# FINAL REPORT

April 7, 2009

# BRIDGESIDE BUILDING II

Pittsburgh, PA


# ERIK CARLSON

Construction Management

Dr. Messner

# BRIDGESIDE BUILDING II
# PITTSBURGH, PA

## PROJECT TEAM

**Owner:** The Ferchill Group
**General Contractor:** Turner Construction
**Architect:** Strada Architecture, LLC
**MEP Engineer:** Allen and Shariff Corporation
**Structural Engineer:** Atlantic Engineering Services
**Civil Engineer:** Gateway Engineers
**Geotechnical Engineer:** Professional Service Industries

## PROJECT FEATURES

**Building Type:** Lab/Office Space
**Building Size:** 160,000 sf
**Number of Stories:** 5 plus a small penthouse
**Dates of Construction:** Nov 2007 to Dec 2008
**Construction Costs:** $18 Million
**Project Delivery Method:** Design-Bid-Build

## ARCHITECTURAL DESIGN

-Shell building to be fit-out when a tenant is contracted
-Industrial design with exposed lateral bracing and steel canopies
-Balconies with views of the Pittsburgh skyline
-Facade consists of storefront windows, metal panels and cast stone
-Built up roof with EPDM roofing membrane surrounded by a steel screen wall

## STRUCTURAL DESIGN

-Pre-drilled H-pile foundations with concrete pile caps
-Structural steel framing with composite steel decks and 32'x30' column grids
-Lateral bracing is constructed of hollow steel tube cross bracing
-Composite decks consist of 3" NW concrete on 3" 20 ga deck

## MEP SYSTEMS

-3 rooftop AHU units which produce 40-75 thousand cfm of supply air and 1 VAV box per floor
-Wet pipe sprinkler system with concealed sprinkler heads
-Main distribution panel is sized for 4000A 480Y/277
-1 mega-watt backup diesel generator
-Lighting consists of recessed incandescent down lights, fluorescent utility lights and exterior wall washers

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www.engr.psu.edu/ae/thesis/portfolios/2009/ejc5000

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| | |
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| | |
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# EXECUTIVE SUMMARY

The purpose of this senior thesis is to study the Bridgeside II project, which is a new building project located in the Technology Center in Pittsburgh, PA. This report is broken up into a project overview and three in-depth analyzes focusing on the foundation, photovoltaic modules, and BIM implementation. Each analysis is working to achieve an overall goal that includes completing the project in a shorter duration and pleasing the potential tenants so they will want to lease a space and will hopefully begin the interior designs before the shell building is complete.

One of the major constructability issues that was faced was the installation of the deep foundation system. Due to underground obstructions from the previous site use the pile contractor was unable to drive most of the steel H-piles to the bedrock. The majority of the piles had to be pre-drilled and this resulted in schedule delays and increased costs. After analyzing several other foundation systems, it was determined that using micro piles would be the most beneficial to the project. In order to fully understand the impacts of a mat slab foundation, a structural analysis was performed to determine the size and reinforcing of the slab. Each micro pile could be drilled into the ground at a high rate of speed and were able to break through the obstructions. Also both crews could be utilized for installing piles. Micro piles ended up being cheaper and can be installed quicker than driven piles or a mat slab. It was determined that using micro piles in lieu of driven piles would create a cost savings of $266,565 and a schedule reduction of 24 days.

The second analysis involves the replacement of certain glass panels on the façade with photovoltaic modules manufactured by Suntech Power. The purpose of implementing the PV modules was to create an energy savings that would reduce the life cycle costs of the building. The Suntech Light-Thru modules will replace some of the non-vision spandrel glass. The modules will still prevent views of the elevated slabs and they will generate 10 watts per square foot. An electrical analysis was necessary to determine the string sizes, number of inverters, and the impact of the inverters on the electrical panels. The PV system can be constructed in the same amount of time and will cost an additional $228,553. The modules can generate 23.4 kWh of energy each year that results in a 119 year payback period. Based on this analysis alone, the PV modules would not be accepted. However, if it is combined with the micro piles, the initial costs would be offset immediately and the owner and tenants would benefit from a yearly cost savings of $1,917.

The final analysis is a study of implementing BIM for core and shell projects focusing on the interior fit-out phases. Owners are often hesitant to use BIM because they are unsure how to assign responsibility and how to apply the model to their project. The new AIA BIM document and the Model Progression Specification help project teams determine how to specify a required level of detail for the model and who is responsible for it. Interior models can benefit potential tenants because many designs can be compared and tenants can see 3D and 4D visualizations of their space. Using interior models will help ease some of the tenant's hesitations about agreeing on a space before it is complete. A level of detail of 300 will provide an accurate model to develop interior designs, and cost estimates and schedules can be developed from the model information.

# PROJECT OVERVIEW

**Introduction**

Bridgeside Building II is a five story shell building located in Pittsburgh, PA. The intended building occupation is 80 percent laboratory space and 20 percent office space. Bridgeside II is being built in response to the local demand for additional laboratory space; however, a tenant has yet to be secured. The goal of the owner is to lease the entire building to a local university, potentially, The University of Pittsburgh. The structure of Bridgeside II is structural steel with composite slabs and the exterior is constructed of balloon framing and metal panels. Storefront windows and cast stone are also utilized on the building's exterior. Bridgeside II is located in the Technology Center, the previous site of J&L Steel. Existing foundations and steel debris created a constructability issue when installing the deep foundation system.

Building Statistics

- Building Size: 162,000 SF
- Project Cost: $18 Million
- Project Duration: 14 months
- Project Completion: January 2009


Figure A – October Progress Photo

**Client Information**

The owner of the Technology Center property and the land on which Bridgeside II is located on is the Urban Redevelopment Authority of Pittsburgh. The URA is a group who purchases and develops land that is unwanted by the private sector. They also construct low-income housing, retirement communities and assist with financing. The URA approved a proposal from the Ferchill Group to purchase land and construct the Bridgeside II Building. The Ferchill Group is a successful developer from Cleveland who made their mark in Pittsburgh with the construction of Bridgeside Building I and Heinz Lofts. To further accommodate Bridgeside II the URA is constructing a 750 space parking garage, relocating Technology Drive and relocating some existing utilities. The Ferchill Group's goal for the project is to rent the space to a local university who needs additional laboratory space, which could create up to 400 new jobs. Also once Bridgeside II is 50 percent leased the Ferchill Group can begin construction on an adjacent 120,000 square foot facility. Therefore, it is important that Bridgeside II be a desirable space that will encourage quick leasing. The Ferchill Group's long-term goal for Pittsburgh is to develop a million square feet of space and the URA plans to further develop the Technology Center with hotels and mixed-use facilities.

**Local Conditions**

Steel has always been the material of choice in Pittsburgh. However, over the past few decades many of the Steel Mills have shut down. Bridgeside II is located on the site of J&L Steel, which shut down in 1981. The large quantities of steel produced in Pittsburgh is said to have built America. Steel is still used for most Pittsburgh buildings; however, the material selection is based on cost and schedule demands rather than tradition.

Since there are three projects being constructed simultaneously, parking on-site is scarce. One of the parking lots was removed to make room for the parking garage therefore the surrounding buildings can't sacrifice any additional parking space. Turner Construction only needs two parking spaces and the subcontractors have been able to sufficiently utilize the space they have been allocated. While typically, there are multiple subcontractors on a building site during fit-out, the parking space has not been a problem because Bridgeside II is a shell space.

The subsurface materials in Pittsburgh consist mostly of bedrock, sandstone, shale and thin limestone. In order to determine the subsurface conditions on site the geotechnical engineer drilled eight borings in the building footprint. Rather than the typical materials, the results showed up to 40 feet of man-placed fill consisting of rock fragments, brick, slag, and clay. Also on site were foundations and debris left from J&L Steel. The man-placed fill was determined to be unsuitable for the building loads due to its variability. Rather than using shallow concrete foundations, piles were driven until bedrock was reached.

**Project Delivery System**

The delivery method for Bridgeside II is technically design-bid-build; however, Turner Construction negotiated with the owner to be involved with the project early. Turner was able to bid out the steel, foundation piles, concrete, and excavation packages, before the design was complete. This was beneficial to the project because the subcontractors were contracted in advance and were able to begin procurement and expedite the schedule. Turner established a GMP contract that gave them the flexibility to join the project early which helped to avoid some of the risk that comes with an incomplete design. The GMP also provides the option of change orders, which may be necessary after a scope change during the completion of the design and throughout the duration of the project.

Turner Construction holds a lump sum contract with all of their subcontractors. This contracting method is appropriate because the scope and schedule are specified in the bid packages allowing the use of change orders if a scope change or an unforeseen incident were to occur. Rather than having Turner bond the project and each of the subs provide a bond, the owner purchased a program from Turner called Subguard. Subguard provides a bond for the entire project including each of the subcontractors. The subcontractors only have to bond any work that they contract to another company. Subguard is beneficial for the project because it prevents double bonding and gives Turner additional solutions and options in the event of a subcontractor default.

The Ferchill Group and Strada Architecture utilize a standard AIA Owner Architect agreement, which is a negotiated fee that Strada charges for their services on the project. Rather than holding separate contracts for each of the consultants and engineers they are listed as subconsultants to Strada under their contract with the owner. The subconsultants include the MEP, structural, civil and geotechnical engineers. Figure B shows the organizational chart for the Bridgeside II project.

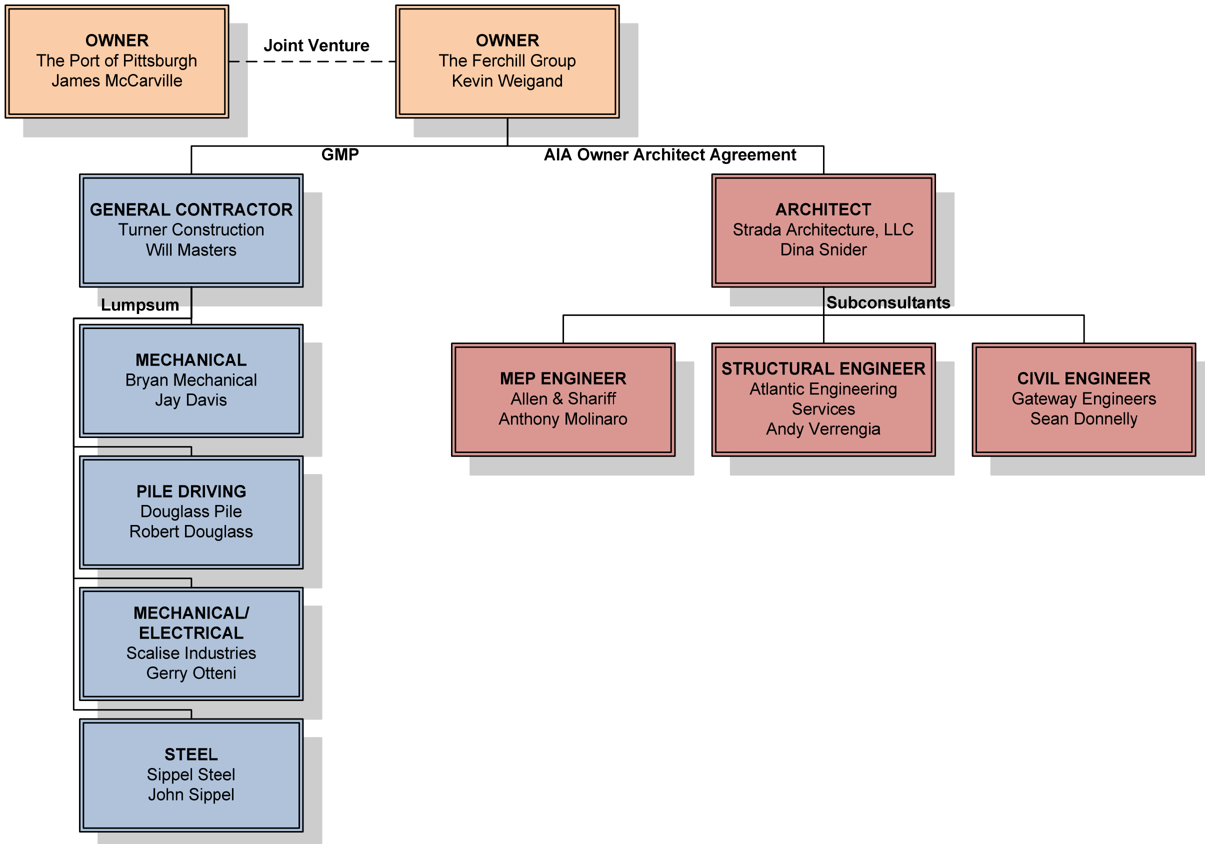



Figure B – Organizational Chart

**Staffing Plan**

Turner Construction utilizes a simple staffing plan for this project. Very few people are involved with the project; however, it is sufficient for successful completion. The Superintendent and the Project Engineer work out of the on-site trailer and report to Dan Sterling, the Project Executive. John Demarco, the Superintendent, is responsible for updating the schedule, holding subcontractor meetings and controlling the flow of the trades. Will Masters, the Project Engineer, is responsible for RFI's, submittals, payment requisitions, and etc. Between the two of them there has not been a need for a Project Manager. The staffing plan has remained constant with the exception of the addition of a summer intern. Turner Construction also has a Special Projects Division that works on interior construction, renovations, and small buildings. Aaron Donahue and William Beck work for Turner's SPD and have contributed to the project. Figure C shows the staffing plan that was utilized for the Bridgeside II project.

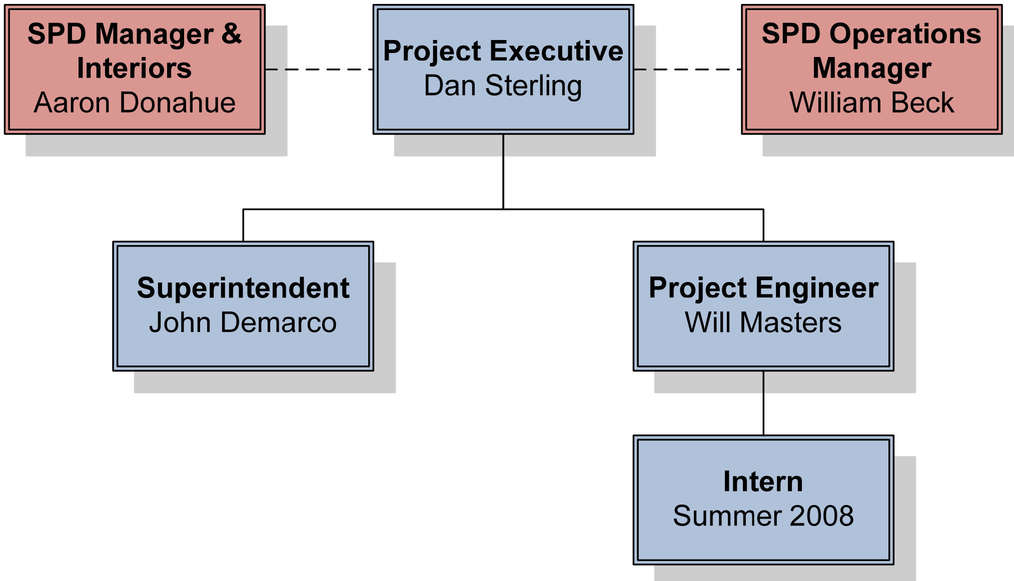



Figure C – Staffing Plan

## Building Overview and Systems Summary

### Architecture

The Bridgeside II building consists of 5 stories and open floor layouts that will accommodate the needs of the tenants once determined. A wet core is located in the center of the building which includes most of the MEP equipment and piping as well as bathrooms on each floor. Bridgeside II is located on the Monongahela River in the Pittsburgh Technology Center, which was once the home of J&L Steel Company. To reflect the sites past history the building was given an industrial design using exposed steel framed canopies, screen walls, and lateral bracing. Storefront windows and balconies facing the river take advantage of the buildings river front location with views of the Pittsburgh skyline.

### Demolition

Bridgeside II was constructed on the site of an old steel mill and some of the building foundations and steel scraps were left buried in the site. Many of the obstructions were up to 25 feet deep and were drilled through, rather than dug out, during the installation of the foundation piles. However, about $4,000 was spent digging up obstructions that were near the surface or could not be drilled through.

### Structural Steel

The structural system for Bridgeside II consists of structural steel and composite slab deck. The lateral bracing is located on each side of the building perimeter and is constructed of hollow steel tube cross bracing. Composite slabs are used on floors 2 through 5 and on the roof. They consist of 3” normal weight concrete on 3” 20 gage steel deck. A combination of ¾” shear studs and welds are used to create the composite assembly. The crane used for the steel erection was a 75 ton Crawler Crane. The crane started inside the footprint at the northeast building corner and moved south, ending outside the building footprint.

**Cast in Place Concrete**

Cast in place concrete is used for the pile caps, slab on grade and composite slabs. The minimum strength requirement for foundation elements is 3,000 psi and the interior slabs are 4,000 psi. A concrete vendor was responsible for supplying the concrete onsite while another company was responsible for pumping the concrete into place. Simon Panels were utilized for the formwork and were capable of being used multiple times. Each floor was divided into three pours, which is about 10,000 square feet each. The pours were positioned side by side and ran the length of the building. Floors 2 through 5 were poured in order, followed by the slab on grade.

**Building Envelope**

The building envelope for Bridgeside II consists of three different wall systems. The majority of the envelope consists of insulated metal panels and aluminum storefront windows. Cast stone is located on the lower quarter of the building occasionally running to the top to provide the building with more vertical elements. The storefront windows surround the main entrance and run to the top of the building. They are also located on the river side to provide the building with views of the river and Pittsburgh skyline. The roof consists of a built up roof with an EPDM roof membrane and sits on 1.5", galvanized roof deck. Surrounding the roof is a steel screen wall which hides the mechanical equipment and enhances the buildings industrial design.

**Masonry**

Cast stone masonry is used on the exterior of the building from the ground up to the second floor. The cast stone is non-load bearing and is supported by 6" metal studs with rigid insulation. Mortar and adjustable wire ties secure the panels to the structure. Once the cast stone becomes out of reach, man lifts are used to install the remaining panels.

**Mechanical System**

The mechanical system is located outside on the building's roof surrounded by steel screen walls to shield the units from the public eye. There are 3 roof top units each of which utilizes hot water pre-heat coils and energy recovery wheels. One unit uses 100% outside air and produces 40,000 cfm of supply air. The other two units each use 17,000 cfm of outside air and produce 75,000 cfm of supply air. Bridgeside II also utilizes a boiler, which is located on the roof, and 5 VAV boxes, one on each floor. Since Bridgeside II currently does not have a tenant the building is being built as a shell space. Therefore the mechanical system had to be sized based off of assumptions and past projects. The building will accommodate both office and lab spaces. To meet the demands of the future lab spaces each floor was designed for 10,000 cfm of lab exhaust and numerous wet stacks were added to allow for easy installation of lab sinks. It will be the job of the owner to understand the systems limitations and to consider them during lease arrangements.

**Fire Protection**

Bridgeside II is fully sprinklered with automatic concealed sprinkler heads making spray-on fireproofing on the exposed steel unnecessary. However, spray on fireproofing is still required on the elevator and stair well framing. The majority of the sprinklers utilize a wet pipe system except for the loading dock and balcony areas which require a dry pipe system. Since the building is type IIB it must meet NFPA 13 regulations meaning that the maximum sprinkler coverage area is 225 sqft. for office space and 130 sqft. for the rest of the spaces. There is a fire department connection located next to the main entrance and the 6" fire service line enters the building at the south-west corner. The fire alarm control panel is located in the main electrical room and is connected to a 120V emergency power source. Fire alarms, heat detectors, and smoke detectors are installed in the finished spaces; however, more will be required when a tenant fits out the space.

