	14K6	16K2	16K3	16K4	16K5	16K6	16K7	16K9
Depth (in.)	8	10	12	12	12	14	14	14	14	16	16	16	16	16	16	16
Approx. Wt (lbs./ft.)	5.1	5.0	5.0	5.7	7.1	5.2	6.0	6.7	7.7	5.5	6.3	7.0	7.5	8.1	8.6	10.0
Span (ft.) ↓																
8	825 550															
9	825 550															
10	825 480	825 550														
11	798 377	825 542														
12	666 288	825 455	825 550	825 550	825 550											
13	565 225	718 363	825 510	825 510	825 510											
14	486 179	618 289	750 425	825 463	825 463	825 550	825 550	825 550	825 550							
15	421 145	537 234	651 344	814 428	825 434	766 475	825 507	825 507	825 507							
16	369 119	469 192	570 282	714 351	825 396	672 390	825 467	825 467	825 467	825 550	825 550	825 550	825 550	825 550	825 550	825 550
17		415 159	504 234	630 291	825 366	592 324	742 404	825 443	825 443	768 488	825 526	825 526	825 526	825 526	825 526	825 526
18		369 134	448 197	561 245	760 317	528 272	661 339	795 397	825 408	684 409	762 456	825 490	825 490	825 490	825 490	825 490
19		331 113	402 167	502 207	681 269	472 230	592 287	712 336	825 383	612 347	682 386	820 452	825 455	825 455	825 455	825 455
20		298 97	361 142	453 177	613 230	426 197	534 246	642 287	787 347	552 297	615 330	739 386	825 426	825 426	825 426	825 426
21			327 123	409 153	555 198	385 170	483 212	582 248	712 299	499 255	556 285	670 333	754 373	822 405	825 406	825 406
22			298 106	373 132	505 172	351 147	439 184	529 215	648 259	454 222	505 247	609 289	687 323	747 351	825 385	825 385
23			271 93	340 116	462 150	321 128	402 160	483 188	592 226	415 194	462 216	556 252	627 282	682 307	760 339	825 363
24			249 81	312 101	423 132	294 113	367 141	442 165	543 199	381 170	424 189	510 221	576 248	627 269	697 298	825 346
25						270 100	339 124	408 145	501 175	351 150	390 167	469 195	529 219	576 238	642 263	771 311
26						249 88	313 110	376 129	462 156	324 133	360 148	433 173	489 194	532 211	592 233	711 276
27						231 79	289 98	349 115	427 139	300 119	334 132	402 155	453 173	493 188	549 208	658 246
28						214 70	270 88	324 103	397 124	279 106	310 118	373 138	421 155	459 168	510 186	612 220
29										259 95	289 106	348 124	391 139	427 151	475 167	570 198
30										241 86	270 96	324 112	366 126	399 137	444 151	532 178
31										226 78	252 87	304 101	342 114	373 124	415 137	498 161
32										213 71	237 79	285 92	321 103	349 112	388 124	466 147

LRFD

STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown in Pounds per Linear Foot (plf)

Joist Designation	18K3	18K4	18K5	18K6	18K7	18K9	18K10
Depth (In.)	18	18	18	18	18	18	18
Approx. Wt. (lbs./ft.)	6.6	7.2	7.7	8.5	9	10.2	11.7
Span (ft.) ↓							
18	825 550	825 550	825 550	825 550	825 550	825 550	825 550
19	771 494	825 523	825 523	825 523	825 523	825 523	825 523
20	694 423	825 490	825 490	825 490	825 490	825 490	825 490
21	630 364	759 426	825 460	825 460	825 460	825 460	825 460
22	573 316	690 370	777 414	825 438	825 438	825 438	825 438
23	523 276	630 323	709 362	774 393	825 418	825 418	825 418
24	480 242	577 284	651 318	709 345	789 382	825 396	825 396
25	441 214	532 250	600 281	652 305	727 337	825 377	825 377
26	408 190	492 222	553 249	603 271	672 299	807 354	825 361
27	378 169	454 198	513 222	558 241	622 267	747 315	825 347
28	351 151	423 177	477 199	519 216	577 239	694 282	822 331
29	327 136	394 159	444 179	483 194	538 215	646 254	766 298
30	304 123	367 144	414 161	451 175	502 194	603 229	715 269
31	285 111	343 130	387 146	421 158	469 175	564 207	669 243
32	267 101	322 118	363 132	396 144	441 159	529 188	627 221
33	252 92	303 108	342 121	372 131	414 145	498 171	589 201
34	237 84	285 98	321 110	349 120	390 132	468 156	555 184
35	223 77	268 90	303 101	330 110	367 121	441 143	523 168
36	211 70	253 82	286 92	312 101	348 111	417 132	495 154
37							
38							
39							
40							
41							
42							
43							
44							

