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University of Pittsburgh CHEVRON ANNEX

PITTSBURGH, PENNSYLVANIA

Senior Thesis Final Report

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University of Pittsburgh Chevron Annex

Pittsburgh, PA

Architecture

- Vertical addition consisting of 2 chemical research floors and 1 mechanical penthouse floor
- Facade system is composed of terra cotta tiles, metal panels, louvers and glazing
- Aluminum cladded eyebrow accents the building's southwest corner
- In pursuit of LEED Gold certification

Project Overview

Owner:	University of Pittsburgh
Architect:	Wilson Architects
General Contractor:	Burchick Construction
Structural Engineer:	Barber & Hoffman, Inc.
MEP/FP:	Affiliated Engineers, Inc.
Civil Engineer:	The Gateway Engineers, Inc.
Size:	35,000 sf addition
Cost:	$25 Million
Duration:	Nov 2009 - Sept 2011
Project Delivery Method:	Design-Bid-Build

MEP Systems

- Addition serviced by 3 air handling units designed as heating-cooling, single duct, variable volume reheat system
- 3 laboratory exhaust fans
- 1 emergency generator providing 1500 kW of power
- 300 kVA transformer
- 1600 A main switchboard, 480/277V 3 phase and 4 wires

Construction Logistics

- 2 phase project consisting of a renovation and vertical addition
- Existing structure not capable of supporting the addition; resulting in the need for new columns, each with a foundation system composed of pile caps and micropiles
- Little space available around site, so minimal laydown area and site trailers were located 200 yards northwest of the site

Structural System

- Structural system of addition consisted of steel beams and columns
- Pile caps supported the new columns of the addition
- Composite steel deck
- Braced frame resisted shear and lateral loads imposed on the building

PENNSTATE

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http://www.engr.psu.edu/ae/thesis/portfolios/2012/RJM5203/index.html

EXECUTIVE SUMMARY

This final report discusses four analyses that will be performed for the University of Pittsburgh's Chevron Annex project. Background research was performed, as well as an examination of the potential solutions, expected outcome and the steps that were performed to achieve the technical analysis/research.

Analysis 1: Integration of Tablet PC's in the Field

The Chevron Annex did not utilize any new or unique methods of technology during construction. It is suggested that the project team implement different forms of technology in the field to increase the productivity of the workers. Tablet PC's are recommended to help control safety, coordinate commissioning, fill out punchlists and close out the project. Applications and programs applicable were also recommended. These programs will help increase the overall productivity of the project. It was discovered that the implementation of new and innovative technology in the field has a drastic effect on the overall cost and time savings for the Chevron Annex.

Analysis 2: Re-Design/Re-Sequence of the Facade

The installation and phasing of the exterior skin caused a number of problems during the construction of the Chevron Annex. A re-sequencing of the installation of the façade systems was completed and compared to the original plan in this analysis. Members of the project team were also interviewed to determine the problems and challenges faced during the installation of these systems. This comparison helped determine the most efficient and effective way to sequence the exterior façade construction, as well as point out any major concerns or problems with the original schedule.

Analysis 3: Commissioning of Laboratory Spaces

The Chevron Annex developed some complications when it came time to turn on the mechanical equipment for the testing and balancing of the systems. Throughout this analysis, the commissioning process was researched and analyzed to determine the most efficient way to commission. Additionally, a new schedule was created and compared to the original plan, determining the problematic areas. These areas were analyzed and solutions were developed to help with this process.

Analysis 4: Addition of a Green Roof

The Chevron Annex's roof was a typical TPO roof that did not use any innovative solutions to help increase the efficiency of the building. This roof was changed to a green roofing system, helping reduce the storm water runoff, the building's heat island effect and the mechanical loads imposed on the building. This analysis also includes structural and mechanical breadths that rely on knowledge that was gained in previous AE courses.