**Electrical System**

The main electrical room is located on the bottom floor along with the generator and back-up generator. There is also an electrical room located in the center core of the building on each floor. The main distribution panel is sized for 4000 amps 480Y/277. Two transformers are located on the first floor and one on each the second, fourth and roof levels. Currently there are only panels designed to feed the mechanical equipment, building core, egress locations, and the building's exterior. Once a tenant moves in there is space for additional panels to be installed in the electrical rooms on each of the floors. Similar to the mechanical system the electrical system had to be designed based off of assumptions. The main service feed was sized for a higher watt per square footage than a typical office building. Also, it is assumed that the labs will require a large number of receptacles; however, there is a large diversity in the amount of usage at any given time. This had to be taken into consideration when sizing the electrical system. The back-up generator is a 1 mega-watt diesel generator that will supply power to life safety systems including the hood exhaust fans. Additionally, the lab equipment will be provided power by the redundancy system.

**Lighting System**

The interior lighting consists of recessed incandescent down lights in the public areas, which are connected to occupancy sensors. Surface mounted fluorescent lights are found in the utility rooms and egress routes. The majority of the interior lighting will be selected by each of the tenants depending on the use of their space. The exterior of the building contains semi-recessed lights and wall washers.

**Transportation**

There are three machine room-less Gen2 traction elevators located in the center of the building. Each elevator has a rated capacity of 3,500 pounds and runs at 350 feet per minute. The building also contains two stair cases which have been spaced to accommodate any floor plan configuration.

## Site Layout Plans

### Existing Conditions

There are currently three projects being constructed on Technology Drive. The projects include Bridgeside Building II, a parking garage, and the relocation of Technology Drive. Technology Drive is being relocated to sit east of Bridgeside II, placing it between Bridgeside II and the parking garage. The large amount of construction has made the site congested. Turner Construction has had limited space for staging areas and parking because they are surrounded by Technology Drive, the Sunoco Building, and the river. This leaves space only on the south side for their trailers, parking and storage. The majority of the utilities had to be installed because the only existing line was an electric line, which serviced the parking lots on the east of Bridgeside II.

### Foundation Site Plan

The project did not require any excavation however, there was extensive foundation work. The bulk of this work was drilling and driving steel H-Piles until bedrock was reached. The equipment used on site was an 80 ton crawler crane and a 60 ton truck crane. The crawler crane was equipped with a rotary hydraulic unit that was used to pre-drill the pile holes. The truck crane was then equipped with a hammer to drive the piles into place. Layout space was located on the north and south ends of the building to store the piles. Entering and exiting the site was accommodated with an access road off the existing Technology Drive and the new Technology Drive that was laid out but not paved. The contractor’s trailers are located adjacent to the access road, which is the main entrance to the site. The parking area surrounds the trailers and sits adjacent to the storage area for equipment and tools.

### Superstructure Site Plan

The superstructure site plan includes the steel erection phase and the exterior façade phase. The structure is composed of structural steel and composite slabs. The façade is constructed of insulated metal panels, storefronts, and cast stone. The main issue for this phase of the project was layout space. The steel was fabricated and stored prior to the start of the project. It was then delivered to the site in phases because there wasn’t enough room to store all of the steel on site. The route for the steel trucks was to travel on the future Technology Drive location and then exit on the existing Technology Drive. A 75 ton crawler crane was used to erect the steel. Since there is limited space for material storage, the exterior façade panels and windows were stored inside the building. Materials were lifted up to each floor with the 30 ton truck crane and the boom truck and then the JLG lifts were used to lift individual panels into place.

*See Appendix A for three site plans*

## Project Cost Evaluation

### Construction and Total Project Costs

Actual Building Construction Cost (CC) = $14,816,497

Actual Building Construction Cost per Square Foot = $14,816,497 / 162019 SF = $99.45/GSF

Total Project Cost = $18,032,803

Total Project Cost per Square Foot = $18,032,803 / 162019 SF = $111.30/GSF

Major Building Systems Costs and Costs per Square Foot:

- Mechanical System = $3,916,609; $24.17/GSF
- Electrical System = $1,263,159; $7.80/GSF
- Structural System = $3,725,927; $23.00/GSF
- Metal Panels = $1,226,772; $7.57/GSF
- Glass and Glazing = $1,303,489; $8.05/GSF

### D4Cost 2002 Estimate

The D4Cost estimate was performed by selecting four projects similar in size, cost, and function to obtain a cost per square foot similar to Bridgeside Building II. The three shell office buildings were chosen because Bridgeside II is a shell space and therefore should have a similar cost per square foot. Since Bridgeside II is planned to be 80% lab space, the Medical Office Building Shell was chosen because the mechanical equipment and piping in a Medical Office would be sized closer to a lab space than a typical office building. Table A shows each of the D4 buildings.

*See Appendix B for the D4Cost Estimate*

Table A – D4 Cost Estimate

| Project Name | Building Use | Size (SF) | Floors | Cost |
|---|---|---|---|---|
| Knollwood Office Building (Shell) | Office | 55,998 | 3 | $3,496,274 |
| Atwood Professional Center (Shell) | Office | 70,884 | 3 | $2,989,670 |
| Oakbend Office Building (Shell) | Office | 18,800 | 3 | $1,556,110 |
| Medical Office (Building Shell) | Medical Office | 122,442 | 4 | $10,832,146 |

D4Cost reported an estimate of **$143.28/GSF** and **$22,924,306** for the total project cost, which is 27% higher than the actual project cost for Bridgeside II. The elevated price is a result of each of the projects having a different scope than Bridgeside II. If each of the compared projects had the same structure, exterior, and MEP systems as Bridgeside II, the estimate would be more exact. D4Cost is appropriate for providing ballpark estimates, but not for dependable project estimates.

**R.S. Means 2008 Square Foot Estimate**

The following R.S. Means estimate is based off a 5 to 10 story office building with face brick and concrete block back-up. The model costs are calculated for an 8-story building with 12' story heights and 80,000 square feet. Perimeter, height and location adjustments were necessary to complete the estimate.

Bridgeside II
SF Area = 160,000 SF
LF Perimeter = 773 LF
5 Stories – 14' Average Story Height

Cost per Square Foot of Floor Area = $129.04/SF

Perimeter Adjustment - $3.32/100LF = $7.87/SF
Height Adjustment - $1.40/1FT = $2.80/SF
Location Modifier: Pittsburgh, PA = .99

**Total Cost per Square Foot of Floor Area = $138.31/SF**
Estimated Project Cost = $22,129,600

Additives total to $402,900 for 3, 3500lb passenger elevators

**Total Project Estimate Cost = $22,532,500**

The R.S. Means estimate is 25% higher than the actual project cost for Bridgeside II. The cost difference can be attributed to the fact that Bridgeside II is a shell office space and the R.S. Means estimate includes costs for interior fit-out. Another reason for the cost difference is because for the R.S. Means estimate the building exterior was assumed to be face brick with concrete block back up and Bridgeside II has insulated metal panels on rigid metal studs.

## General Conditions Estimate

Table B shows a summary of the General Condition Estimate divided into general expenses, project staff, temporary utilities, fees and permits and the CM Fee. The estimate totaled to **$945,288** which is **5.25%** of the contract value. Each of the general conditions is priced per month, week or lump sum and most of the items span the entire length of the project, which is 14 months. The cost data was obtained primarily from R.S. Means 2007 and also from actual project data. The Pittsburgh Technology Center is controlled by one owner therefore some of the utilities could be tapped into neighboring buildings. Turner Construction was able to save money by digging a trench to the Pittsburgh Biotech Building and running power and telephone lines back to the site. Duquesne Light, the utility company, provided a temporary transfer switch and a shed was built to house a meter and panel. Parking did not have to be paid for; however, there is limited space on site.

*See Appendix C for the General Conditions Estimate*

Table B – GC Estimate Summary

| General Conditions Estimate Summary | |
|---|---|
| **Description** | **Total Cost** |
| **General Expenses** | $60,348 |
| **Project Staff** | $263,050 |
| **Temporary Utilities** | $132,245 |
| **Fees and Permits** | $456,797 |
| **CM Fee** | $32,848 |
| **Total** | **$945,288** |

## Detailed Project Schedule

The contract for Bridgeside II was executed on October 22, 2007 followed by a Notice to Proceed issued on November 2, 2007. The building is scheduled to finish on January 9, 2009 making the project duration approximately 14 months. If a tenant or multiple tenants are determined before the completion date then Turner Construction may be given the contract to fit-out the building therefore lengthening the project duration. Table C shows some of the key schedule dates for the project.

Table C - Key Schedule Dates

| Item | Date | Total Duration |
|---|---|---|
| Notice to Proceed | 11/2/2007 | - |
| Foundation Complete | 5/9/2008 | 123 Days |
| Final Concrete Slab Pour | 7/9/2008 | 31 Days |
| Topping Out | 5/12/2008 | 26 Days |
| Building Enclosure | 9/18/2008 | 60 Days |
| Certificate of Occupancy | 12/9/2008 | - |

**Foundation Sequence**

The foundation was constructed in approximately 4 months and is comprised of steel piles and concrete pile caps, grade beams, piers and foundation walls. Approximately, 2 months were required for drilling and driving the piles. Two crews were utilized for the piles. One crew used an 80 ton crawler crane with a rotary hydraulic unit for the drilling and the other crew used a 60 ton truck crane with a hammer for the driving. The drilling crew started ahead of the driving crew because drilling is a much slower operation. A night crew was also utilized to accelerate the drilling schedule. Once the drilling was complete both cranes were used for driving the piles. With 1 month of pile work remaining the concrete crews were able to start forming and pouring the concrete foundation structures. They were sequenced in the following order; pile caps, grade beams and piers, then foundation walls.

**Concrete Slab Sequence**

The concrete pours started with the elevated slabs at floor 2 and worked up to the roof. Once the elevated slabs were completed, the slab on grade was poured. In addition to the sequencing shown on the detailed schedule, each floor was divided into three pours of equal size shown in Figure D. Since each elevated slab is the same shape and size and a typical pour sequence was used, a learning curve developed. Simon Panels were used for the formwork, which can be used multiple times. The learning curve most likely developed around tearing down and setting up the Simon Panels. Floors 2 and 3 took 8 days to pour then floors four and five decreased to six days. Table D shows the pour sizes and durations for floors two and four.

Table D – Pour Durations

| Floor | Pour | Square Feet | Duration |
|---|---|---|---|
| 2 | 1 | 10,468 | 3 Days |
| 2 | 2 | 11,579 | 3 Days |
| 2 | 3 | 10,656 | 2 Days |
| 4 | 1 | 10,850 | 2 Days |
| 4 | 2 | 9,840 | 2 Days |
| 4 | 3 | 11,900 | 2 Days |

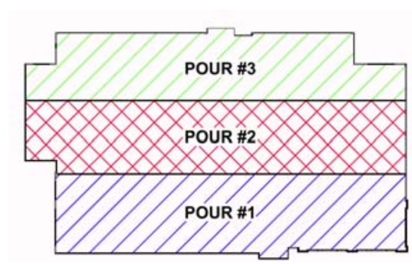



Figure D - Pour Sequence

**Structural Steel Sequence**

The structural steel was erected by bay rather than by floor. This enabled the crane to travel the least amount possible. The 75 ton crawler crane was placed in the northeast corner and moved down the south side of the building. The crane moved in and out of the building footprint in order to reach the opposite side. The steel decking followed close to the structural steel because as the crane moved south there was no steel being erected over top of the steel decking workers. Once the building was topped out and the second floor decking was installed the concrete contractor was able to begin placing formwork and reinforcing. There were no lead time issues because the fabrication process was started early. However, due to limited lay down space the steel had to be delivered in multiple phases.

**Interior Sequence**

Since Bridgeside II is a shell building there is limited fit-out work to be completed. For the interior work that does need to be constructed a parade of trades is being utilized. Table E shows the typical floor sequence for the interior trades and some of the MEP trades

*See Appendix D for a Detailed Project Schedule*

Table E – Interior Construction Sequences

| Trade | Floor Sequence |
|---|---|
| Interior Finishes | 2-3-1-4-5-Penthouse |
| F.P. Piping and Heads | 1-2-3-4-5 |
| Ductwork | 2-3-4-5-1-Roof |
| Grilles, Registers, Diffusers | 2-3-1-4-5 |
| Electrical Rough-In | 2-3-1-4-5 |

## ANALYSIS 1: Alternative Foundation System

**Problem Identification**

Bridgeside II sits on 25 to 40 feet of man placed fill that was placed after the demolition of J&L Steel. The fill has variable strengths and properties and is unsuitable to support the building loads with a typical shallow foundation system. Therefore a deep foundation system was utilized to reach bedrock. Steel H-piles were selected; however, due to existing concrete foundations and steel debris they could not be easily driven. The majority of the piles had to be pre-drilled with a rotary hydraulic drill. The drill was able to break through concrete but was not effective with the steel debris. Some of the shallow debris had to be excavated out of the site. The extensive amount of drilling created schedule delays and increased the foundation costs.

**Proposal**

Potential foundation systems that could be used include Micro piles, a Mat Slab, and Drilled Caissons. I plan on investigating the cost, schedule, and feasibility of these systems to determine an appropriate replacement for the driven H-piles. The structural requirements will also need to be analyzed to determine the required strengths, sizes, and reinforcing.

**Goal**

The goal of this analysis is to determine a new foundation system that can be installed more efficiently and in less time. Cost savings will also be strived for but the main purpose of this analysis is to create a schedule reduction. Bridgeside II faced schedule delays while installing the deep foundation system due to underground obstructions. This created delays because the majority of the piles had to be predrilled, which is a slow process. Creating a schedule reduction is important to the owner, The Ferchill Group, because once the building is complete they can lease the space and start collecting payments. Also once 50 percent of the building is leased, the owner can begin the next speculative building in the Pittsburgh Technology Center.

**Methodology**

1) Research alternative foundation systems that could be applied to the Bridgeside II project.
2) Calculate structural requirements to determine the necessary foundation strengths and sizes.
3) Compare the cost and schedule of the current deep foundation system with alternative foundation systems.

**Current Foundation System - Steel H-Piles**

Steel H-piles were selected as the foundation system due to the variable fill on site; however, the amount of underground obstructions were underestimated. Test borings and knowledge of the previous site use warned of potential concrete and steel obstructions. The owners chose to provide a $150,000 allowance for pre-drilling that was consumed along with an additional $135,000. In addition, approximately $4,000 was spent to remove shallow obstructions. Some of the obstructions could be driven through but if the pile experienced excessive driving stresses then the pile integrity would be decreased.

There are two types of driven piles; end bearing piles and friction piles. End bearing piles are driven into rock far under the building surface. Friction piles rely on the soil pressure around the pile to prevent uplift from occurring. Friction still provides support for end bearing piles because when the pile is driven the soil compresses around it, increasing the frictional force. End bearing piles were utilized for the Bridgeside II project due to the poor soil conditions. Each pile had to be driven to refusal into bedrock that was 45 to 55 feet below the surface. The two sizes of H-piles used were HP 10x57 and HP 14x73 which have a capacity of 210 kips and 260 kips respectively.

The following are the advantages and disadvantages of a driven steel pile foundation system.

Advantages:

- Can be driven in long lengths
- Can be driven easily and quickly through soft soils
- The piles can carry heavy loads
- Limited soil displacement which is important if the soil is contaminated
- Steel piles can easily be cut or spliced for different lengths
- Can be anchored into flat or sloped rock

Disadvantages:

- Underground objects or boulders can block or deviate the pile
- Corrosion can occur
- Relatively expensive
- The hammer is noisy and the vibrations can disrupt or damage adjacent structures
- Requires a lot of headroom

Cost and Schedule

The total duration to construct the driven pile foundation system is **123 days**. This also includes the time for constructing the concrete foundations including the pile caps, grade beams, piers, and foundation walls. The phasing of the foundation system enables the structural steel erection to overlap the foundation construction by 25 days. This time needs to be considered when comparing other systems because the construction phases will vary. Tables 1.1 and 1.2 show the schedules for the foundations and structural steel. The total cost for the piles, including pre-drilling and driving, is $905,565. The concrete foundation's cost is $214,435, which totals to **$1,119,999** for the entire foundation system. Table 1.3 shows the costs for the piles and each of the concrete foundation structures.

Table 1.1 – Foundation Schedule

| Foundations | 123 days | Wed 11/21/07 | Fri 5/9/08 |
|---|---|---|---|
| Pre-drill Piles | 47 days | Wed 11/21/07 | Thu 1/24/08 |
| Install H-Piles | 36 days | Tue 12/18/07 | Tue 2/5/08 |
| Concrete Pile Caps | 60 days | Tue 1/8/08 | Mon 3/31/08 |
| Concrete Grade Beams and Piers | 64 days | Tue 1/29/08 | Fri 4/11/08 |
| Concrete Foundation Walls | 30 days | Wed 3/12/08 | Tue 4/22/08 |
| Grout Base Plates | 11 days | Fri 4/25/08 | Fri 5/9/08 |

Table 1.2 – Partial Steel Schedule

| | | | |
|---|---|---|---|
| Structural/Misc. Steel | 137 days | Mon 4/7/08 | Tue 10/14/08 |
| Erect Structural Steel | 26 days | Mon 4/7/08 | Mon 5/12/08 |
| Detailing and Decking | 56 days | Fri 4/11/08 | Fri 6/27/08 |
| Stair ST-1/ST-2 | 14 days | Wed 5/7/08 | Mon 5/26/08 |

Table 1.3 – Driven Pile Estimate

| Driven Pile Estimate | |
|---|---|
| Item | Cost |
| Pre-Drilling | $285,000 |
| Steel H-Piles | $620,565 |
| F/R/P Pile Caps | $39,039.56 |
| F/R/P Grade Beams and Piers | $75,354.92 |
| F/R/P Foundation Walls | $18,583.76 |
| Concrete - 3000 psi | $81,456 |
| **Total Cost** | **$1,119,999** |

**Drilled Caissons**

Drilled Caissons are installed by augering a large hole with a diameter ranging between 30 and 72 inches and backfilling the holes with concrete. The geotechnical engineer stated that if drilled caissons were used for the Bridgeside II project the minimum required diameter would be 30 inches and the allowable end bearing capacity would be 15 kips per square foot. In addition the contractor would be required to install a temporary casing to support the walls and control groundwater inflows. Casings are not always required if the soils have a large enough cohesion force such as most clays. However, the soil on site is variable and requires the use of a temporary casing. Drilled Caissons are also required to reach bedrock resulting in 45 to 55 foot depths.

The following are the advantages and disadvantages of a Drilled Caisson foundation system.

Advantages:

- Large diameters can be used which results in fewer piles
- Can be installed in long lengths
- Minimal noise and vibration levels
- No risk of ground heave

Disadvantages:

- Obstructions can damage the auger
- Risk of groundwater infill
- Large amount of soil displacement
- The bottoms must be cleaned out before concrete is poured
- The concrete must cure before supporting any loads

Based on knowledge of the site and the geotechnical report, it is guaranteed that obstructions, groundwater, and contaminated soils will be an issue for installing Drilled Caissons. Since the caissons will be bigger than the driven piles the auger will face a larger amount of obstructions. This may result in the auger getting stuck or damaged on the concrete and steel debris. The site is adjacent to the Monongahela River which adds the risk of increased groundwater levels. Initial test borings showed that groundwater depths range from 24 to 45 feet. This may result in the water needing to be pumped if the casings are infiltrated before concrete can be poured. Boring reports also revealed the existence of contaminated soils ranging from 24 to 40 feet deep. Since the Drilled Caissons will displace the contaminated soils appropriate measures will need to be taken to store and remove the soil from the site. Based on this information and recommendations from the geotechnical engineer Drilled Caissons will not be investigated any further due to the amount of potential schedule delays.

**Mat Slab Foundation**

A mat slab foundation is a continuous concrete slab that covers the entire building area. The slabs are typically several feet thick and are heavily reinforced. Mat slabs can carry heavy loads because the loads are distributed over the entire slab; however, they are very dependent on the soil conditions beneath it. The soil beneath the slab needs to be consistent and have a bearing capacity strong enough to support the building loads. If the soil is not consistent then differential settlement could occur. The geotechnical engineer recommends that a two foot undercut be dug from the Bridgeside II site and replaced with a compacted engineered fill. This will provide a level and consistent surface for the mat slab to be placed on. If necessary, piles can be installed to support weaker areas within the slab. Mat Slabs are simple to construct and can result in schedule reductions and cost savings but attention must be given to trade coordination. Once the slab is being poured, no other trades can be working within the building footprint. In addition the MEP trades need to coordinate with the Mat Slab contractor to allow for any underground utilities that need to be installed prior to the concrete pour.