Joist Designation	20K3	20K4	20K5	20K6	20K7	20K9	20K10
Depth (In.)	20	20	20	20	20	20	20
Approx. Wt. (lbs./ft.)	6.7	7.6	8.2	8.9	9.3	10.8	12.2
Span (ft.) ↓							
18							
19							
20	775 517	825 550	825 550	825 550	825 550	825 550	825 550
21	702 453	825 520	825 520	825 520	825 520	825 520	825 520
22	639 393	771 461	825 490	825 490	825 490	825 490	825 490
23	583 344	703 402	793 451	825 468	825 468	825 468	825 468
24	535 302	645 353	727 396	792 430	825 448	825 448	825 448
25	493 266	594 312	669 350	729 380	811 421	825 426	825 426
26	456 236	549 277	618 310	673 337	750 373	825 405	825 405
27	421 211	508 247	573 277	624 301	694 333	825 389	825 389
28	391 189	472 221	532 248	579 269	645 298	775 353	825 375
29	364 170	439 199	495 223	540 242	601 268	723 317	825 359
30	340 153	411 179	462 201	504 218	561 242	675 286	799 336
31	318 138	384 162	433 182	471 198	525 219	631 259	748 304
32	298 126	360 147	406 165	442 179	492 199	592 235	702 276
33	280 114	339 134	381 150	415 163	463 181	556 214	660 251
34	264 105	318 122	358 137	391 149	435 165	523 195	621 229
35	249 96	300 112	339 126	369 137	411 151	493 179	585 210
36	235 88	283 103	319 115	348 125	388 139	466 164	553 193
37	222 81	268 95	303 106	330 115	367 128	441 151	523 178
38	211 74	255 87	286 98	312 106	348 118	418 139	496 164
39	199 69	241 81	271 90	297 98	330 109	397 129	471 151
40	190 64	229 75	258 84	282 91	313 101	376 119	447 140
41							
42							
43							
44							

Joist Designation	22K4	22K5	22K6	22K7	22K9	22K10	22K11
Depth (In.)	22	22	22	22	22	22	22
Approx. Wt. (lbs./ft.)	8	8.8	9.2	9.7	11.3	12.6	13.8
Span (ft.) ↓							
18							
19							
20							
21							
22	825 548	825 548	825 548	825 548	825 548	825 548	825 548
23	777 491	825 518	825 518	825 518	825 518	825 518	825 518
24	712 431	804 483	825 495	825 495	825 495	825 495	825 495
25	657 381	739 427	805 464	825 474	825 474	825 474	825 474
26	606 338	682 379	744 411	825 454	825 454	825 454	825 454
27	561 301	633 337	688 367	768 406	825 432	825 432	825 432
28	522 270	588 302	640 328	712 364	825 413	825 413	825 413
29	486 242	547 272	597 295	664 327	798 387	825 399	825 399
30	453 219	511 245	556 266	619 295	745 349	825 385	825 385
31	424 198	478 222	520 241	580 267	697 316	825 369	825 369
32	397 180	448 201	489 219	544 242	654 287	775 337	823 355
33	373 164	421 183	459 199	511 221	615 261	729 307	798 334
34	352 149	397 167	432 182	481 202	579 239	687 280	774 314
35	331 137	373 153	408 167	454 185	546 219	648 257	741 292
36	313 126	354 141	385 153	429 169	516 201	612 236	700 269
37	297 116	334 130	364 141	406 156	487 185	579 217	663 247
38	280 107	316 119	345 130	384 144	462 170	549 200	628 228
39	267 98	300 110	327 120	364 133	438 157	520 185	595 211
40	253 91	285 102	310 111	346 123	417 146	495 171	565 195
41	241 85	271 95	295 103	330 114	396 135	471 159	538 181
42	229 79	259 88	282 96	313 106	378 126	448 148	513 168
43	219 73	247 82	268 89	300 99	360 117	427 138	489 157
44	208 68	235 76	256 83	286 92	343 109	408 128	466 146