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PROJECT BACKGROUND

PROJECT INFORMATION

The Chevron Annex is an addition to the University of Pittsburgh's Chevron Tower and Ashe auditorium. The construction of the Annex started on November 20, 2009 and was completed in September 2011. The facility is a two phase project located in Pittsburgh, Pennsylvania that included a renovation to the existing auditorium, as well as a three story vertical addition above that is approximately 35,000 square feet. The Chevron Annex was a $25 million design-bid-build project that was bid as a multi-prime job. Burchick Construction was the General Contractor that was awarded this project, and is also the sponsor for this thesis.

Included in the project are spaces which encompass a number of functions. The first floor and mezzanine level consist of a main lobby, computer lab, auditoriums and lounge area. The second and third floors are similar to each other and are devoted to chemistry labs and student desk areas. A few offices and other rooms are also scattered throughout the floor. The fourth floor of the new addition is a mechanical space that houses most of the mechanical equipment.

The façade of the building is a combination of a number of systems. Some of these systems include terra cotta, metal panels, louvers and glazing. Additionally, a sunshade system is integrated into the curtain wall and an aluminum cladded eyebrow (Figure 1) accents the southwest corner of the façade.

Figure 1 Aluminum Cladded Eyebrow

Additionally, the Chevron Annex is currently in pursuit of a LEED Gold rating. Being certified as a LEED Gold building will help acknowledge the building in its attempt to implement strategies for better environmental and health performance, as well as adding another LEED certified building to the University of Pittsburgh's campus.

The schedule was the main concern of this project because the University needed to turnover certain areas of the building once the students returned to class. Another area that was a risk for the completion of the project was the ongoing changes that were requested by the University. Constant change orders were developed; however, there was no additional time added to the schedule. Overall, the Chevron

Annex had several problematic features that were previously identified in Technical Report 3. These problems are expected to be solved throughout the analysis of four technical areas during the Spring 2012 semester.

EXISTING CONDITIONS

The project is located in Oakland, Pennsylvania; which is large neighborhood in Pittsburgh where the University of Pittsburgh's main campus is located. The site and surrounding buildings are shown in the aerial photograph below. The Chevron Annex is outlined in **RED**.

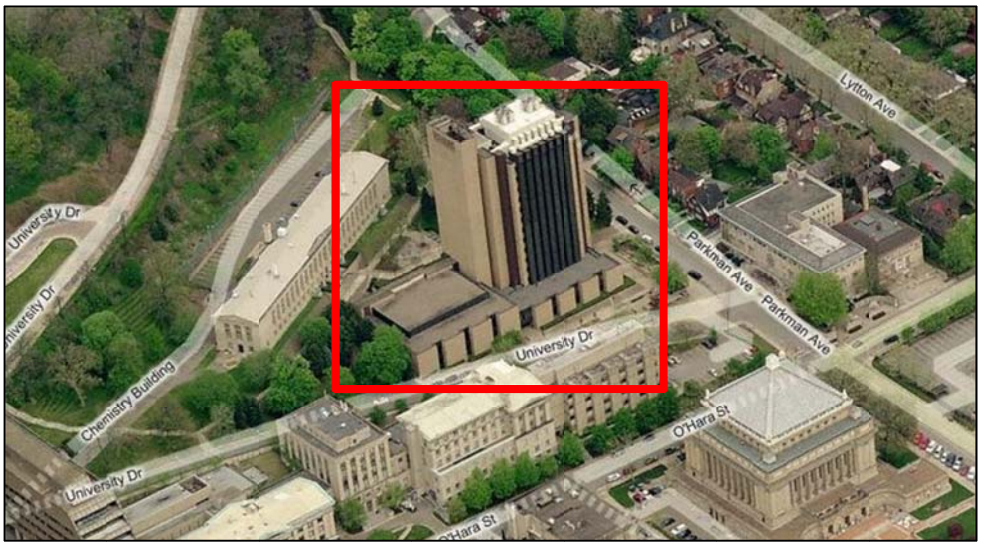


Figure 2 Bird's Eye View of the Chevron Annex and adjacent structures prior to construction

The new addition is placed on top the western section of building above the Ashe Auditorium and will be accessible from both the Chevron Tower and the Ashe Auditorium. The compact site made it difficult for material storage and locating an on-site office.