The following are the advantages and disadvantages of a Mat Slab foundation.

Advantages:

- Relatively inexpensive
- Simple to construct
- Distributes heavy loads over the entire slab
- Very stable and durable if the soil conditions are sufficient

Disadvantages:

- Differential settlement can occur
- Must be done correctly the first time
- Substantial excavation is necessary
- Tying the rebar is time consuming
- Limits underground utility access

Structural Analysis

- Slab Area: 32,038 SF
- Live Loads: 24,956 kips
- Dead Loads: 56,556 kips
- Critical Column Load(Pu): 805 kips
- Slab Thickness:
    - Punching shear controls the thickness : $4d^2+2d(b+c) = Pu/vc$
        - b and c are the base plate dimensions for the column
        - vc = 0.75(4)sqrt(3000)/1000 = 0.164 kips
        - d = 25.71"   use 30" for slab thickness
- Reinforcing: #6's @ 12" o.c. – 3 layers each way
- Allowable bearing pressure = 1,500 psf
- Actual bearing pressure = 2,168 psf
    - Soil bearing pressure is unacceptable for the building loads
        - 2 foot undercut is required per the geotechnical engineer

*See Appendix E for the complete calculations*

Cost and Schedule Comparison

The Mat Slab Foundation will take approximately 112 days to complete. The majority of the time will be spent tying the rebar cage. Most likely, additional crews would be utilized to expedite the work. Compared to the original foundation schedule the mat slab can be constructed in 11 fewer days. However, the steel erection cannot begin until the concrete slab has cured. In the original foundation schedule the steel erection was able to start before all the foundations were constructed. In the Mat Slab schedule the steel erection cannot begin until 4/24/08, which is 14 days slower than the Driven Pile schedule. Additional schedule delays are possible if the excavation crew encounters many obstructions when excavating the slab area. Table 1.4 shows the schedule for the Mat Slab construction.

The Mat Slab will cost approximately $704,252, which is a substantial cost savings of $415,747 compared to the original foundation costs. Additional costs are likely to be incurred during excavation and to remove contaminated soils. In addition, the 14 day schedule delay will reduce the rent income by $274,000, which will reduce the cost savings to $141,747. Table 1.5 shows the cost breakdown for the Mat Slab construction.

Table 1.4 – Mat Slab Schedule

| Mat Slab Foundation | 112 days | Wed 11/21/07 | Thu 4/24/08 |
|---|---|---|---|
| Slab Excavation | 10 days | Wed 11/21/07 | Tue 12/4/07 |
| Undercut Fill | 3 days | Wed 12/5/07 | Fri 12/7/07 |
| Tie Reinforcing | 63 days | Mon 12/10/07 | Wed 3/5/08 |
| Pour Mat Slab | 8 days | Thu 3/6/08 | Mon 3/17/08 |
| F/R/P Piers | 2 days | Tue 3/18/08 | Wed 3/19/08 |
| Slab Curing | 28 days | Tue 3/18/08 | Thu 4/24/08 |

Table 1.5 – Mat Slab Estimate

| Mat Slab Estimate | | | | |
|---|---|---|---|---|
| Item | Quantity | Unit | Cost/Unit | Total Cost |
| Excavation | 9493 | CY | $1.59 | $15,093.87 |
| Fill | 2373 | CY | $3.96 | $9,397.08 |
| Hauling | 9493 | CY | $4.16 | $39,490.88 |
| Reinforcing | 145 | Tons | $1,800 | $261,000.00 |
| Concrete Placing | 3115 | CY | $8.90 | $27,723.50 |
| Concrete - 3000 psi | 3140 | CY | $110.00 | $345,400.00 |
| F/R/P Concrete Piers | - | - | - | $6,146.44 |
| | | | **Total** | **$704,252** |

**Micro Piles**

Micro Piles are small diameter, high capacity piles that are drilled into the ground. The piles are constructed with a structural steel casing and filled with a high strength cement grout. The type of drill used is a rotary drill with carbide teeth. Since micro piles are smaller in diameter they can be advanced through the ground at a higher speed and can break through materials with greater ease than a caisson casing or a driven pile. Based on conversations with Penn State professor, Walter Schneider, it was determined that at 10" diameter pile with a 250 kip capacity would be sufficient to support the building loads for Bridgeside II. Micro Piles are supported by skin friction in soil and rock. On the Bridgeside II site the piles will need to be drilled 45 to 55 feet into bedrock.

The following are the advantages and disadvantages of a Micro Pile foundation.

Advantages:

- Appropriate for any type of ground condition
- Can penetrate most obstacles
- Low noise and vibration
- Can be installed in low headroom situations
- Design loads can range from 3 to 500 tons

Disadvantages:

- If there are no obstacles they are more time consuming than a driven pile
- Expensive
- Ground water infill can be an issue

Cost and Schedule Comparison

The original schedule was delayed due to the unforeseen amount of pre-drilling. Two crews were used on site to help expedite the schedule. One crew would pre-drill the piles while the other crew would drive them. Micro Piles do not require pre-drilling and both crews can be used for drilling. This results in a 6 pile per day production rate and a schedule reduction of 24 days. The Micro Piles will be drilled in the same locations as the Driven Piles; therefore, the concrete foundation structures will keep the original design. The structural steel is still able to overlap the foundation construction, which results in the entire schedule being reduced by **24 days**. Table 1.6 shows the schedule for the Micro Pile foundations.

Micro Piles cost about $120 per linear foot, which is more expensive than the original H-piles. Changing the foundation system to Micro Piles will cost an additional $120,435. However, the Micro Piles also reduce the schedule by 24 days and allows the building to be rented sooner. The additional 24 days of rent time will increase the owner’s income by approximately $387,000. Taking this into consideration, the use of Micro Piles will result in a cost savings of **$266,565**. A breakdown of the Micro Pile foundation costs can be seen in table 1.7.

Table 1.6 – Micro Pile Schedule

| Micro Pile Foundation | 99 days | Wed 11/21/07 | Mon 4/7/08 |
|---|---|---|---|
| Install Micropiles | 29 days | Wed 11/21/07 | Mon 12/31/07 |
| Concrete Pile Caps | 60 days | Fri 12/7/07 | Thu 2/28/08 |
| Concrete Grade Beams and Piers | 54 days | Fri 12/28/07 | Wed 3/12/08 |
| Concrete Foundation Walls | 30 days | Mon 2/11/08 | Fri 3/21/08 |
| Grout Base Plates | 11 days | Mon 3/24/08 | Mon 4/7/08 |

Table 1.7 – Micro Pile Estimate

| Micro Pile Estimate | |
|---|---|
| **Item** | **Cost** |
| Micro Piles | $1,026,000 |
| F/R/P Pile Caps | $39,039.56 |
| F/R/P Grade Beams and Piers | $75,354.92 |
| F/R/P Foundation Walls | $18,583.76 |
| Concrete - 3000 psi | $81,456 |
| **Total cost** | **$1,240,434** |

**Conclusions and Recommendations**

After analyzing three different foundation systems it was determined that the Micro Pile foundation system will provide the greatest cost savings and schedule reduction. Since Bridgeside II is being leased upon completion it is important to complete the building as quickly as possible. This enables the owner to begin collecting rent from the building occupants. It is also important because they can start their next project in the Pittsburgh Technology Center at an earlier date. A Micro Pile system is also the most feasible because it faces the least resistance to obstructions and will not displace any soil that may be contaminated.

In conclusion I recommend the use of a Micro Pile foundation system over a driven H-pile system because based on my analysis it will result in a schedule reduction of 24 days and a cost savings of $266,565.

## ANALYSIS 2: Photovoltaic Glass Replacement

**Problem Identification**

Bridgeside II is designed to accommodate 80 percent lab space and 20 percent office space. Laboratory equipment can consume a considerable amount of energy compared to a typical office building and this will increase the life cycle costs of the building. The goal of the Ferchill Group is to lease the building as quickly as possible and energy saving features could a be strong selling point. Photovoltaic glass panels can provide significant energy savings if installed on a south facing façade that has unobstructed solar views. The U.S. Department of Energy selected Pittsburgh, PA as one of the thirteen inaugural Solar America Cities. Installing photovoltaic glass panels on Bridgeside II would also help support the solar power movement in Pittsburgh.

**Proposal**

Photovoltaic glass modules have the potential to reduce the energy costs for Bridgeside II as long as the payback period is reasonable. For this analysis I plan on investigating the initial costs of the system as well as the payback period. I will also perform an energy analysis to determine if using photovoltaic glass in Pittsburgh will supply Bridgeside II with enough energy to result in a beneficial investment.

**Goal**

The goal of this analysis is to research photovoltaic glass modules and determine the amount of energy savings if they were to be implemented in the Bridgeside II facade. The calculation of the payback period and the energy production by the panels will determine whether or not the system is feasible. Ideally the panels will provide enough energy to offset the initial costs and to provide the owner and tenants with a cost savings. Another goal of implementing photovoltaic panels is to make the building more appealing to potential tenants.

**Methodology**

1) Research photovoltaic panels and the opportunities for solar energy in Pittsburgh, PA.
2) Investigate the design of the panels and determine where they would be appropriate on the Bridgeside II façade.
3) Determine the initial costs of adding photovoltaic panels.
4) Determine the schedule impacts of the panels.
5) Calculate the energy savings and the payback period of the panels.

**Solar Benefits**

The demand for solar power increases each year especially with the growing popularity of LEED certified buildings. Home owners are also demanding solar panels to help offset some of their rising energy costs. Prices for solar panels have drastically reduced over the past 20 years, making them more affordable to home owners and commercial developers. The sun emits enough energy to power human kind for an entire year in 1/816,000$^{th}$ of a second. Solar panels harness this energy and reduce the need for fossil fuels, which is good for the environment and helps lower energy costs. One photovoltaic module also has the potential to offset 7.5 tons of $CO_2$ emissions over its 25 year life span.

Solar energy continues to prove that it can reduce energy costs for commercial buildings and residential homes; however, the initial costs cannot be afforded by everyone, especially in areas where the payback period is longer. Cities are starting to realize the potential of solar energy and are aiding solar energy investors with tax credits, federal grants, and rebates. The U.S. Department of Energy is also encouraging cities to adopt solar power by providing grant money. Pittsburgh, PA was named one of the thirteen inaugural Solar America Cities. The title comes with $200,000 in grant money and an additional $250,000 in technical assistance from the Department of Energy. Pittsburgh will be using the money to provide solar power to the city infrastructure. The first project is to install a solar hot water system at one of the firehouses. This is especially beneficial to Pittsburgh because in the next few years the electricity rate caps will be removed from the majority of Pennsylvania's power companies resulting in increased rates.

**Photovoltaic Modules**

Photovoltaic modules are constructed with many cells that consist of two or more layers of silicon and create electrical charges when exposed to sunlight. The silicon forms a positive and negative layer that absorbs the energy packets from the sun and release electrons. The electrons then flow along the metal contacts as direct current. An inverter is required to convert the direct current into alternating current, which is required for most building applications. Figure 2.1 illustrates the process of collecting electrons that are absorbed by the silicon.

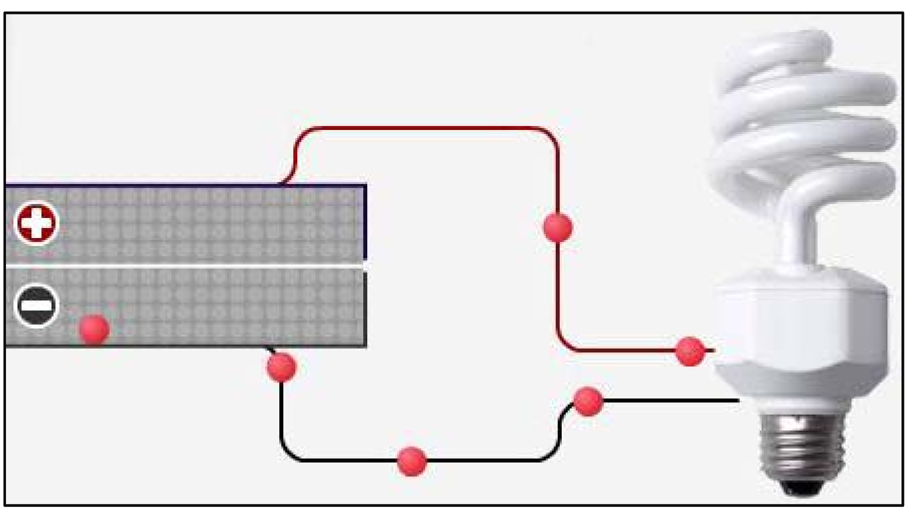


Figure 2.1 – Electron Flow Diagram

The photovoltaic cells are grouped together and housed in a module that has the ability to create useable amounts of energy. There are two types of PV cells; Monocrystalline cells and Polycrystalline cells. Monocrystalline cells are cut from a single cylindrical crystal of silicon and are capable of converting up to 18 percent of the incident sunlight into energy. Polycrystalline cells are cut from recrystallized silicon and are cheaper to manufacturer but they also have a lower efficiency rate of 14 percent. The two types of photovoltaic cells can be seen in figure 2.2. In addition to material, they also differ in color, shape, and size.

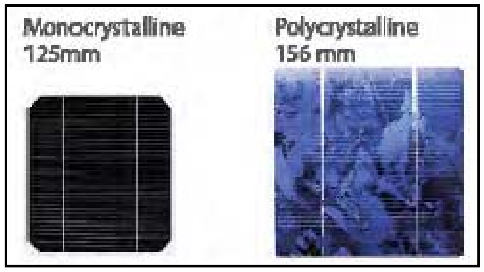



Figure 2.2 – Photovoltaic Cells

For buildings that utilize photovoltaic modules, there are two options for managing electricity use. The first option is to connect to the local power grid. The method will use all of the electricity generated by the modules and any excess electricity is sold back to the power company for the price that it costs them to produce it. The other option is to use an off grid PV system. Off grid systems are typically utilized for small and mobile applications. It is also used in developing countries where a power grid is unavailable. Figure 2.3 shows the typical components of a grid connected photovoltaic system.

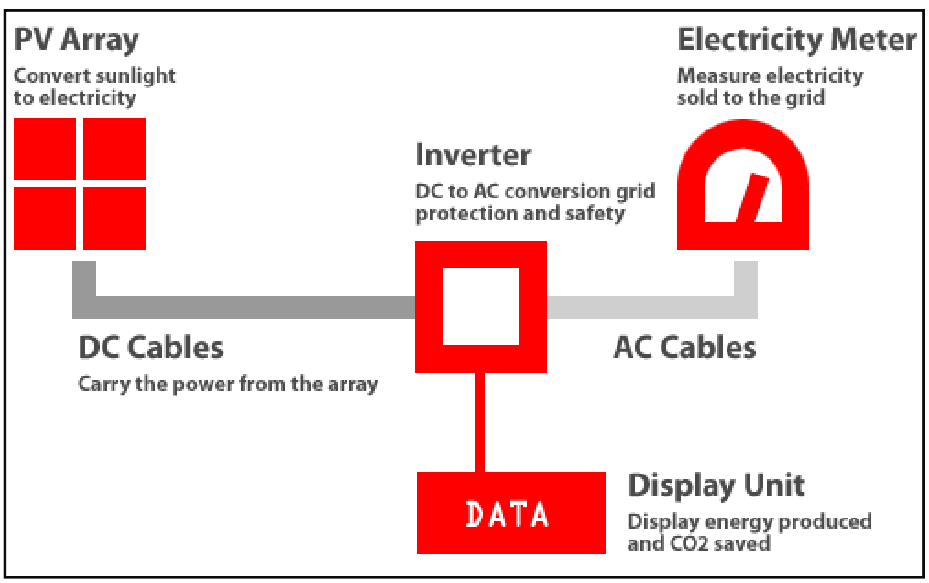



Figure 2.3 – Typical Photovoltaic Components

**Suntech Photovoltaic Modules**

Building Integrated Photovoltaic systems provide a more aesthetically pleasing design than standard photovoltaic modules. BIPV modules are built into the building's skin rather than serving as an add-on component. They are installed like a typical building material with the added benefit of generating electricity. This reduces unnecessary costs for materials that are covered by the panels. In addition the glass BIPV modules create shading, which reduces the amount of heat entering the building and reduces the energy required to cool the space.

Additional BIPV module benefits include:

- Higher resale value of the building
- Reduction of interior damage by UV rays
- Thermal and acoustic protection
- Educational value

Suntech Power manufacturers several BIPV modules that can be implemented on vertical facades. Each of the BIPV modules allows light to pass between the cells and the See Thru module can be seen through similar to a tinted pane of glass. For the Bridgeside II project I am proposing to implement the Suntech Light Thru panels on the south and west facades. The two proposed facades face southwest and southeast respectively and are adjacent to the Monongahela River allowing for unobstructed solar views. The Light Thru modules cannot be seen through but they will provide light into the building and have a lower cost per watt than the See Thru modules. They also can be ordered in custom sizes, unlike the See Thru modules, and will generate 10 watts per square foot when the cells are spaced at the minimum of 4 mm. The cells are sandwiched between two sheets of tempered clear glass and can be spaced according to preference. More space between the cells will allow more light to pass through but it will reduce the output of the modules. Figures 2.4 and 2.5 are images of the Suntech Light Thru modules.

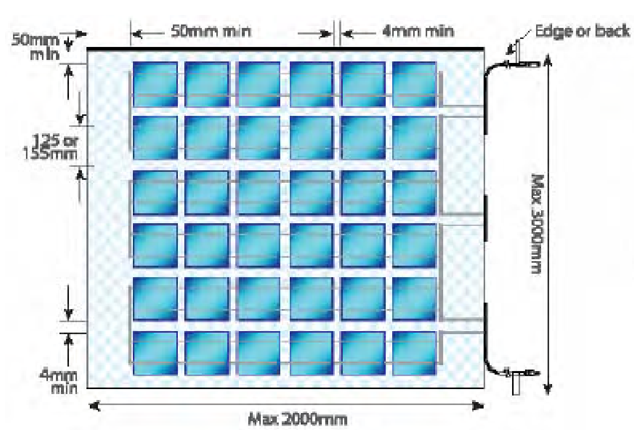



Figure 2.4 – Light Thru module Diagram

Figure 2.5 – Light Thru modules

**Design and Constructability Considerations**

The window walls on the south and west elevations are a selling point for Bridgeside II because they provide excellent views of the Monongahela River and the Pittsburgh skyline. It is important to consider these views when proposing BIPV modules. In the original design the top 4 feet of each window is non-vision spandrel glass. The spandrel glass allows the façade to be a continuous window wall and it prevents views of the elevated slab edges. The Suntech Light Thru panels will still prevent views of the slab edges and will allow up to 10 percent light transmittance. The Light Thru panels will accomplish all the goals of the spandrel panels and they will blend in with the modern, industrial design of the building. Figures 2.6 and 2.7 are sketches to compare the original and proposed designs.