20.0 Appendix H: UniRac Large Array Roof Mount Support System

(Quotation and Engineering Reports)

UNIRAC

Custom Solutions Quotation

Quote Number: DRB-LA-100301-1147
Revision: 0
Quoted By: Daniel Bernal

Customer Information

Customer: Penn State
Address: 1515 The Fairway
City, State Zip: Jenkins, PA 19046
Contact: Matthew Dabrowski
Phone: 484-553-1887
Email: dabrowandski@gmail.com

Project Information

Project: Rydal Pak Medical Center
Address:
City, State Zip: Jenkins, PA 19046
Description: Rydal Pak Medical Center

Module Specification

Module Model: Kyocera - KD210GX-LP
Height: 38.98
Width: 59.05
Module Quantity: 50
Module Power: 210 Watts (DC Rated)
Project Power: 10.5 Kilowatts (DC Rated)

Racking Specifications

Pipe Selection: 2 in. Schedule 40
Rail Selection: SolarMount HD
Brace Selection: 2" x 2" Aluminum Square Tube
Pipe Cap Selection: Steel - 2" Front Cap
Number of Rows: 5
Number of Columns: 10
Arrays: 1

Bill of Materials

Category	Quantity	Part #	Description	Unit Price	Total
Module Racking					
	30	301014	RAIL, SMHD, MILL, 204"	$191.50	$5,745.00
	60	330104	U-LA 2" RAIL BRACKET	$18.08	$1,084.80
Module Attachment					
	10	321002	SM CLIP, CLR, HDW @20	$38.50	$385.00
ULA Connections					
	13	330001	U-LA 2" FRONT CAP, STEEL	$67.50	$877.50
	13	330002	U-LA 2" REAR CAP, STEEL	$52.00	$676.00
	13	330021	U-LA 2" SLIDER, ALUMINUM	$19.63	$255.19
	13	330102	U-LA 2" 10.5` BRACE	$94.00	$1,222.00
Racking Attachments					
	26	330004	U-LA 2" THREADED FOOT, STEEL	$39.50	$1,027.00
Seismic Bracing Materials					
	1	330101	U-LA 2" 7` BRACE	$65.00	$65.00
	1	330103	U-LA 2" 14` BRACE	$123.00	$123.00
	4	330021	U-LA 2" SLIDER, ALUMINUM	$19.63	$78.52
Grounding					
	8	980011	GROUNDING LUG NO. 1 @ 10 EA	$119.50	$956.00
Other					
	302		Pipe Req. (Feet, above ground)	$0.00	$0.00
	0			$0.00	$0.00

Totals

Total List Price for all components ($USD)	**$12,495.01**
List price per watt ($USD)	**$1.19**
List price per module ($USD)	**$249.90**

