SENIOR THESIS

FINAL REPORT

PENN STATE AE SENIOR CAPSTONE PROJECT

New York Police Academy

College Point, New York

Shawn Sidelinger

Construction Management

Dr. Robert Leicht

New York Police Academy

28-11 28^{th} Avenue, Queens, New York

Shawn Sidelinger - Construction Management

http://www.engr.psu.edu/ae/thesis/portfolios/2011/sus264/index.html

Project Overview

Owner: NYC Department of Design and Construction, NYC Police Department

Construction Manager: Turner Construction

Size: 720,000 SF

Occupancy: B, Business

Start/End: 10/01/10 to 12/31/13

Architecture

New York City Police Academy design is focused around the conjuration of the five current facilities into one. Exterior Façade is a combination of metal panels, precast concrete, and glazed glass.

Structural

Foundation: Pile cap design ranging from 100 to 180 tons in capacity with piles being sixteen inches in diameter.

Superstructure: Steel system consisting of rigid and braced frame design, with composite decking for floor and roof support.

Construction

The project is being constructed under a modified fast track construction style, due to local law requirements, with intentions to obtain a LEED Silver Rating as well. A portion of the site is on an old landfill, causing extra precautions in soil testing and foundation design. This however allows for onsite parking and storage, a rarity in New York.

Mechanical

Cooling: Chilled water system containing four chillers, four cooling tower and up to eight pumps to supply the facility.

Heating: Traditional boiler system containing five industrial boilers that are supplied by eight fuel oil tanks.

Air handling units will be installed to ensure proper air quality.

Electrical/Lighting

Lighting: Variety of light fixtures to accompany the architectural feel for the surrounding, all to be energy efficient.

Electrical: Administration is supplied by (1) 3000A/460V 3-Phase, and (1) 2500A/460V 3-Phase Switchboard. The Central Plant will be supplied by (2) 4000A/460V 3-Phase Switchboards, and (2) 2.5MW Diesel Generators for emergency power.

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Academic Acknowledgments:

The Pennsylvania State University Architectural Engineering Faculty

Dr. Robert Leicht – Construction Management Advisor

Industry Acknowledgments:

Turner

PERKINS + WILL

DDC
NEW YORK CITY DEPARTMENT OF
DESIGN + CONSTRUCTION

POLICE DEPARTMENT CITY OF NEW YORK

Special Thanks To:

Pat Murray and Jose Class of the Turner Construction Company Project Team
SVT Project Team
Ming Leung at Perkins+Will
Yegal Shamash at Robert Silman Associates
My Fiancée Crystal Davies
My Family and Friends

Executive Summary

Plans for the New York Police Academy were drafted to allow the five current facilities used to train law enforcement for the New York Police Department to be performed in one central facility. This project consists of the new construction of a 720,000 SF facility in College Point, New York, equipped with space for academics, administrations, physical training, and a central utility plant; with plans for renovations in the future. At the moment there are no major challenges that await the project team due to size and location of the site.

Analysis #1 focuses around the implantation of a cellular beam design for the roof and floor systems of the Physical Plant of the project; originally the roof design involves additional work to allow the cellular beams to support the 180ft span which can cause schedule delays if not monitored. Tasks involved with this analysis involved the implementation of a structural truss system in place of the current roof system and a replacement wide flange beam system for the floor. Overall the system change will save **$4 Million** but would increase the schedule by **45 Days.**

Analysis #2 focuses around the potential safety threat of the original trade sequencing within the fuel tank rooms inside the Central Utility Plant. During the early stages of scheduling, an active concrete pit was planned to be placed while steel erection occurred overhand. Tasks involved within this analysis involved a cost analysis of contracting the concrete subcontractor to perform work during the second shift, causing the workers to be accommodated with a time and a half pay rate. By allowing the concrete work to be performed after regular work hours with overtime pay will increase work within the area by **$8,000**.

Analysis #3 focuses on the addition of a photovoltaic system to the southern façade of the Administration / Academics Building to help reduce overall consumption from the city's power grid. After performing the research related to a typical photovoltaic panel design, panel selection, inverter selection, etc., the overall cost of implementing a system to benefit from the architectural features will cost **$497,000**, save **$4,500 annually**, and take approximately **108 Years** to pay the original investment back.

Analysis #4 focuses on the idea of schedule and cost savings from repetitive work by exchanging the current precast concrete panel façade along the shorter ends with insulated metal panel façade. After consulting with industry professionals holding experience with New York City construction, it was determined that changing the systems will increase the cost by approximately **$2,000,000** and increasing the project schedule by **59 Days**.

This report details the New York Police Academy Project as well as each Analysis summarized above.

Staffing Plan

Turner Construction and SVT are currently involved in a joint venture for the project employing both a preconstruction team and primary construction team. Since this project is consited of a joint venture, the project staff may be modified from its general apperance. Joint ventures are usually formed for large projects to help share the risk involved; the actual project team will likely be larger and contain more divisions than what is normally experienced. Due to this, the below diagram represents the overall team in general terms instead of a typical "personalized" staffing plan diagram.

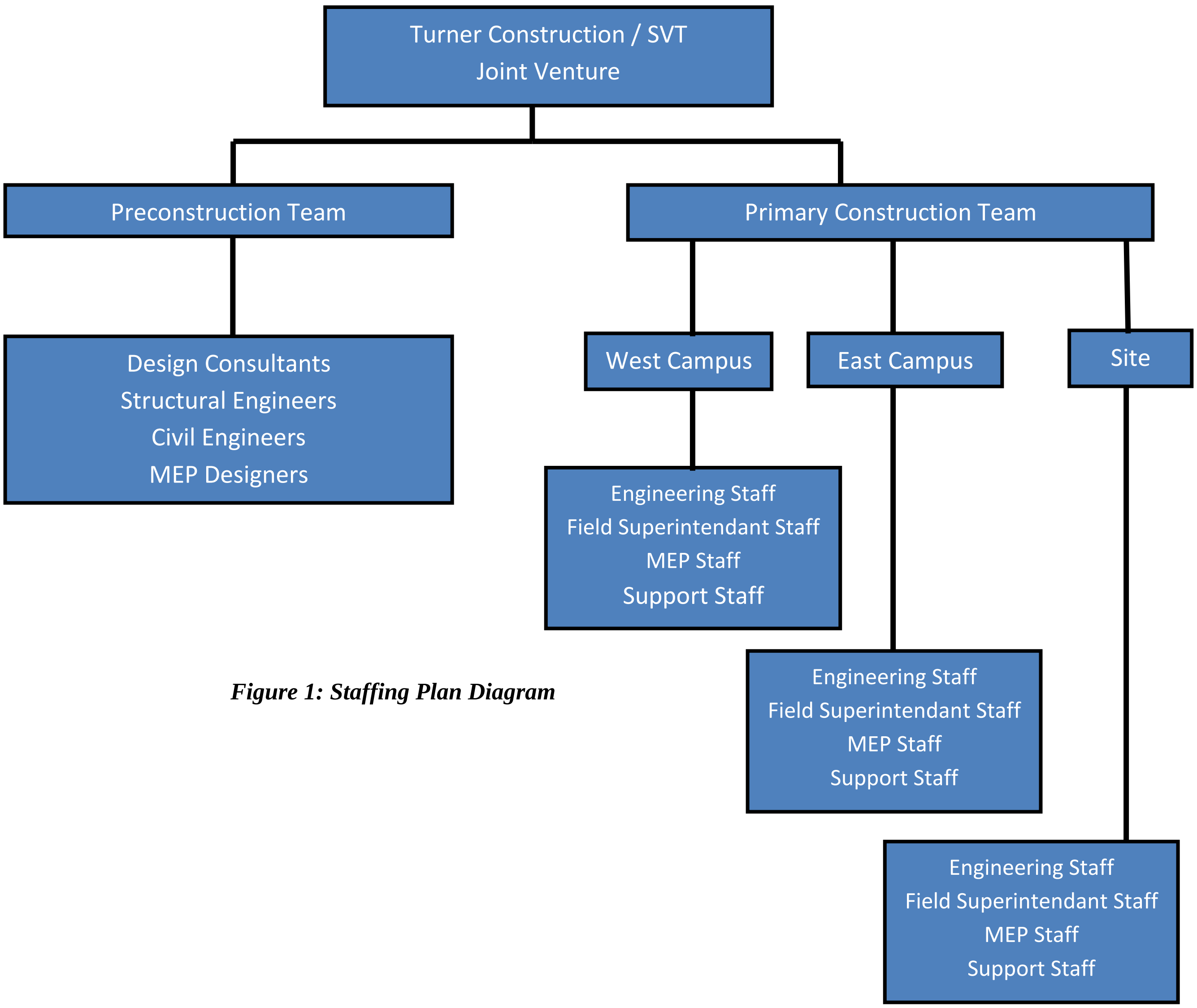

Figure 1: Staffing Plan Diagram

Project Delivery System

New York City Department of Design and Construction typically purchases all contracts with 100% construction documents, which is Design-Bid-Build in nature. Due to the lengthy duration of the build and the political terms of the current administration, the City of New York contracted Turner Construction to help modify the document delivery system to a “modified fast track”. Early packages for piles, foundation, structural steel, curtain wall system, mechanical, electrical and plumbing were released. After the early packages were distributed among early bidders, Turner would then create scope documents to delineate work and fill in missing information on the drawings related to scope. However, at the time of this report, no contracts have been issued to any contractors. See APPENDIX A for a complete list of consultants and engineering firms that were involved with the design and construction.

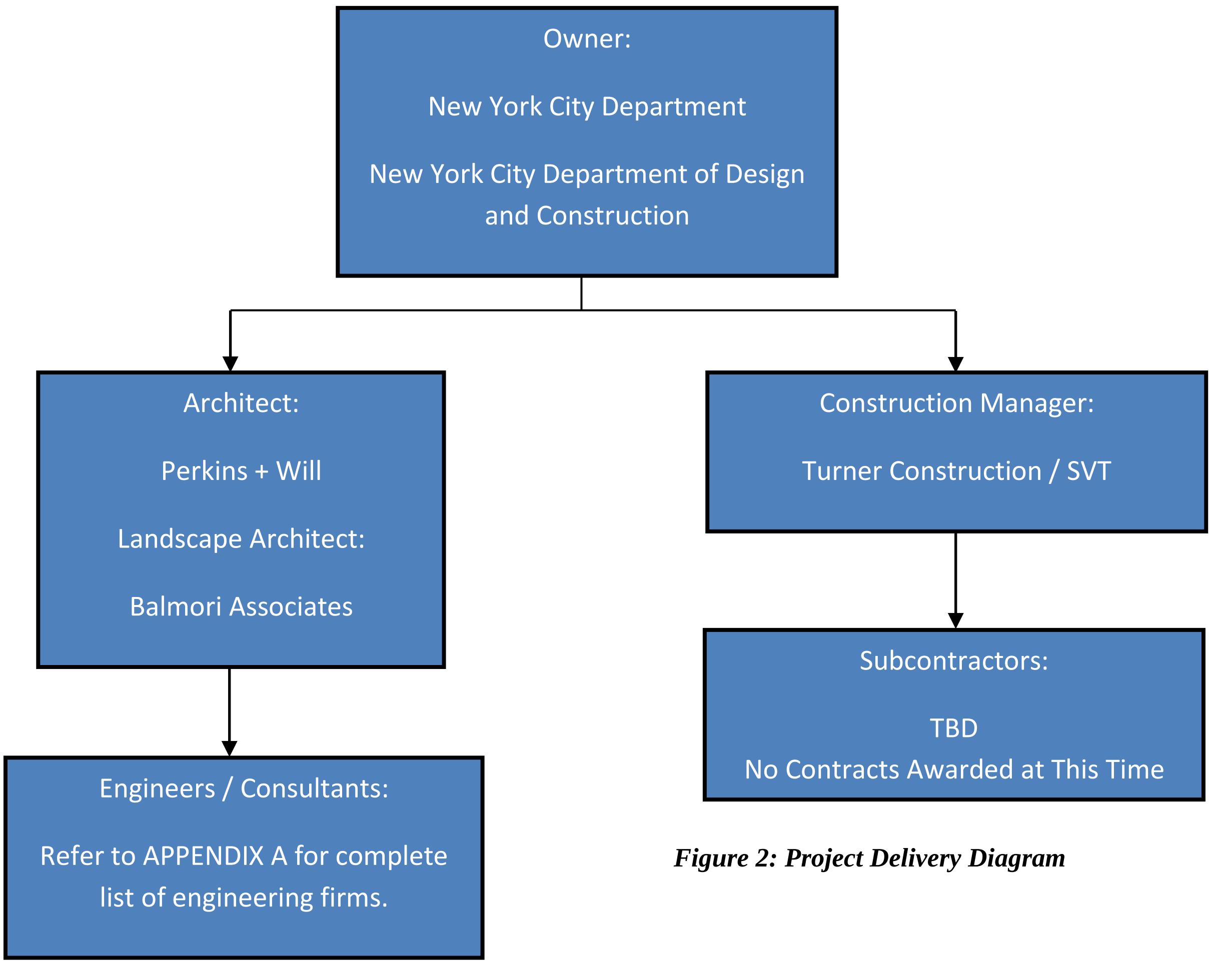

Figure 2: Project Delivery Diagram

Client Information

New York City Department of Design and Construction and New York Police Department are the primary owners of the project with New York Police Department being the primary occupant. Currently, the law enforcement of the NYPD is currently trained in five separate facilities, one in each of the major bureaus. With this in mind, the overall purpose of the project is to bring together all the facilities to one central facility; this will allow a more efficient method to perform the law enforcement training. Original designs allowed for a complete facility to be constructed that ranged from academics to tactical and firearm training, but due to funding the project was redesigned to allow for the construction of an academic/administration building and the central plant/physical training facility with plans for the additional training facility. Consultants of all kinds were brought on to ensure that the best possible project be constructed. The original master plan for the project can be found at the New York City website (www.nyc.gov).

As mentioned, funding was an issue with the project and the owners are very diligent in estimates and costs. To ensure that the cost is controlled on the project, special measures and procedures are in place to verify all estimates and costs. To counteract the effect that cost control can have on the quality of the project, the owners have also decided to perform inspections through a confidential third party. Schedule specialists from a third party consultant are employed by the owner to help aid the construction team with keeping the party on track.

The owners expect the a safe project by complying with OSHA as well as any site specific protocols that are enforced by either the general contractor or construction manager. A key in the overall safety plan is dealing with all subsurface conditions, due to the land being a former landfill before being implemented as an impound lot. Once contractors and subcontractors become contracted for the project, the owners require them to provide their safety plans before being allowed to work. Owners then review and approve the individual safety plans to meet the minimum requirements detailed by OSHA.

Site Plan of Existing Conditions

See APPENDIX B for Existing Conditions Site Plan

Figure 3: Bing Map of New York Police Academy Site and Surrounding Area

The site for New York Police Academy is located in College Point, New York on the former NYPD's College Point Tow Pound which is approximately 35 acres in size with face fronts along 28th Avenue and Ulmer Street. To the North on the other side of 28th Avenue lies the MTA Bus Facility and The Crystal Windows manufacturing facility to the South along 31st Avenue. Directly to the right of the site, lies a church facility that runs along the drainage ditch that is seen in the above image. All primary utilities have easy access into the project via surrounding roadways and structure complexes. Pedestrian and vehicular traffic is not of concern due to the privately owned land and somewhat secluded area outside of the busy streets of New York City. See APPENDIX B for the existing conditions site plan detailing utilities, traffic patterns, and general building footprint.

Local Conditions

New York Police Academy is located 28-11 28th Avenue, College Point, New York. Surrounding the project is the old neighborhood of College Point. College Point is currently going through a zoning revival, known as the Urban Renewal Plan, and is home to several different zoning sections ranging, commercial, industrial, manufacturing, transportation, utility, and public facilities.

College Point's zoning had to be modified to allow for New York Police Academy to be constructed due to the project site consisting of several different zoning areas. During design, the area was designated as M1-1 and M3-1; M1-1 allows for an open area after construction but restricts many construction processes while M3-1 allows for heavy construction but requires the final project to be enclosed to protect public issues. Through modifying the current zoning code, the project was given a zoning of M2-1, which allows for construction that causes noise and vibration but does not need to be enclosed after completion.

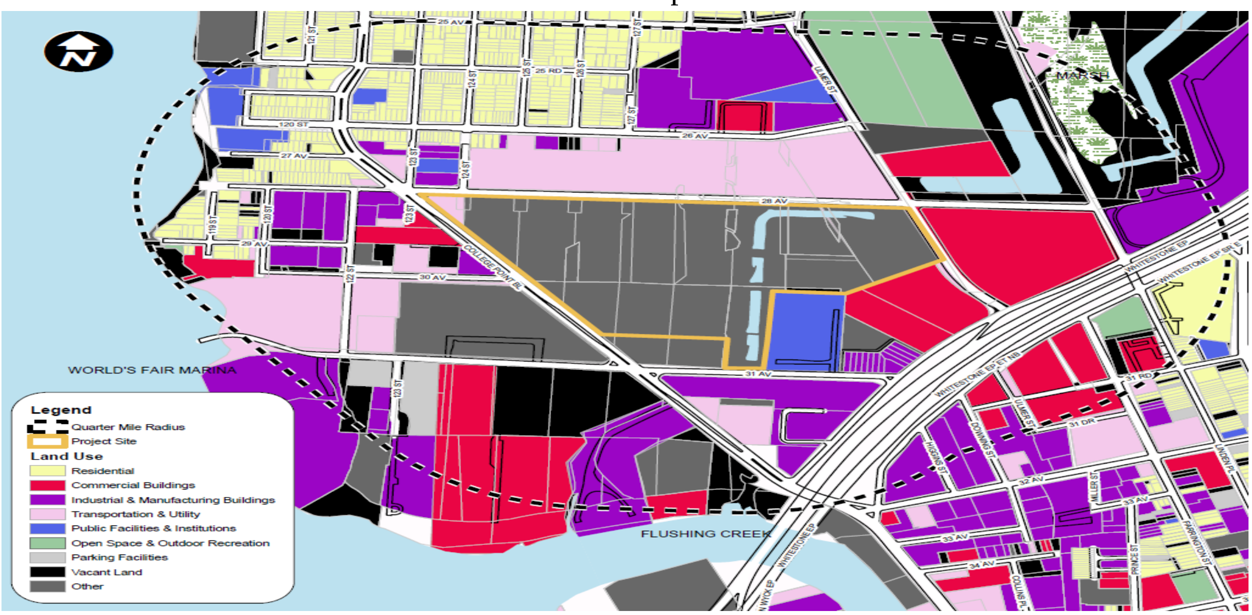

Figure 4: Zoning Map of College Point, New York

According to reports, the site used to maintain a landfill and such is expected to settle after construction. To ensure that this does not happen, pile caps were required to be installed; one of the main factors to change the zoning, since driving piles causes high levels of noise and vibration.

Many project managers and superintendents will say that the biggest hurdle to jump while working construction in New York City is that material storage and onsite parking is either limited or nonexistent. Due to the large size of the site, 35-acre, and the size of the actual project, 720,000 square feet, onsite parking and material storage is available which is a rarity for the area.

Building Systems Summary

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

Table 1: Building Systems Summary Checklist

****NOTE: At the time of this report, no subcontractors were contracted for the project. Some items such as equipment are unknown at this time. Typical items are assumed based on other projects in the field.***

Demolition

Demolition work for the project will consist of removing any concrete, asphalt, structures, or any other man-made object that is within the designated construction project. Since the site is a former landfill, any demolished material that has traces of hazardous components will be disposed of according to state law of New York; any material that is recyclable will be.

Structural Steel Frame

New York Police Academy was designed to use a traditional structural steel frame system to support all the loading from the project. Like most buildings and complexes that utilize steel frames, New York Police Academy's steel frame is consisted of a hybrid system between a braced frame and rigid frame. For example, the Administration Building supports moment connections, causing to behave like a rigid frame, along Column Lines A1, A4, and A5. This pattern tends to run along the East-West direction of the building while the braced frame design appears along one bay section that runs from North-South. Bay sizes run on average of fifteen (15) and thirty (30) feet in the Administration and Central Plant, respectively. Even though both buildings appear to form a general box shape, allowing for an easy installation for the steel system, the Administration Building is designed with some irregular installed pieces. Along the eighth floor and mechanical penthouse, the Administration Building shows off many angular connected pieces; these help grant shape for the auditorium that is located on the upper floor as well as some of the mechanical penthouse that is in place. Both Administration and Central Plant's steel system is made of mostly wide flange steal members, but the Central Plant supports a castellated and cellular beam. These unique beams are crafted into two pieces that are later welded together; what makes them so special is that they have precut hexagons (castellated) or circles (cellular) in their design. This allows for easy collaboration with mechanical system piping and ductwork; as well for any electrical or low voltage conduit.

Composite decks represent the general support system for not only the floor system, but the roof system as well. New York Police Academy's composite deck system is comprised of metal decking, 4000 psi concrete, 6x6 W2.1xW2.1 welded wire fabric with a ¾" clear from the metal decking, and #4 rebar along the top when necessary.

All steel frame erection is assumed to be completed with a high-capacity mobile crane; in circumstances involving heavy or complicated lifts, two cranes will be used.

Cast-in-Place Concrete

Reinforced cast-in-place concrete is the primary system in use for the foundation pile caps, foundation walls, shear walls, grade beams, slab on grade, and all top layers of the composite decking. There is no general formwork needed for all the foundation cast-in-place concrete due to the condition that the ground soil is used as basic formwork; special care is needed to ensure that all foundation trenches and pits are excavated to the exact measurement. However, the composite decking systems have pour stops installed from the manufacturer to ensure that the concrete remains on the deck during the curing process. All concrete will ideally be placed with the use of a concrete truck and pump.

Precast Concrete

Like similar projects, the precast that is to be installed for New York Police Academy is primarily for architectural appearance. There are two kinds of panels that will be installed throughout Administration and Central Plant; angular and vertical pieces both gray in color. Administration's lower level will support the angular pieces, which act as window awnings on the North and South sides, while the levels above use angular metal panels. Along the East and West sides, vertical pieces are installed.

Mechanical System

There are two primary locations for all the current mechanical equipment, Administration's Mechanical Penthouse and Central Plant. Administration houses mostly air handling units to supply itself with enough airflow to ensure a comfortable environment. There will be a total of nineteen (19) AHU's installed in the penthouses that have a supply ranging from 7500 to 30000 cubic feet per minute (CFM). Central Plant will have thirteen (13) AHU's installed that will range from 6500 to 29000 CFM.

With the updated design being smaller than what was originally planned, extra space is being left open for the addition of future equipment when renovations take place. Cooling loads will be delivered through the use of a chilled water system consisting of four (4) chillers and four (4) cooling towers. To aid the chillers with adequate resources, four (4) chilled water pumps and four (4) condenser water pumps are to be installed alongside the chillers. Future additions include three (3) cooling towers, two (2) chillers, two (2) chilled water pumps, and two (2) condenser pumps. Heating will be provided through five (5) industrial boilers that are supplied by eight (8) fuel oil tanks.

Electrical System

Depending on the atmosphere of the space, New York Police Academy can deploy a variety of luminaire designs, which were designed to be high efficiency to help aid with the LEED rating that is being pursued for the project.

Administration is supplied with power via Central Plant with a primary switchboard rated at 3000 A – 460 V 3 Phase, and a secondary 2500 A – 460 V 3 Phase switchboard. Central Plant obtains its power via the exterior utilities and employs two (2) switchboards rated at 4000 A – 460 V 3 Phase. Intended total load for the building is approximately 9000 kW.

Through the above switchboards, power will be provided to the following equipment scattered throughout the facility: mechanical and fire suppression pumps, Administration's AHU's, Central Plant's AHU's, twenty one (21) 460 V 3 Phase motors, twenty (20) 208 V 3 Phase motors, and several other misc. items.

In case of emergencies, two (2) 2.5 MW diesel generators are to be installed, with two (2) future ones, to provide power for the entire complex if the situation calls for it.

Curtain Wall

There are three different design concepts that make up the exterior curtain wall for New York Police Academy; metal panels, precast concrete, and glazed glass. All curtain wall components are attached to the superstructure via metal tubes that run horizontally along the building. As mentioned in the above precast section, the precast panels will either be a vertical panel or angular panel. Like the precast, the metal panels that are being installed on the North and South side will have similar angular and vertical pieces. Besides the areas with glass, the curtain wall shall be constructed with a water barrier, insulation, and either precast or metal panel installed in that order.

Support of Excavation

Excavation is the key starting point to any project, it allows for the beginning of the building by allowing the installation of the foundation system. However, most sites in bigger cities are crowed from neighboring properties and simple step-backs are not possible. In most cases, contractors usually employ a tieback system, shotcrete, or shoring and sheeting.

Due to the size of the site, New York Police Academy is able to use a step-back system as long as it corresponds to OSHA regulations, usually a four foot high by four foot deep step. A step-back system is when the excavators remove the site in a way that it creates a stepping system along the walls. This allows for a cheaper alternative to the methods listed above by saving on installation and materials.

Site Layout Planning

See APPENDIX B for Site Layout Plans

Figure 5: Bing Map of New York Police Academy Site and Surrounding Area

The site for New York Police Academy is located on the former NYPD College Point Tow Pound in College Point, New York. As shown in Figure One above, construction will flow down College Point Boulevard into the primary entrance to the project site which lies on the west perimeter; two additional entrances run along Ulmer Street to the East, these will primary be used for smaller traffic and deliveries for the East Campus construction. College Point Boulevard will be the primary road for all construction traffic due to the surrounding properties being under a light industrial zoning, and therefore receives little traffic during day hours. There are also several secondary gates surrounding the jobsite that will be used for additional egress and entrance into the site in case of emergencies. Due to thirty-five acre project site, on-site parking is available and will be located on the west side near the trailers. Based on the schedule, the project will consist of two major phases: Foundation / Superstructure and MEP / Interior Finishes.