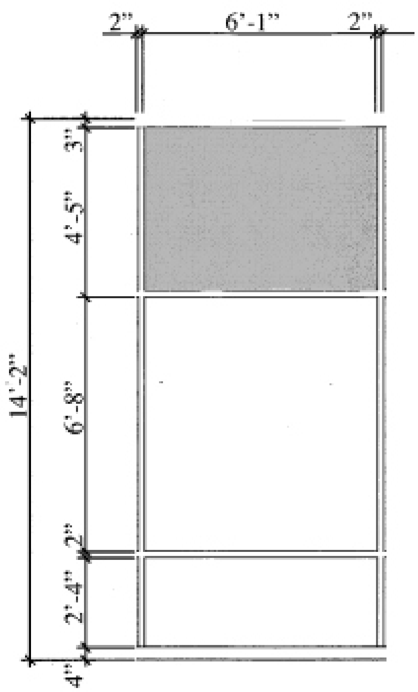



Figure 2.6 – Original Window Design

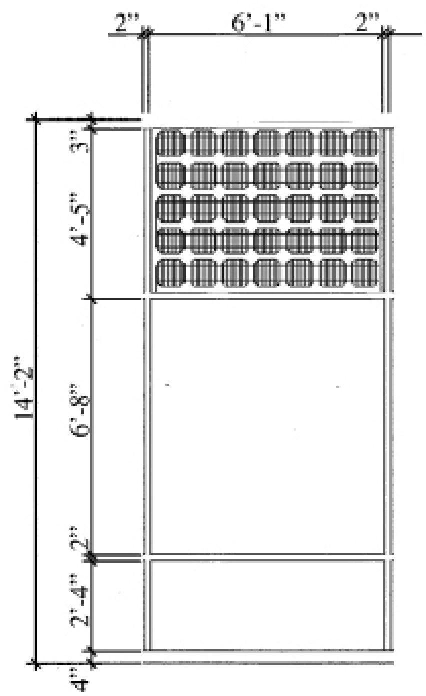



Figure 2.7 – Proposed Window Design

The Light Thru module is unique to the other Suntech modules because it can be manufactured in any size up to 9.5'x6.5'. It also varies in thickness from 3.2mm to 12mm (.12in to .5in). This is important because the Light Thru modules can be manufactured with the same dimensions as the spandrel panels and the aluminum frames will be able to accommodate the PV modules without a redesign of the window wall. As long as the lead times for the glass and PV modules are coordinated there will not be an issue with the installation. Each of the Light Thru modules is manufactured with plug and play connectors that allow for simple and efficient installations. Inverters are required to convert the direct current generated by the modules into alternating current that can be use by the building. The inverter I am proposing to use is the GT 5.0 Grid Tie Solar Inverter manufactured by Xantrex. The GT 5.0 inverter has a maximum AC power output of 5000 watts. Tables 2.1 and 2.2 show the technical specifications for the PV modules and inverters.

*See Appendices E and F for additional product data for the PV modules and inverters*

**Design Calculations**

Table 2.1 – Light Thru Module Specs

Light Thru Modules:

- Number of Modules: 168 modules
- Total Area: 3697 SF

| Light Thru Modules | |
|---|---|
| **Technical Specifications** | |
| Maximum Power ($P_{max}$) | 290 W |
| Optimum Operating Voltage ($V_{mp}$) | 66.3 V |
| Optimum Operating Current ($I_{mp}$) | 4.37 A |
| Open Circuit Voltage ($V_{oc}$) | 80 V |
| Short Circuit Current ($I_{sc}$) | 4.8 A |

Based on the specifications of the modules and the inverters, each inverter will be able to support three strings of modules. Each string consists of five modules that are connected in series. The goal when sizing the strings is to be near the middle of the inverter voltage range. Temperature will change the voltage generated by the modules and it is important that the voltage variations stay within the inverters operating range. When determining how many strings the inverter can support the total power input must be considered.

Table 2.2 – Inverter Specs

Xantrex Inverter:

- Number of modules per string:
  - 550 $V_{dc}$ / 80 V = 6.8 modules
  - 240 $V_{dc}$ / 80 V = 3 modules
  - **Use 5 modules per string**
- Number of strings per inverter:
  - 5000 W / (290 W x 5 modules) = 3.44 strings
  - **Use 3 strings per inverter**
  - **Total of 15 modules per inverter**
- Number of Inverters
  - 168 modules / 15 modules per string = 11.2 inverters
  - **Use 12 inverters**

| GT 5.0 Xantrex Inverter | |
|---|---|
| **Technical Specifications** | |
| AC Output Voltage(V) | 240 V |
| Max AC Power Output (W) | 5000 W |
| Max Array Open Circuit Voltage ($V_{dc}$) | 600 $V_{dc}$ |
| MPPT Voltage Range ($V_{dc}$) | 240-550 $V_{dc}$ |
| Max Input Current ($A_{dc}$) | 22 $A_{dc}$ |
| Inverter Efficiency | 95.90% |
| Dimensions | 28.6x16x5.75" |

Electrical Panel Loading:

Another aspect of the design that had to be considered is the effect of the inverters on the electrical panels. I am proposing to tie the inverters into an extra panel located in the first floor electrical closet. The reasoning for this is that electrical room 102 is the closest to the PV modules resulting in shorter wiring spans. Also room 102 has enough room to mount the 12 inverters. Panelboard SEM1 has a voltage of 480/277V and a 400 Amp rating. The maximum panel loading is 192 kW and since the panel is empty it has enough room to hold all the inverters, which have a total load of 60 kW. This risk in this decision is that an additional panel may be needed in the future once the building is completely leased. Each inverter will also require a circuit breaker with a 20 Amp capacity.

- Maximum Panel Loading = (1.732)(277V)(400A) = 192 kW
- Total Inverter Load = 12 inverters x 5000W = 60 kW
  - **60 kW < 192 kW - Acceptable**
- Circuit Breaker Size = 5000W / 277V = 18.05
  - **Use 20A circuit breakers**

**Cost and Schedule Comparison**

The total cost of the Light Thru modules and the inverters, is $306,190. This is a $228,553 increase in cost compared to the original spandrel glass design. An energy analysis will determine how long it will take for the cost savings from the energy production to offset the initial costs of the system. Table 2.3 shows the cost break down of the PV system.

The spandrel glass is constructed with 4 lites in each panel. A typical glass lite takes approximately 15 to 20 minutes to install. The Light Thru modules are constructed as a single unit but they will take longer to install into the aluminum frames. Each module has to be drilled into the frame and connected to the rest of the modules in the string. The time saved by installing only one lite compared to four is about 15 days. This time will be applied to the longer durations of the PV modules and the time it will take to mount and install the inverters. The proposed system should be installed in a similar duration to the original spandrel glass.

Table 2.3 – Proposed PV system costs

| Photovoltaic System Costs | | | |
|---|---|---|---|
| **Item** | **Quantity** | **Unit Cost** | **Total Cost** |
| Spandrel Glass | 3697 SF | $21/SF | ($77,637) |
| Light Thru Modules | 3697 SF | $70/SF | $258,790 |
| Inverters | 12 | $3,950 | $47,400 |
| | | **Total** | **$228,553** |

**Energy Analysis**

In order to perform an energy analysis and calculate a payback period I used a program by the National Renewable Energy Laboratory called PVWatts calculator version 2. PVWatts can determine the energy production and cost savings of grid connected PV systems anywhere in the world. The program works by using historical hourly solar data to create monthly and annual energy estimates for a photovoltaic system. Weather patterns vary every year and as a result PVWatts typically will not be accurate for performing short term estimates compared to long term periods which are accurate to within 10 percent. The input parameters can be modified to accurately represent the size of any system including the panel production, panel orientation, and DC to AC derate factor. The derate factor takes into consideration the inverter efficiency, shading, and panel conditions.

The first step when using PVWatts 2 is to select the location for my building on the solar atlas. Figure 2.8 shows the map and the location of Bridgeside II, which is marked with an X. The solar atlas can render highways and geographical features that allowed me to find the exact location of my building. PVWatts will then use the solar data for that location in the energy estimate.

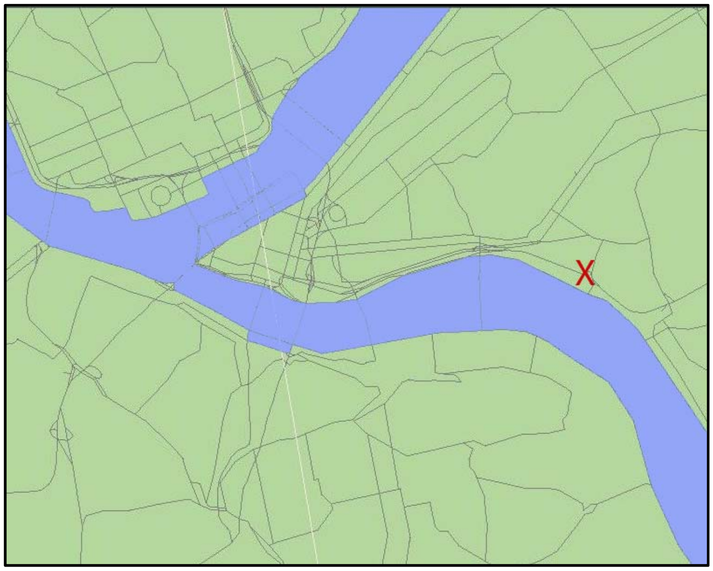


Figure 2.8 – Solar Atlas – Pittsburgh, PA

The next step was to determine the analysis parameters which required a few calculations. I ran two analyzes to provide a more accurate energy estimate of the two proposed facades. One façade faces southwest and the other is southeast; therefore, the azimuth angles had to be adjusted accordingly. Since the modules are being installed on the façade, the tilt angle was set to 90 degrees. Also an electricity rate of 8.19 cents per kWh was entered to determine the cost savings.

- DC Rating
  - Southwest Façade: 2713 SF x 10 W/SF = 27.13 kW
  - Southeast Façade: 984 SF x 10 W/SF = 9.83 kW
- DC to AC Derate Factor: 0.802

**Calculator for Overall DC to AC Derate Factor**

| Component Derate Factors | Component Derate Values | Range of Acceptable Values |
|---|---|---|
| PV module nameplate DC rating | 0.95 | 0.80 - 1.05 |
| Inverter and Transformer | 0.959 | 0.88 - 0.96 |
| Mismatch | 0.98 | 0.97 - 0.995 |
| Diodes and connections | 0.995 | 0.99 - 0.997 |
| DC wiring | 0.98 | 0.97 - 0.99 |
| AC wiring | 0.99 | 0.98 - 0.993 |
| Soiling | 0.95 | 0.30 - 0.995 |
| System availability | 0.98 | 0.00 - 0.995 |
| Shading | 1.00 | 0.00 - 1.00 |
| Sun-tracking | 1.00 | 0.95 - 1.00 |
| Age | 1.00 | 0.70 - 1.00 |
| Overall DC to AC derate factor | **0.802** | |

Figure 2.9 – Derate Factors

Once all the inputs are provided and the analysis is performed, PVWatts outputs the daily solar radiation values, the AC energy production values, and the cost savings that the energy will provide. Figures 2.10 and 2.11 show the output charts for the analysis on each façade.

| Station Identification | |
|---|---|
| Cell ID: | 0257372 |
| State: | Pennsylvania |
| Latitude: | 40.3 ° N |
| Longitude: | 79.8 ° W |
| **PV System Specifications** | |
| DC Rating: | 27.1 kW |
| DC to AC Derate Factor: | 0.800 |
| AC Rating: | 21.7 kW |
| Array Type: | Fixed Tilt |
| Array Tilt: | 90.0 ° |
| Array Azimuth: | 225.0 ° |
| **Energy Specifications** | |
| Cost of Electricity: | 8.2 ¢/kWh |

| Results | | | |
|---|---|---|---|
| Month | Solar Radiation (kWh/m²/day) | AC Energy (kWh) | Energy Value ($) |
| 1 | 1.67 | 1055 | 86.40 |
| 2 | 2.07 | 1198 | 98.12 |
| 3 | 2.71 | 1658 | 135.79 |
| 4 | 2.86 | 1680 | 137.59 |
| 5 | 2.76 | 1606 | 131.53 |
| 6 | 2.80 | 1504 | 123.18 |
| 7 | 2.66 | 1476 | 120.88 |
| 8 | 2.96 | 1696 | 138.90 |
| 9 | 2.92 | 1627 | 133.25 |
| 10 | 2.62 | 1559 | 127.68 |
| 11 | 1.78 | 1026 | 84.03 |
| 12 | 1.58 | 922 | 75.51 |
| Year | 2.45 | 17006 | 1392.79 |

Figure 2.10 – Southwest Façade Results

| Station Identification | |
|---|---|
| Cell ID: | 0257372 |
| State: | Pennsylvania |
| Latitude: | 40.3 ° N |
| Longitude: | 79.8 ° W |
| **PV System Specifications** | |
| DC Rating: | 9.84 kW |
| DC to AC Derate Factor: | 0.800 |
| AC Rating: | 7.87 kW |
| Array Type: | Fixed Tilt |
| Array Tilt: | 90.0 ° |
| Array Azimuth: | 135.0 ° |
| **Energy Specifications** | |
| Cost of Electricity: | 8.2 ¢/kWh |

| Results | | | |
|---|---|---|---|
| Month | Solar Radiation (kWh/m²/day) | AC Energy (kWh) | Energy Value ($) |
| 1 | 1.74 | 406 | 33.25 |
| 2 | 2.20 | 467 | 38.25 |
| 3 | 2.85 | 647 | 52.99 |
| 4 | 2.82 | 604 | 49.47 |
| 5 | 2.85 | 606 | 49.63 |
| 6 | 2.80 | 551 | 45.13 |
| 7 | 2.94 | 606 | 49.63 |
| 8 | 2.82 | 586 | 47.99 |
| 9 | 3.01 | 620 | 50.78 |
| 10 | 2.63 | 577 | 47.26 |
| 11 | 1.82 | 383 | 31.37 |
| 12 | 1.63 | 351 | 28.75 |
| Year | 2.51 | 6403 | 524.41 |

Figure 2.11 – Southeast Façade Results

The two facades will produce a total of 23.4 kWh of AC energy per year, which will provide a cost savings of $1917.2 each year.

- Payback period
  - o $228,553 / $1917.2 = **119.2 years**
- Payback period after 30% tax incentive
  - o $159,987 / $1917.2 = **83.5 years**

Even after the potential 30 percent tax break for applying solar energy the payback period for the Light Thru PV system is 83 years. The typical life of the modules is 25 years which means they would never pay back the initial costs of the system. In order for the payback period to be reasonable the modules would have to generate at least 70 watts per square foot compared to 10 watts per square foot. This would result in a 20 year payback period, which is still slightly long but in the lifetime of the modules.

**Conclusions and Recommendations**

After analyzing the energy output for the Light Thru modules it was determined that the payback period would be 83 years, which is not acceptable. The payback period would need to fall within the life of the panels so that the initial investment is offset and the owner begins to benefit from the cost savings. Other options include using more efficient modules and increasing the number of modules used. However, this will increase the price of the PV system and it still may not pay off for the owner. Also adding more modules onto the Bridgeside II façade would reduce the light into the building and block the views of the river and Pittsburgh skyline. A PV system is not a valuable investment for Bridgeside II but they are still beneficial. Utilizing solar energy reduces building's carbon output and it reduces the dependence on power companies. Pittsburgh is striving to become a solar city and each investment in solar energy is valuable to the city. In conclusion I do not recommend the use of Suntech Light Thru modules for Bridgeside II, however, solar technology is advancing and I believe there will be a time when PV modules will be more efficient and affordable for cities such as Pittsburgh.

## ANALYSIS 3: Interior Fit-Out BIM Implementation

**Problem Identification**

When building a speculative office building, owner's are burdened with finding a tenant to lease the space. This can be a stressful situation especially when the speculative office market is on a decline. One reason that leasing a space can be difficult is most potential tenants cannot visualize the space and prefer to wait to sign a contract until the shell building is complete. Bridgeside II is designed to meet the demand for laboratory space and will accommodate 80 percent laboratory space and 20 percent office space. It is also designed with an open floor plan to accommodate a variety of layouts. Once a tenant is identified, it is their responsibility to determine their space layout. Building Information Modeling can be beneficial during the design phase due to its ability to organize information. It also provides a stronger visualization of the building. BIM was not utilized during the core and shell phase or the interior design phase of the Bridgeside II project.

**Proposal**

For this analysis I will propose to utilize BIM for the interior design phase of Bridgeside II. Owners are sometimes hesitant to utilize BIM because they are unfamiliar with it and do not know how to apply it to their project. For this analysis I will determine how much detail should be incorporated into the model, who will be responsible for the details, and what some of the specifications should be for how BIM will be applied. This will be accomplished through research, case studies, and interviews with industry members who are familiar with BIM.

**Goal**

The goal of this analysis is to determine a standard of detail to be used for interior fit-out models and to determine how BIM should be applied to the Bridgeside II project. This analysis will define responsibilities and what the owner should expect by utilizing BIM. The goal when determining the model requirements is to use enough detail so the designers and potential tenants can design a space and allow the tenants to see what they would be paying for. This would be beneficial to the project because multiple layouts can be designed more efficiently and tenants will hopefully agree on a lease before the shell building is complete, which would speed up the fit-out process.

**Methodology**

1) Determine a set of questions to base the analysis on.
2) Answer the questions through research and interviews with industry members.
3) Determine the benefits of using BIM on the Bridgeside II project and what the specifications should be.
4) Analyze the model benefits for potential clients.
5) Develop a set of criteria for the amount of detail incorporated into the interior models.

**Analysis Questions**

1) In what ways is BIM beneficial for interior fit-outs?
2) How will potential tenants utilize a BIM model when designing their space?
3) What are the cost and schedule implications of implementing BIM?
4) What deters owners from implementing BIM on their projects?
5) What are the model requirements for interior design?

**BIM and Interior Design**

It has already been proven that BIM is a valuable resource for construction projects. It provides 3D and 4D visualizations, detects clashes, manages changes, and acts as a database for all the project information. For obvious reasons, the BIM benefits that are typically focused on pertain to the structural, building enclosure, and MEP phases. These phases drive the schedule of a building project. BIM also provides a number of benefits for the interior fit-out phases especially for core and shell projects where a tenant has not been arranged and the interior layout is not designed. Some of the benefits and uses are listed below.

- The speed and ease of creating an interior model.
- The ability to visualize the design, which is important to potential tenants.
- The ability to create multiple interior designs on one building model, which will accommodate multiple tenants or multiple ideas.
- Organizing material information, cost data, schedules, and material quantities.

One of the difficulties with core and shell projects is the change in teams for the fit-out phase. Core and shell projects typically have a different design team for the interior phases and this can be difficult because they are unfamiliar with the project. The new team will be given the plans but they essentially have to redesign the project similar to a building renovation. If BIM is used on a core and shell project then the interior design team can start with an accurate model, which will save time.

One of the benefits of BIM that will be useful for the Bridgeside II project is the service it will provide for the potential tenants. Interior models allow tenants to plan their space before the building is complete. Tenants can design open floor plans, closed office space, material selections, and furniture locations efficiently. The model can also be rendered to give the tenant a clear visualization of their material and lighting selections. The visualization aspect of BIM is important because it allows designers to try different materials and evaluate their designs. It is easy to picture a brick building verses a metal panel façade but interior spaces are more difficult. Figure 3.1 is an example of an interior rendering developed by Autodesk. Non-graphical information, such as material properties, lead times, and cost data, is also important to owners and tenants. BIM models easily organize this information for each interior design and can perform material takeoffs. This is important because tenants typically have a budget and the material takeoffs can be used to perform quick estimates for their designs.

Figure 3.1 – Interior Rendering Example

Bridgeside II is designed to accommodate multiple layouts per floor or a tenant can lease entire floors. With all the tenant and floor plan combinations there are many potential designs. Modeling software allows you to create multiple floor plan designs within one model. This is beneficial because the different designs, costs, and schedules can be easily compared. Currently the only potential tenant for Bridgeside II is the University of Pittsburgh. They would be leasing the building to fill their need for additional laboratory space. One of the most difficult tasks for inexperienced building tenants is to visualize a building or floor plan when looking at two dimensional drawings. This often makes them hesitant to lease a space before they can see it. I believe that implementing BIM for interior fit-outs will help potential tenants visualize their space and help alleviate some of their hesitations. The University of Pittsburgh would be able to use BIM to layout their laboratory and office spaces in relation to the utilities, wet stacks, and fume hoods. They could also utilize the model to organize all the information for their equipment and appliances that will be in the labs.

**Cost and Schedule**

The use of BIM on construction projects is becoming an expected service. Architects and engineers previously charged extra and required extra time to develop the model. However, as owners started to expect BIM models the initial charges have decreased or were removed and the modeling time became part of the schedule rather than a delay. Many design professionals develop models regardless of whether it is required; therefore, their fees and schedules are not affected. Design professionals who lack the technology and training to accommodate BIM specifications may find themselves at a competitive disadvantage. The transition from core and shell teams to interior fit-out teams is improved with the use of BIM. Assuming that BIM is utilized for the entire project, the interior fit-out schedule would be reduced because the design team would have an accurate informational model to work with. The alternative would require the design team to work off of two dimensional drawings and redesign parts of the building. A BIM model provides more project information and is in a format that can be developed further, compared to a set of as-built documents.