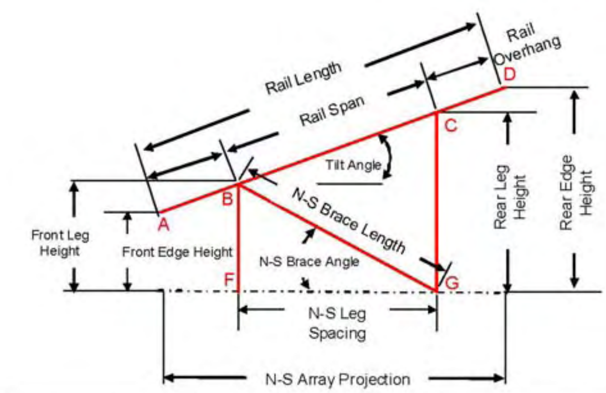
UNIRAC

Custom Solutions Quotation

Quote Number: **DRB-LA-100301-1147** Quoted By: **Daniel Bernal**
Revision: **0**

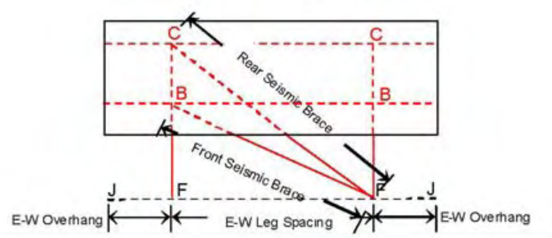
ULA Geometry

Side Elevation

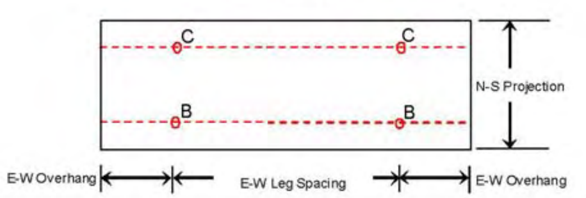


Member Description	Maximum	Revised	Units
Rail Length (in):	197	197	in
Tilt Angle (deg):	45	45	degrees
Rail Span:	118.2	118.79	in
Rail Overhang:	39.4	39.11	in
Front Edge Height:	24	24	in
Rear Edge Height:	163.3	163.3	in
Front Leg Length:	51.86	51.65	in
Rear Leg Length:	135.44	135.65	in
N-S Cross Brace Length:	148.64	98.61	in
N-S Cross Brace Angle:	20.42	31.59	degrees
N-S Leg Spacing:	139.3	84	in
E-W Leg Spacing:	57	47	in
E-W Overhang (in):		15.61	in

Front Elevation



Plan View



Module Specification

Mfr:	Kyocera	Mod:	Kyocera - KD210GX-LP
N-S Dim (in):	38.98	N-S Spacing (in):	0.25
E-W Dim (in):	59.05	E-W Spacing (in):	0.25
Thickness (in):	1.42	Power Rating (W):	210
Orientation:	L	Weight (lbs):	40.8

Sub-Array Configuration

# Rows:	5	
# Columns:	10	
SubArray Modules:	50	
Rails Per Module:	3	
Extended Rail (in):	0	
Seismic Brace Pairs:	1	
Column N-S Length (in):	197	
Array E-W Dimension (in):	593	
Array N-S Projection (in):	197	
Number of Leg Pairs:	13	
Footing Diameter:	12	in.
Footing Depth:	36	in.

ULA Array Totals

# SubArrays:	1
Total Modules:	50
ULA Power Rating (kW):	10.5

Project Rydal Pak Medical Center | **Quote** DRB-LA-100301-1147

Project Ident:	Rydal Pak Medical Center	Customer:	Penn State	Contact:	Matthew Dabrowski	Revision	0
Address1:		Address:	1515 The Fairway	Phone:	484-553-1887	Preparer	danb
Address2:		Address2:		Phone2:			
City, ST, Zip:	Jenkins, PA 19046	City, ST, Zip:	Jenkins, PA19046	Email:	dabrowandski@gmail.com		