Foundation / Superstructure Site Layout

****Note: At the time of this report, the majority of trade contracts are still out to bid. Their trailers are included with the Subcontractor Trailers displayed on the site layout plan with their storage area included in the staging area.***

This phase of construction will feature the completion of the pile caps, mat slabs, and structural steel system. Three pile rigs will drive the piles in three separate regions, denoted as Pile Rig #1, #2, and #3, with three separate regions for pile driving. Pile Rig #1 will move from South to North; Pile Rig #2 will move from South to North; Pile Rig #3 with move from West to East and will be accompanied by Pile Rig #1 once it finishes its area. As the pile rigs move along their respective paths, concrete subcontractors will move in and start placing concrete for the pile caps. After all pile caps are finished, the structural mat slab will be placed separated between East and West Campus. To ease the process of placing concrete for both pile caps and slab, a concrete pump truck

At least two cranes will be used to erect the steel skeleton of the project. Crane #1 will be located on the West Side of West Campus and will move from South to North, while Crane #2 will be located on the South Side of East Campus and will move from West to East. It is unknown on what size crane will be used, but a simple 125 ton crane will be efficient since there are no beams over the weight capacity. However, with the size of East Campus, eight stories plus one mechanical, a larger crane will have to be used in order to reach the upper floors; a crane around a 200 ton capacity should have a long enough arm to succeed this challenge. Refer to APPENDIX B for the Foundation / Superstructure Phase Site Plan.

MEP / Interior Finishes

The change from Foundation / Superstructure to MEP / Interior Finishes is present with the reduction of exterior staging areas as well as the removal of the two cranes with their last job consisting of lifting all large mechanical equipment into place. During this phase of construction, the material storage is within the building with denoted staging areas for larger materials. Construction workflow will flow from the North to South via several hoist complexes along the southern side of the buildings as the primary entrances. Refer to APPENDIX B for the MEP / Interior Finishes Phase Site Plan.

Contractor Layout Critique

Turner Construction Company and SVT provided three site plans to aid this report; one being the location of the gates and fencing, pile rig movement and location, and hoist complex locations with trailer location. Items such as staging areas, crane locations, dumpsters, and other items were not identified.

With a basic education on site logistics and the known location of the site trailers, cranes were placed in the most logical spots to service the project. After this process, dumpsters and temporary toilets were placed out of range from the cranes to improve the safety of the site and to attempt in the reduction of incidents. Finally, staging areas were zoned to allow for cranes to have easy access to materials. Both site layouts are provided in APPENDIX B help illustrate the ideas described above in order to finish the planning of the site organization.

Detailed Project Schedule

See APPENDIX C for the Detailed Project Schedule

New York's current police academy is currently spread throughout the five boroughs of New York City. Noted in Technical Assignment One, Design Documents were completed in April of 2010 with the Construction Documents to be completed in December of 2010; with the start of construction to undergo in October of 2010, a modified fast-track delivery method was implemented. Constructing and testing the piles is the key start of the project and relates to the starting activity in the schedule provided in APPENDIX A.

Construction for New York Police Academy will occur over the next four years and achieve substantial completion reports in December of 2013 according to information provided in Technical Assignment One. However, delays must have occurred during the first month of construction due to the identification of several activities not ending until January of 2014. During research for this report, it was noted that the critical path will follow along piles, foundations, structural steel, structural concrete, curtain wall and finally mechanical HVAC.

For ease of organization, the schedule was split into three sections, Campus Fundamentals, East Campus, and West Campus. Campus Fundamentals details all activities that were stated as "Entire Campus" while West Campus consists of all activities relating to either the central utility plant or physical training, and East Campus was any activity that relates to administration and academic. Activities in Campus Fundamentals section consist of items such as demolition, curtain wall, underground utilities, and many more; while the West and East Campus activities consist of foundation, structure and interior finishes. Most of the structural components start early in the East Campus and move over to the West Campus while interior finishes is reverse and starts in the West Campus prior to the East Campus.

The schedule aid provided for this report was consisted of a summary by trades for New York Police Academy. During the organization of tasks based on a time frame, several errors were noted. These errors consist of mostly of tasks being out of sequence based on the start day provided. One key example is that task sixteen (Window Washing) of Campus Fundamentals starts approximately one and a half months before task sixteen (Storefronts / Exterior Glass and Glazing). Task thirty-seven (Ornamental Metal and Glazing) of West Campus is out of sequence as well.

Detailed Structural Estimate

****Note: Due to the overall size of the quantity takeoff performed, Microsoft Excel was used to help manage all calculations. The tables that were configured are NOT presented in this report; however, a brief summary table of the components analyzed is present.***

New York Police Academy uses a complete structural steel frame for is superstructure with pile caps and structural mat slabs for the substructure. Detailed construction drawings were provided but due to inconsistent bay and framing design per floor, a complete detailed estimate was used in place of a typical modular technique.

Due to confidentiality, actual prices for the structure were not released. R.S. Means provides national averages for all types of construction costs, and lists that the structural system of a building will be 12 – 18 % of the construction cost for the project. Twelve percent was used during the structural takeoff which is approximately $70,800,000.

Structural steel members, structural metal decking, concrete, welded wire fabric, and rebar were analyzed in their respectful unit. Once this step was completed, R.S. Means CostWorks software was used in identifying the material, labor, and equipment cost for each item, APPENDIX C contains a complete list of all take-off values for the project. The overall cost obtained from the construction drawing take-offs is approximately $27,000,000. Table One shows the comparison between the "ideal" actual and the estimated cost for the entire structural system.

	Total Cost	Cost / SF
Actual	$70,800,000	$983.33
Estimated	$27,000,000	$37.50

Table 2: Actual versus Estimated Cost Comparison

Table Two summarizes the cost and quantity for each division of the CSI Masterformat that was included in the estimate; while Figure Two represents a percentage breakdown of the respective structural systems.

Component	Quantity	Unit	Unit Cost	Total Cost
032110 – Uncoated Reinforcing Steel	598.19	TONS	$1,595.84	$954,616.50
032205 Uncoated WWF	4,417.16	C.S.F	$37.93	$167,526.18
033053 – Cast-In-Place Concrete	315,178.17	CY	$11.13	$3,508,667.71
051223.17 – Structural Steel Columns	20,747	LF	$152.49	$3,163,635.50
051223.75 – Structural Steel Beams	111,453.5	LF	$130.89	$14,587,845.75
053113.50 – Metal Decking	441,716.3	S.F.	$3.80	$1,677,132.96
			Total	$27,233,424.85

Table 3: Estimate Summary by CSI Masterformat Divisions

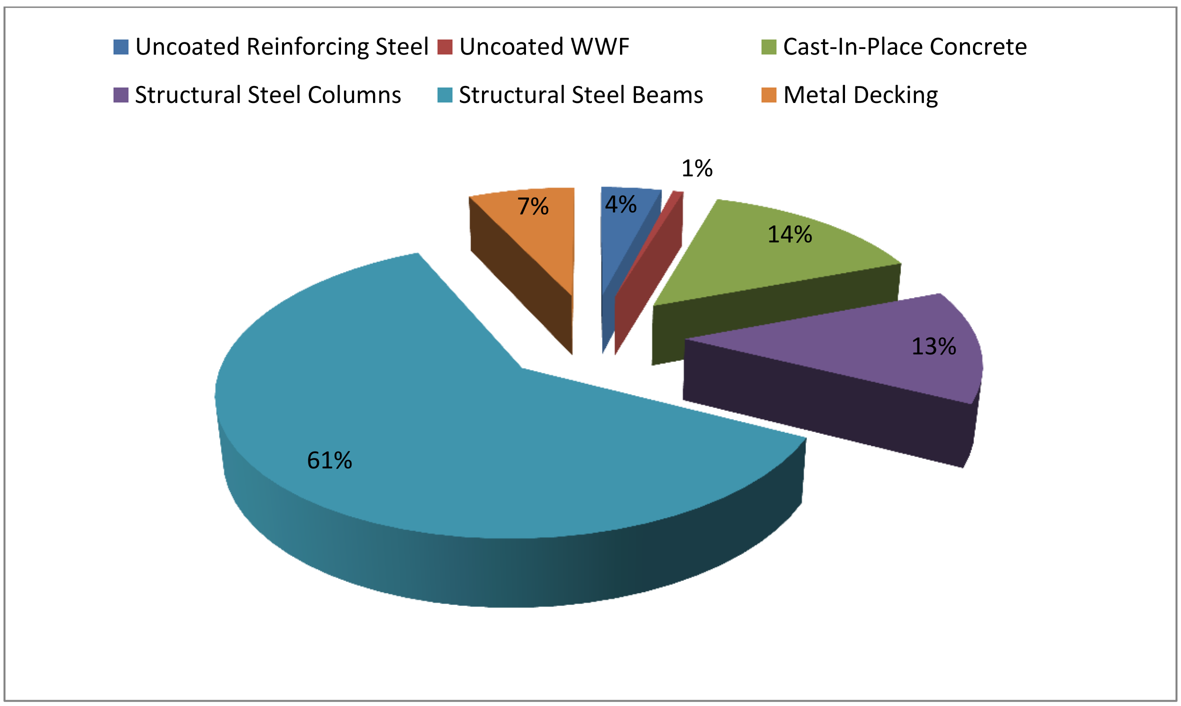

Figure 6: New York Police Academy - Structural System Component Percentages

While using R.S. Means CostWorks, several factors and assumptions were incorporated throughout the estimate in order to provide an accurate estimate. A time modification was used to balance the cost of materials, labor, and equipment due to inflation from 2009 to 2010, however the location was able to be set as Queens, New York to provide an accurate location factor for the unit prices.

Due to the difficulty in calculating the amount of rebar in cast-in-place concrete, a 5% factor was configured to allow for any rebar ties or anchors that were not shown in the construction drawings; a 5% factor was also employed for the welded wire fabric to allow for overlapping and ties. Another 5% was added to rebar and welded wire fabric to allow for construction waste while 10% was added to the concrete. All concrete was assumed to be placed with the aid of a pump truck and chute.

As mentioned earlier, the structure cost of the building was considered confidential and was not released for use; this left several variables unanswered, leading to a 61.86% error with the overall cost. Without knowing exactly what was included in the scope of the structural system caused the error that arose during the take-off estimate analysis for this report. Even though R.S. Means CostWorks software provided a vast array of knowledge, an accurate estimate could not be obtained due to the secrecy of the overall cost.

R.S. Means CostWorks did not provide pricing data for several structural steel beams specified in the construction drawings for New York Police Academy. Roughly 75% of the members listed had pricing available, while the other members had to use the next size up, if possible. In some instances, the larger members could not be accurately priced, and therefore the biggest member available was used. This process that was performed is the second key reason that the structural cost was inaccurate. An example of this would be using the pricing of a W36 x 230 for a W40 x 211.

General Conditions Estimate

See APPENDIX D for Detailed General Conditions Estimate

The general conditions cost was not released for this report due to confidentiality, however it was stated that the general conditions should be around 15% of the construction cost of the project which is approximately $88,500,000. Due to the high level of variables and unknowns, the estimated general conditions resulted in a total of approximately $28,000,000.

Table Three summarizes the total costs of each subdivision within the general conditions estimate that was performed. All values came from either R.S. Means CostWorks, colleagues, or past school assignments and do reflect on the actual costs provided by either The Turner Construction Company or SVT.

Item	Unit	Quantity	Cost / Unit	Total
Supervision and Personal	Month	48.00	$519,883.33	$24,954,400.00
Construction Facilities	Month	48.00	$20,743.75	$995,700.00
Excess Equipment	Month	48.00	$11,850.00	$568,800.00
Temporary Utilities	Month	48.00	$12,118.75	$581,700.00
Permits / Miscellaneous Costs	Month	48.00	$11,895.83	$571,000.00
Total			$27,671,600.00	

Table 4: General Conditions Estimate Summary

The overall estimate was broken into five subcategories: Supervision and Personal, Construction Facilities, Excess Equipment, Temporary Utilities, and Permits/Miscellaneous Costs. Supervision and Personal is consisted of the entire management and support staff for New York Police Academy. A rather large staff was designed due to the mass size of the project and is consisted of a Project Executive, Project Managers, Field Support, and Miscellaneous Team Support. Construction Facilities is consisted of all field trailers, storage trailers, dumpsters, construction fence, office equipment, and office support. Excess Equipment includes the gang boxes, tools, signage, temporary toilets, fall protection, personal protection equipment, fire extinguishers, and medical supplies. Temporary Utilities consist of the connections for power and information technology as well as the usage of power and water and sanitation. Estimating the temporary utilities proved to be not too challenging due the project being all new construction and requiring at least temporary power in order to operate and construct the project. Permits and Miscellaneous Costs is a combination of all permits that are generally required and other services such as progression photos, delivery and shipping expenses, document production, and travel expenses.

Figure Three displays the percentages of the subcategories used within the general conditions estimate. Supervision and personal consist of 89% of the general conditions costs which is typical for many projects in the field.

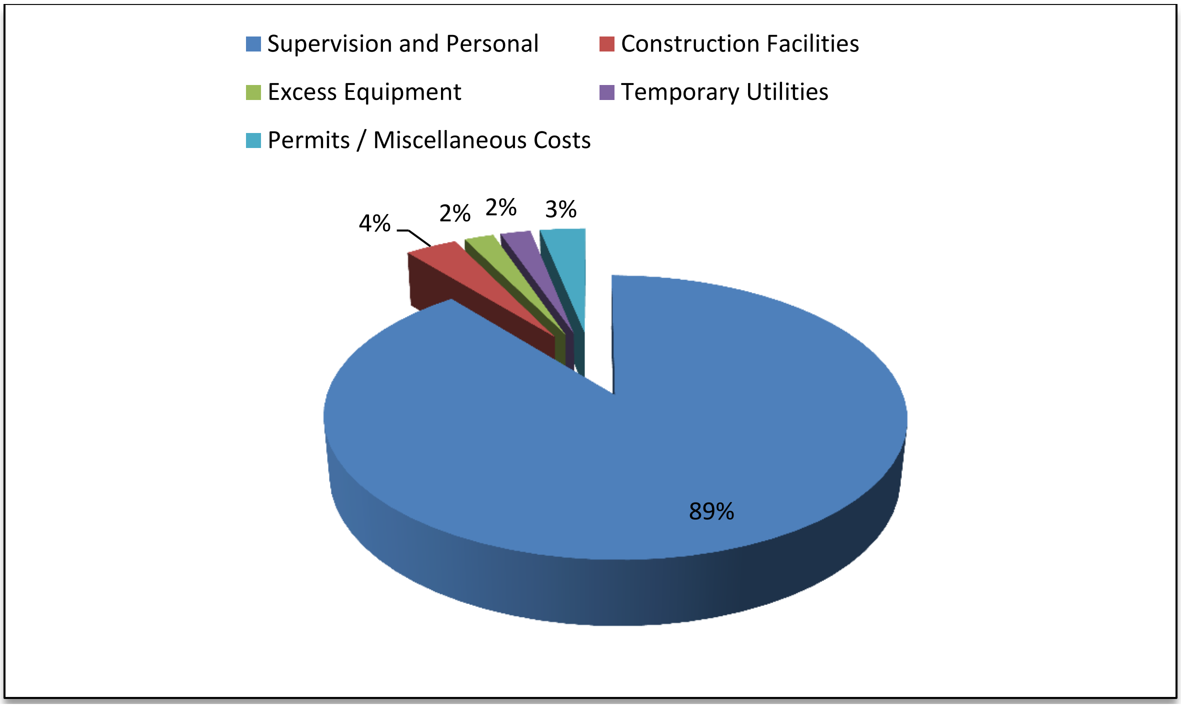

Figure 7: General Conditions Component Percentages

Similar to the structural system described in the last section, the general conditions estimate is inaccurate due to the same reasons. Every company compiles different items within their general conditions, this makes generating an estimate rather difficult when the items in question are unknown. Therefore, R.S. Means and past projects could not prepare a proper general conditions estimate for New York Police Academy due to the overall cost and contents being confidential.

Analysis #1: Redesign of Cellular Beams: (Structural Breadth)

Note: In the original proposal it was stated that the floor system was comprised of castellated beams; however upon further research it was determined that castellated beams were actually cellular beams. Methodology in the proposal was still carried out as described.

Problem Identification

Inside the Physical Training portion of New York Police Academy is an indoor training facility. Areas include tactical training, baton training, and an inside quarter mile track for calisthenics training. Due to the large size of the track, the overall span of the area is approximately 180 feet; with cellular beams supporting both the track and roof system. The indoor track can easily be supported by cellular beams due to the 60 foot span in supporting columns, but in order for the roof system to be properly supported, 8 inch diameter steel piping filled with concrete will be welded to the top flange to increase the overall stiffness of the beams. This process will drastically increase the overall erection, assembly, and cost of the beam system within the Physical Training area.

Research Goal

The goal of this analysis is to investigate the possible replacement of the floor cellular beams with traditional wide flange beams, and the roof cellular beams with a suitable steel truss system to determine the overall impact on the schedule and total construction cost.

Methodology

- Contact Pat Murray from Turner Construction Company to acquire information regarding the design of the castellated and cellular beams, as well as any similar projects
- Calculate overall loading onto beams from designated live and dead loads for the region of construction
- Determine a suitable replacement for the castellated and cellular beams
- Determine overall cost of material, labor and equipment used between original design and new design
- Determine overall schedule impact between the construction time of original design and new design
- Develop a summary of findings between the original design of castellated and cellular beams and the new design of replacement systems

Resources and Tools to be Used

- Pat Murray and other Industry Professionals
- Turner Construction Company / SVT
- AE 404: Building Structural Systems in Steel and Concrete
- Applicable literature

Expected Outcome

After completing research and an in-depth structural design, it is believed that a steel truss system and wide flange member replacement will effectively reduce the structural steel schedule. There is a possibility that the truss system may be more expensive than the original design but the overall savings in the schedule should counter act the addition costs.

Background in Original Design

In order to properly understand the reasoning behind the original design of the floor and roof systems for the Physical Training area, two kinds of research were performed; traditional "text book" style research and an interview with Yegal Shamash from Robert Silman Associates, the structural engineer of New York Police Academy.

Cellular beams are constructed from traditional wide flange structural beams and follow the below construction method:

- Cutting mechanism moves horizontally across the web of the wide flange members
- Semi-circle shapes are cut out as the cutting mechanism moves horizontally across the web of the wide flange beam forming two separate WT members
- Both members are then welded back together, creating a deeper member than the original wide flange beam

Overall, the cellular beams become approximately 1.6 times as deep but overall strength is increased by approximately 2.5 times; however, this process increases the overall labor per member, and with that the overall cost of each member will increase. Currently there are 156 cellular members planned to be installed within the Physical Training Facility.

Figure 8: Cutting of a Cellular Beam

During the interview with Yegal Shamash, the overall design of the area was discussed. Yegal mentioned that this area's design is based strictly upon the overall function of the area, the indoor track. Key factors of the design are the overall span of the roof system and the location of several classrooms below the indoor track. Another trait of cellular beams that was identified by Yegal, is that cellular beams do not allow noise or vibrations to transfer through the structure of the building as easily as more traditional designs. For the floor system, cellular beams were chosen to meet the strict vibration requirements. Cellular beams were chosen to allow for simple coordination within the roof system by providing easy access for piping and/or duct-work to easily maneuver across the open ceiling space without the need of expensive in-field splicing. Yegal stated that the only possible replacement that could have been implemented into the design was a structural truss system, but would increase the square foot of curtain wall that would need to be installed; causing the selection of the cellular beams.

Structural Impact

See APPENDIX E for Hand Calculations of Structural Redesign

In order to properly determine a suitable replacement for the floor and roof systems, fundamentals from the course *AE 404: Building Structural Systems in Steel and Concrete*, taught at The Pennsylvania State University, were implemented; this allows for the understanding of basic structural design for non-structural options.

Roof System Redesign

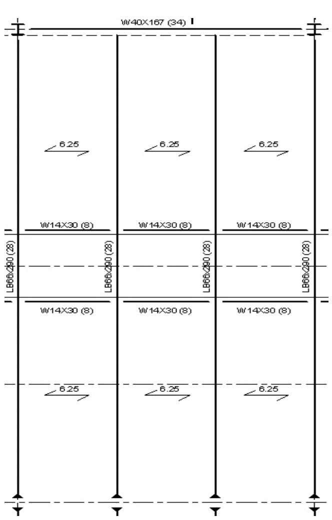

Figure 9: Portion of Cellular Roof System

The roof system of the Physical Training area is consisted of three (3) cellular beams connected end-on-end via high strength connections with eight-inch steel pipes, filled with high strength concrete, attached to the bottom flanges of the cellular beams to increase in overall strength. According to an interview with Pat Murray during earlier research, the process will increase field labor and quality control on each composite beam, causing an increase in cost and schedule time. To aid in the selection of a possible replacement, these two factors must be kept in mind. A structural steel truss system was chosen to replace the roof cellular beams; this will allow other trades to easily be integrated with the structural system. The image to the left displays a bay of the span, approximately one third, and the cellular beams are denoted as LB66x299 on the respected drawings.

During the early stages of design, several factors were identified as key starting blocks; overall loading of the area and beginning steps for structural truss design. Upon conversations with industry professionals, a key place to start was to identify how deep the overall truss system and divide the overall loading by that depth to get a "feel" for the overall loading onto members, which was calculated to be approximately 12ft; which was later confirmed by Yegal Shamash to be reasonable when comparing to early design ideas. With this in mind the following factors were considered in determining overall loading for the roof system:

Live Loads

- Design Roof Live Load = 10 PSF
- Snow Load = 30 PSF

Dead Loads

- Built-Up Roof = 20 PSF
- Decking and Concrete = 37 PSF
- Superimposed Dead Load = 20 PSF

Due to the low value identified for the live load, a typical live load reduction calculation was not performed. Total loading was determined to be **122 PSF**. By looking at the tributary area of each composite beam, 10ft x 180ft, a load of **1.419 klf** was applied to the 180ft span

A typical truss design was implemented with the use of basic fundamental engineering mechanic courses; below is an image that represents the truss design that was performed for this analysis. In order to identify the loads within the members, the software *RISA-2D Educational* was used. Before all tests were performed, discussions were held with fellow colleagues in the structural option to determine possible member identification; at which point it was determined that that **Double Angles (LLBB)** would be used and the description below details the steps involved.

**** Refer to APPENDIX E for RISA-2D Educational Truss Model and Member Loads***

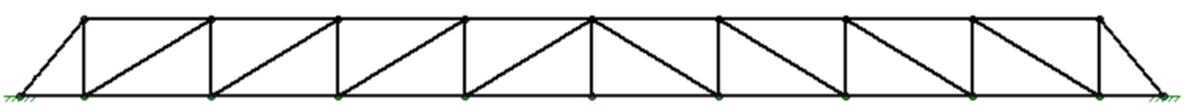

Figure 10: Truss Design for Analysis 1

Upon analyzing the data provided by *RISA*, the largest force present was **406.667 kips.** This number was then divided by 36 kips/in^2, F_y of A36 steel, to determine the required gross area, **11.29 in^2**, to identify the possible member sizes. Member sizes for the horizontal, vertical, and short diagonals on the end were determined to be **2L8x6x7/8** which had a gross area of **23.1 in^2** and met the required axial loading listed above.

For the long diagonals throughout the design, the largest force present was **165.988 kips**. Again, this number was divided by 36 kips/in^2 to calculate the required gross area of **4.61 in^2**. Initially **2L5x3 ½x5/16** were chosen but did not met the axial loading requirement and were adjusted to

2L5x3 ½x3/8 to support the axial loading and had a gross area of **6.10 in^2**, which met the gross area requirement as well.

The above members were determined from the AISC Steel Manual from the following tables

- ***Appropiate area derived from Table 1-15 for both member selections***
- ***2L8x6x7/8 strength sizing derived from Table 4-9***
- ***2L5x3 ½x5/16 and 2L5x3 ½x3/8 strength sizing derived from Table 5-8***

When looking on each individual span, the weights of the original design and new design were analyzed to determine if the supporting members could be downsized. Each truss will weigh approximately 40,000 lbs. or 20 tons each, while the original composite beams will weigh approximately 54,000 lbs. or 27 tons each. Through basic calculations, represented in APPENDIX E, it was determined that the truss system will produce a moment of **1480 foot-kips** onto the supporting members. Based on Table 3-2 of the AISC Steel Manual, a **W18x175** will support the new design due to the max moment value of the W18x175 equaling **1490 foot-kips**, greater than the required 1480 foot-kips. Original design requested W40x167 to be installed to support the composite beams; by replacing the beams with a smaller depth member, the overall cost of the structural steel package will decrease.

Floor System Redesign

Similar to the roof system of the Physical Training area, the floor system employs cellular beams to support the loading from the above indoor track. Unlike the roof system, steel pipes filled with concrete were not required to help strengthen the beams due to the span between columns is only 60ft, unlike the 180ft span for the roof system. The image to the right displays a typical bay of the system, with the cellular beams being denoted as LB66x199 on the respected drawings. Again all hand calculations can be found in APPENDIX E.