**BIM Specifications**

One of the largest obstacles when choosing to utilize BIM on a construction project is getting all the project teams to agree on their responsibilities to each other and to the model. The ambiguity in implementing BIM causes many owners to shy away. The key to success is defining the responsibilities from the beginning of the project to prevent future conflicts. This can be difficult because BIM often requires different relationships between project participants than those they typically employ. The model requires timely and updated information, increasing the amount of communication required. Other specifications regarding the model that need to be stated include; who owns the model rights, access rights, and the model intentions. If the model is only being used during the design phase and not for construction, it should be specified because it will affect the level of detail in the model.

There are two documents that were released to assist project teams in adopting BIM. The first is a Model Progression Specification developed by Webcor Builders, VICO, and AIA California Council's Integrated Project Delivery Task Force. The second document is AIA Document E202 titled Building Information Modeling Protocol Exhibit. These two documents assist project teams to determine the purpose of the model, the level of detail, and the responsible parties.

The Bridgeside II project team had considered using BIM for pieces of the interior design but opted against it due to uncertainties about responsibilities and schedule implications. AIA E202 is an important tool for implementing BIM because it allows owners to specify some of the BIM requirements in a contractual form for the owner/architect and owner/contractor agreements. It is especially beneficial for inexperienced project teams because it identifies the important aspects of BIM such as responsibilities, level of detail, and file requirements. AIA E202 was released in 2008, after the start of the Bridgeside II project. If they had this document they may have been more willing to utilize BIM because it provides a more user friendly method to determine the scope of the model. The AIA document defines important BIM decisions and provides the owner with a space to specify their preferences. The items set up for the owner to specify within the contract language are listed below.

- Model standards
- File formats for model uses
- Responsible parties for model management
- Model archive requirements
- Model uses per level of detail
- Model Element Authors

After the owner determines who will be responsible for managing the model, the AIA document specifies the initial responsibilities required for the model and what the ongoing responsibilities will be throughout the project. This is especially important because the responsibilities of the model manager are written in a contractual language preventing future conflicts regarding responsibility for updating and managing the model. The initial and ongoing model responsibilities are shown in figures 3.2 and 3.3.

§ 2.4.2 **Initial Responsibilities.** The party responsible for managing the Model shall facilitate the establishment of protocols for the following:

- .1 Model origin, coordinate system, and units
- .2 File storage location(s)
- .3 Processes for transferring and accessing Model files
- .4 Clash detection
- .5 Access rights
- .6 Other protocols:
  *(Insert additional protocols below.)*

Figure 3.2 – Initial Model Responsibilities

§ 2.4.3 **Ongoing Responsibilities.** The party responsible for managing the Model shall have the following ongoing responsibilities:

- .1 Collect incoming Models:
  - .1 Coordinate submission and exchange of Models
  - .2 Log incoming Models
  - .3 Validate that files are complete and usable and in compliance with applicable protocols
  - .4 Maintain record copy of each file received
- .2 Aggregate Model files and make available for viewing
- .3 Perform clash detection in accordance with established protocols and issue periodic clash detection reports
- .4 Maintain Model archives and backups
- .5 Manage access rights
- .6 Follow protocols established in Section 2.4.2

Figure 3.3 – Ongoing Model Responsibilities

Another requirement that owners experienced in BIM often specify is for the general contractor or construction manager to submit an implementation plan. The implementation plan will describe how the model will be utilized from the conceptual design phase through the as-builts. Areas where the model will be used and should be described include; design, construction, coordination, scheduling, cost estimating, and documentation. This is beneficial because the owner and contractor will have to come to an agreement on how the model will be utilized.

**Model Requirements**

A BIM has many potential uses and each use requires a certain level of detail in the model. Through each phase of the project the model becomes more precise and it can be confusing to determine what it can be used for. In addition, it is possible that the author of the model did not consider all of the potential uses. If the model is misinterpreted then this will lead to inaccurate outputs. The Model Progression Specification was developed to assign specific uses to each level of detail as the model progresses. It is also beneficial to owners because they can specify what they want to use the model for and what level of detail will be required. The MPS was incorporated into the AIA BIM Protocol document to allow the levels of detail to be specified in the contract. This prevents confusion over when the model can be used and who is responsible for each level of detail.

The Model Progression Specification defines 5 levels of detail labeled 100 through 500. Each of the 5 levels has a minimum level of detail that must be incorporated into the model and specifies how the model can be used at that level. The authorized uses per level of detail include; cost estimating, 4D scheduling, program compliance, sustainable materials, and environmental. Each level in the MPS is authorized to provide more detail for each of the uses than the previous level. The AIA E202 incorporates each of the detail levels and authorized uses and it allows the owner to write in additional uses at each level. Table 3.1 shows each of the levels of detail and how detailed each of the authorized uses can be. The second part of the Model Progression Specification is used to determine responsibility. Most of the building components are listed, such as the structure and the shell, and under each level of detail the responsible party is listed. This clearly defines who is responsible for the details at each phase of the model. Table 3.2 shows the model progression responsibilities for the interior components. The responsible parties can be adjusted to meet the needs of the project and team members. The MPS is progressing BIM because it clearly defines how much detail is necessary for certain model purposes and who is responsible for the detail. This prevents conflicts and misinterpretations of the model.

Table 3.1 – MPS Levels of Detail

| Model Content | 100 | 200 | 300 | 400 | 500 |
|---|---|---|---|---|---|
| Design & Coordination~(function / form / behavior) | Non-geometric data<br><br>or line work, areas, volumes zones, etc. | Generic elements shown in three dimensions<br><br>- maximum size<br>- purpose | Specific elements Confirmed 3D Object Geometry<br><br>- dimensions<br>- capacities<br>- connections | Shop drawing/ fabrication<br><br>- purchase<br>- manufacture<br>- install<br>- specified | As-built<br><br>- actual |
| **Authorized uses** | **100** | **200** | **300** | **400** | **500** |
| 4D Scheduling | total project construction duration<br><br>phasing of major elements | Time-scaled, ordered appearance of major activities | Time-scaled, ordered appearance of detailed assemblies | fabrication and assembly detail including construction means and methods (cranes, man-lifts, shoring, etc.) | |
| Cost Estimating | Conceptual cost allowance Example $/sf of floor area, $/hospital bed, $/parking stall, etc.<br><br>assumptions on future content | Estimated cost based on measurement of generic element. E.g., generic interior wall. | Estimated cost based on measurement of specific assembly. E.g., specific wall type. | Committed purchase price of specific assembly at Buyout. | Record costs |
| Program Compliance | Gross departmental areas | Specific room requirements | FF&E, casework, utility connections | | |
| Sustainable Materials | LEED strategies | Approximate quantities of materials by LEED categories | Precise quantities of materials with percentages of recycled/locally purchased materials | Specific manufacturer selections | purchase documentation |
| Environmental: Lighting, Energy use, air movement Analysis/Simulation | Strategy and performance criteria based on volumes and areas | Conceptual design based on geometry and assumed system types | Approximate simulation based on specific building assemblies and engineered systems | Precise simulation based on specific manufacturer and detailed system components | Commissioning and recording of measured performance |

Table 3.2 – Interior Model Responsibilities

| Element (ASTM Uniformat II Classification) | | | | Level of Detail (LOD) and Model Component Author (MCA) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Conceptual-ization | | Criteria Design | | Detailed Design | | Implemen-tation Docs | |
| | | | | LOD | MCA | LOD | MCA | LOD | MCA | LOD | MCA |
| C | INTERIORS | C10 Interior Construction | C1010 Partitions | 100 | PD | 200 | PD | 300 | PD | 400 | TC |
| | | | C1020 Interior Doors | 100 | PD | 200 | PD | 300 | PD | 400 | TC |
| | | | C1030 Fittings | 100 | PD | 100 | PD | 300 | PD | 400 | TC |
| | | C20 Stairs | C2010 Stair Construction | 100 | PD | 200 | PD | 300 | TC | 400 | TC |
| | | | C2020 Stair Finishes | 100 | PD | 100 | PD | 100 | TC | 100 | TC |
| | | C30 Interior Finishes | C3010 Wall Finishes | 100 | PD | 100 | PD | 100 | PD | 100 | TC |
| | | | C3020 Floor Finishes | 100 | PD | 100 | PD | 100 | PD | 100 | TC |
| | | | C3030 Ceiling Finishes | 100 | PD | 100 | PD | 100 | PD | 100 | TC |

Model Component Authors:

- PD – Prime Designer
- DC – Design Consultants
- PC – Prime Constructor
- TC – Trade Contractors
- S – Suppliers

**BIM Implementation**

The Bridgeside II project could benefit from any of the various BIM uses, however, based on the project needs I believe the most beneficial aspect would be visualization. Throughout the duration of the project, the Ferchill Group has been working to obtain tenants for the building. As soon as a tenant is arranged then the preconstruction work can begin for the interior design and this will expedite the schedule if it can be overlapped with the shell construction. The Bridgeside II floor plans are flexible and can be designed to the tenants needs. Unless the potential tenant is experienced in interior design, they probably won't be able to visualize the space from a set of two dimensional drawings. This may make them hesitant toward leasing an unfinished space. Being able to visualize the space with the use of a model is very beneficial because it allows the design team and tenants to work together and agree on a design. It also allows the tenants to select materials and compare various layouts with one model. If some or all of the tenants were arranged during the core and shell phases then they would be able to have their design finalized and get their long lead time materials and equipment ordered before the interior fit-out phases begin. By speeding up the schedule the tenants will be able to move in sooner and the Ferchill Group will begin receiving rent payments.

In order to provide the tenants with a valuable design tool the interior model would need to have at least a level of detail of 300. A model with a level of detail of 300 requires all the assemblies to be accurate including; quantity, size, shape, location, and orientation. This level of detail also accommodates non-geometrical information attached to the model. In addition to visualization, the cost and schedule data is very important to tenants. A 300 level of detail will have enough information to create cost estimates based on specific data and conceptual estimate techniques. With this model tenants will be able to create accurate budgets and compare the cost of several designs and material selections. For the schedule, the tenants will be provided with an accurate completion date and the model will have enough detail and information to support a four dimensional model. A 4D model will be more beneficial for the designers and contractors during the construction phases but it will also provide the tenants with a graphical method of keeping track of progress. If BIM is utilized for the entire project then the interior designers can take the existing model and add the interior details. Otherwise, the interior designers would also have to model the building shell and it would take more work to develop a model with a level of detail of 300. The 300 level is detailed enough to create shop drawings and as more detail is added it will result in an as-built model that can be saved by the building owners for future construction and reference.

**Conclusions and Recommendations**

The use of Building Information Modeling is growing in the construction industry and with the creation of the Model Progression Specification and the AIA BIM Protocol Exhibit it is easier for owners to specify in contract language how they want to apply a model. They also help owners, designers, and contractors determine who is responsible for the various details in the model. Out of all the benefits that BIM can provide for a building project I believe the visualization aspect is the most beneficial for Bridgeside II. I feel that the ability to see a three dimensional space and easily alter designs will attract potential tenants and help them reach an agreement with the owner at an earlier date in the project. I recommend that at least a detail level of 300 be developed in the model to provide the tenants with an accurate representation of their space and reliable cost and schedule data. Using BIM from the start of the project could result in a schedule reduction for the interior fit-out phases. This is because the interior designers will have an accurate model to work with and they won't need to redesign any part of the building. Also the use of BIM will hopefully attract some tenants earlier in the project resulting in earlier design considerations. In conclusion I feel that utilizing BIM for at least the interior fit-out phases of Bridgeside II would be a valuable addition to the project. This is based on the benefits it provides for the project teams and potential tenants and the use of the BIM specifications to provide contract requirements.

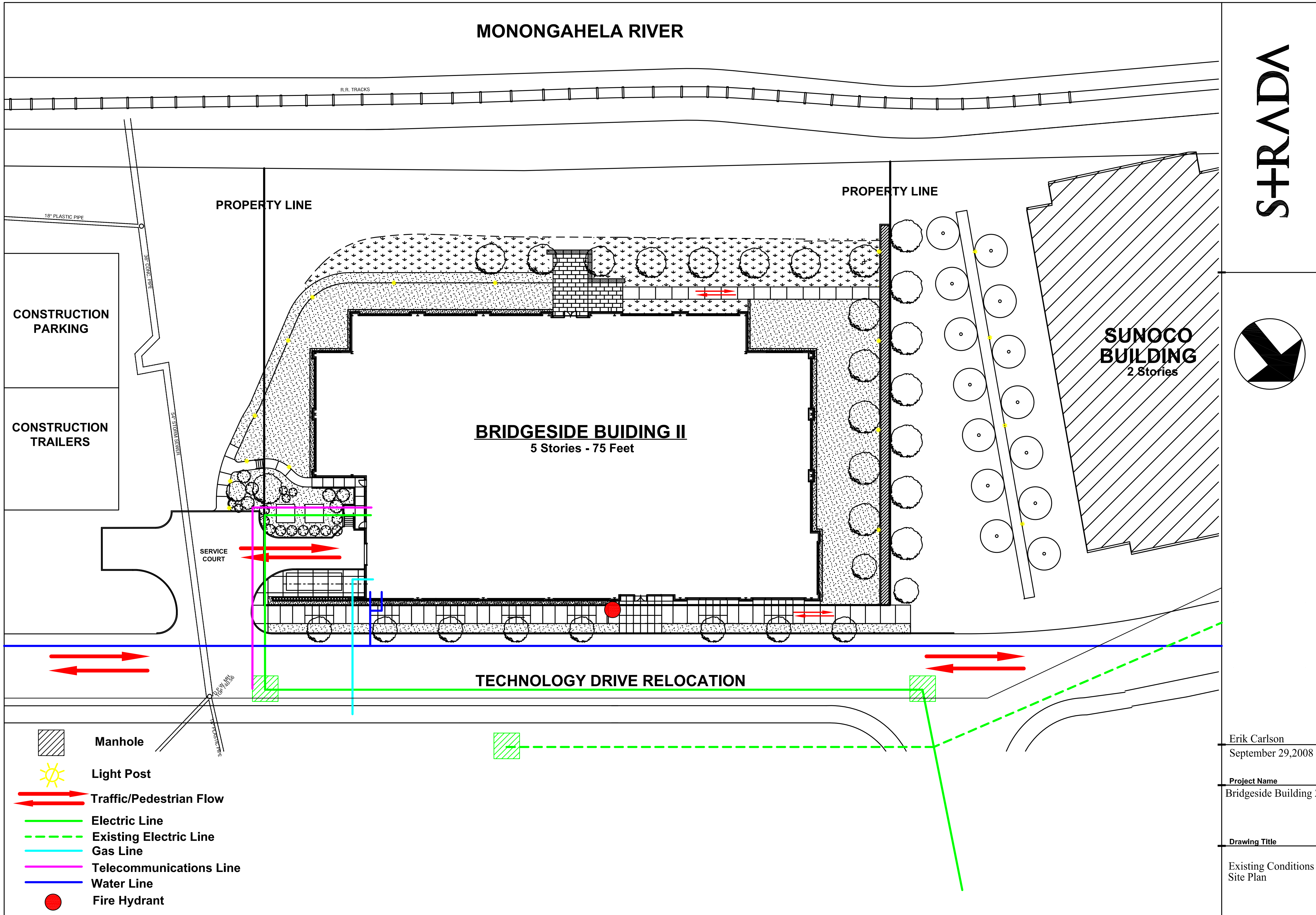
# THESIS CONCLUSIONS AND RECOMMENDATIONS

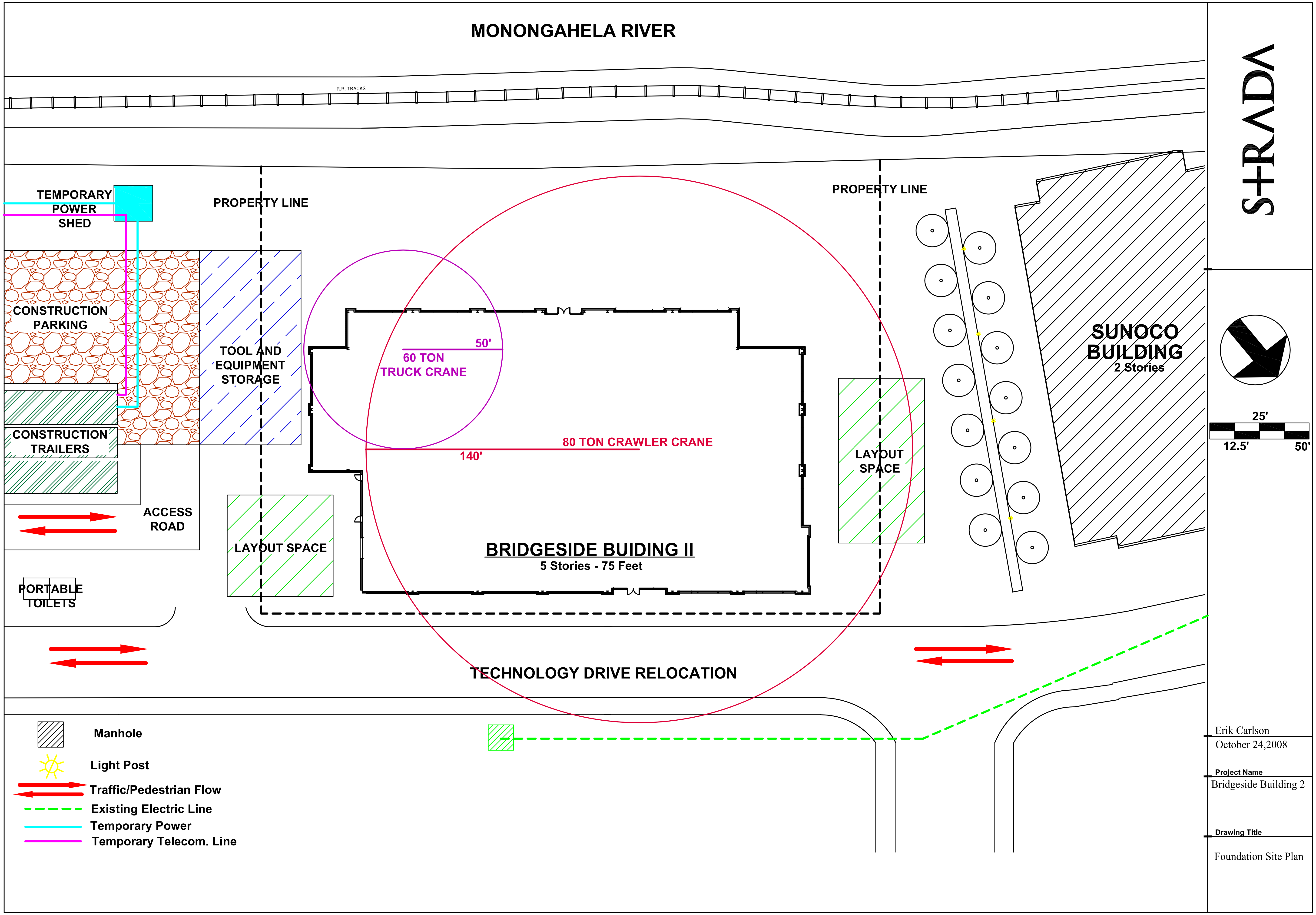
The main goals of the owner during the construction of Bridgeside II were to get the project completed as quickly as possible and to lease at least 50 percent of the space. Once the building is completed and the tenants can fit-out their space then the Ferchill Group will begin receiving rent income and can start their next project in the Pittsburgh Technology Center. The overall goals of this thesis were to decrease the project duration, make the building more attractive to potential tenants, and to help tenants design their desired space earlier in the project.