LOCAL CONDITIONS

The Chevron Annex is located at 219 Parkman Avenue in Oakland, Pennsylvania. The building is located on a site located in the corner of The University of Pittsburgh's main campus at the intersection of Parkman Avenue and University Drive.

Due to the fact that the project site was located in a densely populated area, parking and other areas of need were hard to come by. A site office was needed for the multiple primes involved with the project and was located approximately a quarter mile west of the site. The site office complex consisted of two small trailers and one larger double-wide trailer. The two smaller trailers were occupied by the General Contractor and the Lighting Contractor. The larger double-wide trailer was for the Construction Manager of the project.

Limited parking was available at this site-office.

The following figure displays the locations of the site, office, and lay-down areas.

RED: Project Site

BLUE: Field Offices & Limited Parking

GREEN: Lay-down/Storage Areas

Figure 3 Overhead View of Project Area

CLIENT INFORMATION

The University of Pittsburgh, commonly referred to as Pitt, is the owner of the project. The University of Pittsburgh is a public institution that is highly recognized in a number of academic areas ranging from philosophy to dentistry. The University is comprised of five campuses. The main campus is located in Oakland, with the other campuses located around western Pennsylvania. The Oakland campus has over one hundred academic, research and administrative buildings located on it. The most notable of all the buildings is the Cathedral of Learning. This building is one of the tallest academic buildings in the world, at an astonishing 42-stories and 535 feet tall.

Enrollment at the University is more than 35,000 students, which accounts for roughly five percent of all students enrolled in institutions of higher education in the state of Pennsylvania. Over 13,500 faculty and staff members assist and support the needs of the University.

Although The University of Pittsburgh is the outright owner of the project, the University's Chemistry Department is the main tenant of the space. The department is led by Dr. Peter Wipf, who is an extremely notable professor with multiple awards and publications involved with the chemistry of natural products. The space will be fitted for the department's synthetic chemistry research program. The research interests of the tenant include the total synthesis of natural products, organometallic and heterocyclic chemistry, combinatorial, medicinal and computational chemistry.

In addition to the University and their Chemistry Department, The University of Pittsburgh's Facilities Management Department is another party involved in the project. The Facilities Management Department is the main representative for the University and is led by Chris Niemann along with David Klimchock as two main representatives for the department.

PROJECT DELIVERY SYSTEM

The University of Pittsburgh used a Design-Bid-Build with CM Agency project delivery method for the Chevron Annex project. The University broke the project into eight bid packages. Each package was competitively bid and was each awarded as a lump sum contract. Contracts held between each of the primes and their subcontractors were also lump sum contracts. Due to the project's complexity, the University chose to hire a CM Agent. Mascaro Construction was the CM Agent that Pitt hired and they held a cost plus a fee contract with the owner. The organizational chart for the Chevron Annex is shown below.