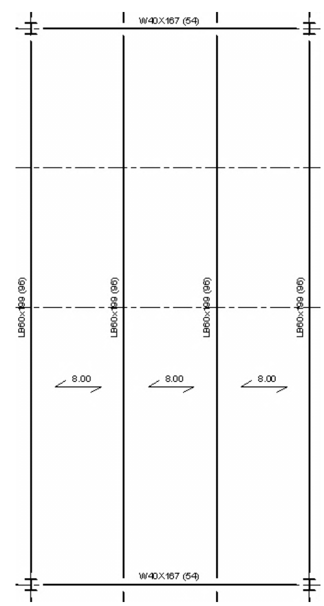

Figure 10: Bay of Floor System

To identify a wide flange beam that had the needed properties to support the floor system, a different approach had to be performed compared to the above analysis. First step was to identify the approximate loads that would be applied and are listed below:

Live Loads

- Design Assembly Live Load = 150 PSF

Dead Loads

- Decking and Concrete = 37 PSF
- Superimposed Dead Load = 25 PSF

Due to the large live load that is applied, it is safe to assume that the total load will not always be present and a live load reduction can be calculated. In order to calculate the live load reduction, the tributary area, 60ft x 10ft, must be multiplied by 2, K_T factor, and if the resultant is greater than 400, then the load can be reduced. The two following equations will be used in determining the loading on the beam span:

$$L = L_0\left(.25 + \frac{15}{\sqrt{A_T K_T}}\right)$$

Where L = reduced live load, L_0 = initial live load, A_T = tributary area, and K_T is a constant factor equaling 2. Knowing L_0 and A_T, L can be calculated to be approximately **102 PSF**.

$$w_u = 1.2D_L + 1.6L_L$$

Where w_u = distributed load, D_L = dead load, and L_L = reduced live load. By knowing D_L and L_L, w_u can be calculated to be approximately **2.383 klf**. This leads to an overall moment of approximately **1072 foot-kips** resulting in a beam size of **W24x104**; smaller than the designed cellular beam. The W24x104 and floor loading will result in an overall moment of **1210 foot-kips** onto the supporting member; this allows for the member to be reduced from the originally designed W40x167 to a **W24x117**, causing the overall structural steel cost to be reduced as well. Each beam was selected from Table 3-2 of the AISC Steel Manual.

Cost Impact

Refer to APPENDIX F for Detailed Cost Data Regarding this Analysis

All values are obtained from RS Means: Building Construction Cost Data 2011 with a multiplier of 1.10 for base material and base equipment cost, and a multiplier of 1.60 for base labor cost for construction work in Queens, New York.

To fully understand the cost impacts of the new design, several items were taken into consideration. There were several items that were not analyzed during the several quantity takeoffs that were performed and are listed below:

- Roof materials – not changing between designs
- Floor materials – not changing between designs

The items that were considered during the takeoffs of the roof system are as follows:

- Structural truss members
- Supporting beams for structural truss system and floor system
- Increase materials for addition of curtain wall from implementation of truss system

- Cellular beams from original design
- Supporting beams for cellular design
- Steel piping and concrete for added strength to cellular design

After performing all calculations through the ease of *Microsoft Excel*, the total cost of the original cellular beam design is approximately **$6 Million** while the cost of the structural truss system is approximately **$4 Million** including the addition of approximately **$550,000** from the required addition of curtain wall area. Overall, there is a possible savings of **$2 Million** if the owner would choose to switch out the cellular beam design for a structural truss design. The table below represents a summary of all the tables relating to the implementation of the structural truss system represented in APPENDIX F.

For the floor system, similar calculations were performed but proved to be less tedious due to the fact that the only item changing was beam sizes. Overall cost for the original cellular beam design is approximately **$3 Million** while the redesigned wide-flange design will cost approximately **$1 Million**, resulting in a savings of **$2 Million**.

Original Cellular Beam System	
Item	Cost
LB66 x 290, Cellular Beam	$3,070,113.28
W14 x 30, Structural Beam	$34,761.51
Steel Pipe, 8" Diameter Hollow	$293,662.01
Concrete, 4000 psi	$2,589,129.69
W40 x 167, Structural Beam	$136,203.12
Total	$6,123,869.61
Replacement Truss System	
Item	Cost
2L8 x 6 x 7/8	$2,838,361.24
2L5 x 3 1/2 x 3/8	$364,424.58
Fabrication / Transportation	$150,000.00
Framework, Aluminum	$407,272.32
Metal Panel, Aluminum	$128,602.08
Vapor Barrier	$25,878.18
W18 x 175, Structural Beam	$47,994.66
Total	$3,962,533.06
Total Savings	$2,161,336.54

Table 5: Summary of Cost Comparison for Analysis

Schedule Impact

If planned accordingly, the installation of the truss system can take place during the allotted time that is currently being assigned to install the current roofing system which is fourteen (14) workdays. This is assuming that two (2) trusses can be delivered and assemble on site per day, and that two (2) cranes can successfully pick and place both trusses within that same day. Even though the truss system can be placed within the original allotted time slot, causing no delay on the critical path, the problem arises with the increased in curtain wall for the Physical Training Facility. According to *RS Means Building Cost Data 2011* duration values, the shortest reasonable time duration for the curtain wall addition is approximately **45 days**; increasing the overall critical path of the project, delaying the schedule by a maximum of 45 days unless additional crew members are assigned to the project to reduce this value. The table below represents the crew size, daily output, and days required for each activity of the new design; while the figure below represents a brief idea of how the activities will be schedule with the overall actual duration of the design. Due to no major system changes with the floor design, it was analyzed that no major schedule changes would happen and the critical path of the schedule will be maintained throughout the project.

Replacement Cellular Beam Design (Truss Implementation)					
Item	Crew Size	Unit	Daily Output	Total Material Amount	Days Required
Truss Assembly (On-Site)	10	EA	2	26	13.00
Truss Installation	10	EA	2	26	13.00
Metal Framing, Aluminum	4	SF	340	8640	25.41
Vapor Barrier	2	SF	500	8640	17.28
Metal Panels, Aluminum Insulated	2	SF	375	8640	23.04
Actual Duration				52	Days

Table 6: Schedule Duration Calculations for Truss Design Implementation

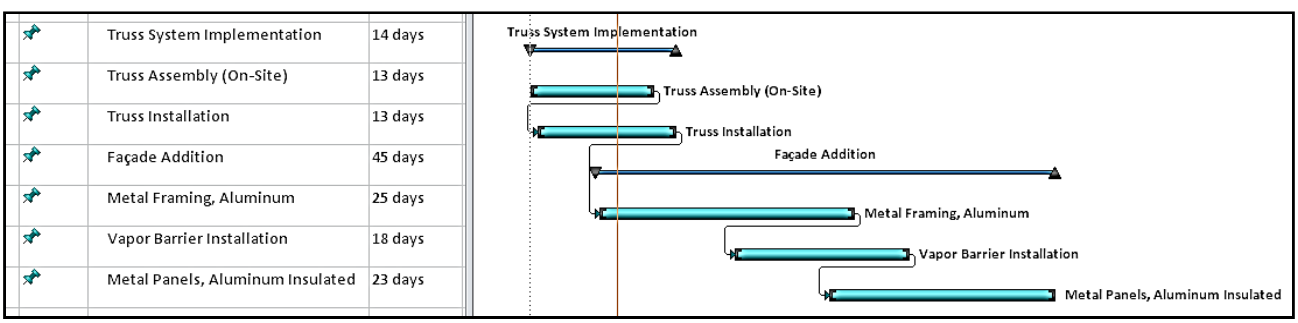

Figure 11: Schedule Layout of Tasks Related to Truss Design Implementation

Transportation

As mentioned in the previous section, a big key in allowing for the truss system to be installed in the original allotted time as the original design is by ensuring that the truss systems are delivered on time. For this analysis the truss systems are assumed to be semi-prefabricated to allow for shorter infield assembly. Due to the fact that each truss, when fully assembled, is 180 feet in length, they must be placed on the trucks in four separate pieces, approximately 45 feet in length, to allow for easy transportation to the site. It is also assumed that the trusses will be assembled in Pittsburgh, Pennsylvania, a town known for steel work and supports several steel fabrication plants within the area; this also provides easy transportation to the job site via several interstate highways. The below image shows the shortest route that can be taken from Pittsburgh to College Point starting with I-76 and connecting to the following interstates throughout the travel, I-81, I-78, I-95, and finally I-678. This route is probably the most efficient route from the assumed factory in Pittsburgh due to the fact that one of the key off-ramps for I-678, the final stretch of the trip, is right by the job site, allowing for easy access.

It is also noted that due to high traffic congestion in the surrounding area, the deliveries to the site either have to happen prior to 6:00 A.M. or after 8:00 P.M. to allow for easy transportation and meet the limited amount of time that drivers can drive during one day. Below is an image from Bing Maps representing the route that will be taken for the deliveries from Point A, Pittsburgh, to Point B, College Point.

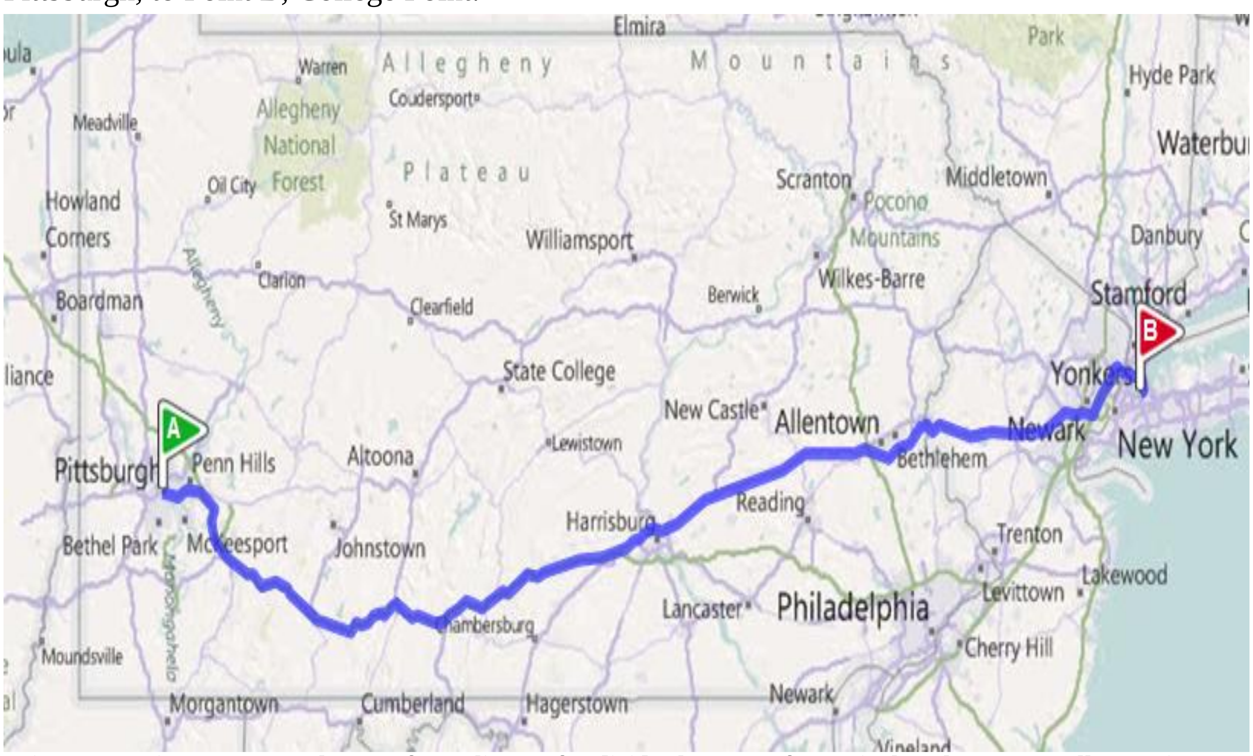

Figure 12: Bing Map Travel Route for Delivery of Individual Trusses from Pittsburgh, PA, to College Point, NY

Conclusions & Recommendations

In conclusion, the tasks performed in this analysis proved to oppose what was initially hypothesized. Originally, the conclusions hypothesized were a reduction in the steel-structure schedule and an increase in cost when switching the design from cellular beams to a structural truss system. While the steel-structure schedule did not change due to predetermined delivery method, there was an increase along the critical path of the project schedule by approximately **45 days** from the curtain wall addition, and the overall cost of the structural truss system, including additional curtain wall costs, came out to be cheaper and will save the owner approximately **$2 Million** from the structural truss implementation and approximately **$2 Million** from the floor system switch.

It is the author's opinion to change some items, while leaving others alone. Implementation of the structural truss system is highly recommended due to the total savings that could be used for other areas of the project that had to be shifted to second phase of construction due to funding problems. However, it is not recommended to change out the cellular beams in the floor system. Reasoning for this is the added benefit of strength, due to possible circumstances of live load being greater than the 150 PSF used earlier, and the ability to greatly reduce the vibrations to the classrooms below.

Analysis #2: Fuel Room Re-Sequencing

Problem Identification

Within the Central Utility Plant lie four separate rooms that contain the fuel oil tanks that supply the fuel to heat the entire facility. Four tanks at 20,000 gallon capacity will be installed during Phase 1 of the facility's construction while four tanks at 15,000 gallon capacity will be installed during the Phase 2 of the facility's construction. At approximately eight pounds per gallon, these tanks, when full, will contribute to a load of approximately 1,150,000 pounds. To countermeasure this force, a double mat slab will be poured in the area. The sequencing of this area consists of placing the first mat slab, steel column erection, and then placing the second mat slab while steel beam erection continues overhead. This sequencing poses many threats to the concrete workers from the overhead iron workers as they are installing structural steel members for the second floor as well as impacts the overall schedule duration of the trades due to the extra safety precautions that are in place.

Research Goals

The goal of this analysis is to perform a restructuring of the project schedule within the fuel tank rooms to shorten the project schedule as well as provide a more safe work environment for both the concrete workers and iron workers.

Methodology

- Interview with Turner Construction Company for sequencing and trade coordination with the fuel room area
- Research the availability of materials and resource leveling to help determine the production capabilities of the trades involved
- Try to contact subcontractors to discuss activity durations and manpower requirements for the fuel room area
- Evaluate findings and develop an updated sequencing for the fuel room area
- Assess impact on overall schedule
- Evaluate the increase of safety within the area, and calculate any possible savings from reduced safety measures of the original sequencing

Resources to be Used

- Pat Murray and other Industry Professionals
- Turner Construction / SVT Project Team
- AE 472: Building Construction Planning and Management
- AE 473: Building Construction Management and Control
- Applicable literature

Expected Outcome

It is expected that the work within the fuel room area can be re-sequenced to allow trades, concrete and structural steel, to perform the required work at separate times. This process will minimize the overall safety risk of the area. At the moment it is unclear if this re-sequencing will reduce the overall schedule and allow an earlier turnover date to the owner; this will be investigated when the proper figures are calculated. With the reduced in safety risk should come a reduce in the cost for overall safety protocols within the area.

Original Trade Sequencing

At the time of this report, and the original problem identification, the sequencing of the fuel room has a high risk of safety hazards. In order to meet earlier deadlines, placement of the second structural mat slab, needed to support the weight of eight fuel oil tanks, was to occur during the erection of the upper floors of the structural steel system. During interviews with Pat Murray, project manager for NYPA, his biggest concern was the safety of the concrete workers during this phase of construction. Pat mentioned that in order to guarantee the safety of the workers, extreme measures of care in the day-to-day operations of the area will have to be carefully observed. To the right is a figure that displays the area that is currently being mentioned. This image is in place to represent the scale of the area that the work will be performed in, take note of the door sizes along the left side of the image. Along the left is an image the highlights the portion of slab that will be placed.

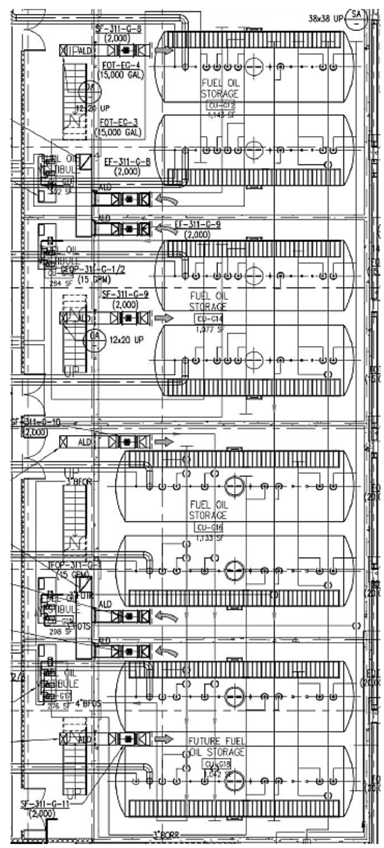

Figure 13: View of the Fuel Tank Rooms

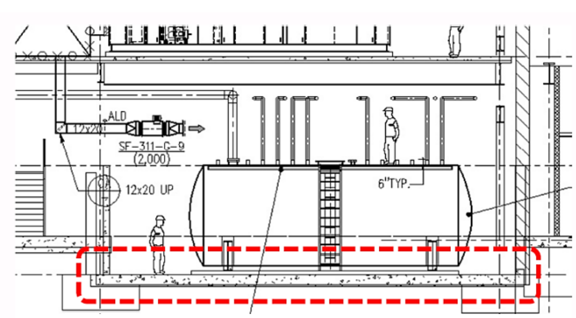

Figure 14: Side View of a Fuel Tank Room

In theory, Turner Construction Company and SVT will have to bring on additional personnel, as a safety crew, and additional equipment onto the project that were not originally planned for. This will cause an increase in overall cost to the owners of the facility due to an increase in change orders to original equipment and personnel costs. Upon recent discussions with Pat and his colleague Jose Class, the overall problem with the situation can be corrected in either two ways which will be explained later in the Proposed Sequencing Section.

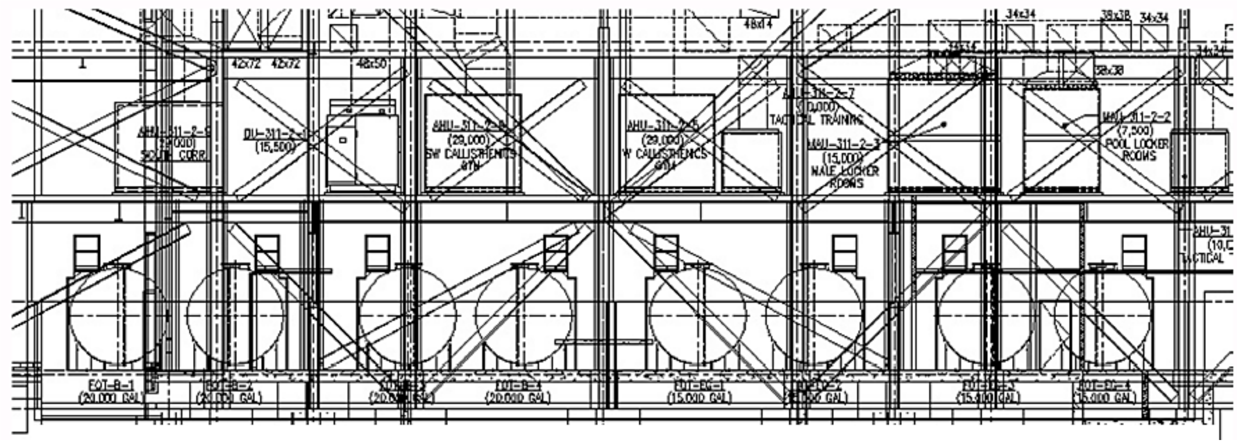

Figure 15: North-South Section of Central Utility Plant Displaying the Structural Steel System Surrounding the Fuel Tank Rooms

OSHA Analysis

To truly understand what is allowed and not allowed to be performed on a construction, one must analyze the requirements that OSHA, Occupational Safety and Health Administration, provides to the industry. These standards cover every activity during the life of a project and demonstrate the proper way to perform each task in the safest matter. According to discussions with Jose Class, he mentioned that all work in this area would focus on the standards related to Subpart R, Steel Construction, due to this being the high-risk activity.

During the research stage of this analysis, an actual OSHA Code Manual could not be acquired; in response to this, the textbook *Handbook of OSHA Construction Safety and Health, Second Edition* was analyzed. This text provides a summarized version of Subpart R, and the following was discovered about performing steel erection over an active work pit:

- Employees are not required to work under suspended loads, except for employees who are engaged in the initial connection of the steel structure

However, the text proceeds to mention that if work is to be performed, the following must happen:

- Materials that are too be hoisted must be rigged to prevent unintentional displacement

- Hooks with self-closing safety latches must be in use
- All lifts must be rigged and inspected by a qualified rigger

Even though the work can be performed in a safe way, the overall project may suffer in time delays and cost increases. Both will be discussed later in the report.

Note: Original plans were too interview the subcontractors to discuss their hazard analysis plans when performing work in this area, but this task proved to be unobtainable due to no contractors being contracted at the time of this report.

Proposed Sequencing

As mentioned above, Pat and Jose mentioned two possible solutions that Turner Construction Company and SVT were analyzing to solve the problem mentioned earlier. Due to the critical path of the schedule, the ideal trade to work with is the concrete subcontractor due to the fact that the addition of the second mat slab will not affect the overall schedule, while any major changes to the steel erection will. Solutions to the problem are as follows:

- Contract the concrete subcontractor to return after all steel erection in the designated area is finished
- Contract the concrete subcontractor to perform all work during the second shift with steel erection taking place during the first shift

Due to the situation that option one will unlikely increase the project schedule or cost, option two will be performed in this analysis to compare the differences in price and schedule, if applicable.

Concrete Work to be Performed

In order to calculate the exact cost and time needed to perform the work on behalf of the concrete subcontractor, project drawings were analyzed for typical scope of work and *RS Means Manuals* were analyzed for time durations and cost information. Below is a list of typical work that will be performed:

- Formwork that will be in place (Assuming that formwork will be used)
- Placement of steel reinforcing prior to pour
- Amount of concrete to be used
- Placing of the concrete (Assuming the use of a traditional concrete pump truck)
- Surface finishing (Assuming the use of a machine trowel)

After analyzing the drawings of the respected area, it was determined that the second mat slab will have the dimensions of 50ft x 120ft x 8in, with #6 rebar spaced 12in on center in both directions along the top and bottom of the slab.

Cost Impact

See APPENDIX F for Detailed Cost Data Regarding this Analysis

All values are obtained from RS Means: Building Construction Cost Data 2011 with a multiplier of 1.10 for base material and base equipment cost, and a multiplier of 1.60 for base labor cost for construction work in Queens, New York.

After running the calculations from the dimensions stated in the previous section, it was determined that approximately 150 cubic yards of concrete would be place, causing 6000 square feet of surface to be finished and roughly 9 tons of reinforcing steel to be erected in place; relating in a cost of **$38,357.87**.

During most construction operations, work outside of the normal work hours is usually compensated by paying overtime wages for the work that is being put into place. By adding a multiplier of 1.50, representing typical time and a half wages, to the Bare Labor Cost column in the *Microsoft Excel* charts in APPENDIX F, the overall cost for the same work is **$46,578.05**. Due to the amount of work that is to be put into place, the rebar placement team will benefit the most from the overtime wages as they will have to work four (4) shifts to erect the 9 tons of rebar, while the other related parties only have to work one (1).

Based on the data above, the placement of the concrete subcontractor onto the second shift increased the overall cost of the work to be put into place by **$8220.18**. However, there is an unknown cost present in allowing the work to happen simultaneously with the steel erection. Key things to keep in mind are the rigging equipment, rigging inspector, and cost of any accidents that can happen.

If rigging were to be denied prior to an expected material lift, a new rigging hoist would have to purchased, and depending on the type can become rather costly. The qualified rigger that will perform the inspection may have a hidden cost as well. Even though there will always be someone on site to inspect the rigging, owners may have a third-party inspector come onto the jobsite and perform the inspections themselves; again, depending on the inspector's overall qualifications and experience, their impact on the overall cost can be unknown. Finally, if an accident would occur, the overall impact on the cost can depend on items such as safety fines from OSHA, workman's compensation, insurance, etc., can bring a cost onto the project that is unforeseen and expensive.

Schedule Impact

Due to the concrete work related to this analysis not being part of the overall critical path, no extensions should take place with New York Police Academy's project schedule.

There is an unknown schedule impact related to the original sequencing of having both trades working side-by-side. Rigging inspections could consume more time than is intended, especially with the large amount of steel that is too be erected over the area in questioned, causing the daily output to slowly dwindle below the rate applied to the project schedule.

Conclusions & Recommendations

In conclusion, the tasks performed in this analysis proved to oppose some aspects of the expected outcome while proving concurrent with others. Originally, the expected outcome was to allow the re-sequencing of both trades to perform the required work and produce a savings in the project cost from reducing the safety measures from the original sequencing. Due to the simplicity of re-sequencing the work by either having the concrete subcontractor perform the work at a later time or during a different shift, **the project schedule will not increase in duration**, delaying turnover to the owner. Overall cost savings from reducing original safety plans could not be computed due to the high level of variables present in the situation; if the concrete work would be performed during the second shift, there will be an **increase in cost of approximately $8000**.

It is this author's opinion to re-sequence the work so that the concrete subcontractor is contracted to perform the work at a later time when the steel contractor is finished in the area. This method will allow a reduction in potential risk of injury, causing a reduction in safety requirements needed, and causing no increase in either the project's overall schedule or cost. To strengthen this argument, during the recent conversations with Pat Murray and Jose Class, Turner Construction Company and SVT are currently pursuing this solution to the problem that was stated earlier.

Analysis #3: Sustainable Design for a Photovoltaic System (Electrical Breadth)

Problem Identification

During the 19th Annual PACE Roundtable, many topics relating to Critical Industry Issues were discussed between students and industry professionals. These topics consisted of Sustainability/Green Building, Technology Applications, and Process Innovation. Upon semester-long research of New York Police Academy, many features of the building were discovered and analyzed. One area that became of interest was the southern side of the building.

New York Police Academy's southern exposure is equipped with a façade design of angular metal panels. These metal panels act as an architectural feature as well as awnings for the windows that are below them which are designed to prevent solar light from becoming an unwelcome disturbance.