ULA Geometry — Complete

Module Specification

Kyocera – KD210GX-LP

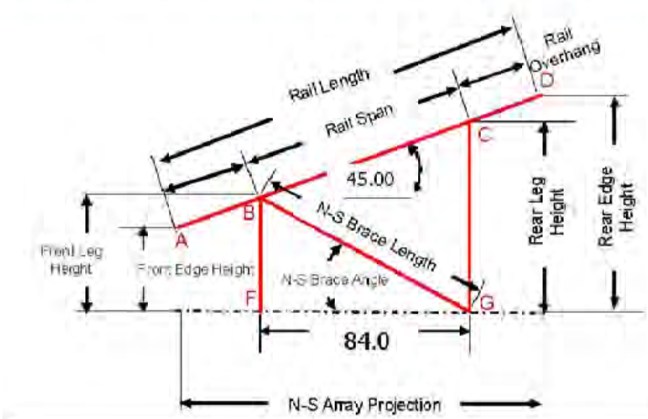
N-S Dim (in):	38.98	N-S Spacing (in):	0.25
E-W Dim (in):	59.05	E-W Spacing (in):	0.25
Thickness (in):	1.42	Power Rating (W):	210
Orientation:	L	Weight (lbs):	40.8

Sub-Array Configuration

# Rows:	5	Column N-S Length (in):	197
# Columns:	10	Array E-W Dimension (in):	593
SubArray Modules:	50	Array N-S Projection (in):	197
Rails Per Module:	3		
Extended Rail (in):	0		

ULA Totals

# SubArrays:	1
Total Modules:	50
ULA Power Rating (kW):	10.5



Member Description	Variables	Standard	Revised	Units
Rail Length (in):	**AD**	197	197	in
Tilt Angle (deg):	**θ**	45	45	degrees
Rail Span:	**BC**	118.2	118.79	in
Rail Overhang:	**AB, CD**	39.4	39.11	in
Front Edge Height:	**AE**	24	24	in
Rear Edge Height:	**DH**	163.3	163.3	in
Front Leg Length:	**BF**	51.86	51.65	in
Rear Leg Length:	**CG**	135.44	135.65	in
N-S Cross Brace Length:	**BG**	148.64	98.61	in
N-S Cross Brace Angle:	**β**	20.42	31.59	degrees
N-S Leg Spacing:	**FG**	139.3	84	in

Project Rydal Pak Medical Center — **Quote** DRB-LA-100301-1147

Project Ident:	Rydal Pak Medical Center	**Customer:**	Penn State	Contact:	MatthewDabrowski	Revision 0
Address1:		**Address:**	1515 The Fairway	Phone:	484-553-1887	Preparer danb
Address2:		**Address2:**		Phone2:		
City, ST, Zip:	Jenkins, PA 19046	**City, ST, Zip:**	Jenkins, PA19046	Email:	dabrowandski@gmail.com	

Wind Load Calculations

Complete

Wind Load Variables

Tilt Angle (deg):	45
Array Height above ground:	60
Exposure Category:	B
Basic Wind Speed, V (mph):	90.00
Importance Factor:	1.15
Roof Zone Multiplier:	1

MWFRS Wind Load Calculation

$$q_h = 0.00256 K_z K_{zt} K_d V^2 I (lb/ft^2)$$

Adjustment Factor for height and Exposure Category	Kz:	0.85
Topographic Factor (assumed to be 1 for level ground)	Kzt:	1
Directionality Factor	Kd:	0.85
Wind Load (psf)	qh:	17.23

Maximum Loads (psf)

	Uplift		Down Force
Front Leg:	-26.36	Front Leg:	38.08
Rear Leg:	-33.68	Rear Leg:	36.61

ASCE 7-05 Open Building Unobstructed Wind Flow Coefficients, Cn

	Load Case A	Load Case B	Load Case A	Load Case B
Front Leg	-1.8	-0.7	2.2	2.6
Rear Leg	-1.6	-2.3	2.5	1.4
Average	-1.7	-1.5	2.35	2

ASCE 7-05 MWFRS Open Buildings Wind Load

Gust Effect Factor (G): 0.85

$$p = q_h G C n$$

	Load Case A	Load Case B	Load Case A	Load Case B
Cn (Front Leg):	-26.36	-10.25	32.22	38.08
Cn (Rear Leg):	-23.43	-33.68	36.61	20.5
Cn (Avg):	-24.9	-21.97	34.42	29.29