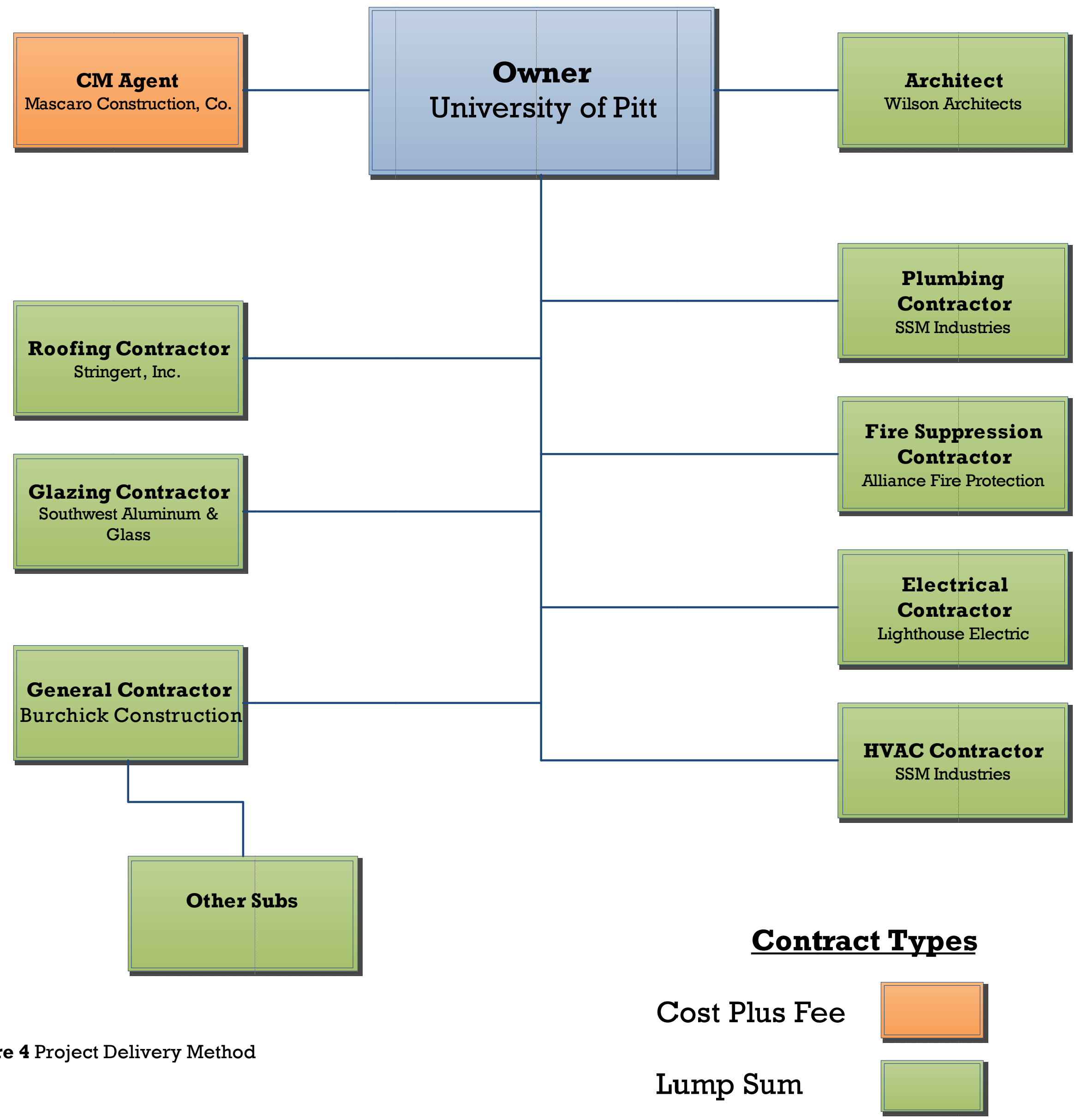


Figure 4 Project Delivery Method

STAFFING PLAN

Burchick organized their staff for this project similar to most of their other projects. However, since this job was complex, Burchick assigned more foreman than usual to this project.

Typically, for most of Burchick's projects, Joe Burchick overlooks the entire process of the project. He does this by staying in constant contact with the project manager that is assigned to the respective project. For the Chevron Annex, Burchick assigned Dave Meuschke to take on the responsibilities of project manager. Dave spent most of his time in the office; while the on-site superintendent, Keith Konesky, kept him updated on the daily tasks that were being performed. Dave also referred to Burchick's chief estimator, Joe Scaramuzzo, for any questions regarding change order costs and any information that pertained to the bidding of the project.

On-site, Keith Konesky is in charge of coordinating all of the contractors involved in the project. He is also in charge of four foremen that help him keep track of the daily activities that are performed by the various tradesmen that Burchick employs. Both, Burchick's accountant and administrative assistant also keep in touch with Dave and Keith to keep track of any accounting or administrative duties that need to be completed. The diagram below outlines the staffing plan that Burchick optimized for the Chevron Annex.