Any southern side will experience the most solar light during the day time. With an understanding of this concept from previous classes, a design for a photovoltaic system will be performed. The ideal place is to install the system on the angular metal panels due to their installed angle to block the existing solar light. This design will help reduce the high electrical loads within the building, resulting in a lower operation costs for the owner after turnover and aiding in the LEED Silver accreditation as per design.

Research Goals

The goal of this analysis is to perform an overall design of an integrated photovoltaic energy system and determine the financial feasibility to include the system within the existing power plan to help reduce future energy costs to the owner as well as aid in the LEED Silver accreditation that New York Police Academy is striving for.

Methodology

- Research photovoltaic panel technologies and sustainable design
- Inquire with photovoltaic panel manufactures on design consultation
- Determine the quantity of panels needed to be installed along the angular metal panels and the amount of kWh that will be able to be produced
- After application of the photovoltaic panel system, determine if the structure will need to be upgraded to handle the additional load
- Perform an analysis on life-cycle cost, payback period, and possible energy savings

Resources and Tools to be Used

- Industry Professionals
- Consultants of New York Police Academy
- AE Faculty – Electrical and Sustainable Design
- Former Studio Professors – Architectural Concepts of Solar Design
- Applicable Literature

Expected Outcome

Through the research and design that is to be involved, it is expected that an integrated photovoltaic energy system will provide New York Police Academy a financial benefit in operation costs through the reduction in power grid dependency. Through government incentives, rebates, and life-cycle costs, it is believed that the photovoltaic energy system will provide an affordable and financially beneficial concept to the turnover operation of the New York Police Academy.

Design of Photovoltaic System

During most design phases of integrated photovoltaic systems, the general idea for placement is to face the panels southwards along the roof of the building, this allows for maximum solar gain; for this analysis, the roof was not analyzed but the southern facing façade was. Along the façade are architectural style awnings that prevent solar light from entering too far into the facility. The angular façade is comprised of a structural frame supporting two (2) separate pieces of insulated metal panel; the top piece of is where the photovoltaic panels will be attach and is highlighted in the section view to the right. Based on basic geometry, each panel was determined to have the dimensions of 5ft in length by 2.5ft in width; each panel is angled at 33.22°. With the angle being fixed, typical design methods of determining most efficient angle to collect solar energy were not plausible.

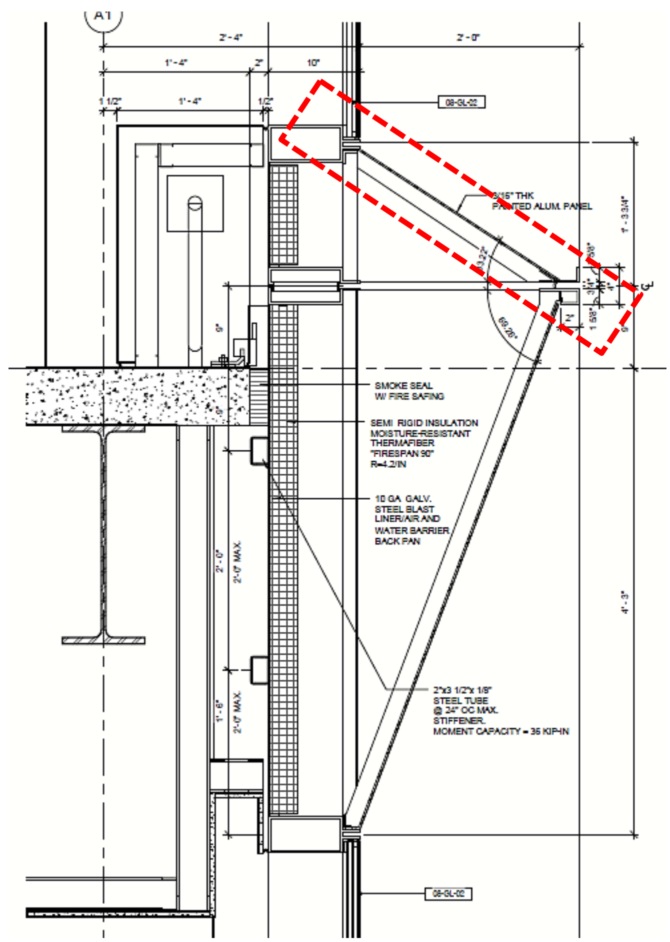

Figure 16: Section of Angular Façade Design

Early concepts revolved around attaching the photovoltaic panels directly to the top panel; this idea was quickly scrapped due to the following reasons:

- The insulated metal panels are too small to support most photovoltaic panels
- With mounting the photovoltaic panels to the insulated metal panel, elevation is increased by several inches, causing an unwanted sight from the interior rooms looking out and for any individuals looking at the southern face

With these two critical design issues in mind, further research was performed into the identification of a photovoltaic panel that could be incorporated into the façade by replacing the top metal panel in the angular design. Upon discussing the situation with Denson Groenendaal, Architecture Instructor for the Architectural Engineering Department, the idea of BIPv was to be researched. BIPv are Building Integrated Photovoltaic and are photovoltaic panels that are designed to behave as traditionally designed but also to replace items in construction such as façade panels or roof sheathing.

Panel Selection

Upon researching several manufacturers in the BIPv world, a panel was finally selected to perform this analysis. The panel that was chosen was the Solar Laminate PVL-Series, Model: PVL-144 manufactured by Uni-Solar. PVL-144 panels are very unique panels in the sense of their appearance; instead of appearing as traditional panel boards, they are a high durable polymer roll, eighteen feet in length. This panel was chosen for the following reasons, with key reasons highlighted:

Figure 17: Image of PVL-144 System

- Extremely flexible
- **Easy to install with high strength adhesive backing and quick-connect terminals**
- **Lightweight, approximately 0.7 PSI *(this allows the weight of the system to be included with Superimposed Dead Load and will have no effect on the structural system)***
- Limited power output warranty: 92% at 10 years, 84% at 20 years, and 80% at 25 years
- Rated power of 144 W
- **Width is small enough, 14.5”, to allow two panels to be applied side-by-side**

**** See APPENDIX G for Technical Data Sheets Regarding the PVL-144 from Uni-Solar***

Uni-Solar was contacted about providing cost of purchasing, installing panels, and a possible critique on the overall design. Due to the fact that Uni-Solar does not personally sell or install, a list of vendors was provided. Upon contacting several vendors, the average price of each individual panel is approximately **$500 a panel**; this information was extremely favorable as some photovoltaic panels can cost upwards to $3000 a panel. At the time of this report, a consultation discussion relating the design of the integrating system for this analysis with the manufacturer could not be arranged.

Location of Panels

In order to determine the number of panels that could be applied to the façade of the southern face of New York Police Academy, a quantity analysis of plausible panels had to be performed. During the early stages of design, each panel was to incorporate its very own photovoltaic panel; this method would allow approximately **300 panels** to be installed along the southern face. With the incorporation of the PVL-144 panels the overall number of panels fell due to the fact that each panel stretches across four (4) metal panels, but can allow two (2) PVL-144 panels to be installed side-by-side. With this in mind, the total number of PVL-144 panels that can be installed is **162 panels**. Provided below are images of the two segments of the southern façade with the location of the panels highlighted in red.

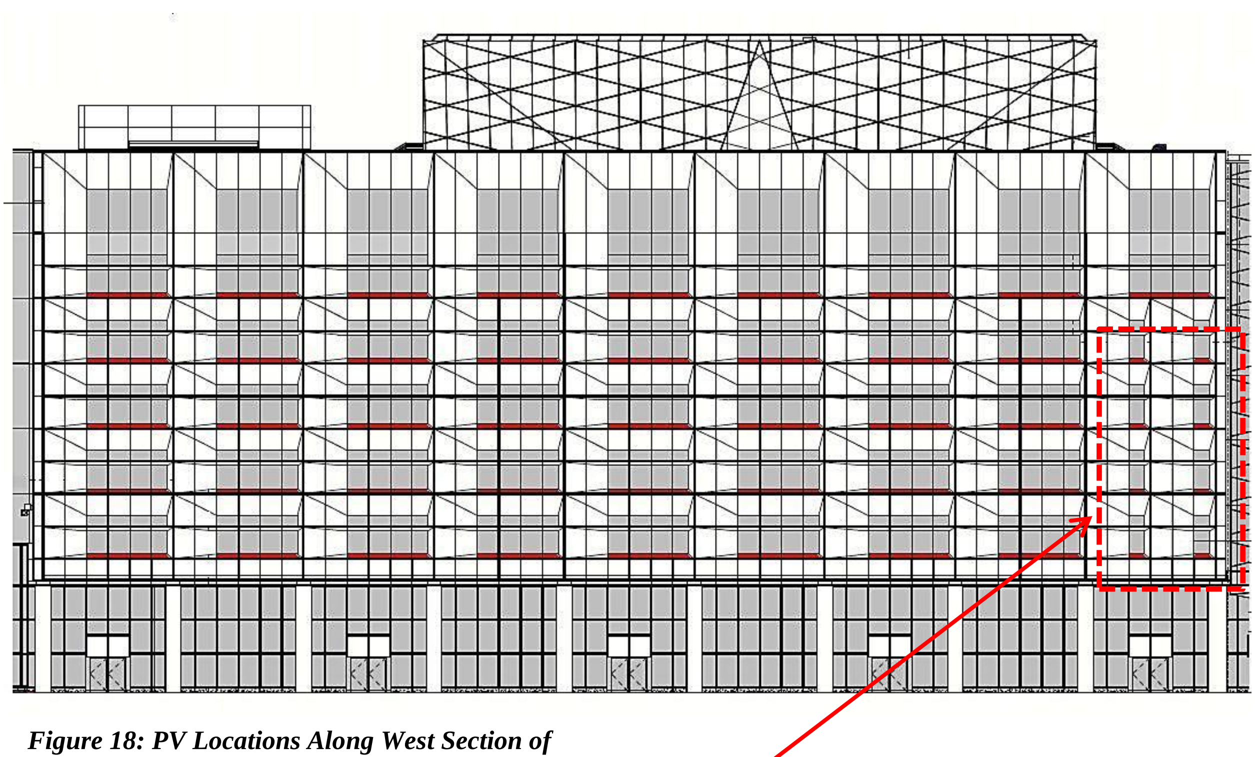

Figure 18: PV Locations Along West Section of Southern Façade

These Eight (8) Panel Locations Allowed for Earlier Design to Commence but are Not Plausible with the PVL-144 Design.

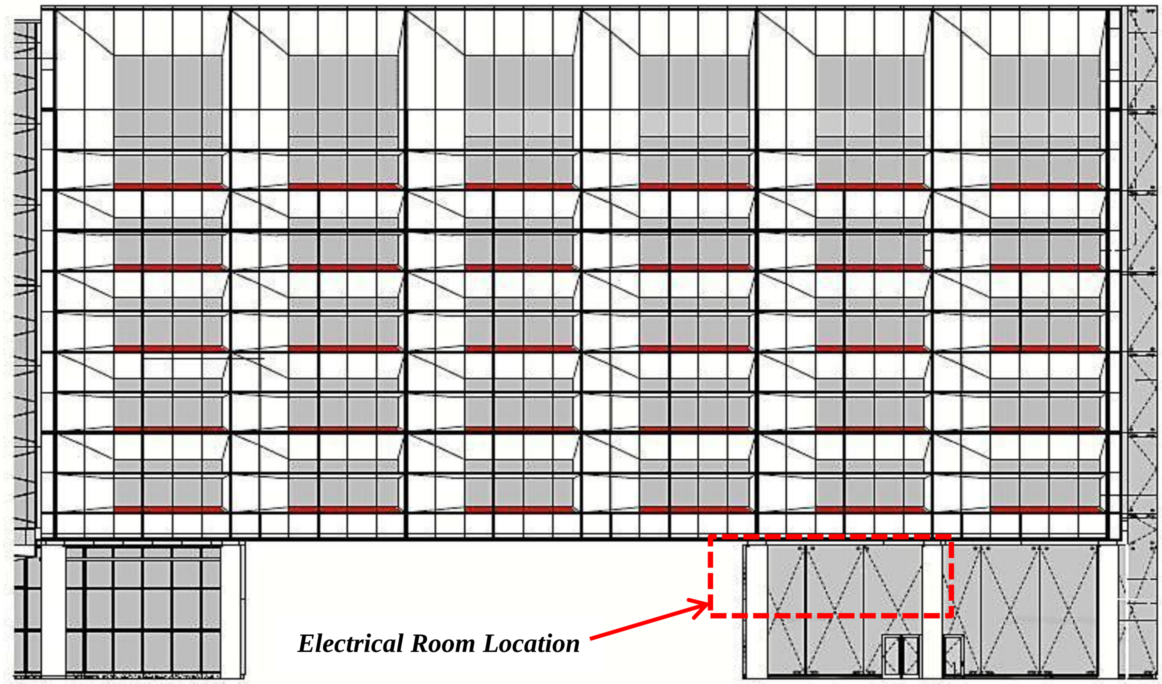

Figure 19: PV Location Along East Section of Southern Facade

Energy Values and Energy Savings

With the known amount of possible photovoltaic panels that can be installed, the total amount of energy that can be produced from the system can be calculated. In order to perform the analysis two (2) separate methods were performed, *PVWatts Online Calculator*, and simple calculations to check the values provided by *PVWatts*. *PVWatts* is a simplistic algorithm in which you input basic information such as location, total system output, tilt angle, solar azimuth, and electricity cost; it will then output tables relating to overall savings throughout the year.

Station Identification	
City	College Point, New York City
State	New York
Latitude	40.78° N
Longitude	73.97° W
Elevation	57 M
PV System Specifications	
DC Rating	23.3
DC to AC Derate Factor	0.85
AC Rating	19.8
Array Type	Fixed Tilt
Array Tilt	33.2°
Array Azimuth	180.0°
Energy Specifications	
Cost of Electricity	14.5 ¢/kWh

Table 7: Algorithm Input Values for PVWatts

Month	Solar Radiation (kWh/m^2/day)	AC Energy (Wh)	Energy Value ($)
1	3.00	1807645.00	$276.66
2	4.03	2169404.00	$332.78
3	4.55	2609996.00	$401.94
4	5.35	2881435.00	$445.15
5	5.51	2990295.00	$463.56
6	6.05	3091197.00	$479.66
7	5.88	3051956.00	$473.57
8	5.66	2964426.00	$458.78
9	5.08	2627448.00	$405.13
10	4.37	2426461.00	$372.80
11	2.79	1539283.00	$236.21
12	2.70	1584089.00	$242.44
Year	4.58	29743636.00	$4,588.68

Table 8: Energy Value and Energy Savings from PVWatts Method

In order to analyze if the *PVWatts Online Calculator* is accurate, a similar method was performed with the use of *Microsoft Excel* for performing calculations and NASA data from *gaisma.com* and the following equation was used:

$$E_O = DI_V P_O \varepsilon_I N$$

Where E_O is the energy output, D is the number of days in the given month, I_V is the insolation value provided from *gaisma.com*, P_O is the panel output in kW, ε_I is the efficiency of the inverter, and N is the number of panels in the system. Once E_O is known, multiplying by the local energy rate will yield the energy cost savings for that month that the system will produce. Overall values proved to be similar.

All values are known except for ε_I, the efficiency of the inverter. In order to select an inverter, the overall system potential must be calibrated; for the 162 panels to be installed, the amount of energy that can be produced is approximately **23.3 kW**. A simple 25 kW or 50 kW inverter could easily support the configuration but due to the high amount of untapped roof space for photovoltaic panels, a 75 kW inverter was selected to allow for future growth. After much consideration, a Satcon PowerGate Plus 75 kW Inverter was selected due to the system allowing for easy system integration, durability, and high efficiency transfer value of 96%.

See APPENDIX H for Technical Data Sheets Regarding the Satcon PowerGate Plus

Solar Radiation Received for College Point, New York												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Insolation, $kWh/m^2/day$	1.7	2.6	3.6	4.4	5.2	5.7	5.6	5.0	3.9	2.8	1.8	1.5

Table 9: NASA Average Daily Insolation Values from Gaisma.com

Energy Output and Energy Cost Savings for Photovoltaic System Integration								
Month	Days in Month	Insolation Value	Energy Rates	Panel Output (kW)	Adj. for Inverter Efficiency	Number of Panels	Energy Output (kWh)	Energy Cost Savings
January	31	1.79	$0.15	0.14	0.96	162	1242.69	$180.19
February	28	2.66	$0.15	0.14	0.96	162	1667.97	$241.86
March	31	3.66	$0.15	0.14	0.96	162	2540.92	$368.43
April	30	4.44	$0.15	0.14	0.96	162	2983.00	$432.53
May	31	5.21	$0.15	0.14	0.96	162	3617.00	$524.46
June	30	5.70	$0.15	0.14	0.96	162	3829.52	$555.28
July	31	5.65	$0.15	0.14	0.96	162	3922.46	$568.76
August	31	5.00	$0.15	0.14	0.96	162	3471.21	$503.32
September	30	3.98	$0.15	0.14	0.96	162	2673.95	$387.72
October	31	2.89	$0.15	0.14	0.96	162	2006.36	$290.92
November	30	1.89	$0.15	0.14	0.96	162	1269.79	$184.12
December	31	1.57	$0.15	0.14	0.96	162	1089.96	$158.04
TOTALS:							30314.83	$4,395.65

Table 10: Energy Output and Energy Cost Savings Based on Equations Above

According to the two methods listed above, the system will net anywhere between **$4,300** and **$4,600** in energy savings throughout the year. Even though this value is rather small in comparison to other systems, the money saved is money that can be used for additional equipment or other operating expenses.

Transferring the Power

In order to benefit from the system, the energy produced from the system has to be able to reach the inverter and then the main electrical switchboard. In order to safely transmit the energy, wiring sizing had to be calculated; other factors that had to be considered was location of the wire within the façade, and the potential for power loss over distance. All wire will be run parallel with the horizontal through the cavities produced from the angular structure. The image to the left displays the ideal area that the cable will be ran.

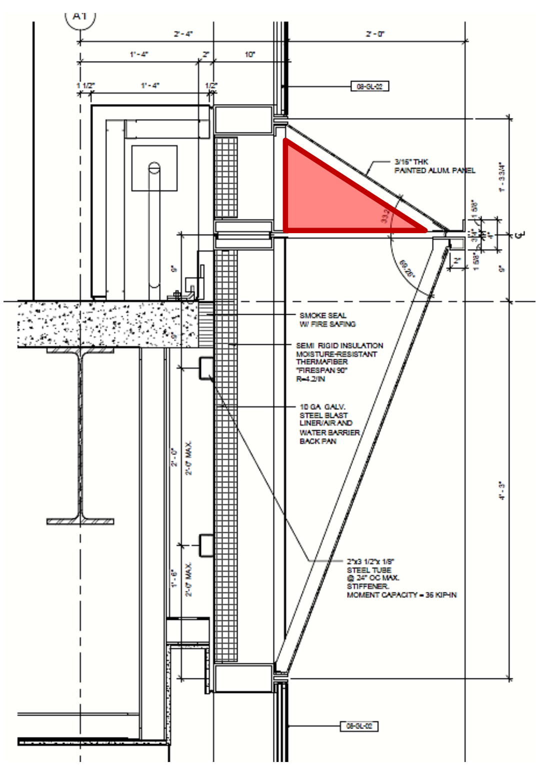

Figure 20: Location of Wire Runs for PV System

Another key factor to determing wire size is the number of panels that will be connected to one another; or in other words the number of panels that will make a string. For this analysis, eight (8) panels will be ran on a string and each string will be ran seperately from one another; refer to the image below representing a string of panels for this design.

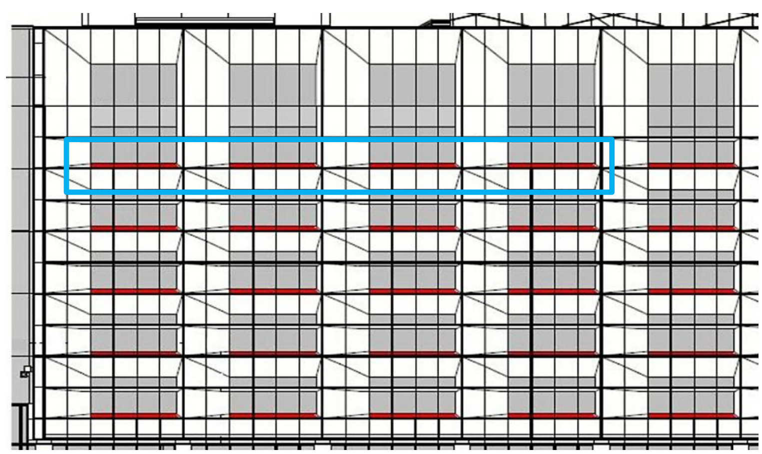

Figure 21: Typical PV Panel String for Proposed Design

Each string will have sixteen (16) current carrying wires present in each run of conduit; based off NEC Table 310.15(B)(2)(a), a correction factor of 0.50 must be applied for any conduit carrying 10-20 current carrying wires. In order to identify the minimal amount of ampacity running through the system, the following equation must be analyzed:

$$A = I_S n * 1.25 * 1.25$$

Where A is the minimal ampacity of the string, I_S is the short circuit current of the photovoltaic panel, n is the number of panels on the string, and 1.25 is a NEC factor that must be multiplied through twice. For the PVL-144 panels, the short circuit current is 5.3 A. By multiplying this value by the eight (8) panels in the string and the two (2) NEC factors, the minimal ampacity for this design is **66.25 A**. With the 0.50 factor in mind from above, NEC Table 3.10.16 is used to determine the size of conductor that will be used. During this design the following two (2) tests were performed:

Wire Size = #2 AWG 130 A * 0.50 = 65.0 A

Wire Size = #1 AWG 150 A * 0.50 = 75.0 A

The #2 AWG wire will not support the 66.25 A current present but the #1 AWG wire will easily support the load provided from the photovoltaic panel string. Finally, to ensure that the wire is sufficient for the strings that are currently the farthest from the location of the inverter; which will be installed on the second floor electrical room outlined in Figure 19, a power drop must be calculated. Currently, the farthest string is approximately 450ft away from the inverter. In order to properly calculate the power drop, Table 8 from Chapter 9 of NEC must be referenced to determine the resistance of the #1 AWG wire, which is 0.160.

Power drop is calculated with the following equation:

$$P_D = C_R \frac{L}{1000} I_{OP}$$

Where P_D is the power drop, C_R is the conductor resistance, L is the length, and I_{OP} is the operating current of the panel, 4.36 A for the PVL-144. By running the calculation the power drop is calculated to be approximately **1.36 A**, which is then multiplied by 2 for two (2) current carrying wires per panel to be given a total power drop of the string to be **2.72 A**. Rule of thumb is that power drop should not exceed 3% of the total power for that string. For the eight panel string, 3% of the total 1152 W is approximately **35 W**; since this value is greater than the power drop, no increases to wire size ampacity are necessary.

Cost Impact, Incentives, and Feasibility

When implementing any kind of photovoltaic system into a building, the one key item that is in mind is the total cost of the system. For this analysis, the four (4) items that were analyzed were the Uni-Solar 144w PV Module, the Satcon PowerGate Plus inverter, #1 AWG conductor, and EMT conduit. As mentioned earlier, vendors provided the pricing of the PVL-144 around $500, but this does not include labor; it is assumed that an additional $500 will be used to cover labor and equipment costs. Upon contacting vendors regarding the Satcon inverter, the total cost of the inverter and installation was approximately **$31,000**. Wire and conduit cost were obtained from RS Means. Overall project cost would increase by approximately **$710,000**.

Several years ago, the federal government started to offer incentives to individuals for integrating green technology into their existing buildings. Some incentives can include covering a percentage of the overall cost, while others may cover up to 100% of the cost. During research for this analysis, it was determined that the only credit that can be obtained is a 30% of Total Installation Cost for systems under 30 kW provided by the federal government. With this incentive in place, the overall cost of the photovoltaic system is reduced from $710,000 to **$497,000**.

Even with the support of the above incentive, it is usually in the owner's best interest to observe the overall payback period for the investment. This relates to how long it will take to produce enough finances from the energy savings to counter act the initial cost of the system. If the system was able to produce $4,600 a year as stated in the PVWatts calculations from earlier, it will take approximately **108 years** to pay off the investment.

Item	Unit	Quantity	Material / Labor Cost per Unit	Total Cost
Uni-Solar 144w PV Module	EA	162.00	$1,000.00	$162,000.00
Satcon PowerGate Plus 75 kW Solar PV Inverter	EA	1.00	$31,000.00	$31,000.00
Conductor, #1 AWG	CLF	510.00	$961.00	$490,110.00
4" Diameter EMT	CLF	65.00	$410.00	$26,650.00
Total Cost of Photovoltaic Panel System			$709,760.00	

Table 11: Quantity Takeoff of Photovoltaic System

Schedule Impact

Due to the simplicity of installation of the photovoltaic panels to the exterior of the façade via the highly durable adhesive, there will be no schedule impact on the overall schedule due to the amount of interior work that must be performed after exterior closure.

Pre-installation of wire and conduit during the phases of constructing the angular pieces would ensure that no extensions relating to the curtain wall duration take place; however, if the curtain wall duration would increase, the total amount would be minimal and should not extend the project schedule past the plan date of completion.

Conclusions and Recommendations

In conclusion, the tasks performed in this analysis proved the hypothesis to be correct, but not in the scale that was initially intended. An integration of a photovoltaic system will reduce the overall consumption from the city-wide power grid but only by a mere **30,000 kWh** per year, roughly **$4,500** in energy savings. The proposed system will cost approximately **$497,000** to install, including incentives, but will take **108 years** to pay back. **No increase in project schedule** should occur with the integration of this system.