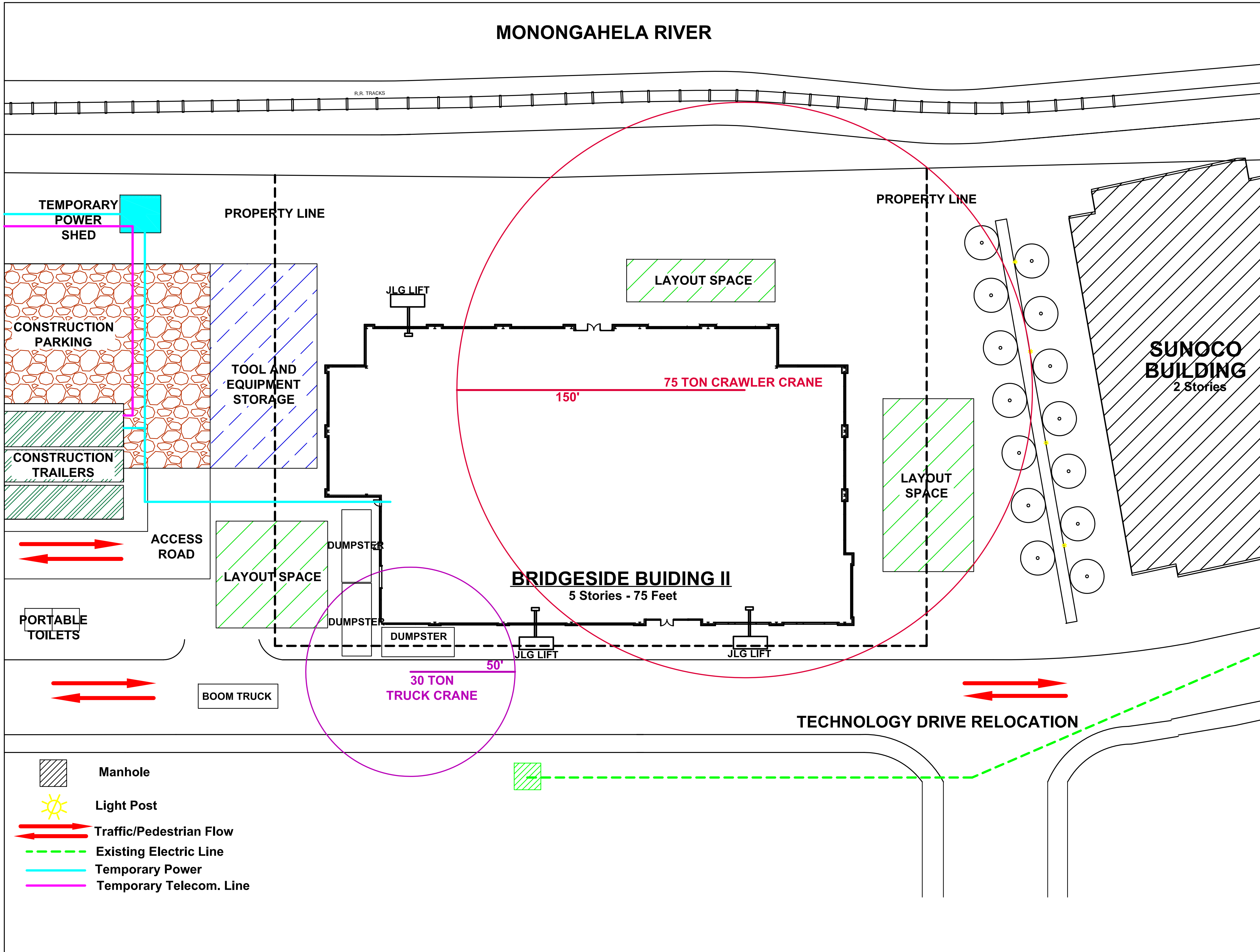
The first analysis was in response to the increased costs and schedule delays during the foundation construction. Underground obstructions prevented the steel piles from being driven into the bedrock and as a result each pile had to be pre-drilled. By replacing the steel H-piles with micro piles, I was able to create a schedule reduction of 24 days and a cost savings of $266,565. The second analysis proposed the replacement of non-vision spandrel panels on two of the facades with photovoltaic Light-Thru modules. The goal of this analysis was to utilize solar energy to create a life cycle cost savings. The Light-Thru modules will cost $228,553 and based on the energy production the payback period is 119 years. Based on the average life of the modules, this is not a reliable investment; however, they still provide a guaranteed reduction in utility costs and they provide environmental benefits such as reduced $CO_2$ emissions. Based on the payback period the owners will probably not choose to install the PV modules. However, if the micro piles are also installed then the owner would still see a total cost savings of $38,012 and a schedule reduction of 24 days. In addition, since the initial costs of the PV modules are offset immediately, the owner and tenants will benefit from a $1917 reduction in utility costs each year. Over the 25 year life span of the modules, they will create an additional cost savings of $48,000, which totals to $86,012.

The final analysis investigated the use of BIM during the interior construction phases. Inexperienced owners are often hesitant to require the use of BIM on their projects because they are unsure how to apply the model and how to assign responsibilities. With the release of the new AIA BIM document and the Model Progression Specification, owners and the rest of the project team are able to plan, during the initial phase, who is responsible for the detail and how the model will be used. By using BIM for core and shell projects, potential tenants will be able to design their future space with ease and may be willing to determine a lease agreement earlier in the project.

# APPENDIX A: SITE LAYOUT PLANS


MONONGAHELA RIVER
R.R. TRACKS
PROPERTY LINE
PROPERTY LINE
CONSTRUCTION PARKING
CONSTRUCTION TRAILERS
BRIDGESIDE BUIDING II
5 Stories - 75 Feet
SUNOCO BUILDING
2 Stories
SERVICE COURT
TECHNOLOGY DRIVE RELOCATION
Manhole
Light Post
Traffic/Pedestrian Flow
Electric Line
Existing Electric Line
Gas Line
Telecommunications Line
Water Line
Fire Hydrant
S+RADA
Erik Carlson
September 29,2008
Project Name
Bridgeside Building 2
Drawing Title
Existing Conditions Site Plan


MONONGAHELA RIVER
R.R. TRACKS
TEMPORARY POWER SHED
PROPERTY LINE
PROPERTY LINE
CONSTRUCTION PARKING
TOOL AND EQUIPMENT STORAGE
50'
60 TON TRUCK CRANE
80 TON CRAWLER CRANE
140'
CONSTRUCTION TRAILERS
ACCESS ROAD
LAYOUT SPACE
LAYOUT SPACE
BRIDGESIDE BUIDING II
5 Stories - 75 Feet
SUNOCO BUILDING
2 Stories
25'
12.5'
50'
PORTABLE TOILETS
TECHNOLOGY DRIVE RELOCATION
Manhole
Light Post
Traffic/Pedestrian Flow
Existing Electric Line
Temporary Power
Temporary Telecom. Line
S+RADA
Erik Carlson
October 24,2008
Project Name
Bridgeside Building 2
Drawing Title
Foundation Site Plan




STRADA

Erik Carlson
October 24,2008

Project Name
Bridgeside Building 2

Drawing Title
Superstructure Site Plan

# APPENDIX B: D4 COST ESTIMATE

# Statement of Probable Cost



Bridgeside Building II - Nov 2007 - PA - Pittsburgh

| | | | |
|---|---|---|---|
| Prepared By: | **Erik Carlson** | Prepared For: | **Dr. Messner** |
| | **,** | | **,** |
| | **Fax:** | | **Fax:** |
| Building Sq. Size: | **160000** | Site Sq. Size: | **84637** |
| Bid Date: | **10/22/2007** | Building use: | **Office** |
| No. of floors: | **5** | Foundation: | **PIL** |
| No. of buildings: | **1** | Exterior Walls: | **PAN** |
| Project Height: | **75** | Interior Walls: | **GYP** |
| 1st Floor Height: | **14** | Roof Type: | **MEM** |
| 1st Floor Size: | **32000** | Floor Type: | **COM** |
| | | Project Type: | **NEW** |

| Division | | Percent | Sq. Cost | Amount |
|---|---|---|---|---|
| **01** | **General Requirements** | **7.93** | **11.36** | **1,817,402** |
| | General Requirements | 7.93 | 11.36 | 1,817,402 |
| **02** | **Existing Conditions** | **3.95** | **5.66** | **904,809** |
| | Existing Conditions | 3.95 | 5.66 | 904,809 |
| **03** | **Concrete** | **7.84** | **11.24** | **1,798,313** |
| | Concrete | 7.84 | 11.24 | 1,798,313 |
| **04** | **Masonry** | **7.28** | **10.44** | **1,669,705** |
| | Masonry | 7.28 | 10.44 | 1,669,705 |
| **05** | **Metals** | **10.81** | **15.48** | **2,477,537** |
| | Metals | 10.81 | 15.48 | 2,477,537 |
| **06** | **Wood, Plastics, and Composites** | **2.00** | **2.87** | **459,591** |
| | Wood, Plastics, and Composites | 2.00 | 2.87 | 459,591 |
| **07** | **Thermal and Moisture Protection** | **5.10** | **7.31** | **1,170,107** |
| | Thermal and Moisture Protection | 5.10 | 7.31 | 1,170,107 |
| **08** | **Openings** | **2.93** | **4.20** | **672,152** |
| | Openings | 2.93 | 4.20 | 672,152 |
| **09** | **Finishes** | **6.13** | **8.79** | **1,406,231** |
| | Finishes | 6.13 | 8.79 | 1,406,231 |
| **10** | **Specialties** | **0.22** | **0.32** | **51,221** |
| | Specialties | 0.22 | 0.32 | 51,221 |
| **11** | **Equipment** | **0.07** | **0.10** | **16,466** |
| | Equipment | 0.07 | 0.10 | 16,466 |
| **12** | **Furnishings** | **0.24** | **0.34** | **54,119** |
| | Furnishings | 0.24 | 0.34 | 54,119 |
| **13** | **Special Construction** | **1.19** | **1.70** | **272,483** |
| | Special Construction | 1.19 | 1.70 | 272,483 |
| **14** | **Conveying Systems** | **2.16** | **3.09** | **495,144** |
| | Conveying Systems | 2.16 | 3.09 | 495,144 |
| **15** | **Mechanical** | **17.63** | **25.26** | **4,041,826** |
| | Mechanical | 17.63 | 25.26 | 4,041,826 |
| **16** | **Electrical** | **10.01** | **14.34** | **2,294,027** |
| | Electrical | 10.01 | 14.34 | 2,294,027 |
| **21** | **Fire Suppression** | **1.08** | **1.55** | **247,716** |
| | Fire Suppression | 1.08 | 1.55 | 247,716 |
| **22** | **Plumbing** | **1.60** | **2.29** | **366,977** |
| | Plumbing | 1.60 | 2.29 | 366,977 |

| | | | | |
|---|---|---|---|---|
| **23** | **HVAC** | **2.64** | **3.78** | **605,010** |
| | HVAC | 2.64 | 3.78 | 605,010 |
| **26** | **Electrical** | **2.22** | **3.17** | **507,819** |
| | Electrical | 2.22 | 3.17 | 507,819 |
| **31** | **Earthwork** | **4.60** | **6.60** | **1,055,359** |
| | Earthwork | 4.60 | 6.60 | 1,055,359 |
| **32** | **Exterior Improvements** | **1.62** | **2.32** | **371,308** |
| | Exterior Improvements | 1.62 | 2.32 | 371,308 |
| **33** | **Utilities** | **0.74** | **1.06** | **168,984** |
| | Utilities | 0.74 | 1.06 | 168,984 |
| **Total Building Costs** | | **100.00** | **143.28** | **22,924,306** |
| **Total Non-Building Costs** | | **100.00** | **0.00** | **0** |
| **Total Project Costs** | | **--** | **--** | **22,924,306** |

# APPENDIX C: GENERAL CONDITIONS ESTIMATE

| General Conditions Estimate | | | | |
|---|---|---|---|---|
| **Description** | **Quantity** | **Unit** | **Cost/Unit** | **Total** |
| **General Expenses** | | | | |
| Field Office | 14 | mo | $282 | $3,948 |
| Office Equipment | 14 | mo | $150 | $2,100 |
| Office Supplies | 14 | mo | $95 | $1,330 |
| Office Furniture | 1 | LS | $1,000 | $1,000 |
| Water and Ice | 14 | mo | $100 | $1,400 |
| Additional Plans | 1 | LS | $2,000 | $2,000 |
| Portable Toilets (2) | 14 | mo | $165 | $4,620 |
| Fire Extinguishers | 7 | ea | $50 | $350 |
| Final Clean-up | 20,000 | SF | $0.20 | $4,000 |
| Dumpsters (3) | 20 | pulls | $440 | $26,400 |
| On-Site Computers | 2 | ea | $1,500 | $3,000 |
| IT Maintenance | 14 | mo | $200 | $2,800 |
| First Aid Supplies | 1 | LS | $1,000 | $1,000 |
| Hardhats, Gloves, Glasses | 1 | LS | $1,500 | $1,500 |
| Courier Service | 14 | mo | $150 | $2,100 |
| Cell Phones | 14 | mo | $200 | $2,800 |
| **Project Staff** | | | | |
| Superintendent | 62 | wks | $1,875 | $116,250 |
| Project Engineer | 62 | wks | $1,250 | $77,500 |
| Project Executive | 15 | wks | $2,500 | $37,500 |
| Summer Intern | 13 | wks | $600 | $7,800 |
| Building Mgmt. Consultant | 1 | LS | $24,000 | $24,000 |
| **Temporary Utilities** | | | | |
| Temporary Lighting | 1 | LS | $80,000 | $80,000 |
| Temporary Water Tap Fees | 1 | LS | $45,000 | $45,000 |
| Temporary Heaters (15) | 7 | mo | $69 | $7,245 |
| **Fees and Permits** | | | | |
| Subguard | 1 | LS | $161,757 | $161,757 |
| Building Permit | 1 | LS | $65,040 | $65,040 |
| Owner Contingency | 1 | LS | $230,000 | $230,000 |
| | | | **Subtotal** | **$912,440** |
| | | | **CM Fee (3.6%** | **$32,848** |
| | | | **Total** | **$945,288** |