Project Rydal Pak Medical Center

Quote DRB-LA-100301-1147

Project Ident:	Rydal Pak Medical Center	**Customer:**	Penn State	Contact:	Matthew Dabrowski	Revision	0
Address1:		**Address:**	1515 The Fairway	Phone:	484-553-1887	Preparer	danb
Address2:		**Address2:**		Phone2:			
City, ST, Zip:	Jenkins, PA 19046	**City, ST, Zip:**	Jenkins, PA19046	Email:	dabrowandski@gmail.com		

Combination Load Analysis — Complete

Load Combination Variable (psf)

Dead Load:	4.95	Assumed
Snow Load:	25	

Max Load Results (psf)

	Down Force	Uplift
Front Leg:	54.31	-22.16
Rear Leg:	53.21	-29.48
Max (Absolute):	53.21	

Load Combination Factors

	Dead Load	Snow Load	Wind Load
Load Case 1 (downforce):	1	1	0
Load Case 2 (downforce):	1	0	1
Load Case 3 (downforce):	1	0.75	0.75
Load Case 4 (uplift):	0.6		1

Front Leg Load Combinations (psf)

	Wind Load Case A	Wind Load Case B
Load Case 1 (downforce):	32	32
Load Case 2 (downforce):	39.22	45.08
Load Case 3 (downforce):	49.92	54.31
Max Downforce:	49.92	54.31
Load Case 4 (uplift):	-22.16	-6.05

Rear Leg Load Combinations (psf)

	Wind Load Case A	Wind Load Case B
Load Case 1 (downforce):	32	32
Load Case 2 (downforce):	43.61	27.5
Load Case 3 (downforce):	53.21	41.13
Max Downforce:	53.21	41.13
Load Case 4 (uplift):	-19.23	-29.48

Project	Rydal Pak Medical Center	Quote	DRB-LA-100301-1147

Project Ident:	Rydal Pak Medical Center	**Customer:**	Penn State	Contact:	Matthew Dabrowski	Revision	0
Address1:		**Address:**	1515 The Fairway	Phone:	484-553-1887	Preparer	danb
Address2:		**Address2:**		Phone2:			
City, ST, Zip:	Jenkins, PA 19046	**City, ST, Zip:**	Jenkins, PA 19046	Email:	dabrowandski@gmail.com		

Force Analysis

Complete

Angles

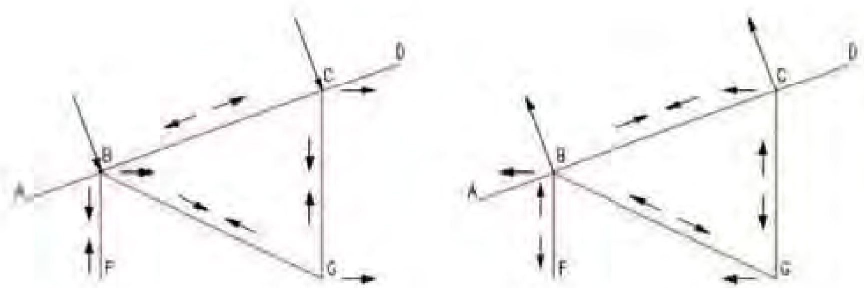
Tilt Angle (deg):	45
Cross Brace Angle (deg):	31.59
F-W Leg Spacing)	47
Rail Length:	197

Design Loads

	Downforce		Uplift	
Front Leg (psf / kip):	54.31	1.74	-22.16	-0.71
Rear Leg (psf / kip):	53.21	1.7	-29.48	-0.94

Maximum Component Forces (kips)