It is this author's opinion to not integrate a photovoltaic system through the use of the angular façade on the southern face of the facility. With a payback period of 108 years, the overall facility may not be in use by the time the system is paid off. Due to the tilt angle not being optimal for the area, other scenarios may prove beneficial; potential untapped square footage above the Central Utility Plant could be analyzed in future studies. Overall, it is not recommended to install the system as designed above, the costs out-weigh the benefits.

Analysis #4: Façade Redesign

Problem Identification

During early research of New York Police Academy, the critical path of the project schedule follows the activities of Piles, Foundations, Structural Steel, Concrete, Curtain Wall, and Mechanical HVAC; the Curtain Wall will be the focus on this Analysis. With a majority of material consisting of metal panels, precast concrete panels, and glass, the curtain wall system is the most logical to look into to help aid the construction process.

Along the west and east facing walls, the primary material is precast concrete panels that resembled the metal panels along the remainder of the building in color. In comparison, the precast concrete panels are generally higher in cost, weight, and installation time than a metal panel system.

Research Goals

The goal for this analysis is to perform an overall redesign of the precast concrete panels to a more functional metal panel system to analyze construction time and construction cost impacts onto the overall project.

Methodology

- Contact Pat Murray to acquire information regarding the design of the curtain wall system and how it will be constructed.
- Calculate the loading resulting from the precast concrete panel system
- Calculate the loading resulting from the redesign metal panel system
- Determine if the beams supporting the wall can be resized
- Determine overall cost of material, labor, and equipment used between original design and new design
- Determine overall schedule impact between the construction time of original design and new design
- Develop a summary of findings between the original design of castellated and cellular beams and the new design of replacement systems

Resources and Tools to be Used

- Pat Murray and other Industry Professionals
- Turner Construction Company / SVT
- AE 404: Building Structural Systems in Steel and Concrete
- AE Faculty – Structural and Construction Management
- Applicable literature

Expected Outcome

Through the design and research that is to be involved with this analysis, it is expected that the replacement of the precast concrete panel system with a metal panel system will reduce the overall construction cost and construction time of the project; this should allow the project to be turned over to the owner at an earlier time.

Original Design

As identified on the drawings for New York Police Academy, the current façade system between the two (2) proposed structures is very similar in material properties; both buildings employ a majority of insulated metal panels for the majority, if not whole, of the façade system. Along the two (2) short faces of the Administration / Academics the façade transforms from the insulated metal panels that run entirely of the long faces of the building to a precast concrete panel system. In order to properly understand why the design combines the principles of two (2) separate curtain wall designs along two (2) separate sets of parallel faces of the building, contact with the project's architect, Perkins+Will, had to be made.

Through communications with Jose Class from Turner Construction Company, a phone interview with Ming Leung from Perkins+Will was arranged. During this interview, the main focus was a discussion around the particular design of the shorter faces of façade being precast concrete panels instead of insulated metal panels to blend with the remaining faces of the building. Ming mentioned that the precast concrete panel design on the ends of the building was designed for the following two reasons:

- Aesthetic reasons – wanted to wrap the ends in the building with a strong material
    - Cheaper than using brick and/or stone
- Blast protection – shorter ends are more liable to come under threat due to location and function

Other reasons such as cost were discussed during the interview but will be explained later in this report.

Proposed Design

For this analysis, the pre-mentioned precast concrete panels will be switched out for insulated metal panels that cover the remaining façade of the facility. Based on previous educational experiences, this design should prove the following:

- Reduction in overall cost of the project
    - Insulated metal panel designs are generally cheaper than precast concrete panel designs
    - Insulated metal panels are lighter than precast concrete panels; allowing a reduction in structural support
- Reduction in project schedule
    - By switching out the designs, there is a possibility to benefit from a repetitive nature; the installation of the panel system will decrease the more it is performed

In order to accurately portray this analysis, a cost and schedule impact will be performed to properly analyze the differences between systems. Below is an image identifying the two faces of the facility that will undergo the changes, approximately **31,000** square feet.

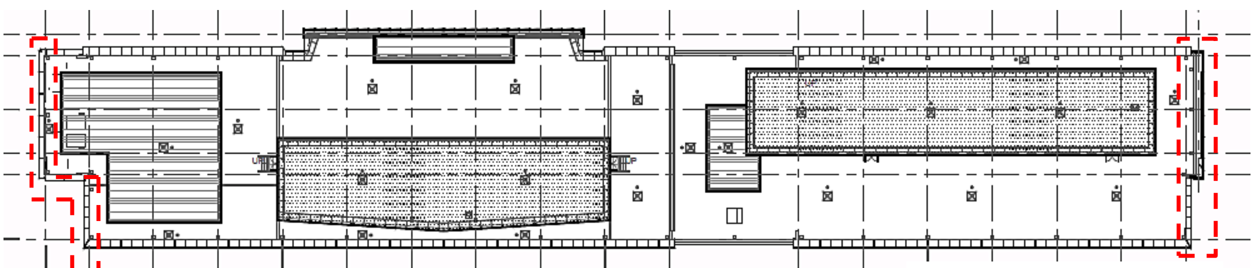

Figure 22: Façade Faces to be Redesign

Structural Impact

By proposing to switch the precast concrete panel design with the insulated metal panel design, a structural analysis on the supporting system had to be performed. During the early stages of this task, a beam had to be selected that supported the highest possible tributary area of façade materials. This step is needed to the overall weight of the two systems, 100 PSF for precast concrete panels and 5 PSF for insulated metal panels. According to the drawings, the beam chosen spans along column line AT between column lines A1 and A2, this span is approximately 25ft. To the right is an image highlighting the beam that will be analyzed for this analysis.

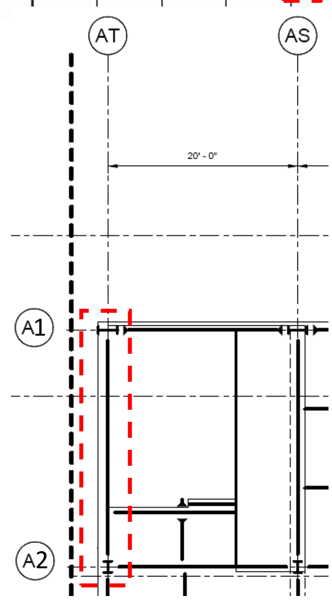

Figure 23: Highlighted Beam that will be Tested for this Analysis

Actual load calculations could not be acquired in time for this report, the beam had to be removed of all classification and a structural analysis to identify what size of wide flange beam would be used for the precast concrete panel design. The following loads were used when calculating the overall loading onto the beam:

Live Loads

- Design Office Live Load= 100 PSF

Dead Loads

- Superimposed Dead Load = 15 PSF
- Decking and Concrete = 42 PSF

See APPENDIX E for Structural Hand Calculations

In order to calculate the loading on a beam from two separate sources, façade weight and floor weight, two (2) separate loadings from two (2) different tributary areas had to be consider. The two equations used in this analysis carry down from *Analysis 1: Redesign of Cellular Beams* and are as follows:

$$L_O = L\left(.25 + \frac{15}{\sqrt{A_T K_T}}\right)$$

$$w_u = 1.2D_L + 1.6L_L$$

As stated in *Analysis 1: Redesign of Cellular*, the first equation relates to live load reduction in which K_T is a constant factor equaling 2, L_O is the reduced live load, L is the design live load, and A_T is the tributary area when calculated were **92 PSF**, **100 PSF**, and **250 SF**, respectively. For the second equation w_u is the calculated distributed load, D_L is the design dead load, and L_L is the reduced live load or design live load, whichever is smaller; w_u is calculated to be **122.4 PSF** which is then multiplied by 15, width of tributary area, to be a total of **1836 PLF** applied to the beam.

After performing the above calculations for the floor loads, similar calculations have to be performed for the façade loads. Only differences are that the tributary area will be **375 SF**, and the second equation will be used to calculate w_u, which results in **2184.5 PLF**; the total loading on the beam for the precast concrete panel will be approximately **4020.5 PLF**.

Based on the moment, **314 ft-kips**, provided by applying the 4020.5 PLF load, a beam at the size of **W21 x 44** will support the loading of the floor and precast concrete panel.

After applying the similar philosophy to the insulated metal panel design, a loading of **2274.5 PLF** is applied to the beam resulting in a moment of **177 ft-kips**. This leads to a wide flange beam size of **W16 x 31** to support the loading of the floor and the insulated metal panel system.

All wide flange member sizing was performed with the use of Table 3-2 from the AISC Steel Manual.

Overall switching the façade system from a precast concrete panel design to an insulated metal panel design will result in smaller structural members but overall cost savings between the two is approximately **$4/ft**.

Cost Impact

During initial stages of this analysis, RS Means was the primary source for compiling all cost data for the construction items involved. According to the data in RS Means, the overall cost per square foot of the insulated metal panel design and precast panel design was approximately **$65.02** and **$66.39**, respectively. Each design's cost comprised of the following materials:

Insulated Metal Panel Design

- Metal Framing, Aluminum
- Insulated Metal Panels, Aluminum
- Vapor Barrier

Precast Concrete Panel Design

- Structural Supports
- Precast Concrete Panel
- Rigid Insulation, 2"
- Vapor Barrier

When spread across the 31,000 square feet of façade area, the overall difference in cost is approximately **$45,000** with the insulated metal panel design coming in at **$2,015,000** and the precast concrete panel design costing **$2,058,000**. This data contradicts early beliefs that precast concrete panels are far more costly than a traditional metal panel design; further research had to be performed.

Another cost impact analysis was performed along the structural beam that was analyzed for structural resizing when switching from the precast concrete panel design to the insulated metal panel design. This analysis incorporates the cost of the beam and reduces the total area to be calculated from 31,000 to **375 square feet**. Final cost values states the insulated metal panel system costing approximately **$26,000** and the precast concrete panel system costing approximately **$31,000**; roughly a difference of **$5,000** for the reduced area.

See APPENDIX F for Detailed Quantity Takeoffs for both Original and Proposed Designs

All values are obtained from RS Means: Building Construction Cost Data 2011 with a multiplier of 1.10 for base material and base equipment cost, and a multiplier of 1.60 for base labor cost for construction work in Queens, New York.

Earlier in this analysis it was stated that Ming provided some insight on the overall design choices based on cost. In typical New York City construction there is no available sight for material lay-down, scaffolding, or additional mobile cranes; this requires metal panel curtain walls to be installed from the interior of the building, which increases the cost and lowers the production rate. Ming mentioned that installation costs for precast concrete panels, clay masonry on CMU, and metal panel for New York City are **$85.00/SF**, **$110.00/SF**, and **$150.00/SF**, respectively; the table below helps represent the overall cost based on the square footage of façade for this analysis.

Item	Unit	Quantity	Cost / SF	Total
Metal Panel (Traditional Curtain Wall System)	SF	31000	$150.00	$4,650,000.00
Precast Concrete Panel (Current Curtain Wall System)	SF	31000	$85.00	$2,635,000.00
Brick on CMU	SF	31000	$110.00	$3,410,000.00
Most Ideal System for Installation		Precast Concrete Panel System		

Table 12: System Comparison Based on Values Provided by Perkins+Will

Based on the information provided by Ming from Perkins+Will, a precast concrete panel system is the most cost efficient system to be used in New York City and will be taken into mind during the conclusion and recommendations section of this analysis.

Schedule Impact

To truly understand the differences in duration of the original and proposed designs, *RS Means Building Cost Data* was used to analyze different daily outputs of the construction items involved. Originally, the metal panel system would be assembled faster on-site due to the relatively light weight of the materials, roughly 5 PSF, compared to the high weight of the precast concrete panels, 100 PSF. Other benefits that were applied to the durations of the insulated metal panel design benefit on the idea that the continuous work will allow for a faster daily output as the project advances. Below are two tables and a figure demonstrating the differences in scheduling the two separate designs.

Insulated Metal Panel Façade Schedule Durations					
Item	Crew Size	Unit	Daily Output	Total Material Amount	Days Required
Metal Framing, Aluminum	4	SF	340	31000	91.18
Vapor Barrier	2	SF	500	31000	62.00
Metal Panels, Aluminum Insulated	2	SF	375	31000	82.67
Actual Duration				136	Days

Table 13: Schedule Duration Calculations for Insulated Metal Panel Design

Precast Concrete Panel Façade Durations					
Item	Crew Size	Unit	Daily Output	Total Material Amount	Days Required
Precast Concrete Panel	8	SF	1400	31000	22.14
Vapor Barrier	3	SF	750	31000	41.33
Insulation, Rigid 2"	1	SF	890	31000	34.83
Actual Duration				77	Days

Table 14: Schedule Duration Calculations for Precast Concrete Panel Design

Based on the calculations performed above, the precast concrete panel system will be finished in approximately **77 days** while the insulated metal panel system will be completed in approximately **136 days**, a difference of **59 days**. The main causes for this is that in order to properly install the insulated metal panels, a frame system must proceed them, causing longer delays for the task; precast concrete panel system benefits from the size of the pieces, 15ft x 5ft while the insulated metal panels are 5ft x 2.5ft, causing a larger daily output when compared.

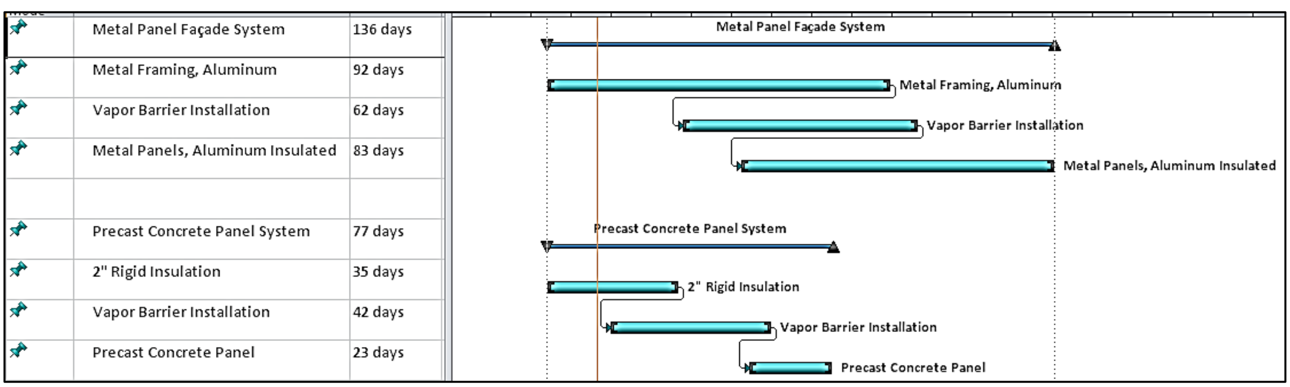

Figure 24: Schedule Layout of Tasks Related to Façade Redesign

Conclusions and Recommendations

In conclusion, the tasks performed in this analysis proved to contradict the original hypothesis stated earlier. According to values provided by RS Means, switching the precast concrete panel design for a traditional insulated metal panel design proved to be more cost efficient than the precast concrete panel design; however, upon talking to Ming Leung, the overall cost for the different designs proved that the precast concrete panel design was more cost efficient due to high level of labor involved with the installation of insulated metal panels. The first cost analysis yielded a savings of **$45,000** by switching the designs while the second cost analysis yields that an increase in **$2,000,000** will be added to the project cost by switching the designs.

It is this author's opinion to not change the original precast concrete panel design for an insulated metal panel design. Based on the cost differences of installation in New York provide by Ming Leung, the additional $2,000,000 needed for the façade would only weaken the overall quality of the project due to the already tight budget. Since the curtain wall falls on the project's critical path, the potential delay of 59 days by switching designs must also be kept in mind. This delay can push the turnover of the project by approximately two (2) months, causing severe interruptions in the planned centralization of facilities for the New York Police Department. In addition, the overall protective feature of the precast concrete panel system is crucial for overall security measures of the facility.

Resources

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APPENDIX A - Consultant and Engineering Firms Involved with Design

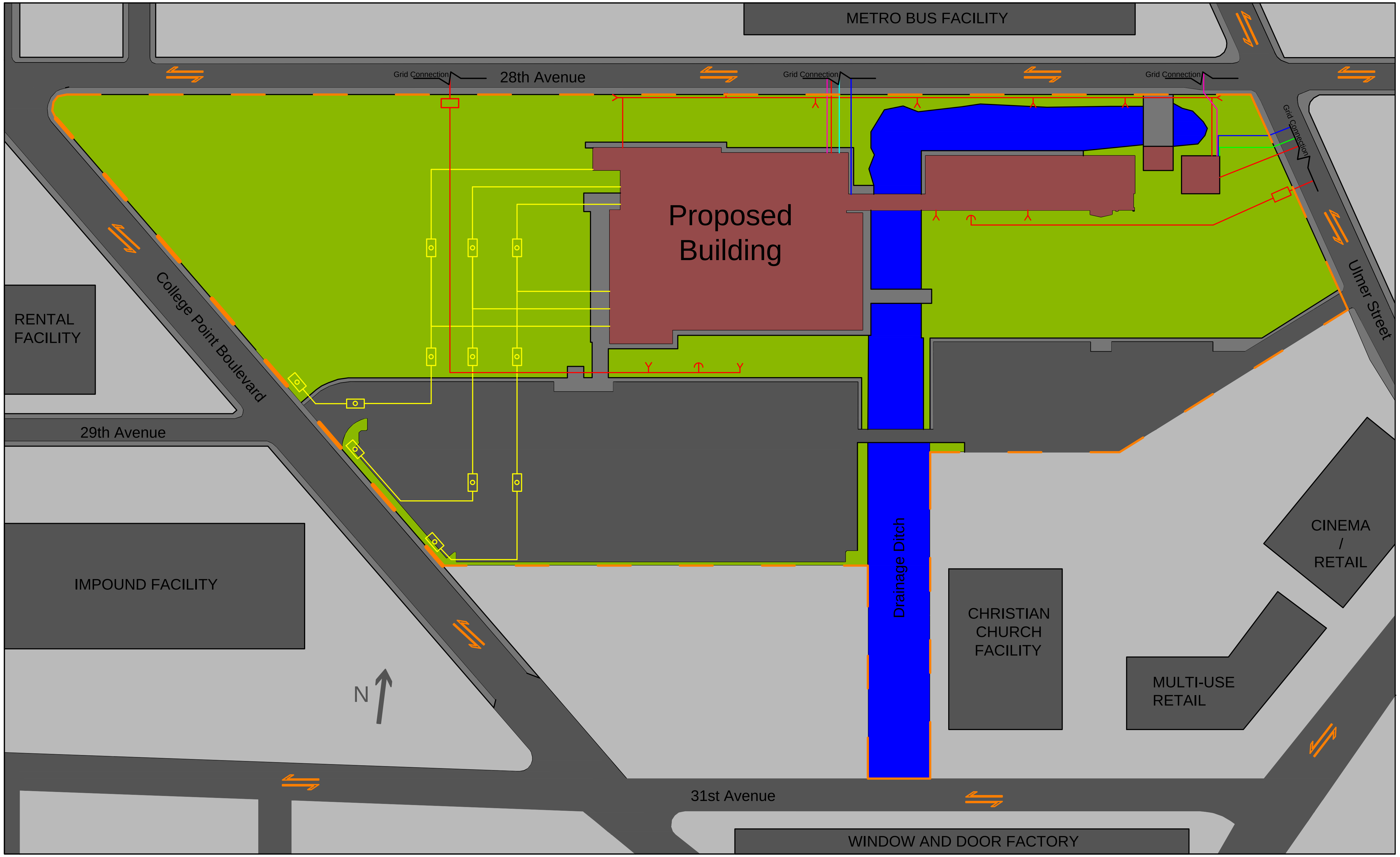
Consultants:

Civil Consultant:	Langan Engineering and Environmental Services
Blast Consultant:	Weidlinger Associates
Traffic Consultant:	Eng-Wong, Taub & Associates
Parking Consultant:	Walker Parking Consultant
Security Consultant:	Kroll
Food Service:	Consultant Cini-Little
Signage Consultant:	Two Twelve Designs
Lighting Consultants:	Bartenbach Lichtlabor GmbH, Hillman DiBernardo, Leiter Castelli
IT Consultant:	TM Technology Partners, Inc.
AV, Acoustics Consultant:	Cerami & Associates Inc.
Geotechnical Consultant:	URS Corporation
Cost Estimating:	Davis Langdon
Cost Control:	Gardiner & Teobald Inc.

Engineering Firms:

Structural Engineer:	Robert Silman Associates
MEPF Engineering:	ESP Flack + Kurtz
Urban Design:	FXFowle
Vertical Transportation:	Van Desusen Associates

APPENDIX B - Existing Conditions Plan and Site Layout Plans



EXISTING CONDITIONS / UTILITIES PLAN

New York Police Academy
College Point
April 7, 2011
Shawn Sidelinger - CM

Legend:

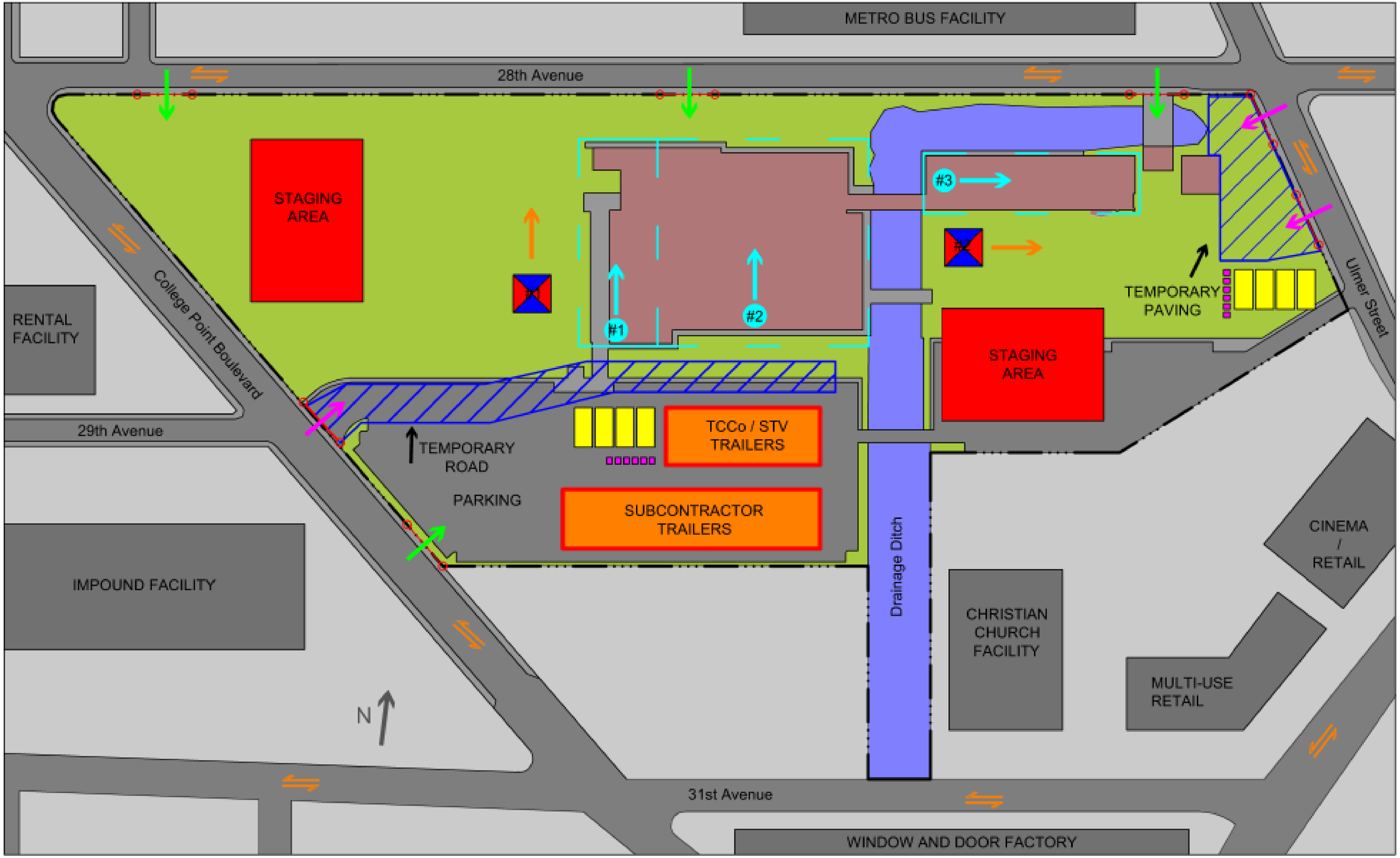
EXISTING UTILITIES:

FIRE DEPT WATER.............
ELECTRICAL.......................
GAS MAIN...........................
SANITARY WATER...............
WATER...............................
TELECOMMUNICATIONS....

SYMBOLS:

VEHICULAR TRAFFIC..............
SIAMESE.................................
ELECTRICAL MANHOLE..........
FIRE HYDRANT........................
CONSTRUCTION FENCE.........