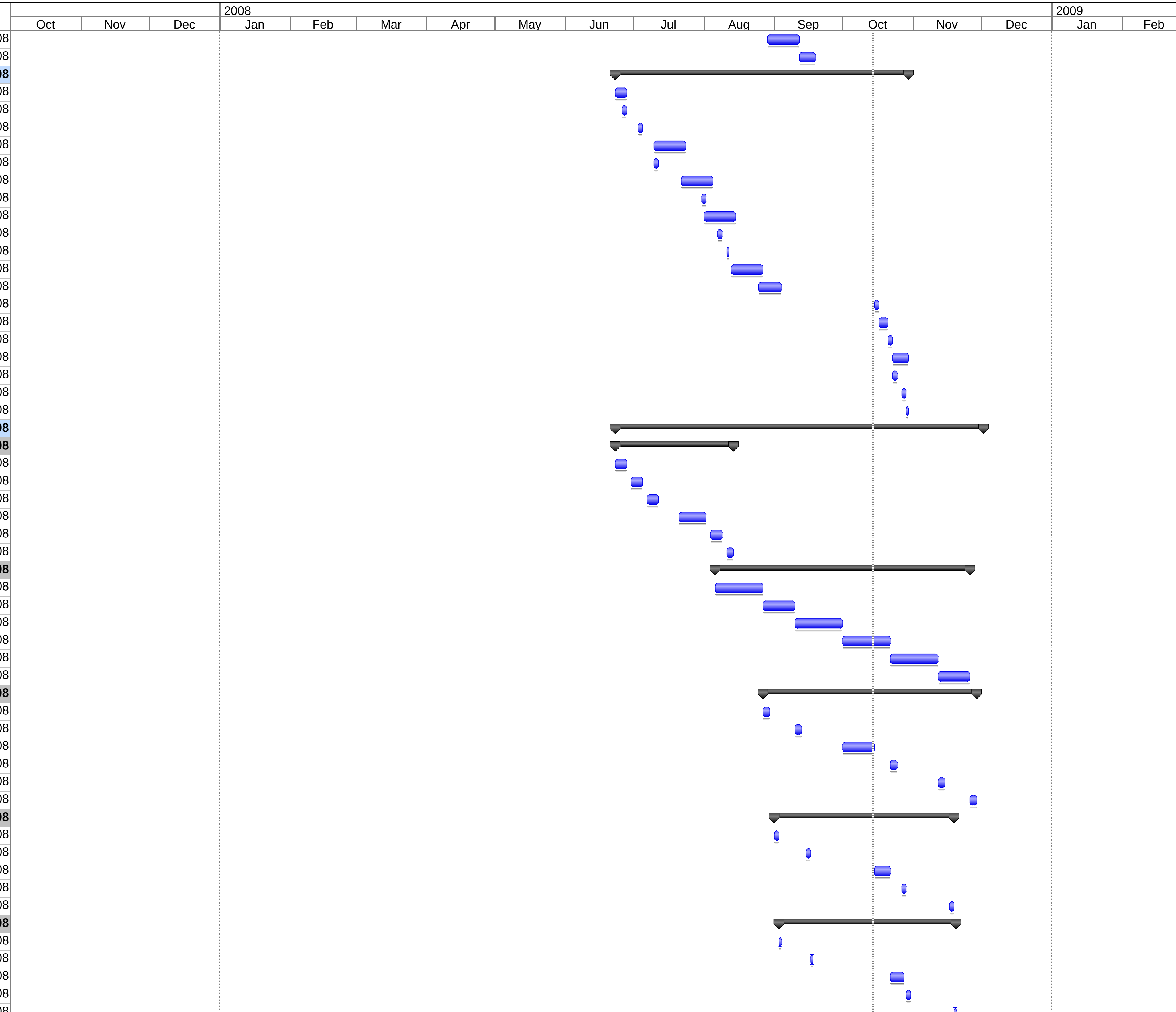
# APPENDIX D: DETAILED PROJECT SCHEDULE

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | Notice to Proceed | 0 days | Fri 11/2/07 | Fri 11/2/07 |
| 2 | **Site Construction** | **245 days** | **Fri 11/2/07** | **Thu 10/9/08** |
| 3 | Mobilization | 11 days | Fri 11/2/07 | Fri 11/16/07 |
| 4 | Erosion and Sediment Controls | 6 days | Fri 11/9/07 | Fri 11/16/07 |
| 5 | Site Clearing/Preparation/Fence | 8 days | Fri 11/9/07 | Tue 11/20/07 |
| 6 | Construction Entrance and Temp Road | 6 days | Tue 11/13/07 | Tue 11/20/07 |
| 7 | Backfill and Site Grading | 53 days | Wed 3/12/08 | Fri 5/23/08 |
| 8 | Site Utilties/Concrete/Pavers | 30 days | Fri 8/1/08 | Thu 9/11/08 |
| 9 | Landscaping | 20 days | Fri 9/12/08 | Thu 10/9/08 |
| 10 | **Foundations** | **123 days** | **Wed 11/21/07** | **Fri 5/9/08** |
| 11 | Pre-drill Piles | 47 days | Wed 11/21/07 | Thu 1/24/08 |
| 12 | Install H-Piles | 36 days | Tue 12/18/07 | Tue 2/5/08 |
| 13 | Concrete Pile Caps | 60 days | Tue 1/8/08 | Mon 3/31/08 |
| 14 | Concrete Grade Beams and Piers | 54 days | Tue 1/29/08 | Fri 4/11/08 |
| 15 | Concrete Foundation Walls | 30 days | Wed 3/12/08 | Tue 4/22/08 |
| 16 | Grout Base Plates | 11 days | Fri 4/25/08 | Fri 5/9/08 |
| 17 | **Concrete** | **31 days** | **Wed 5/28/08** | **Wed 7/9/08** |
| 18 | Slab on Deck Level 2 | 8 days | Wed 5/28/08 | Fri 6/6/08 |
| 19 | Slab on Deck Level 3 | 8 days | Mon 6/2/08 | Wed 6/11/08 |
| 20 | Slab on Deck Level 4 | 6 days | Tue 6/10/08 | Tue 6/17/08 |
| 21 | Slab on Deck Level 5 | 6 days | Fri 6/13/08 | Fri 6/20/08 |
| 22 | Pour Metal Stair Pans | 2 days | Mon 6/23/08 | Tue 6/24/08 |
| 23 | Penthouse Slab on Deck | 3 days | Wed 6/25/08 | Fri 6/27/08 |
| 24 | Slab on Grade | 8 days | Mon 6/30/08 | Wed 7/9/08 |
| 25 | **Masonry** | **61 days** | **Thu 7/10/08** | **Thu 10/2/08** |
| 26 | Interior Masonry Level 1 | 10 days | Thu 7/10/08 | Wed 7/23/08 |
| 27 | Exterior Cast Stone West Elevation | 20 days | Mon 7/14/08 | Fri 8/8/08 |
| 28 | Exterior Cast Stone North Elevation | 10 days | Mon 8/4/08 | Fri 8/15/08 |
| 29 | Exterior Cast Stone East Elevation | 20 days | Mon 8/18/08 | Fri 9/12/08 |
| 30 | Exterior Cast Stone South Elevation | 8 days | Mon 9/15/08 | Wed 9/24/08 |
| 31 | Balcony Pavers | 10 days | Fri 9/19/08 | Thu 10/2/08 |
| 32 | **Structural/Misc. Steel** | **137 days** | **Mon 4/7/08** | **Tue 10/14/08** |
| 33 | Erect Structural Steel | 26 days | Mon 4/7/08 | Mon 5/12/08 |
| 34 | Detailing and Decking | 56 days | Fri 4/11/08 | Fri 6/27/08 |
| 35 | Stair ST-1/ST-2 | 14 days | Wed 5/7/08 | Mon 5/26/08 |
| 36 | Exterior Metal Stud Framing East Elev. | 17 days | Thu 6/5/08 | Fri 6/27/08 |
| 37 | Exterior Metal Stud Framing North Elev. | 7 days | Thu 6/26/08 | Fri 7/4/08 |
| 38 | Exterior Metal Stud Framing West Elev. | 5 days | Thu 7/3/08 | Wed 7/9/08 |
| 39 | Exterior Metal Stud Framing South Elev. | 7 days | Mon 7/7/08 | Tue 7/15/08 |
| 40 | Exterior Metal Studs at Mechanical Room | 8 days | Wed 7/16/08 | Fri 7/25/08 |
| 41 | Railings and Handrails | 43 days | Fri 8/15/08 | Tue 10/14/08 |
| 42 | Aluminum Sunshades | 20 days | Fri 8/22/08 | Thu 9/18/08 |
| 43 | **Woods and Plastics** | **14 days** | **Wed 10/22/08** | **Mon 11/10/08** |
| 44 | Vanity Tops | 10 days | Wed 10/22/08 | Tue 11/4/08 |
| 45 | Reception Desk | 4 days | Wed 11/5/08 | Mon 11/10/08 |
| 46 | **Thermal and Moisture Protection** | **64 days** | **Mon 6/23/08** | **Thu 9/18/08** |
| 47 | Spray on Fireproofing Level 1-5 Shafts | 15 days | Mon 6/23/08 | Fri 7/11/08 |
| 48 | Insulation and Vapor Barrier East Elev. | 10 days | Fri 6/27/08 | Thu 7/10/08 |
| 49 | Insulation and Vapor Barrier North Elev. | 7 days | Thu 7/3/08 | Fri 7/11/08 |
| 50 | Insulation and Vapor Barrier West Elev. | 5 days | Tue 7/8/08 | Mon 7/14/08 |
| 51 | Metal Panels East Elev. | 15 days | Fri 7/11/08 | Thu 7/31/08 |
| 52 | Insulation and Vapor Barrier South Elev. | 7 days | Mon 7/14/08 | Tue 7/22/08 |
| 53 | Roof Insulation and Membrane | 15 days | Wed 7/16/08 | Tue 8/5/08 |
| 54 | Metal Panels North Elevation | 10 days | Fri 8/1/08 | Thu 8/14/08 |
| 55 | Metal Panels West Elevation | 10 days | Fri 8/15/08 | Thu 8/28/08 |
| 56 | Metal Coping and Roof Flashing | 15 days | Fri 8/29/08 | Thu 9/18/08 |


Project: Detailed Project Schedule.mp
Date: Tue 10/14/08

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

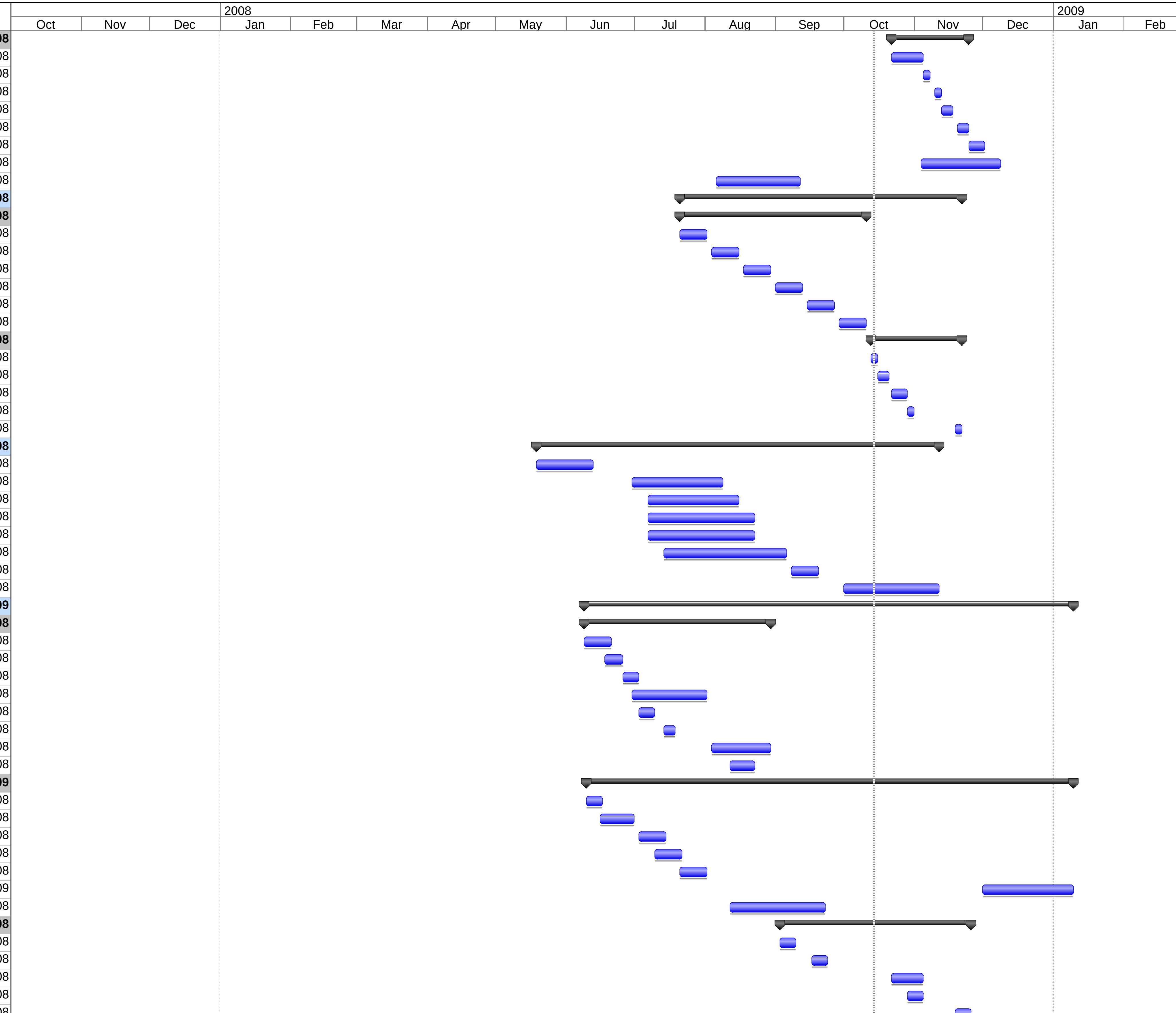
| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 57 | Metal Panels South Elevation | 10 days | Fri 8/29/08 | Thu 9/11/08 |
| 58 | Waterproofing Membrane at Balconies | 5 days | Fri 9/12/08 | Thu 9/18/08 |
| 59 | **Doors and Windows** | **93 days** | **Mon 6/23/08** | **Wed 10/29/08** |
| 60 | Exterior Aluminum Entrance Doors | 5 days | Mon 6/23/08 | Fri 6/27/08 |
| 61 | Hollow Metal Door Frames Level 2 | 2 days | Thu 6/26/08 | Fri 6/27/08 |
| 62 | Hollow Metal Door Frames Level 3 | 2 days | Thu 7/3/08 | Fri 7/4/08 |
| 63 | Punch Windows Level 1 | 10 days | Thu 7/10/08 | Wed 7/23/08 |
| 64 | Hollow Metal Door Frames Level 4 | 2 days | Thu 7/10/08 | Fri 7/11/08 |
| 65 | Punch Windows Level 2 | 10 days | Tue 7/22/08 | Mon 8/4/08 |
| 66 | Hollow Metal Door Frames Level 1 | 2 days | Thu 7/31/08 | Fri 8/1/08 |
| 67 | Punch Windows Level 3 | 10 days | Fri 8/1/08 | Thu 8/14/08 |
| 68 | Hollow Metal Door Frames Level 5 | 2 days | Thu 8/7/08 | Fri 8/8/08 |
| 69 | Hollow Metal Door Frames Penthouse | 1 day | Mon 8/11/08 | Mon 8/11/08 |
| 70 | Punch Windows Level 4 | 10 days | Wed 8/13/08 | Tue 8/26/08 |
| 71 | Punch Windows Level 5 | 8 days | Mon 8/25/08 | Wed 9/3/08 |
| 72 | Doors and Hardware Level 1 | 2 days | Wed 10/15/08 | Thu 10/16/08 |
| 73 | Doors and Hardware Level 2 | 2 days | Fri 10/17/08 | Mon 10/20/08 |
| 74 | Doors and Hardware Level 3 | 2 days | Tue 10/21/08 | Wed 10/22/08 |
| 75 | Interior Glazing | 5 days | Thu 10/23/08 | Wed 10/29/08 |
| 76 | Doors and Hardware Level 4 | 2 days | Thu 10/23/08 | Fri 10/24/08 |
| 77 | Doors and Hardware Level 5 | 2 days | Mon 10/27/08 | Tue 10/28/08 |
| 78 | Doors and Hardware Penthouse | 1 day | Wed 10/29/08 | Wed 10/29/08 |
| 79 | **Interior Finishes** | **116 days** | **Mon 6/23/08** | **Mon 12/1/08** |
| 80 | **Interior Metal Studs** | **38 days** | **Mon 6/23/08** | **Wed 8/13/08** |
| 81 | Level 2 | 5 days | Mon 6/23/08 | Fri 6/27/08 |
| 82 | Level 3 | 5 days | Mon 6/30/08 | Fri 7/4/08 |
| 83 | Level 4 | 5 days | Mon 7/7/08 | Fri 7/11/08 |
| 84 | Level 1 | 10 days | Mon 7/21/08 | Fri 8/1/08 |
| 85 | Level 5 | 5 days | Mon 8/4/08 | Fri 8/8/08 |
| 86 | Penthouse | 3 days | Mon 8/11/08 | Wed 8/13/08 |
| 87 | **Hang/Tape/Finish GWB** | **80 days** | **Wed 8/6/08** | **Tue 11/25/08** |
| 88 | Level 2 | 15 days | Wed 8/6/08 | Tue 8/26/08 |
| 89 | Level 3 | 10 days | Wed 8/27/08 | Tue 9/9/08 |
| 90 | Level 1 | 15 days | Wed 9/10/08 | Tue 9/30/08 |
| 91 | Level 4 | 15 days | Wed 10/1/08 | Tue 10/21/08 |
| 92 | Level 5 | 15 days | Wed 10/22/08 | Tue 11/11/08 |
| 93 | Penthouse | 10 days | Wed 11/12/08 | Tue 11/25/08 |
| 94 | **Paint Walls** | **68 days** | **Wed 8/27/08** | **Fri 11/28/08** |
| 95 | Level 2 | 3 days | Wed 8/27/08 | Fri 8/29/08 |
| 96 | Level 3 | 3 days | Wed 9/10/08 | Fri 9/12/08 |
| 97 | Level 1 | 10 days | Wed 10/1/08 | Tue 10/14/08 |
| 98 | Level 4 | 3 days | Wed 10/22/08 | Fri 10/24/08 |
| 99 | Level 5 | 3 days | Wed 11/12/08 | Fri 11/14/08 |
| 100 | Penthouse | 3 days | Wed 11/26/08 | Fri 11/28/08 |
| 101 | **ACT Ceiling Grid** | **57 days** | **Mon 9/1/08** | **Tue 11/18/08** |
| 102 | Level 2 | 2 days | Mon 9/1/08 | Tue 9/2/08 |
| 103 | Level 3 | 2 days | Mon 9/15/08 | Tue 9/16/08 |
| 104 | Level 1 | 5 days | Wed 10/15/08 | Tue 10/21/08 |
| 105 | Level 4 | 2 days | Mon 10/27/08 | Tue 10/28/08 |
| 106 | Level 5 | 2 days | Mon 11/17/08 | Tue 11/18/08 |
| 107 | **ACT Ceiling Tile** | **56 days** | **Wed 9/3/08** | **Wed 11/19/08** |
| 108 | Level 2 | 1 day | Wed 9/3/08 | Wed 9/3/08 |
| 109 | Level 3 | 1 day | Wed 9/17/08 | Wed 9/17/08 |
| 110 | Level 1 | 4 days | Wed 10/22/08 | Mon 10/27/08 |
| 111 | Level 4 | 2 days | Wed 10/29/08 | Thu 10/30/08 |
| 112 | Level 5 | 1 day | Wed 11/19/08 | Wed 11/19/08 |




Project: Detailed Project Schedule.mp
Date: Tue 10/14/08

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

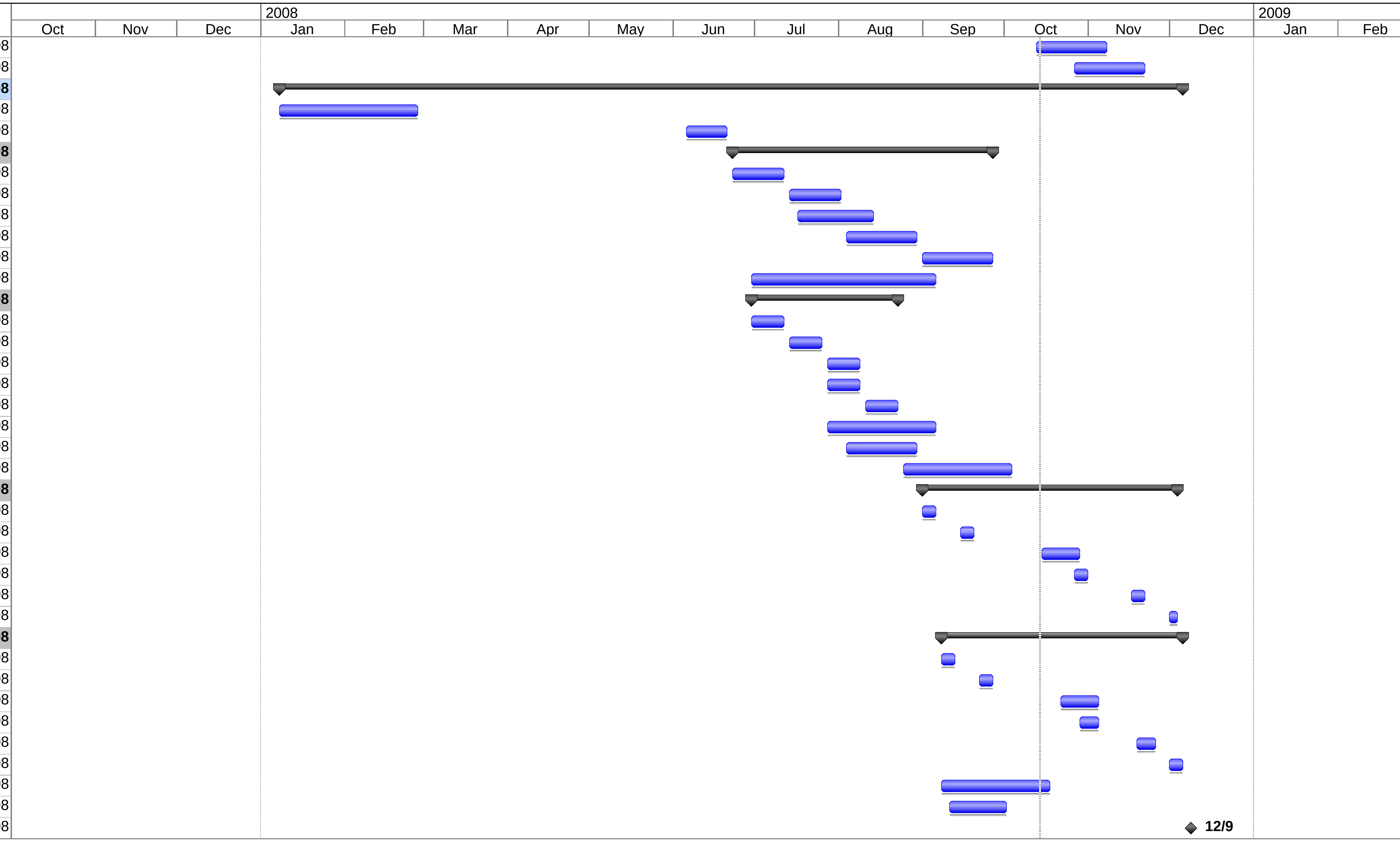
| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 113 | **Ceramic Tile** | **24 days** | **Wed 10/22/08** | **Mon 11/24/08** |
| 114 | Level 1 | 10 days | Wed 10/22/08 | Tue 11/4/08 |
| 115 | Level 2 | 3 days | Wed 11/5/08 | Fri 11/7/08 |
| 116 | Level 3 | 3 days | Mon 11/10/08 | Wed 11/12/08 |
| 117 | Level 4 | 3 days | Thu 11/13/08 | Mon 11/17/08 |
| 118 | Level 5 | 3 days | Thu 11/20/08 | Mon 11/24/08 |
| 119 | Rubber Base Level 1-5 | 5 days | Tue 11/25/08 | Mon 12/1/08 |
| 120 | Toilet Partitions and Accessories | 25 days | Tue 11/4/08 | Mon 12/8/08 |
| 121 | Elevator Rails/Door Frames/Cabs | 27 days | Wed 8/6/08 | Thu 9/11/08 |
| 122 | **Fire Protection** | **90 days** | **Mon 7/21/08** | **Fri 11/21/08** |
| 123 | **Piping and Heads** | **60 days** | **Mon 7/21/08** | **Fri 10/10/08** |
| 124 | Level 1 | 10 days | Mon 7/21/08 | Fri 8/1/08 |
| 125 | Level 2 | 10 days | Mon 8/4/08 | Fri 8/15/08 |
| 126 | Level 3 | 10 days | Mon 8/18/08 | Fri 8/29/08 |
| 127 | Level 4 | 10 days | Mon 9/1/08 | Fri 9/12/08 |
| 128 | Level 5 | 10 days | Mon 9/15/08 | Fri 9/26/08 |
| 129 | Penthouse | 10 days | Mon 9/29/08 | Fri 10/10/08 |
| 130 | **Building Core Heads** | **30 days** | **Mon 10/13/08** | **Fri 11/21/08** |
| 131 | Level 2 | 3 days | Mon 10/13/08 | Wed 10/15/08 |
| 132 | Level 3 | 3 days | Thu 10/16/08 | Mon 10/20/08 |
| 133 | Level 1 | 5 days | Wed 10/22/08 | Tue 10/28/08 |
| 134 | Level 4 | 3 days | Wed 10/29/08 | Fri 10/31/08 |
| 135 | Level 5 | 3 days | Wed 11/19/08 | Fri 11/21/08 |
| 136 | **Plumbing** | **127 days** | **Mon 5/19/08** | **Tue 11/11/08** |
| 137 | Underground Plumbing | 19 days | Mon 5/19/08 | Thu 6/12/08 |
| 138 | RO/DI Water Equipment/Piping | 30 days | Mon 6/30/08 | Fri 8/8/08 |
| 139 | Above Ground Storm Piping | 30 days | Mon 7/7/08 | Fri 8/15/08 |
| 140 | Domestic Water | 35 days | Mon 7/7/08 | Fri 8/22/08 |
| 141 | Rough-In Toilet Rooms | 35 days | Mon 7/7/08 | Fri 8/22/08 |
| 142 | Above Ground Sanitary Piping | 40 days | Mon 7/14/08 | Fri 9/5/08 |
| 143 | Gas Riser | 10 days | Mon 9/8/08 | Fri 9/19/08 |
| 144 | Install Fixtures and Trim | 30 days | Wed 10/1/08 | Tue 11/11/08 |
| 145 | **HVAC** | **155 days** | **Mon 6/9/08** | **Fri 1/9/09** |
| 146 | **Install Ductwork** | **60 days** | **Mon 6/9/08** | **Fri 8/29/08** |
| 147 | Level 2 | 10 days | Mon 6/9/08 | Fri 6/20/08 |
| 148 | Level 3 | 6 days | Wed 6/18/08 | Wed 6/25/08 |
| 149 | Level 4 | 5 days | Thu 6/26/08 | Wed 7/2/08 |
| 150 | Supply Air Shafts | 25 days | Mon 6/30/08 | Fri 8/1/08 |
| 151 | Level 5 | 5 days | Thu 7/3/08 | Wed 7/9/08 |
| 152 | Level 1 | 5 days | Mon 7/14/08 | Fri 7/18/08 |
| 153 | Return/Outside Air | 20 days | Mon 8/4/08 | Fri 8/29/08 |
| 154 | Rooftop Units | 9 days | Tue 8/12/08 | Fri 8/22/08 |
| 155 | **Install HVAC Piping** | **154 days** | **Tue 6/10/08** | **Fri 1/9/09** |
| 156 | Level 2 | 5 days | Tue 6/10/08 | Mon 6/16/08 |
| 157 | Level 3 | 11 days | Mon 6/16/08 | Mon 6/30/08 |
| 158 | Level 4 | 8 days | Thu 7/3/08 | Mon 7/14/08 |
| 159 | Level 5 | 8 days | Thu 7/10/08 | Mon 7/21/08 |
| 160 | Level 1 | 10 days | Mon 7/21/08 | Fri 8/1/08 |
| 161 | Mechanical Room | 30 days | Mon 12/1/08 | Fri 1/9/09 |
| 162 | Install Rooftop Units | 30 days | Tue 8/12/08 | Mon 9/22/08 |
| 163 | **Install GRD's** | **60 days** | **Wed 9/3/08** | **Tue 11/25/08** |
| 164 | Level 2 | 5 days | Wed 9/3/08 | Tue 9/9/08 |
| 165 | Level 3 | 5 days | Wed 9/17/08 | Tue 9/23/08 |
| 166 | Level 1 | 10 days | Wed 10/22/08 | Tue 11/4/08 |
| 167 | Level 4 | 5 days | Wed 10/29/08 | Tue 11/4/08 |
| 168 | Level 5 | 5 days | Wed 11/19/08 | Tue 11/25/08 |