	Down Force	Uplift
Axial Force in Front Leg:	1.23	-0.5
Axial Force in Front Cap:	3.69	-1
Shear Force Front Cap:	2.46	Max Magnitude
Axail Force in Rear Leg:	1.2	-0.66
Axial Force in Rear Cap:	0	0
Shear Force Rear Cap:	1.2	Max Magnitude
Shear Force Rear Foot:	2.46	Max Magnitude
Axial Force in N-S Brace:	2.46	-0.5
Resultant Shear N-S Brace:	2.1	Max Magnitude
Resultant Axial N-S Brace:	1.29	-0.26
Axal Force Rail:	1.2	-0.66
Resultant Shear Rail:	0.85	Max Magnitude
Resultant Axial Rail:	0.85	-0.47



21.0 Appendix I: USGBC LEED V 3.0 Scorecard

LEED 2009 for New Construction and Major Renovation

Project Checklist

Project Name

Date

Y	N	?			Points
12	0	0	**Sustainable Sites**		Possible Points: 26
Y			Prereq 1	Construction Activity Pollution Prevention	
0	0	0	Credit 1	Site Selection	1
1	0	0	Credit 2	Development Density and Community Connectivity	5
0	0	0	Credit 3	Brownfield Redevelopment	1
1	0	0	Credit 4.1	Alternative Transportation—Public Transportation Access	6
1	0	0	Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
1	0	0	Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
1	0	0	Credit 4.4	Alternative Transportation—Parking Capacity	2
1	0	0	Credit 5.1	Site Development—Protect or Restore Habitat	1
1	0	0	Credit 5.2	Site Development—Maximize Open Space	1
1	0	0	Credit 6.1	Stormwater Design—Quantity Control	1
1	0	0	Credit 6.2	Stormwater Design—Quality Control	1
1	0	0	Credit 7.1	Heat Island Effect—Non-roof	1
1	0	0	Credit 7.2	Heat Island Effect—Roof	1
1	0	0	Credit 8	Light Pollution Reduction	1

2	0	0	**Water Efficiency**		Possible Points: 10
Y			Prereq 1	Water Use Reduction—20% Reduction	
0	0	0	Credit 1	Water Efficient Landscaping	2 to 4
				[ ] Reduce by 50%	2
				[ ] No Potable Water Use or Irrigation	4
0	0	0	Credit 2	Innovative Wastewater Technologies	2
2	0	0	Credit 3	Water Use Reduction	2 to 4
				[X] Reduce by 30%	2
				[ ] Reduce by 35%	3
				[ ] Reduce by 40%	4

9	0	0	**Energy and Atmosphere**		Possible Points:	35
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems		
Y			Prereq 2	Minimum Energy Performance		
Y			Prereq 3	Fundamental Refrigerant Management		
3	0	0	Credit 1	Optimize Energy Performance		1 to 19
			X	Improve by 12% for New Buildings or 8% for Existing Building Renovations		1
			X	Improve by 14% for New Buildings or 10% for Existing Building Renovations		2
			X	Improve by 16% for New Buildings or 12% for Existing Building Renovations		3
				Improve by 18% for New Buildings or 14% for Existing Building Renovations		4
				Improve by 20% for New Buildings or 16% for Existing Building Renovations		5
				Improve by 22% for New Buildings or 18% for Existing Building Renovations		6
				Improve by 24% for New Buildings or 20% for Existing Building Renovations		7
				Improve by 26% for New Buildings or 22% for Existing Building Renovations		8
				Improve by 28% for New Buildings or 24% for Existing Building Renovations		9
				Improve by 30% for New Buildings or 26% for Existing Building Renovations		10
				Improve by 32% for New Buildings or 28% for Existing Building Renovations		11
				Improve by 34% for New Buildings or 30% for Existing Building Renovations		12
				Improve by 36% for New Buildings or 32% for Existing Building Renovations		13
				Improve by 38% for New Buildings or 34% for Existing Building Renovations		14
				Improve by 40% for New Buildings or 36% for Existing Building Renovations		15
				Improve by 42% for New Buildings or 38% for Existing Building Renovations		16
				Improve by 44% for New Buildings or 40% for Existing Building Renovations		17
				Improve by 46% for New Buildings or 42% for Existing Building Renovations		18
				Improve by 48%+ for New Buildings or 44%+ for Existing Building Renovations		19
3	0	0	Credit 2	On-Site Renewable Energy		1 to 7
			X	1% Renewable Energy		1
			X	3% Renewable Energy		2
			X	5% Renewable Energy		3
				7% Renewable Energy		4
				9% Renewable Energy		5
				11% Renewable Energy		6
				13% Renewable Energy		7
1	0	0	Credit 3	Enhanced Commissioning		2
0	0	0	Credit 4	Enhanced Refrigerant Management		2
0	0	0	Credit 5	Measurement and Verification		3
2	0	0	Credit 6	Green Power		2