SCALE 1" = 225'



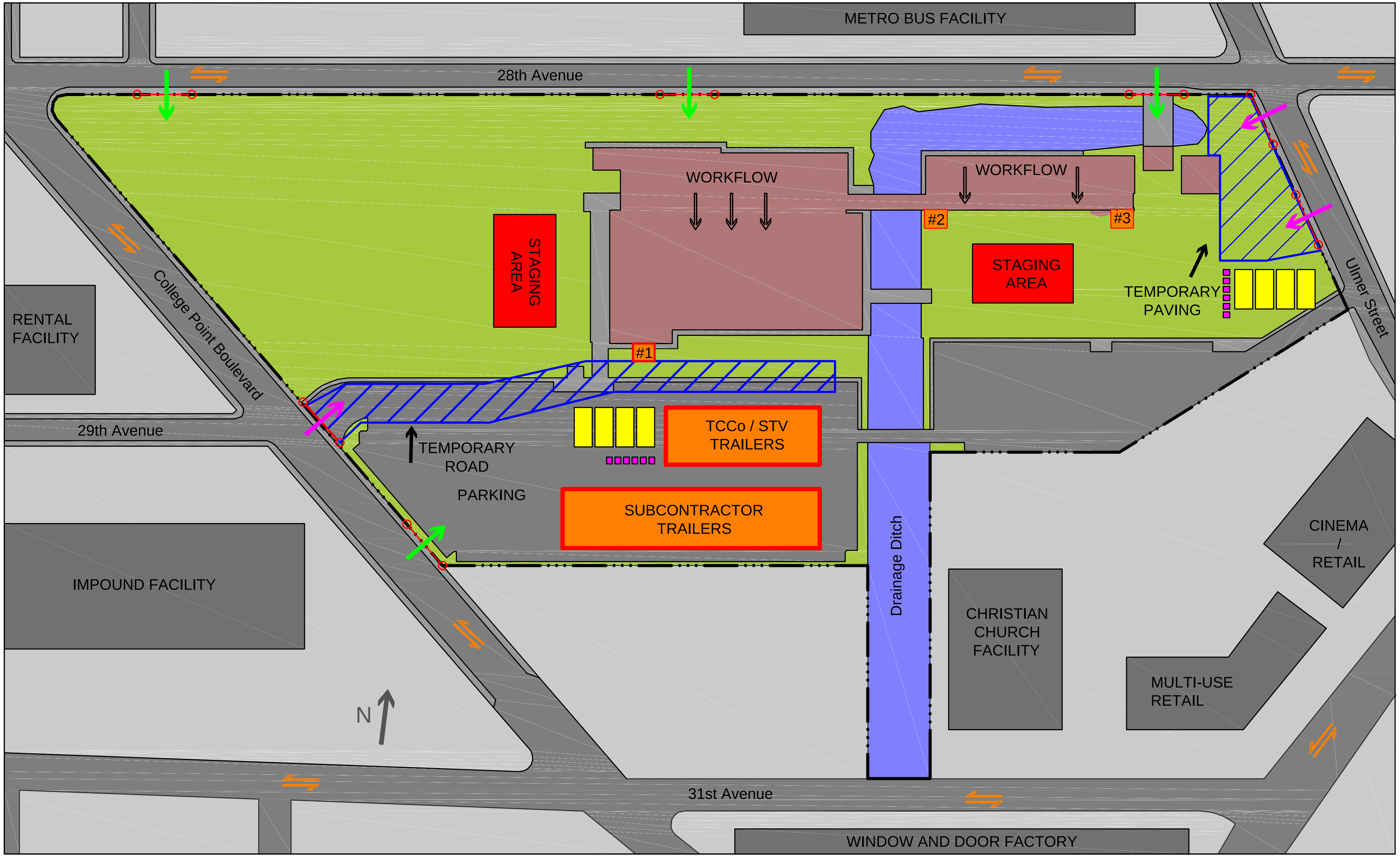
FOUNDATION / SUPERSTRUCTURE SITE LAYOUT

New York Police Academy
College Point, New York
April 7, 2011

Shawn Sidelinger - CM

Legend:
- Fence:
- Gate:
- Dumpster:
- Vehicular Traffic:
- Crane Location: Movement:
- Pile Rig: Movement:
- Temporary Toilets:
- Primary Site Entrance:
- Secondary Site Entrance:

SCALE 1" = 225'



MEP / INTERIOR FINISHES SITE LAYOUT

New York Police Academy
College Point, New York
April 7, 2011

Shawn Sidelinger - CM

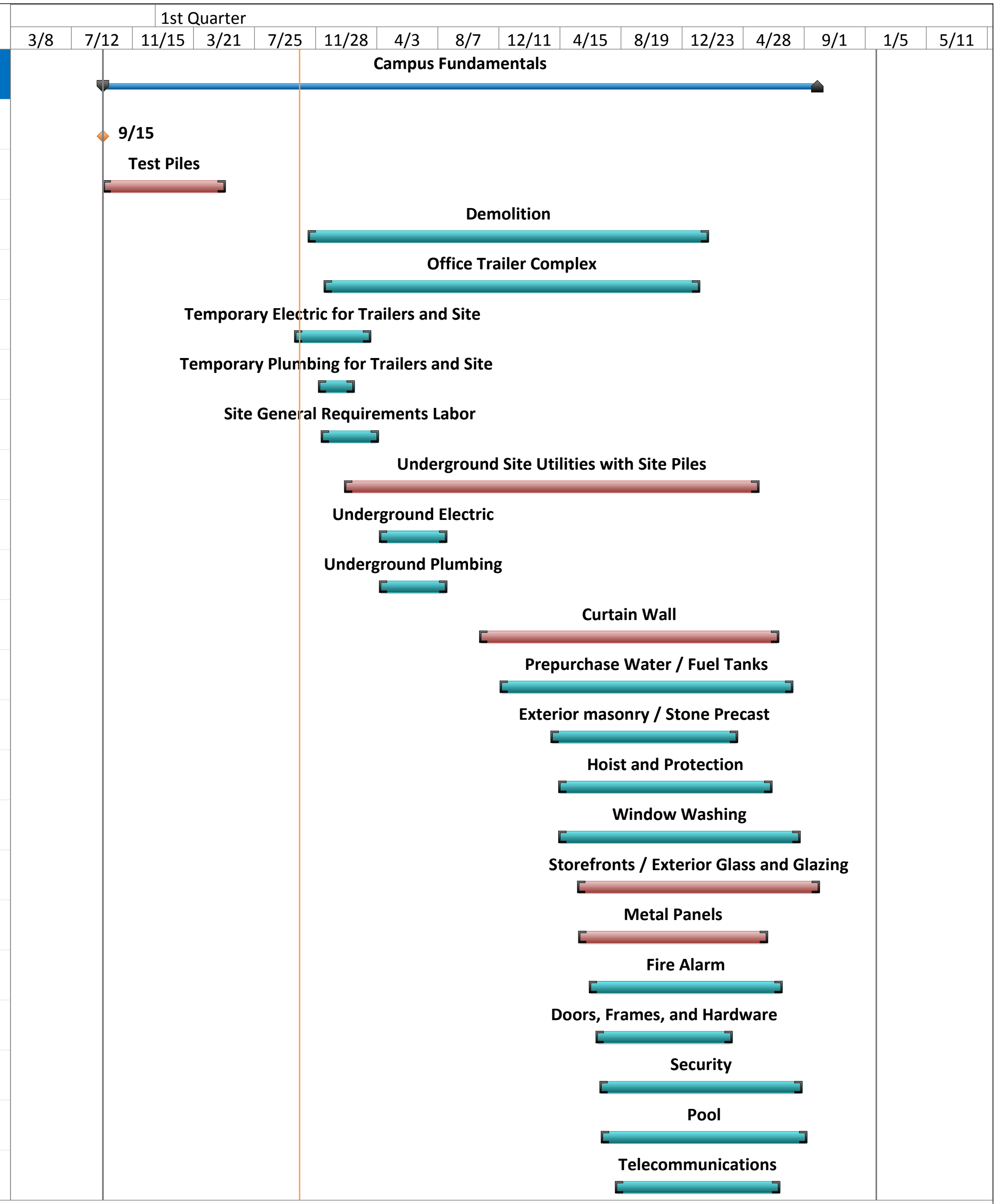
Legend:

- Fence:
- Gate:
- Dumpster:
- Vehicular Traffic:
- Hoist Complex:
- Temporary Toilets:
- Primary Site Entrance:
- Secondary Site Entrance:

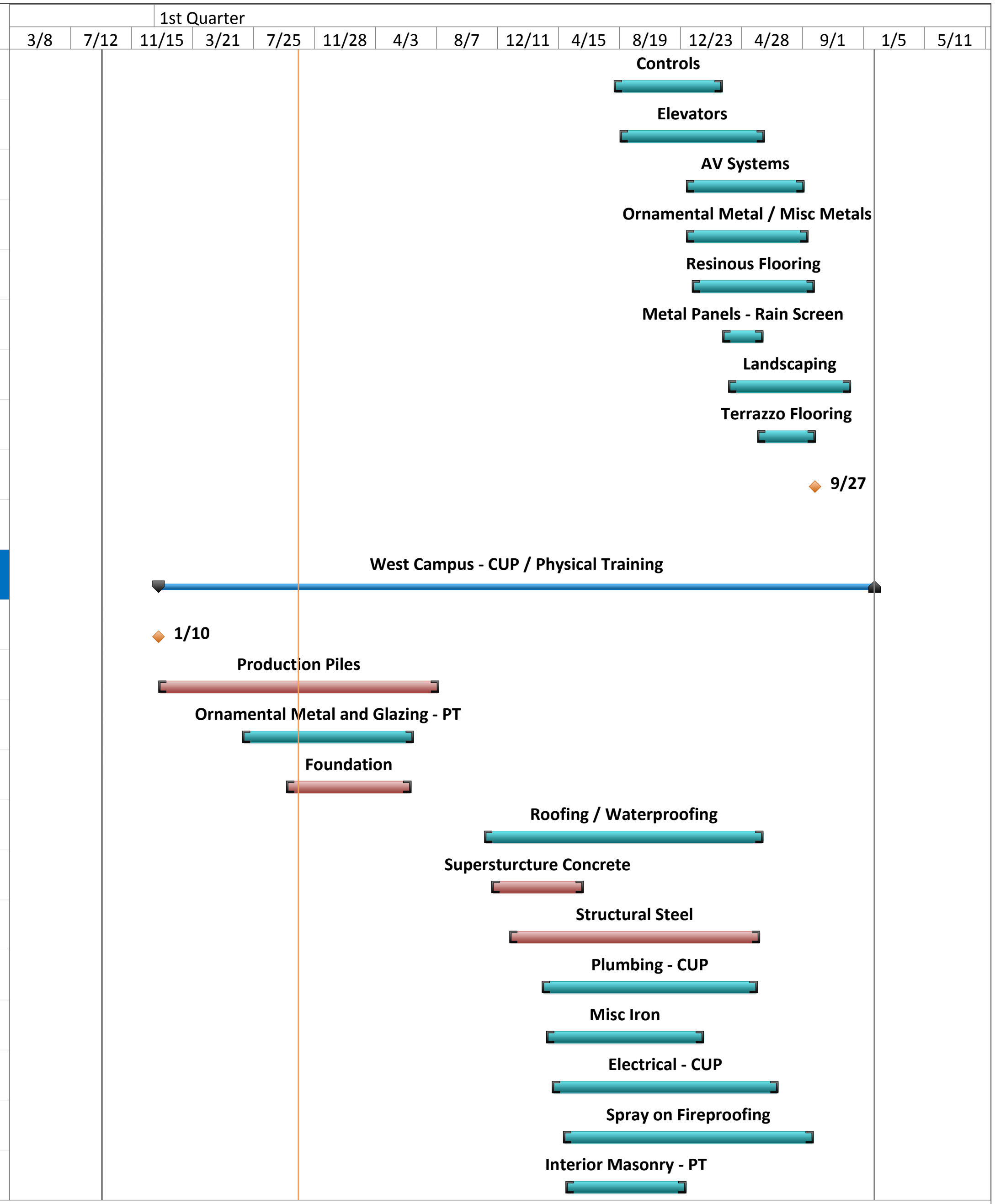
SCALE 1" = 225'

APPENDIX C - Detailed Project Schedule

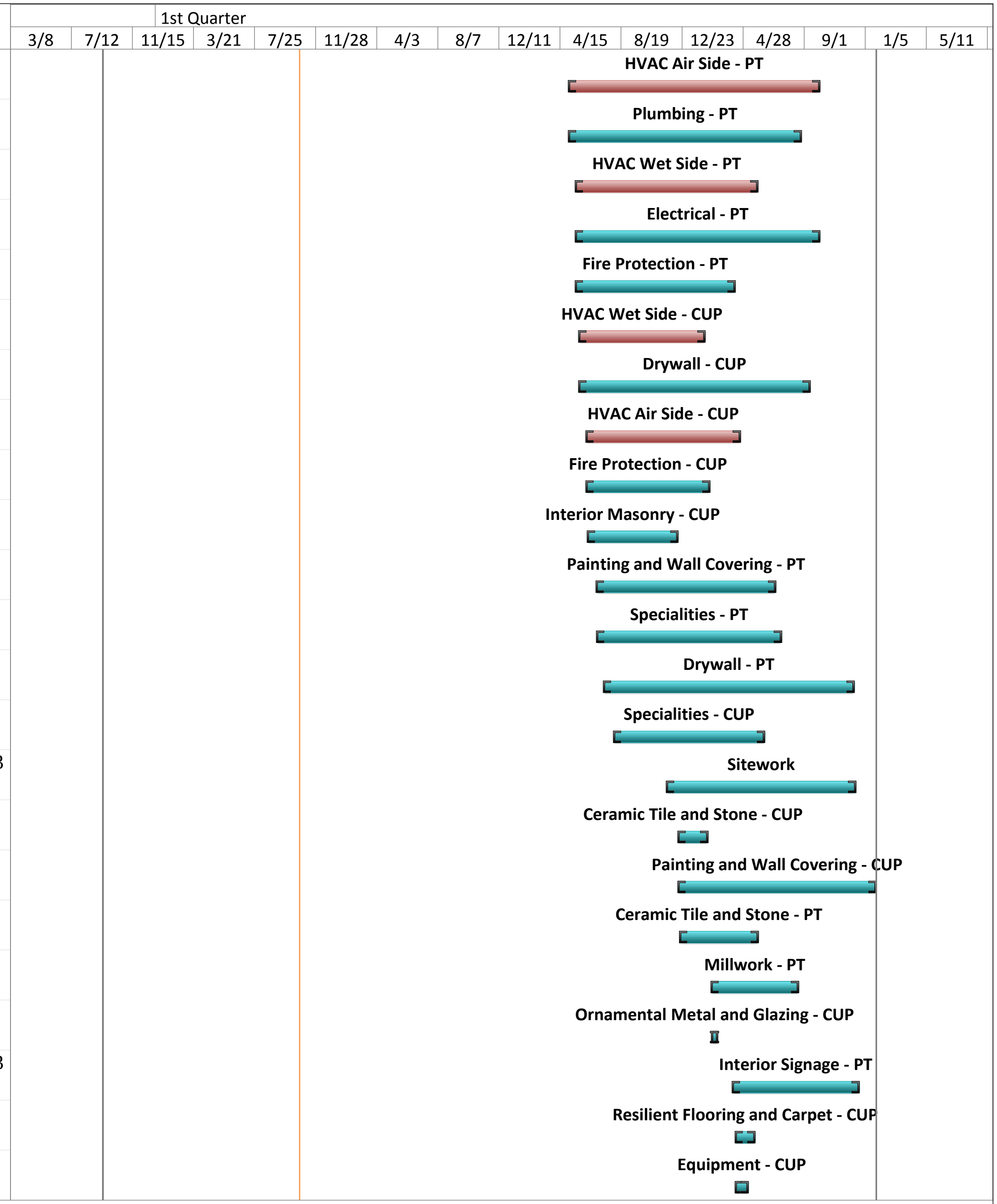
ID	Task Name	Duration	Start	Finish
1	Campus Fundamentals	1054 days	Tue 9/15/09	Fri 9/27/13
2	Campus Fundamentals - Start	0 days	Tue 9/15/09	Tue 9/15/09
3	Test Piles	181 days	Tue 9/15/09	Tue 5/25/10
4	Demolition	591 days	Fri 11/12/10	Fri 2/15/13
5	Office Trailer Complex	554 days	Wed 12/15/10	Mon 1/28/13
6	Temporary Electric for Trailers and Site	112 days	Fri 10/15/10	Mon 3/21/11
7	Temporary Plumbing for Trailers and Site	53 days	Fri 12/3/10	Tue 2/15/11
8	Site General Requirements Labor	85 days	Thu 12/9/10	Wed 4/6/11
9	Underground Site Utilities with Site Piles	612 days	Wed 1/26/11	Thu 5/30/13
10	Underground Electric	100 days	Fri 4/8/11	Thu 8/25/11
11	Underground Plumbing	100 days	Fri 4/8/11	Thu 8/25/11
12	Curtain Wall	442 days	Tue 11/1/11	Wed 7/10/13
13	Prepurchase Water / Fuel Tanks	433 days	Tue 12/13/11	Thu 8/8/13
14	Exterior masonry / Stone Precast	276 days	Tue 3/27/12	Tue 4/16/13
15	Hoist and Protection	315 days	Thu 4/12/12	Wed 6/26/13
16	Window Washing	357 days	Thu 4/12/12	Fri 8/23/13
17	Storefronts / Exterior Glass and Glazing	358 days	Mon 5/21/12	Wed 10/2/13
18	Metal Panels	279 days	Wed 5/23/12	Mon 6/17/13
19	Fire Alarm	285 days	Thu 6/14/12	Wed 7/17/13
20	Doors, Frames, and Hardware	202 days	Thu 6/28/12	Fri 4/5/13
21	Security	298 days	Fri 7/6/12	Tue 8/27/13
22	Pool	305 days	Mon 7/9/12	Fri 9/6/13
23	Telecommunications	244 days	Tue 8/7/12	Fri 7/12/13



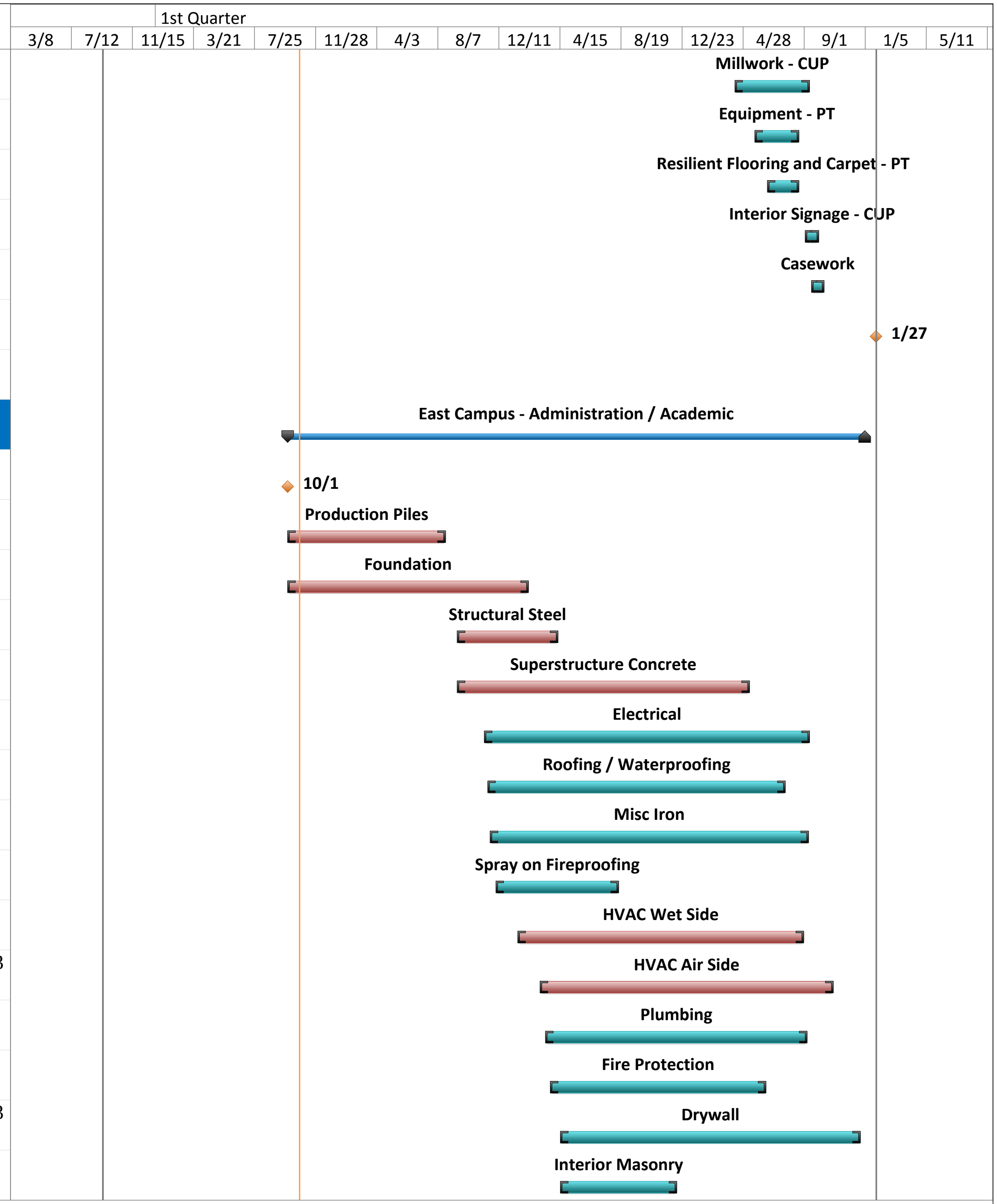
ID	Task Name	Duration	Start	Finish
24	Controls	160 days	Wed 8/8/12	Tue 3/19/13
25	Elevators	215 days	Mon 8/20/12	Fri 6/14/13
26	AV Systems	174 days	Fri 1/4/13	Wed 9/4/13
27	Ornamental Metal / Misc Metals	180 days	Fri 1/4/13	Thu 9/12/13
28	Resinous Flooring	181 days	Wed 1/16/13	Wed 9/25/13
29	Metal Panels - Rain Screen	60 days	Wed 3/20/13	Tue 6/11/13
30	Landscaping	181 days	Mon 4/1/13	Mon 12/9/13
31	Terrazzo Flooring	86 days	Fri 5/31/13	Fri 9/27/13
32	Campus Fundamentals - Completion	0 days	Fri 9/27/13	Fri 9/27/13
33				
34	West Campus - CUP / Physical Training	1057 days	Sun 1/10/10	Mon 1/27/14
35	West Campus - Start	0 days	Sun 1/10/10	Sun 1/10/10
36	Production Piles	415 days	Sun 1/10/10	Thu 8/11/11
37	Ornamental Metal and Glazing - PT	252 days	Fri 7/2/10	Mon 6/20/11
38	Foundation	184 days	Fri 10/1/10	Wed 6/15/11
39	Roofing / Waterproofing	412 days	Mon 11/14/11	Tue 6/11/13
40	Supersturcture Concrete	136 days	Tue 11/29/11	Tue 6/5/12
41	Structural Steel	369 days	Thu 1/5/12	Tue 6/4/13
42	Plumbing - CUP	319 days	Mon 3/12/12	Thu 5/30/13
43	Misc Iron	233 days	Wed 3/21/12	Fri 2/8/13
44	Electrical - CUP	335 days	Mon 4/2/12	Fri 7/12/13
45	Spray on Fireproofing	369 days	Wed 4/25/12	Mon 9/23/13
46	Interior Masonry - PT	179 days	Mon 4/30/12	Thu 1/3/13



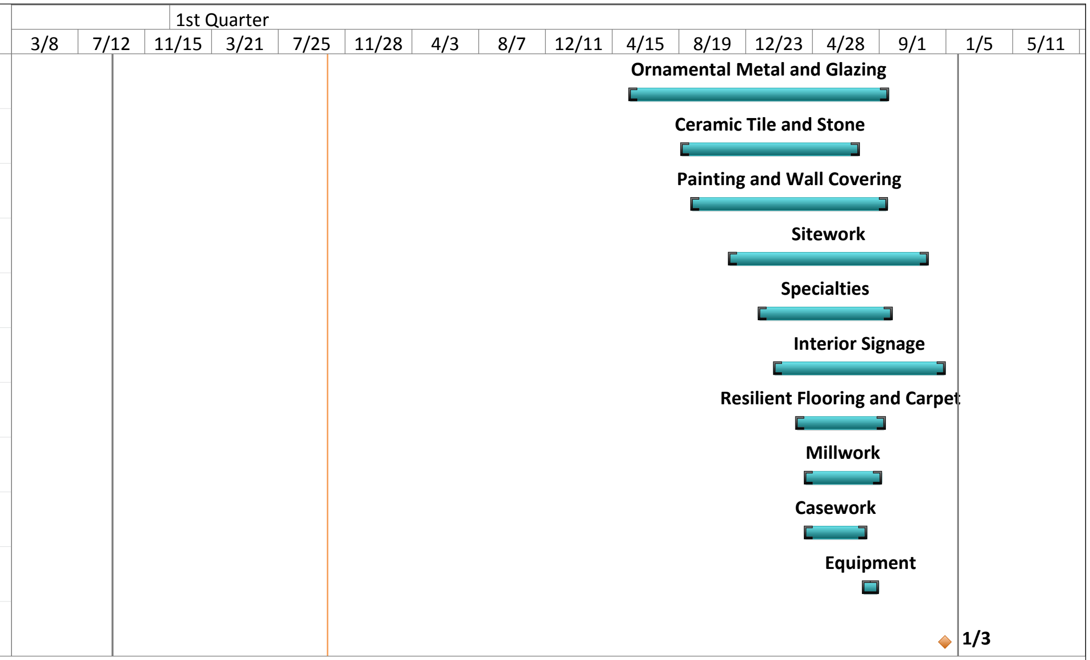
ID	Task Name	Duration	Start	Finish
47	HVAC Air Side - PT	372 days	Wed 5/2/12	Thu 10/3/13
48	Plumbing - PT	344 days	Wed 5/2/12	Mon 8/26/13
49	HVAC Wet Side - PT	270 days	Wed 5/16/12	Tue 5/28/13
50	Electrical - PT	362 days	Wed 5/16/12	Thu 10/3/13
51	Fire Protection - PT	237 days	Wed 5/16/12	Thu 4/11/13
52	HVAC Wet Side - CUP	188 days	Wed 5/23/12	Fri 2/8/13
53	Drywall - CUP	343 days	Wed 5/23/12	Fri 9/13/13
54	HVAC Air Side - CUP	228 days	Thu 6/7/12	Mon 4/22/13
55	Fire Protection - CUP	183 days	Thu 6/7/12	Mon 2/18/13
56	Interior Masonry - CUP	136 days	Sun 6/10/12	Fri 12/14/12
57	Painting and Wall Covering - PT	266 days	Thu 6/28/12	Thu 7/4/13
58	Specialities - PT	273 days	Fri 6/29/12	Tue 7/16/13
59	Drywall - PT	371 days	Fri 7/13/12	Fri 12/13/13
60	Specialities - CUP	223 days	Fri 8/3/12	Tue 6/11/13
61	Sitework	280 days	Tue 11/20/12	Mon 12/16/13
62	Ceramic Tile and Stone - CUP	45 days	Fri 12/14/12	Thu 2/14/13
63	Painting and Wall Covering - CUP	292 days	Fri 12/14/12	Mon 1/27/14
64	Ceramic Tile and Stone - PT	118 days	Mon 12/17/12	Wed 5/29/13
65	Millwork - PT	130 days	Wed 2/20/13	Tue 8/20/13
66	Ornamental Metal and Glazing - CUP	10 days	Thu 2/21/13	Wed 3/6/13
67	Interior Signage - PT	187 days	Fri 4/5/13	Mon 12/23/13
68	Resilient Flooring and Carpet - CUP	30 days	Thu 4/11/13	Wed 5/22/13
69	Equipment - CUP	20 days	Thu 4/11/13	Wed 5/8/13