Project: Detailed Project Schedule.mp
Date: Tue 10/14/08

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 169 | Install FPB and VAV's | 20 days | Mon 10/13/08 | Fri 11/7/08 |
| 170 | Install Boiler | 20 days | Mon 10/27/08 | Fri 11/21/08 |
| 171 | **Electrical** | **239 days** | **Tue 1/8/08** | **Fri 12/5/08** |
| 172 | Temporary Power | 37 days | Tue 1/8/08 | Wed 2/27/08 |
| 173 | Underground Electrical | 11 days | Fri 6/6/08 | Fri 6/20/08 |
| 174 | **Above Ceiling Rough-In** | **70 days** | **Mon 6/23/08** | **Fri 9/26/08** |
| 175 | Level 2 | 15 days | Mon 6/23/08 | Fri 7/11/08 |
| 176 | Level 3 | 15 days | Mon 7/14/08 | Fri 8/1/08 |
| 177 | Level 1 | 20 days | Thu 7/17/08 | Wed 8/13/08 |
| 178 | Level 4 | 20 days | Mon 8/4/08 | Fri 8/29/08 |
| 179 | Level 5 | 20 days | Mon 9/1/08 | Fri 9/26/08 |
| 180 | Conduit/Power Rough-In - Elec Room | 50 days | Mon 6/30/08 | Fri 9/5/08 |
| 181 | **Electrical Wall Rough-In** | **40 days** | **Mon 6/30/08** | **Fri 8/22/08** |
| 182 | Level 2 | 10 days | Mon 6/30/08 | Fri 7/11/08 |
| 183 | Level 3 | 10 days | Mon 7/14/08 | Fri 7/25/08 |
| 184 | Level 1 | 10 days | Mon 7/28/08 | Fri 8/8/08 |
| 185 | Level 4 | 10 days | Mon 7/28/08 | Fri 8/8/08 |
| 186 | Level 5 | 10 days | Mon 8/11/08 | Fri 8/22/08 |
| 187 | Fire Alarm Rough-In | 30 days | Mon 7/28/08 | Fri 9/5/08 |
| 188 | Install Switchgear | 20 days | Mon 8/4/08 | Fri 8/29/08 |
| 189 | Install Emergency Generator | 30 days | Mon 8/25/08 | Fri 10/3/08 |
| 190 | **Install Devices/Trimout** | **68 days** | **Mon 9/1/08** | **Wed 12/3/08** |
| 191 | Level 2 | 5 days | Mon 9/1/08 | Fri 9/5/08 |
| 192 | Level 3 | 5 days | Mon 9/15/08 | Fri 9/19/08 |
| 193 | Level 1 | 10 days | Wed 10/15/08 | Tue 10/28/08 |
| 194 | Level 4 | 5 days | Mon 10/27/08 | Fri 10/31/08 |
| 195 | Level 5 | 5 days | Mon 11/17/08 | Fri 11/21/08 |
| 196 | Penthouse | 3 days | Mon 12/1/08 | Wed 12/3/08 |
| 197 | **Install Light Fixtures** | **65 days** | **Mon 9/8/08** | **Fri 12/5/08** |
| 198 | Level 2 | 5 days | Mon 9/8/08 | Fri 9/12/08 |
| 199 | Level 3 | 5 days | Mon 9/22/08 | Fri 9/26/08 |
| 200 | Level 1 | 10 days | Wed 10/22/08 | Tue 11/4/08 |
| 201 | Level 4 | 5 days | Wed 10/29/08 | Tue 11/4/08 |
| 202 | Level 5 | 5 days | Wed 11/19/08 | Tue 11/25/08 |
| 203 | Penthouse | 5 days | Mon 12/1/08 | Fri 12/5/08 |
| 204 | Install Fire Alarm Devices | 30 days | Mon 9/8/08 | Fri 10/17/08 |
| 205 | Install Exterior Lighting Fixtures | 15 days | Thu 9/11/08 | Wed 10/1/08 |
| 206 | Certificate of Occupancy | 0 days | Tue 12/9/08 | Tue 12/9/08 |

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| | | | |
|---|---|---|---|
| Task | Progress | Summary | External Tasks |
| Split | Milestone | Project Summary | External Milestone |
| Deadline | | | |

Mat Slab Structural Calcs

Foundation Area

220' x 60' = 13200 SF
245' x 62' = 15190 SF
192' x 19' = 3648 SF
32038 SF

Building Area

1 → 31340 SF
2 → 32703 SF
3 → 32590 SF
4 → 32590 SF
5 → 32590 SF

Roof Area

Total → 32590 SF
SOD → 5440 SF

Live Loads

(max LL due to unknown floor layout) (snow load)

161813 SF x 150 PSF + 32590 SF x 21 PSF
= 24271.95 kips + 684.39 kips
= 24956.34 kips ≈ 24956 kips

Dead Loads

composite slabs (6" - 3" 20 ga)
→ 130473 SF x 57 psf = 7436.96 kips

partitions
→ 161813 SF x 20 psf = 3236.26 kips

Roof Loads

comp slabs → 5440 SF x 57 psf = 310.1 kips
RTU's → 50,000 lbs x 3 = 150 kips
Deck, insulation, built up roof → 25 psf x 29676 SF = 741.9 kips
Misc → 15 psf x 32590 SF = 488.9 kips
1690.9 kips

Dead Loads cont

Steel

Beams → 931.94 kips

Roof / Penthouse → 228.96 kips

Columns → 290.72 kips

Bracing → 38.96 kips

Total Dead load = 13854.7 kips ≈ 13855 kips

Non-Factored load = 38,811 kips

Factored Load = 1.2 (13855) + 1.6 (24956) = 56555.6 k ≈ 56556 kips

Slab Thickness

critical column load → 805 kips (col E-3) = $P_u$

Base plate dimensions → 2.5" x 22" x 22" = B, C

Foundation required concrete strength → 3000 psi

punching shear controls $4d^2 + 2d(b+c) = \frac{P_u}{v_c}$

$v_c = \frac{0.75(4)\sqrt{3000}}{1000} = 0.164$ kips

$4d^2 + 2d(22+22) = \frac{805}{0.164}$

$4d^2 + 88d = 4908.5$ $d = 25.71''$

Use $d = 30''$

Reinforcing Requirements

$As_{min} = \frac{200}{f_y} bd = \frac{200}{60{,}000}(12)(30) = 1.2\ in^2/ft$

Use # 6's @ 12" - 3 layers E.W.

$As = 1.32 > 1.2$ ✓

Weight of Mat Slab

Concrete → $\frac{30}{12}$ × 32038 SF × 150 PCF × 1.05 (waste) = 12,615 kips
→ 3114.8 CY

Reinforcement → 6 ft/SF × 32038 SF = 192,228 ft

192,228 ft × 1.502 lb/ft = 289 kips

Total wt = 12,615 kips + 289 kips = 12,904 kips

Bearing Capacity

allowable bearing pressure = 1500 psf

Actual bearing pressure → $\frac{56,336 \text{ kips} + 12,904 \text{ kips}}{32038 \text{ SF}}$ × 1000 lbs/kip

= 2168 psf

2168 psf > 1500 psf ∴ unacceptable

Excavation / Fill

Frost depth = 3.5'
Slab depth = 2.5'
required undercut = 2'
8'

8' × 32038 SF × $\frac{1 \text{ CY}}{27 \text{ CF}}$ = 9493 CY

Fill → 2' × 32038 × $\frac{1}{27}$ = 2373 CY

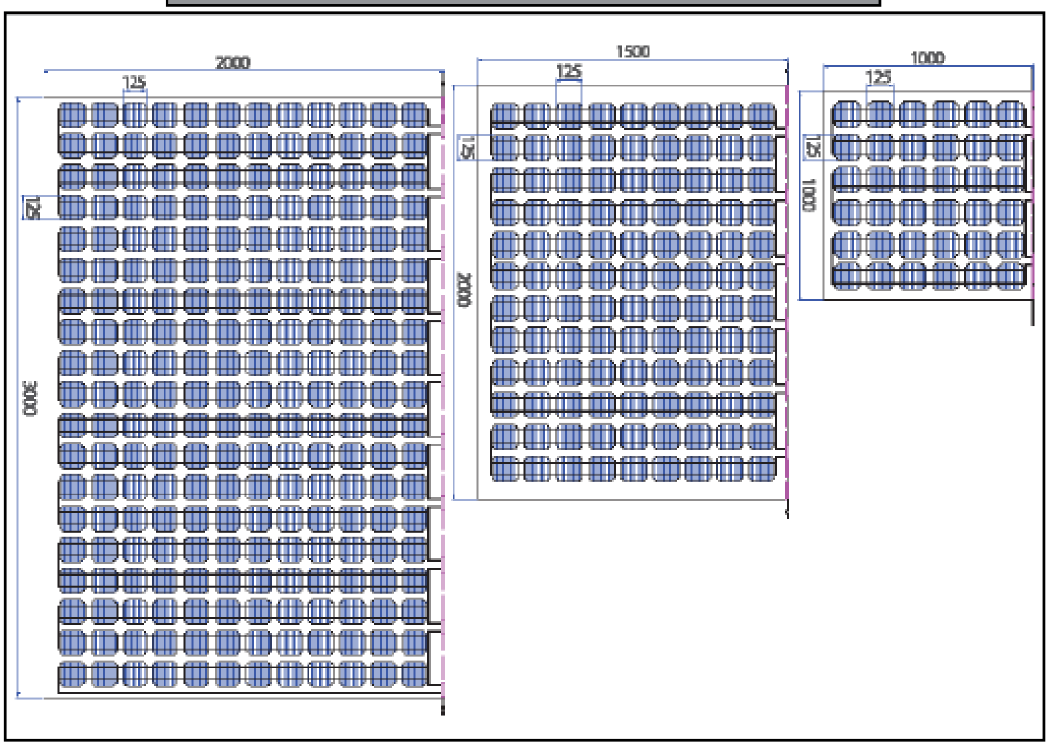
# APPENDIX F: SUNTECH PV MODULE PRODUCT DATA

## Technical specifications

Light Thru modules are made to custom order (refer to page **3** for options). Examples of typical characteristics are given as a guide.

| Length (m) | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 |
|---|---|---|---|---|---|---|---|---|---|
| Width (m) | 1 | 1 | 1 | 1.5 | 1.5 | 1.5 | 2 | 2 | 2 |
| Cell spacing (mm) | 4 | 15 | 30 | 4 | 1.5 | 30 | 4 | 15 | 30 |
| Transparency (%) | 25 | | 45 | 18 | 30 | 45 | 18 | 26 | 43 |
| Cells (No) | 7x7 | 6x6 | 6x6 | 11x15 | 10x14 | 9x12 | 15x22 | 13x21 | 12x19 |
| | 49 | 36 | 36 | 165 | 140 | 108 | 330 | 273 | 228 |
| Pmax (W) | 109 | 80 | 80 | 368 | 312 | 241 | 736 | 609 | 509 |
| Vpm (V) | 25.0 | 18.4 | 18.4 | 84.2 | 71.4 | 55.1 | 168.3 | 139.2 | 116.3 |
| Ipm (A) | 4.37 | 4.37 | 4.37 | 4.37 | 4.37 | 4.37 | 4.37 | 4.37 | 4.37 |
| Voc (V) | 30.1 | 22.1 | 22.1 | 101.5 | 86.1 | 66.4 | 203.0 | 169.7 | 140.2 |
| Isc (A) | 4.80 | 4.80 | 4.80 | 4.80 | 4.80 | 4.80 | 4.80 | 4.80 | 4.80 |
| Wind load (Pa) | 27,563 | 27,563 | 27,563 | 9,188 | 9,188 | 9,188 | 4,594 | 4,594 | 4,594 |
| Snow load (Pa) | 18,375 | 18,375 | 18,375 | 6,125 | 6,125 | 6,125 | 3,063 | 3,063 | 3,063 |

(Loads assume module is fixed on all four sides. Glass thickness 5mm+5mm tempered glass.)



# APPENDIX G: XANTREX INVERTER PRODUCT DATA

**Specifications**

| **Models** | GT5.0 | | GT4.0N | | GT3.8 | | GT3.3N | | GT2.8 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Output | 240 V | 208 V | 240 V | 208 V | 240 V | 208 V | 240 V | 208 V | 240 V | 208 V |
| Max. AC power output | 5000 W | 4500 W | 4000 W | 3800 W | 3800 W | 3500 W | 3300 W | 3100 W | 2800 W | 2700 W |
| AC output voltage (nominal) | 240 V | 208 V | 240 V | 208 V | 240 V | 208 V | 240 V | 208 V | 240 V | 208 V |
| AC output voltage range | 211-264 Vac<br>183-229 Vac | | | | | | | | | |
| AC frequency (nominal) | 60 Hz | | | | | | | | | |
| AC frequency range | 59.3 - 60.5 Hz | | | | | | | | | |
| Startup current | 0 Aac | | | | | | | | | |
| Max. continuous output current | 21 A | 22 A | 16.7 A | 18.3 A | 15.8 A | 16.8 A | 13.8 A | 14.9 A | 11.7 A | 13.0 A |
| Max. output over-current protection | 30 A | | 25 A | | 20 A | 25 A | 20 A | | 15 A | |
| Max. utility backfeed current | O A | | | | | | | | | |
| Total harmonic distortion (THD) | < 3 % | | | | | | | | | |
| Power factor | > 0.99 % (at rated power), > 0.95 % (full power range) | | | | | | | | | |
| Utility monitoring, islanding protection | UL1741-2005 / IEEE 1547 | | | | | | | | | |
| Output characteristics | Current Source | | | | | | | | | |
| Output current waveform | True sine wave | | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Max. array open-circuit voltage | 600 Vdc | | | | | | | | | |
| MPPT voltage range (CEC & CSA) | 240 - 550 Vdc | | 240 - 480 Vdc | | 195 - 550 Vdc | | 200 - 400 Vdc | | 195 - 550 Vdc | |
| MPPT operating range | 235 - 550 Vdc | | 235 Vdc - 550 Vdc | | 195 Vdc - 550 Vdc | | 200 Vdc - 550 Vdc | | 193 Vdc - 550 Vdc | |
| Max. input current | 22.0 Adc | 20.0 Adc | 18.0 Adc | 17.0 Adc | 20.8 Adc | 19.5 Adc | 17.5 Adc | 16.5 Adc | 15.4 Adc | 14.9 Adc |
| Max. array short-circuit current | 24.0 Adc | | | | | | | | | |
| Reverse-polarity protection | Short-circuit diode | | | | | | | | | |
| Ground-fault protection | GF detection, IDIF > 1 A | | | | | | | | | |
| Max. inverter efficiency | 95.9% | 95.5% | 96.0% | 95.7% | 95.9% | 95.6% | 95.9% | 95.6% | 95.0% | 94.6% |
| CEC efficiency | 95.5% | 95.0% | 95.5% | 95.0% | 95.0% | 95.0% | 95.5% | 95.0% | 94.0% | 93.5% |
| Night-time power consumption | 1 W | | | | | | | | | |
| | | | | | | | | | | |
| Operating temperature range | -13°F to +149°F (-25°C to +65°C) | | | | | | | | | |
| Enclosure type | NEMA 3R (outdoor rated) | | | | | | | | | |
| Inverter weight | 58.0 lb (25.8 kg) | | 58.0 lb (25.8 kg) | | 58.0 lb (25.8 kg) | | 49.0 lb (22.2 kg) | | 49.0 lb (22.2 kg) | |
| Shipping weight | 65.0 lb (27.2 kg) | | 65.0 lb (27.2 kg) | | 65.0 lb (27.2 kg) | | 57.0 lb (25.9 kg) | | 57.0 lb (25.9 kg) | |
| Inverter dimensions (H x W x D) | 28 1/2 x 16 x 5 3/4” (724 x 403 x 145 mm) | | | | | | | | | |
| Shipping dimensions (H x W x D) | 34 x 20 1/2 x 10 5/16” (866 x 518 x 262 mm) | | | | | | | | | |
| | | | | | | | | | | |
| Mounting | Wall mount (mounting bracket included) | | | | | | | | | |
| Input and output terminal | AC and DC terminals accept wires sizes of #14 to #6 AWG | | | | | | | | | |
| PV / Utility disconnect | Eliminates need for external PV (DC) disconnect. Complies with NEC requirements | | | | | | | | | |
| Cooling | Convection cooled, fan not required | | | | | | | | | |
| Display | Backlit, two-line, 16-character liquid crystal display provides instantaneous power, daily and lifetime energy production, PV array voltage and current, utility voltage and frequency, time online “selling”, fault messages, and installer-customizable screens | | | | | | | | | |
| Communications | Integrated RS232 and Xanbus™ RJ45 communication ports | | | | | | | | | |
| Wiring box | PV, utility, ground, and communications connections. The inverter can be separated from the wiring box. | | | | | | | | | |
| Warranty | 10-year standard | | | | | | | | | |
| Model name (negative ground) | GT5.0-NA-240/208 UL-05 | | GT4.0N-NA-240/208 UL-05 | | GT3.8-NA-240/208 UL-05 | | GT3.3N-NA-240/208 UL-05 | | GT2.8-NA-240/208 UL-05 | |
| Part number (negative ground) | 864-1009 | | 864-1008 | | 864-1032 | | 864-1006 | | 864-1001 | |
| | Positive ground inverters are also available | | | | | | | | | |