5	0	0		**Materials and Resources**	Possible Points:	**14**
Y			Prereq 1	Storage and Collection of Recyclables		
0	0	0	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof		1 to 3
				[ ] Reuse 55%		1
				[ ] Reuse 75%		2
				[ ] Reuse 95%		3
0	0	0	Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements		1
1	0	0	Credit 2	Construction Waste Management		1 to 2
				[X] 50% Recycled or Salvaged		1
				[ ] 75% Recycled or Salvaged		2
1	0	0	Credit 3	Materials Reuse		1 to 2
				[ ] Reuse 5%		1
				[ ] Reuse 10%		2
1	0	0	Credit 4	Recycled Content		1 to 2
				[X] 10% of Content		1
				[ ] 20% of Content		2
1	0	0	Credit 5	Regional Materials		1 to 2
				[X] 10% of Materials		1
				[ ] 20% of Materials		2
1	0	0	Credit 6	Rapidly Renewable Materials		1
0	0	0	Credit 7	Certified Wood		1

13	0	0		**Indoor Environmental Quality**	Possible Points:	**15**
Y			Prereq 1	Minimum Indoor Air Quality Performance		
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control		
1	0	0	Credit 1	Outdoor Air Delivery Monitoring		1
1	0	0	Credit 2	Increased Ventilation		1
1	0	0	Credit 3.1	Construction IAQ Management Plan—During Construction		1
1	0	0	Credit 3.2	Construction IAQ Management Plan—Before Occupancy		1
1	0	0	Credit 4.1	Low-Emitting Materials—Adhesives and Sealants		1
0	0	0	Credit 4.2	Low-Emitting Materials—Paints and Coatings		1
1	0	0	Credit 4.3	Low-Emitting Materials—Flooring Systems		1
0	0	0	Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products		1
1	0	0	Credit 5	Indoor Chemical and Pollutant Source Control		1
1	0	0	Credit 6.1	Controllability of Systems—Lighting		1
1	0	0	Credit 6.2	Controllability of Systems—Thermal Comfort		1
1	0	0	Credit 7.1	Thermal Comfort—Design		1
1	0	0	Credit 7.2	Thermal Comfort—Verification		1
1	0	0	Credit 8.1	Daylight and Views—Daylight		1
1	0	0	Credit 8.2	Daylight and Views—Views		1

Y	?	N	Category / Credit		Possible Points
1	0	0	**Innovation and Design Process**		**Possible Points: 6**
			Credit 1.1	Innovation in Design: Specific Title	1
			Credit 1.2	Innovation in Design: Specific Title	1
			Credit 1.3	Innovation in Design: Specific Title	1
			Credit 1.4	Innovation in Design: Specific Title	1
			Credit 1.5	Innovation in Design: Specific Title	1
1	0	0	Credit 2	LEED Accredited Professional	1
0	0	0	**Regional Priority Credits**		**Possible Points: 4**
			Credit 1.1	Regional Priority: Specific Credit	1
			Credit 1.2	Regional Priority: Specific Credit	1
			Credit 1.3	Regional Priority: Specific Credit	1
			Credit 1.4	Regional Priority: Specific Credit	1
42	0	0	**Total**		**Possible Points: 110**

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110