ID	Task Name	Duration	Start	Finish
70	Millwork - CUP	110 days	Thu 4/11/13	Wed 9/11/13
71	Equipment - PT	65 days	Wed 5/22/13	Tue 8/20/13
72	Resilient Flooring and Carpet - PT	47 days	Mon 6/17/13	Tue 8/20/13
73	Interior Signage - CUP	20 days	Tue 9/3/13	Mon 9/30/13
74	Casework	20 days	Mon 9/16/13	Fri 10/11/13
75	West Campus - Completion	0 days	Mon 1/27/14	Mon 1/27/14
76				
77	East Campus - Administration / Academic	851 days	Fri 10/1/10	Fri 1/3/14
78	East Campus - Start	0 days	Fri 10/1/10	Fri 10/1/10
79	Production Piles	232 days	Fri 10/1/10	Mon 8/22/11
80	Foundation	355 days	Fri 10/1/10	Thu 2/9/12
81	Structural Steel	148 days	Fri 9/16/11	Tue 4/10/12
82	Superstructure Concrete	431 days	Fri 9/16/11	Fri 5/10/13
83	Electrical	479 days	Fri 11/11/11	Wed 9/11/13
84	Roofing / Waterproofing	438 days	Fri 11/18/11	Tue 7/23/13
85	Misc Iron	469 days	Wed 11/23/11	Mon 9/9/13
86	Spray on Fireproofing	181 days	Mon 12/5/11	Mon 8/13/12
87	HVAC Wet Side	422 days	Thu 1/19/12	Fri 8/30/13
88	HVAC Air Side	433 days	Mon 3/5/12	Wed 10/30/13
89	Plumbing	386 days	Fri 3/16/12	Fri 9/6/13
90	Fire Protection	319 days	Mon 3/26/12	Thu 6/13/13
91	Drywall	443 days	Mon 4/16/12	Wed 12/25/13
92	Interior Masonry	172 days	Mon 4/16/12	Tue 12/11/12



ID	Task Name	Duration	Start	Finish
93	Ornamental Metal and Glazing	351 days	Wed 5/16/12	Wed 9/18/13
94	Ceramic Tile and Stone	242 days	Wed 8/22/12	Thu 7/25/13
95	Painting and Wall Covering	266 days	Mon 9/10/12	Mon 9/16/13
96	Sitework	270 days	Tue 11/20/12	Mon 12/2/13
97	Specialties	182 days	Tue 1/15/13	Wed 9/25/13
98	Interior Signage	233 days	Wed 2/13/13	Fri 1/3/14
99	Resilient Flooring and Carpet	122 days	Wed 3/27/13	Thu 9/12/13
100	Millwork	105 days	Fri 4/12/13	Thu 9/5/13
101	Casework	85 days	Fri 4/12/13	Thu 8/8/13
102	Equipment	23 days	Wed 7/31/13	Fri 8/30/13
103	East Campus - Completion	0 days	Fri 1/3/14	Fri 1/3/14



APPENDIX D – Detailed General Conditions Estimate

Supervision and Personal				
Item	Unit	Quantity	Cost / Unit	Total
Project Executive	Week	576.00	$2,250.00	$1,296,000.00
Senior Superintendent	Week	576.00	$1,950.00	$1,123,200.00
Senior Superintendent	Week	576.00	$1,950.00	$1,123,200.00
Superintendent	Week	576.00	$1,750.00	$1,008,000.00
Superintendent	Week	576.00	$1,750.00	$1,008,000.00
Superintendent	Week	576.00	$1,750.00	$1,008,000.00
Assistant Superintendent	Week	576.00	$1,550.00	$892,800.00
Assistant Superintendent	Week	576.00	$1,550.00	$892,800.00
Assistant Superintendent	Week	576.00	$1,550.00	$892,800.00
Assistant Superintendent	Week	576.00	$1,550.00	$892,800.00
Assistant Superintendent	Week	576.00	$1,550.00	$892,800.00
Senior Project Manager	Week	576.00	$2,100.00	$1,209,600.00
Senior Project Manager	Week	576.00	$2,100.00	$1,209,600.00
Project Manager	Week	576.00	$1,800.00	$1,036,800.00
Project Manager	Week	576.00	$1,800.00	$1,036,800.00
Project Manager	Week	576.00	$1,800.00	$1,036,800.00
Assistant Project Manager	Week	576.00	$1,600.00	$921,600.00
Assistant Project Manager	Week	576.00	$1,600.00	$921,600.00
Assistant Project Manager	Week	576.00	$1,600.00	$921,600.00
Assistant Project Manager	Week	576.00	$1,600.00	$921,600.00
Assistant Project Manager	Week	576.00	$1,600.00	$921,600.00
Field Engineer	Week	576.00	$1,125.00	$648,000.00
Field Engineer	Week	576.00	$1,125.00	$648,000.00
Field Engineer	Week	576.00	$1,125.00	$648,000.00
Field Engineer	Week	576.00	$1,125.00	$648,000.00
Field Engineer	Week	576.00	$1,125.00	$648,000.00
Field Engineer	Week	576.00	$1,125.00	$648,000.00
Safety Manager	Week	576.00	$900.00	$518,400.00
Assistant Safety Manager	Week	576.00	$750.00	$432,000.00
Assistant Safety Manager	Week	576.00	$750.00	$432,000.00
Project Scheduler	Week	576.00	$725.00	$417,600.00
Project Scheduler	Week	576.00	$725.00	$417,600.00
Estimating Costs	LS	1.00	$100,000.00	$100,000.00
Total			$24,954,400.00	

Construction Facilities				
Item	Unit	Quantity	Cost / Unit	Total
Field Trailer – Set Up	Lump Sum	1.00	$2,000.00	$2,000.00
Field Trailer – Rental	Month	48.00	$2,500.00	$120,000.00
Field Trailer – Tear Down	Lump Sum	1.00	$2,500.00	$2,500.00
Office Equipment – Rental	Month	48.00	$3,250.00	$156,000.00
Local Area Network	Month	48.00	$2,750.00	$132,000.00
Office Supplies	Month	48.00	$1,000.00	$48,000.00
Telephone	Month	48.00	$500.00	$24,000.00
Lights & HVAC	Month	48.00	$550.00	$26,400.00
Storage Trailers	Month	48.00	$350.00	$16,800.00
Construction Fence	Month	48.00	$750.00	$36,000.00
Dumpsters	Week	576.00	$750.00	$432,000.00
Total			$995,700.00	

Excess Equipment				
Item	Unit	Quantity	Cost / Unit	Total
Gang Box	Month	48.00	$700.00	$33,600.00
Tools – Equipment	Month	48.00	$750.00	$36,000.00
Signage	Month	48.00	$175.00	$8,400.00
Material Hoist, 3 Total	Month	30.00	$11,000.00	$330,000.00
Surveying	Month	48.00	$900.00	$43,200.00
Temp Toilets	Month	48.00	$900.00	$43,200.00
Personal Protection Equipment	Month	48.00	$250.00	$12,000.00
Fall Protection	Month	48.00	$700.00	$33,600.00
Fire Extinguishers	Month	48.00	$300.00	$14,400.00
First Aid Kit / Medical Supplies	Month	48.00	$300.00	$14,400.00
Total			$568,800.00	

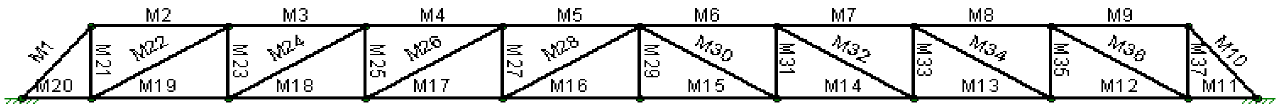
Temporarily Utilities				
Item	Unit	Quantity	Cost / Unit	Total
IT / Phone Connection	LS	1.00	$10,000.00	$10,000.00
Temporary Power Installation	LS	1.00	$12,500.00	$12,500.00
Temporary Power Usage	Month	24.00	$22,500.00	$540,000.00
Temporary Water / Sanitation	Month	48.00	$400.00	$19,200.00
Total			$581,700.00	

Permits / Misc. Costs				
Item	Unit	Quantity	Cost / Unit	Total
Building Permit	LS	1.00	$2,500.00	$2,500.00
Occupancy Permit	LS	1.00	$2,500.00	$2,500.00
Trade Permits	LS	1.00	$2,000.00	$2,000.00
Progression Photos	Month	48.00	$750.00	$36,000.00
Document Production	Month	48.00	$1,500.00	$72,000.00
Delivery / Shipping Expenses	Month	48.00	$750.00	$36,000.00
Travel Expenses (Staff)	Month	48.00	$5,000.00	$240,000.00
Clean Up Expenses	Month	40.00	$1,500.00	$60,000.00
Misc. Expenses	Month	48.00	$2,500.00	$120,000.00
Total			$571,000.00	
Total General Conditions Estimate			$27,671,600.00	

Summary				
Item	Unit	Quantity	Cost / Unit	Total
Supervision and Personal	Month	48.00	$519,883.33	$24,954,400.00
Construction Facilities	Month	48.00	$20,743.75	$995,700.00
Excess Equipment	Month	48.00	$11,850.00	$568,800.00
Temporarily Utilities	Month	48.00	$12,118.75	$581,700.00
Permits / Misc. Costs	Month	48.00	$11,895.83	$571,000.00
Total			$27,671,600.00	

APPENDIX E – Structural Design Hand Calculations

RISA 2D-Educational Model and Chart



RISA 2D- Educational Model

Member Label	Section	Axial (kips)	Shear (kips)	Moment (kips - ft)	Member Selceted
M1	1	127.047	0	0	2L5 x 3 1/2 x 3/8
	2	127.047	0	0	
	3	127.047	0	0	
	4	127.047	0	0	
	5	127.047	0	0	
M2	1	81.333	12.2	0	2L8 x 6 x 7/16
	2	81.333	6.1	45.75	
	3	81.333	0	61	
	4	81.333	-6.1	45.75	
	5	81.333	-12.2	0	
M3	1	223.667	12.2	0	2L8 x 6 x 7/16
	2	223.667	6.1	45.75	
	3	223.667	0	61	
	4	223.667	-6.1	45.75	
	5	223.667	-12.2	0	
M4	1	325.333	12.2	0	2L8 x 6 x 7/16
	2	325.333	6.1	45.75	
	3	325.333	0	61	
	4	325.333	-6.1	45.75	
	5	325.333	-12.2	0	
M5	1	386.333	12.2	0	2L8 x 6 x 7/16
	2	386.333	6.1	45.75	
	3	386.333	0	61	
	4	386.333	-6.1	45.75	
	5	386.333	-12.2	0	

M6	1	386.333	12.2	0	2L8 x 6 x 7/16
	2	386.333	6.1	45.75	
	3	386.333	0	61	
	4	386.333	-6.1	45.75	
	5	386.333	-12.2	0	
M7	1	325.333	12.2	0	2L8 x 6 x 7/16
	2	325.333	6.1	45.75	
	3	325.333	0	61	
	4	325.333	-6.1	45.75	
	5	325.333	-12.2	0	
M8	1	223.667	12.2	0	2L8 x 6 x 7/16
	2	223.667	6.1	45.75	
	3	223.667	0	61	
	4	223.667	-6.1	45.75	
	5	223.667	-12.2	0	
M9	1	81.333	12.2	0	2L8 x 6 x 7/16
	2	81.333	6.1	45.75	
	3	81.333	0	61	
	4	81.333	-6.1	45.75	
	5	81.333	-12.2	0	
M10	1	127.047	0	0	2L8 x 6 x 7/16
	2	127.047	0	0	
	3	127.047	0	0	
	4	127.047	0	0	
	5	127.047	0	0	
M11	1	-81.333	0	0	2L8 x 6 x 7/16
	2	-81.333	0	0	
	3	-81.333	0	0	
	4	-81.333	0	0	
	5	-81.333	0	0	
M12	1	-223.667	0	0	2L8 x 6 x 7/16
	2	-223.667	0	0	
	3	-223.667	0	0	
	4	-223.667	0	0	
	5	-223.667	0	0	
M13	1	-325.333	0	0	2L8 x 6 x 7/16
	2	-325.333	0	0	
	3	-325.333	0	0	
	4	-325.333	0	0	
	5	-325.333	0	0	

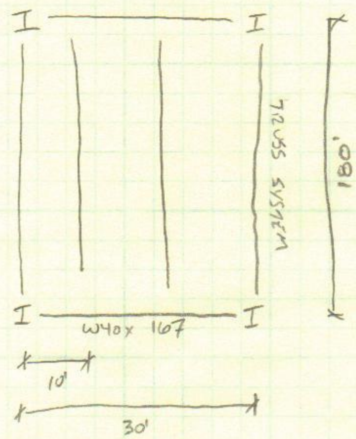
M14	1	-386.333	0	0	2L8 x 6 x 7/16
	2	-386.333	0	0	
	3	-386.333	0	0	
	4	-386.333	0	0	
	5	-386.333	0	0	
M15	1	-406.667	0	0	2L8 x 6 x 7/16
	2	-406.667	0	0	
	3	-406.667	0	0	
	4	-406.667	0	0	
	5	-406.667	0	0	
M16	1	-406.667	0	0	2L8 x 6 x 7/16
	2	-406.667	0	0	
	3	-406.667	0	0	
	4	-406.667	0	0	
	5	-406.667	0	0	
M17	1	-386.333	0	0	2L8 x 6 x 7/16
	2	-386.333	0	0	
	3	-386.333	0	0	
	4	-386.333	0	0	
	5	-386.333	0	0	
M18	1	-325.333	0	0	2L8 x 6 x 7/16
	2	-325.333	0	0	
	3	-325.333	0	0	
	4	-325.333	0	0	
	5	-325.333	0	0	
M19	1	-223.667	0	0	2L8 x 6 x 7/16
	2	-223.667	0	0	
	3	-223.667	0	0	
	4	-223.667	0	0	
	5	-223.667	0	0	
M20	1	-81.333	0	0	2L8 x 6 x 7/16
	2	-81.333	0	0	
	3	-81.333	0	0	
	4	-81.333	0	0	
	5	-81.333	0	0	
M21	1	-85.4	0	0	2L8 x 6 x 7/16
	2	-85.4	0	0	
	3	-85.4	0	0	
	4	-85.4	0	0	
	5	-85.4	0	0	

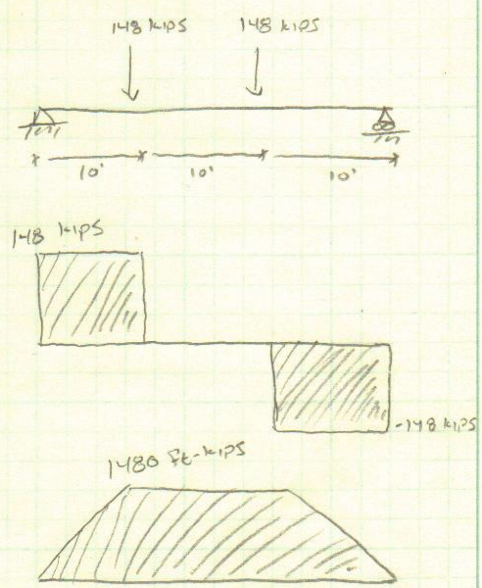
M22	1	165.988	0	0	2L5 x 3 1/2 x 3/8
	2	165.988	0	0	
	3	165.988	0	0	
	4	165.988	0	0	
	5	165.988	0	0	
M23	1	-61	0	0	2L8 x 6 x 7/16
	2	-61	0	0	
	3	-61	0	0	
	4	-61	0	0	
	5	-61	0	0	
M24	1	118.563	0	0	2L5 x 3 1/2 x 3/8
	2	118.563	0	0	
	3	118.563	0	0	
	4	118.563	0	0	
	5	118.563	0	0	
M25	1	-36.6	0	0	2L8 x 6 x 7/16
	2	-36.6	0	0	
	3	-36.6	0	0	
	4	-36.6	0	0	
	5	-36.6	0	0	
M26	1	71.138	0	0	2L5 x 3 1/2 x 3/8
	2	71.138	0	0	
	3	71.138	0	0	
	4	71.138	0	0	
	5	71.138	0	0	
M27	1	-12.2	0	0	2L8 x 6 x 7/16
	2	-12.2	0	0	
	3	-12.2	0	0	
	4	-12.2	0	0	
	5	-12.2	0	0	
M28	1	23.713	0	0	2L5 x 3 1/2 x 3/8
	2	23.713	0	0	
	3	23.713	0	0	
	4	23.713	0	0	
	5	23.713	0	0	
M29	1	0	0	0	2L8 x 6 x 7/16
	2	0	0	0	
	3	0	0	0	
	4	0	0	0	
	5	0	0	0	

M30	1	23.713	0	0	2L5 x 3 1/2 x 3/8
	2	23.713	0	0	
	3	23.713	0	0	
	4	23.713	0	0	
	5	23.713	0	0	
M31	1	-12.2	0	0	2L8 x 6 x 7/16
	2	-12.2	0	0	
	3	-12.2	0	0	
	4	-12.2	0	0	
	5	-12.2	0	0	
M32	1	71.138	0	0	2L5 x 3 1/2 x 3/8
	2	71.138	0	0	
	3	71.138	0	0	
	4	71.138	0	0	
	5	71.138	0	0	
M33	1	-36.6	0	0	2L8 x 6 x 7/16
	2	-36.6	0	0	
	3	-36.6	0	0	
	4	-36.6	0	0	
	5	-36.6	0	0	
M34	1	118.563	0	0	2L5 x 3 1/2 x 3/8
	2	118.563	0	0	
	3	118.563	0	0	
	4	118.563	0	0	
	5	118.563	0	0	
M35	1	-61	0	0	2L8 x 6 x 7/16
	2	-61	0	0	
	3	-61	0	0	
	4	-61	0	0	
	5	-61	0	0	
M36	1	165.988	0	0	2L5 x 3 1/2 x 3/8
	2	165.988	0	0	
	3	165.988	0	0	
	4	165.988	0	0	
	5	165.988	0	0	
M37	1	-85.4	0	0	2L5 x 3 1/2 x 3/8
	2	-85.4	0	0	
	3	-85.4	0	0	
	4	-85.4	0	0	
	5	-85.4	0	0	

SHAWN SIDELINGER | AE SENIOR THESIS | ANALYSIS #1

ROOF SYSTEM





LIVE LOADS:

DESIGN = 10 PSF

SNOW LOAD = 30 PSF

DEAD LOADS:

BUILT UP ROOF = 20 PSF

INSULATION = 5 PSF

DECKING + CONCRETE = 37 PSF

SUPERIMPOSED DEAD LOAD = 20 PSF

* BASED ON RISA 2-D EDUCATIONAL MODEL, EACH TRUSS WEIGHS APPROXIMATELY 39,736 lbs OR 39.736 kips

BY REDESIGNING THE W40x167

$39.736 \text{ kips} \times 2/(180' \times 30') = 14.717 \text{ PSF}$

$A_{TR} = 30' \times \left(\frac{180+25}{2}\right) = 3075 \text{ SF} \times 2 = 6150 \text{ SF}$

$L = L_o\left(.25 + \frac{15}{\sqrt{A_{TR}}}\right)$

$= 40\left(.25 + \frac{15}{\sqrt{6150}}\right) = 17.65 \text{ PSF}$

$W_u = 1.2(D_L) + 1.6(L_L)$

$= 1.2(82 + 14.717) + 1.6(17.65) = 144.30 \text{ PSF}$

$P_u = 144.30 \times 10\left(\frac{180+25}{2}\right)$

$= 148 \text{ kips}$

$M_u = 148 \text{ kips} \times 10 \text{ ft}$

$= 1480 \text{ ft-kips}$

AISC TABLE 3-2 ON PG 3.14

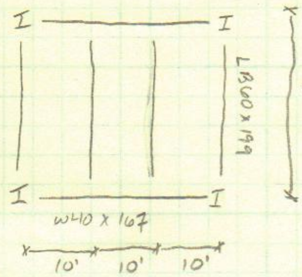
W18 x 175 MAX MOMENT IS 1490 ft-kips

1490 > 1480

∴ OK

SHAWN SIDELINGER | SENIOR AE THESIS | ANALYSIS #1

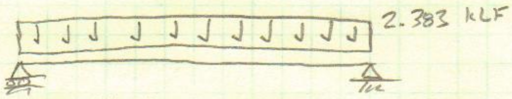
FLOOR SYSTEM

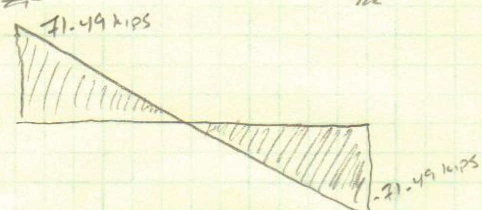


LIVE LOADS :
DESIGN = 150 PSF
DEAD LOADS :
DECKING AND CONCRETE = 37 PSF
SUPER IMPOSED DEAD LOAD = 25 PSF

* RESIZING LB60 x 199
AT = 60' x 10' = 600 SF
AT KL = 600 x 2 = 1200 > 400 ∴ CAN BE REDUCED

$L = 150\left(.25 + \frac{15}{\sqrt{1200}}\right)$
= 102.452 PSF
$W_u = 1.2(62) + 1.6(102.452) = 238.32$ PSF
238.32 PSF x 10' = 2.383 KLF





SHEAR = 2.383 KLF x 60' = 71.49 kips

$M_u = 71.49\text{ kips} \cdot \frac{1}{2}\left(\frac{30\text{ ft}}{2}\right) = 1072.35$ ft-kips

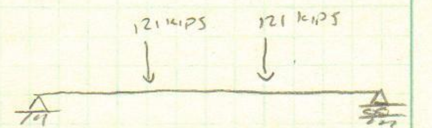
AISC TABLE 3-2
PAGE 3-15
W24 x 104 MAX MOMENT IS
1080 ft-kips
1080 > 1072.35
∴ OK

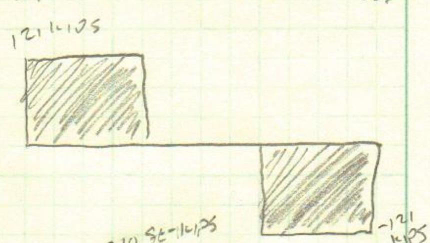
* RESIZING W40 x 167
AT = 60' x 30' = 1800 SF
KL AT = 2 x 1800 = 3600 SF > 400
∴ CAN BE REDUCED

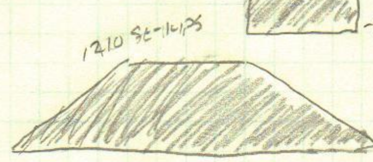
$L = 150\left(.25 + \frac{15}{\sqrt{3600}}\right) = 75$ PSF

$W_u = 1.2(62+7) + 1.6(75)$
= 202.8 PSF

$P_u = 202.8$ PSF x 10'(60')
= 121 kips







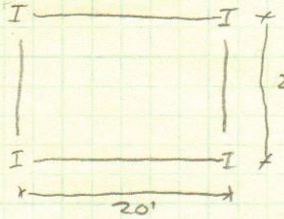
M_u = 121 kips x 10' = 1210 ft-kips

AISC TABLE 3-2
PAGE 3-15
W24x117 MAX MOMENT IS 1230 ft-kips
1230 > 1210
∴ OK

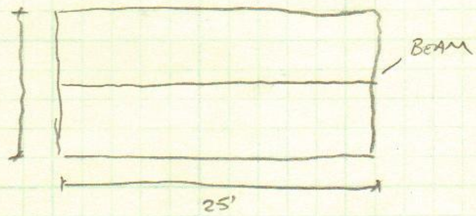
SHAWN SIDELINGER | AE SENIOR THESIS | ANALYSIS #4

FACADE REDESIGN

FLOOR PLAN



WALL



LIVE LOADS:
DESIGN = 100 PSF

DEAD LOADS:
CONCRETE + DECKING = 42 PSF
SUPERIMPOSED DEAD LOAD = 15 PSF

AT = 25' × 10' = 250 SF
ATLL = 250 × 2 = 500 SF > 400, CAN BE REDUCED

L = 100 (.25 + 15/√500)
= 92 PSF

Wu = 1.2 (57) + 1.6 (92)
= 218.45 PSF × 10' = 2184.5 PLF

PRECAST CONCRETE PANEL DESIGN:
PANEL = 100 PSF
INSULATION = 2 PSF

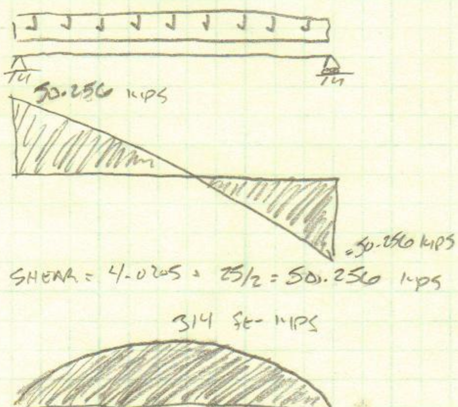
INSULATED METAL PANEL DESIGN
PANEL = 5 PSF

PCP
Wu = 1.2 (102) + 1.6 (0)
= 122.4 PSF × 15'
= 1836 PLF

IMP
Wu = 1.2 (5) + 1.6 (0)
= 6 PSF × 15'
= 90 PLF

PCP DESIGN

2184.5 + 1836 = 4020.5 PLF



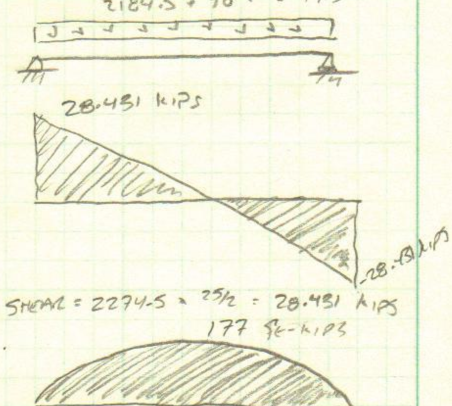
SHEAR = 4.0205 × 25/2 = 50.256 KIPS

M = 50.256 × 1/2 (25/2) = 314 ft-KIPS

AISC TABLE 3-2
PG 3-17
W21×44 MAX MOMENT = 358 ft-KIPS
358 > 314
∴ OK

IMP DESIGN

2184.5 + 90 = 2274.5 PLF



SHEAR = 2274.5 × 25/2 = 28.431 KIPS

M = 28.431 × 1/2 × (25/2) = 177 ft-KIPS

AISC TABLE 3-2
PG 3-18
W16×31 MAX MOMENT = 203 ft-KIPS
203 > 177
∴ OK

APPENDIX F – Cost Estimates

Analysis 1: Redesign of Cellular Beams Detailed Cost Tables

Member	Area (SF)	Length (ft)	Volume (CF)	Weight (lb)	Cost per Pound	Total Cost
2L8 x 6 x 7/8	0.16042	448	71.86816	35215.3984	$3.10	$109,167.74
2L5 x 3 1/2 x 3/8	0.04236	217.8314	9.227338104	4521.39567	$3.10	$14,016.33
Individual Truss Cost				$123,184.06		
Total Truss System Cost				$3,202,785.60		

Item	Unit	Quantity	Bare Material Cost	Material Cost	Bare Labor Cost	Labor Cost	Bare Equipment Cost	Equipment Cost	Total
LB66 x 290, Cellular Beam	LF	4160	$715.00	$2,974,400.00	$14.56	$60,569.60	$5.28	$21,964.80	$3,056,934.40
Steel Pipe, 8" Diameter Hollow	EA	338	$631.75	$213,531.50	$45.89	$15,509.13	$27.27	$9,215.57	$238,256.20
Concrete, 4000 psi	CY	8712.68	$176.00	$1,533,431.68	$54.50	$474,841.06	$0.33	$2,875.18	$2,011,147.92
W14 x 30, Beam	LF	690	$36.50	$25,185.00	$2.60	$1,794.00	$1.74	$1,200.60	$28,179.60
Original Cost of Cellular Beam System						$5,334,518.12			

Item	Unit	Quantity	Bare Material Cost	Material Cost	Bare Labor Cost	Labor Cost	Bare Equipment Cost	Equipment Cost	Total
Framework, Aluminum	SF	8640	$41.65	$359,856.00	$5.49	$47,416.32	$0.00	$0.00	$407,272.32
Metal Panels, Aluminum	SF	8640	$11.36	$98,189.28	$3.52	$30,412.80	$0.00	$0.00	$128,602.08
Vapor Barrier	SF	8640	$0.48	$4,112.64	$1.34	$11,612.16	$0.30	$2,566.08	$18,290.88
Total Increase in Façade Cost						$554,165.28			

Item	Unit	Quantity	Bare Material Cost	Material Cost	Bare Labor Cost	Labor Cost	Bare Equipment Cost	Equipment Cost	Total
LB66 x 199	LF	4160	$742.50	$3,088,800.00	$8.26	$34,344.96	$3.55	$14,780.48	$3,137,925.44
W24 x 104	LF	540	$138.60	$74,844.00	$5.17	$2,790.72	$1.78	$962.28	$78,597.00
Original Floor Design						$3,216,522.44			
Item	Unit	Quantity	Bare Material Cost	Material Cost	Bare Labor Cost	Labor Cost	Bare Equipment Cost	Equipment Cost	Total
W40 x 167	LF	4160	$226.60	$942,656.00	$4.72	$19,635.20	$1.63	$6,772.48	$969,063.68
W24 x 117	LF	540	$156.20	$84,348.00	$5.17	$2,790.72	$1.78	$962.28	$88,101.00
Proposed Floor Design						$1,057,164.68			

Analysis 2: Fuel Room Re-sequencing

Cost of Concrete Work Performed in Fuel Tank Rooms (Normal Wages)									
Item	Unit	Quantity	Bare Material Cost	Total Material Cost	Bare Labor Cost	Total Labor Cost	Bare Equipment Cost	Total Equipment Cost	Total
Forms in Place, Mat Foundation	SFCA	226.67	$2.14	$484.58	$9.46	$2,145.17	$0.00	$0.00	$2,629.75
#6 Reinforcing Steel	TON	9.01	$670.45	$6,042.10	$915.20	$8,247.78	$0.00	$0.00	$14,289.88
Concrete, 4000 psi	CY	148.15	$81.59	$12,087.78	$0.00	$0.00	$0.00	$0.00	$12,087.78
Concrete Pump Truck	CY	148.15	$0.00	$0.00	$7.97	$1,180.21	$2.31	$342.96	$1,523.16
Machine Trowel	SF	6000.00	$0.00	$0.00	$0.81	$4,867.20	$0.49	$2,960.10	$7,827.30
							Total Cost of Concrete Work	$38,357.87	

Cost of Concrete Work Performed in Fuel Tank Rooms (Overtime Wages)									
Item	Unit	Quantity	Bare Material Cost	Total Material Cost	Bare Labor Cost	Total Labor Cost	Bare Equipment Cost	Total Equipment Cost	Total
Forms in Place, Mat Foundation	SFCA	226.67	$2.14	$484.58	$14.20	$3,217.76	$0.00	$0.00	$3,702.34
#6 Reinforcing Steel	TON	9.01	$670.45	$6,042.10	$1,372.80	$12,371.67	$0.00	$0.00	$18,413.77
Concrete, 4000 psi	CY	148.15	$81.59	$12,087.78	$0.00	$0.00	$0.00	$0.00	$12,087.78
Concrete Pump Truck	CY	148.15	$0.00	$0.00	$11.95	$1,770.31	$2.31	$342.96	$2,113.27
Machine Trowel	SF	6000.00	$0.00	$0.00	$1.22	$7,300.80	$0.49	$2,960.10	$10,260.90
							Total Cost of Concrete Work	$46,578.05	

Analysis 4: Façade Redesign

Item	Unit	Quantity	Bare Material Cost	Material Cost	Bare Labor Cost	Labor Cost	Bare Equipment Cost	Equipment Cost	Total
Metal Framing, Aluminum	SF	31000	$41.65	$1,291,150.00	$5.49	$170,128.00	$0.00	$0.00	$1,461,278.00
Metal Panel, Aluminum Insulated	SF	31000	$11.36	$352,299.50	$3.52	$109,120.00	$0.00	$0.00	$461,419.50
Vapor Barrier	SF	31000	$0.63	$19,625.48	$1.79	$55,413.12	$0.57	$17,811.36	$92,849.96
Total Cost of Metal Panel Façade							$2,015,547.46	Cost per SF	$65.02

Item	Unit	Quantity	Bare Material Cost	Material Cost	Bare Labor Cost	Labor Cost	Bare Equipment Cost	Equipment Cost	Total
Structural Connections	EA	1350	$100.00	$135,000.00	$100.00	$135,000.00	$50.00	$67,500.00	$337,500.00
Precast Concrete Panel	SF	31000	$42.25	$1,309,595.00	$3.92	$121,520.00	$2.18	$67,456.00	$1,498,571.00
Vapor Barrier	SF	31000	$0.63	$19,625.48	$1.79	$55,413.12	$0.57	$17,811.36	$92,849.96
Insulation, Rigid 2"	SF	31000	$1.47	$45,448.48	$0.53	$16,492.00	$2.17	$67,287.36	$129,227.84
Total Cost of Precast Concrete Panel Façade							$2,058,148.80	Cost per SF	$66.39

Item	Unit	Quantity	Bare Material Cost	Material Cost	Bare Labor Cost	Labor Cost	Bare Equipment Cost	Equipment Cost	Total
Metal Framing, Aluminum	SF	375	$41.65	$15,618.75	$5.49	$2,058.00	$0.00	$0.00	$17,676.75
Metal Panel, Aluminum Insulated	SF	375	$11.36	$4,261.69	$3.52	$1,320.00	$0.00	$0.00	$5,581.69
Vapor Barrier	SF	375	$0.63	$237.41	$1.79	$670.32	$0.57	$215.46	$1,123.19
W16 x 31, Structural Beam	LF	25	$57.72	$1,442.88	$4.69	$117.20	$3.14	$78.40	$1,638.48
Total Cost of Select Metal Panel Façade							$26,020.10	Cost per SF	$69.39

Item	Unit	Quantity	Bare Material Cost	Material Cost	Bare Labor Cost	Labor Cost	Bare Equipment Cost	Equipment Cost	Total
Structural Connections	EA	36	$100.00	$3,600.00	$100.00	$3,600.00	$50.00	$1,800.00	$9,000.00
Precast Concrete Panel	SF	375	$42.25	$15,841.88	$3.92	$1,470.00	$2.18	$816.00	$18,127.88
Vapor Barrier	SF	375	$0.63	$237.41	$1.79	$670.32	$0.57	$215.46	$1,123.19
Insulation, Rigid 2"	SF	375	$1.47	$549.78	$0.53	$199.50	$2.17	$813.96	$1,563.24
W21 x 44, Structural Beam	LF	25	$63.07	$1,576.75	$5.10	$127.60	$2.56	$64.00	$1,768.35
Total Cost of Select Precast Concrete Panel Façade							$31,582.65	Cost per SF	$84.22

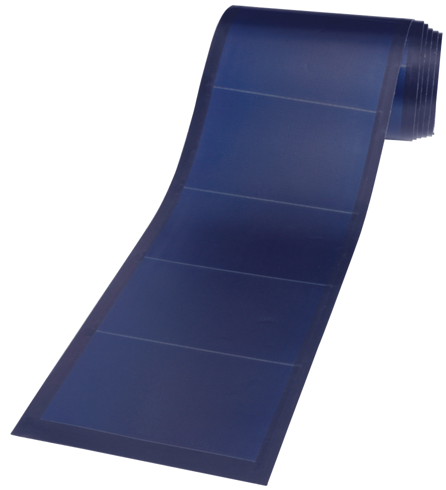
APPENDIX G: Uni-Solar Solar Laminate PVL-Series, Model: PVL-144

Technical Data Sheets

UNI-SOLAR

PowerBond PVL

TECHNICAL DATA SHEET
PVL-144



- High Temperature and Low Light Performance
- 5-Year Limited Product Warranty
- Limited Power Output Warranty:
  92% at 10 years, 84% at 20 years, 80% at 25 years (of minimum power)
- Quick-Connect Terminals and Adhesive Backing
- Bypass Diodes for Shadow Tolerance

Performance Characteristics

Rated Power (P_{max}):	144 Wp
Production P_{max} Tolerance:	± 5 %

Construction Characteristics

Dimensions:	Length: 5486 mm (216"), Width: 394 mm (15.5"), Depth: 4 mm (0.2"), 16 mm (0.6") including potted terminal housing assembly
Weight:	7.7 kg (17.0 lbs)
Output Cables:	4 mm^2 (12 AWG) cable with weatherproof DC-rated quick-connect terminals 560 mm (22") length
Bypass Diodes:	Connected across every solar cell
Encapsulation:	Durable ETFE high light-transmissive polymer
Adhesive:	Ethylene propylene copolymer adhesive sealant with microbial inhibitor
Cell Type:	22 triple junction amorphous silicon solar cells 356 mm x 239 mm (14" x 9.4") connected in series

Qualifications and Safety

UL 1703 Listed by Underwriters Laboratories for electrical and fire safety (Class A Max. Slope 2/12, Class B Max. Slope 3/12, Class C Unlimited Slope fire ratings) for use in systems up to 600 VDC.

IEC 61646 and IEC 61730 certified by TÜV Rheinland for use in systems up to 1000 VDC.

Laminate Standard Configuration

Photovoltaic laminate with potted terminal housing assembly with output cables and quick-connect terminals on top.

Application Criteria*

- Installation temperature between 10 °C - 40 °C (50 °F - 100 °F)
- Maximum roof temperature: 85 °C (185 °F)
- Minimum slope: 3° (1/2:12)
- Maximum slope: 60° (21:12)
- Approved substrates include certain membrane and metal roofing products. See United Solar for details.

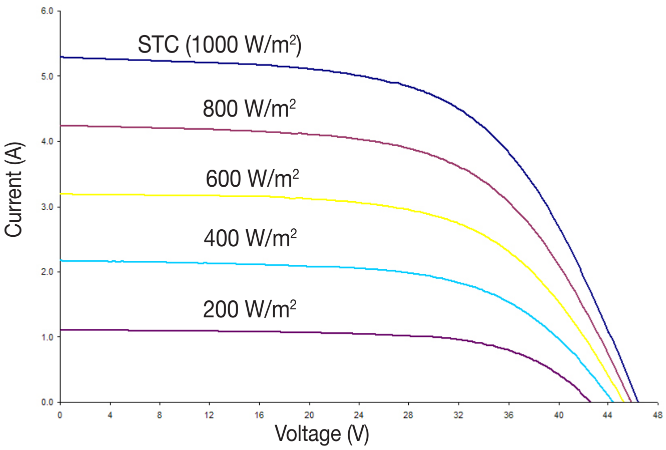
Detailed installation requirements are specified in United Solar's installation manuals.

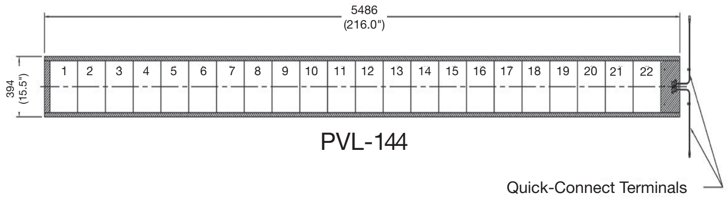
Flexible
Lightweight
Durable
No-Glass
Shadow Tolerant
More kWh
High Temp Performance
Low Light Performance

UNI-SOLAR
PowerBond PVL

TECHNICAL DATA SHEET
PVL-144

IV Curves at various Levels of Irradiance at Air Mass 1.5 and 25 °C Cell Temperature





All measurements in mm
Inches in parentheses
Tolerances: Length: ± 5 mm (1/4"), Width: ± 3 mm (1/8")

Electrical Specifications

STC
(Standard Test Conditions)
(1000 W/m², AM 1.5, 25 °C Cell Temperature)

Maximum Power (P_{max}): 144 W
Voltage at Pmax (V_{mpp}): 33.0 V
Current at Pmax (I_{mpp}): 4.36 A
Short-circuit Current (I_{sc}): 5.3 A
Open-circuit Voltage (V_{oc}): 46.2 V
Maximum Series Fuse Rating: 10 A (UL), 8 A (IEC)

NOCT
(Nominal Operating Cell Temperature)
(800 W/m², AM 1.5, 1 m/sec. wind)

Maximum Power (P_{max}): 111 W
Voltage at Pmax (V_{mpp}): 30.8 V
Current at Pmax (I_{mpp}): 3.6 A
Short-circuit Current (I_{sc}): 4.3 A
Open-circuit Voltage (V_{oc}): 42.2 V
NOCT: 46 °C

Temperature Coefficients
(at AM 1.5, 1000 W/m² irradiance)

Temperature Coefficient (TC) of I_{sc}: 0.001/°K(0.10%/°C)
Temperature Coefficient (TC) of V_{oc}: -0.0038/°K (-0.38%/°C)
Temperature Coefficient (TC) of P_{max}: -0.0021/°K (-0.21%/°C)
Temperature Coefficient (TC) of I_{mpp}: 0.001/°K (0.10%/°C)
Temperature Coefficient (TC) of V_{mpp}: -0.0031/°K (-0.31%/°C)

y = yreference • [1 + TC • (T- Treference)]

Notes:
1. During the first 8-10 weeks of operation, electrical output exceeds specified ratings. Power output may be higher by 15%, operating voltage may be higher by 11% and operating current may be higher by 4%.
2. Production tolerance for P_{max} at standard test conditions (STC) is +/-5% and for other electrical parameters is +/-10%. Electrical specifications are based on measurements performed at standard test conditions of 1000 W/m² irradiance, Air Mass 1.5, and cell temperature of 25 °C after stabilization.
3. Actual performance may vary up to 10% from rated power due to low temperature operation, spectral and other related effects. Maximum system open-circuit voltage not to exceed 600 VDC per UL, 1000 VDC per IEC regulations.
4. Specifications subject to change without notice.

Your *UNI-SOLAR*® Distributor:

Global Headquarters
United Solar Ovonic LLC
3800 Lapeer Road
Auburn Hills, MI 48326
Tel: +1.248.293.0440
Fax: +1.248.364.5678
Toll Free (USA): +1.800.528.0617
info@uni-solar.com

European Headquarters
United Solar Ovonic
Europe SAS
Tour Albert 1er
65, avenue de Colmar
92507 Rueil-Malmaison Cedex
Tel: +33.1.74.70.46.24
Fax: +33.1.41.39.00.22
franceinfo@uni-solar.com

German Office
United Solar Ovonic
Europe GmbH
Robert-Koch-Strasse 50
55129 Mainz
Tel: +49.6131.240.40.400
Fax: +49.6131.240.40.499
europeinfo@uni-solar.com

Italian Office
United Solar Ovonic Italy Srl.
Via Monte Baldo, 14F
37069 Villafranca (VR)
Tel: +39.045.86.00.982
Fax: +39.045.86.17.738
italyinfo@uni-solar.com

Spanish Office
United Solar Ovonic
Europe GmbH
Sucursal Spain
C/ Llull, 321-329
08019 Barcelona
Tel: +34.935.530.752
Fax: +34.935.530.753
spaininfo@uni-solar.com

www.uni-solar.com
A subsidiary of Energy
Conversion Devices, Inc.
(Nasdaq: ENER)

APPENDIX H: Satcon PowerGate Plus 75 kW

Technical Data Sheets

PowerGate Plus 75 kW

Satcon™

PVS-75 (208 V)
PVS-75 (240 V)
PVS-75 (480 V)

Unparalleled Performance

With their advanced system intelligence, next-generation Edge™ MPPT technology, and industrial-grade engineering, PowerGate® Plus inverters maximize system uptime and power production, even in cloudy conditions.

Power Efficiency

Power Level	Output Power[1]	Efficiency[2]
10%	7.5 kW	92.6%
20%	15 kW	95.6%
30%	22.5 kW	96.3%
50%	37.5 kW	96.7%
75%	56.25 kW	96.6%
100%	75 kW	96.3%

[1] 315V minimum [2] 240V model

Edge MPPT

Provides rapid and accurate control that boosts PV plant kilowatt yield

Provides a wide range of operation across all photovoltaic cell technologies

Printed Circuit Board Durability

Wide thermal operating range: -40º C (-40º F) to 85º C (185º F)

Conformal coated to withstand extreme humidity and air-pollution levels

Proven Reliability

Rugged and reliable, PowerGate Plus PV inverters are engineered from the ground up to meet the demands of large-scale installations.

Low Maintenance

Modular components make service efficient

Safety

UBC Seismic Zone 4 compliant

Built-in DC and AC disconnect switches

Integrated DC two-pole disconnect switch isolates the inverter (with the exception of the GFDI circuit) from the photovoltaic power system to allow inspection and maintenance

Built-in isolation transformer

Protective covers over exposed power connections

PV Inverters | PowerGate Plus 75 kW

PowerGate Plus 75 kW Specifications			UL/CSA
Input Parameters			
Maximum Array Input Voltage	600 VDC		•
Input Voltage Range (MPPT; Full Power)	315–600 VDC		•
Maximum Input Current	248 ADC		•
Output Parameters			
Output Voltage Range (L-L)	183–229 VAC	208 VAC	•
	211–264 VAC	240 VAC	•
	422–528 VAC	480 VAC	•
Nominal Output Voltage	208 VAC		•
	240 VAC		•
	480 VAC		•
Output Frequency Range	59.3–60.5 Hz		•
AC Voltage Range (Standard)	-12%/+10%		•
Nominal Output Frequency	60 Hz		•
Number of Phases	3		•
Maximum Output Current per Phase	208A	208 VAC	•
	181A	240 VAC	•
	91A	480 VAC	•
CEC-Weighted Efficiency	96%		•
Maximum Continuous Output Power	75 kW (75 kVA)		•
Tare Losses	65.36 W	208 VAC	•
	71.84 W	240 VAC	•
	69.5 W	480 VAC	•
Power Factor at Full Load	>0.99		•
Harmonic Distortion	<3% THD		•

• Standard ○ Optional

PowerGate Plus 75 kW

Output Options

PowerGate Plus 75 kW	
UL/CSA	208 VAC Output
	240 VAC Output
	480 VAC Output

Streamlined Design

With all components encased in a single, space-saving enclosure, PowerGate Plus PV inverters are easy to install, operate, and maintain.

Single Cabinet with Small Footprint

Convenient access to all components

Large in-floor cable glands make access to DC and AC cables easy

Rugged Construction

Engineered for outdoor environments

Output Transformer

Provides galvanic isolation

Matches the output voltage of the PV inverter to the grid

PowerGate Plus 75 kW Specifications		UL/CSA
Temperature		
Operating Ambient Temperature Range (Full Power)	-20º C to +50º C	•
Storage Temperature Range	-30º C to +70º C	•
Cooling	Forced Air	•
Noise		
Noise Level	<65 dB(A)	•
Combiner		
Number of Inputs and Fuse Rating	5 (100 ADC)	○
	6 (80 ADC)	○
Inverter Cabinet		
Enclosure Rating	NEMA 3R	•
Enclosure Finish (14-Gauge, Powder-Coated G90 Steel)	RAL-7032	•
Cabinet Dimensions (Height x Width x Depth)		80" x 57" x 30.84"
Cabinet Weight		2,150 lbs.
Transformer		
Integrated Internal Transformer		•
Low Tap Voltage[1]	20%	•
Testing and Certification		
UL1741, CSA 107.1-01, IEEE 1547, IEEE C62.41.2, IEEE C62.45, IEEE C37.90.1, IEEE C37.90.2		•
UBC Zone 4 Seismic Rating		•
Warranty		
Five Years		•
Extended Warranty (up to 10, 15, or 20 years)		○
Extended Service Agreement		○
Intelligent Monitoring		
Satcon PV View® Plus		○
Satcon PV Zone®		○
Third-Party Compatibility		•

• Standard
○ Optional

[1] The 20% boost tap on the isolation transformer increases the AC voltage output range for applications where the solar array DC operating voltage is at or near the lower end of the DC input range. This boost allows for continued inverter operation at lower DC voltage input levels.

Note: Specifications are subject to change.

Satcon Corporate
27 Drydock Avenue
Boston, MA 02210
P: +1.617.897.2400
F: +1.617.897.2401
E: sales@satcon.com

Satcon West
2925 Bayview Drive
Fremont, CA 94538
P: +1.510.226.3800
F: +1.510.226.3801
E: sales@satcon.com

Satcon Canada
835 Harrington Court
Burlington, ON L7N 3P3
Canada
P: +1.905.639.4692
F: +1.905.639.0961
E: sales@satcon.com

Satcon Greece
Athanasiou Diakou 2 &
Marathonas Ave
Gerakas 15344
Greece
P: +30.210.6654424
F: +30.210.6654425
E: sales@satcon.com

Satcon Czech Republic
Classic 7 Business Park
Jankovcova 1037/49
170 00 Praha 7
Czech Republic
P: +420.255.729.610
F: +420.255.729.611
E: sales@satcon.com

Satcon Shenzhen China
Room 1112, 11/F, International
Chamber of Commerce,
No. 168 FuHua San Road,
FuTian District, Shenzhen, P.R.C.
518048
P: +86.755.6168.2588
F: +86.755.6168.2599
E: sales@satcon.com

Satcon Shanghai China
Room 2308, 23/F, New
HongQiao Center Building,
No. 83 LouGuanShan Road,
Changning District,
Shanghai, P.R.C.
P: +86.139.1811.2818
E: sales@satcon.com