Burchick Staffing Plan

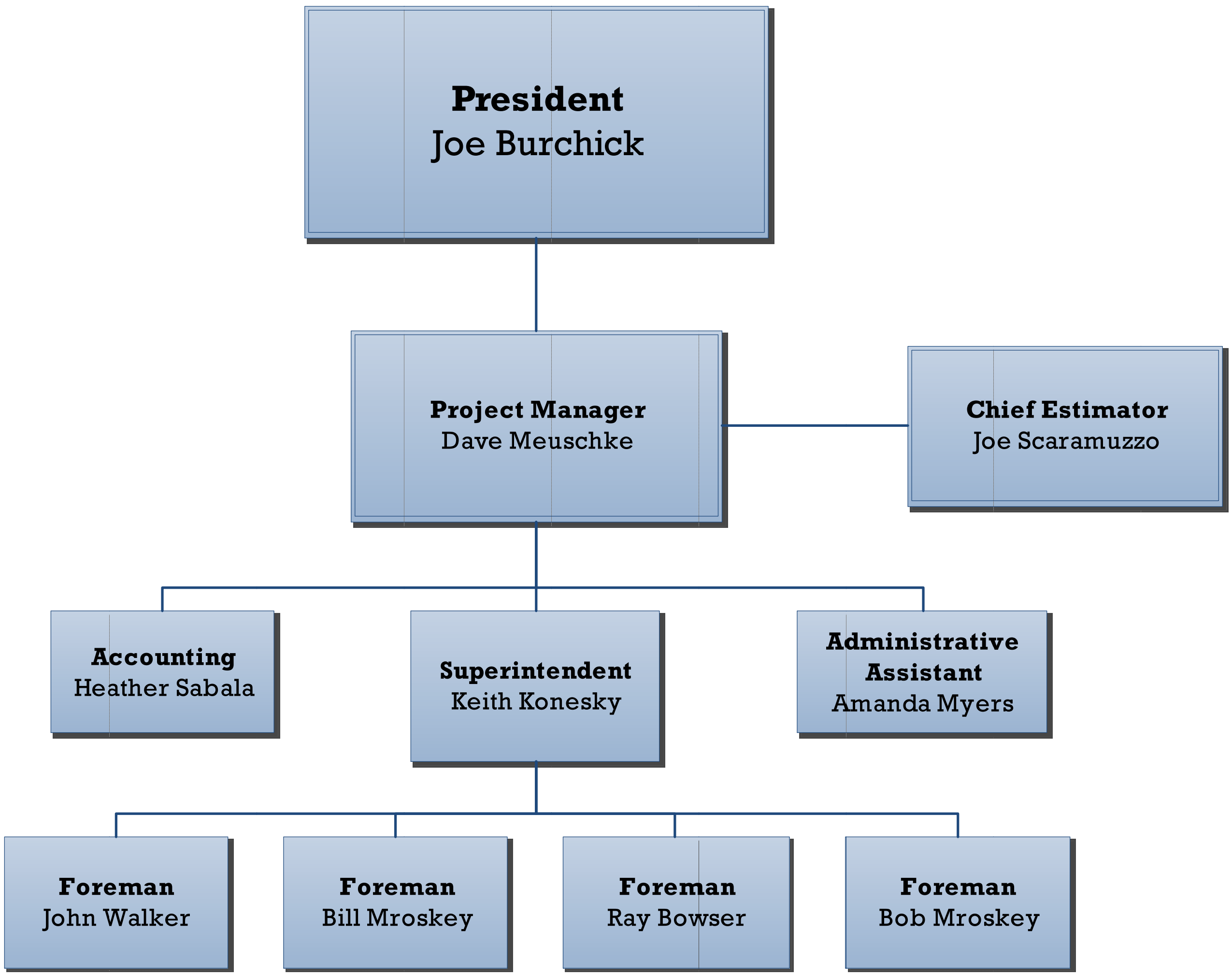


Figure 5 Burchick Staffing Plan

TECHNICAL ANALYSIS 1 – INTEGRATION OF TECHNOLOGY IN THE FIELD

PROBLEM IDENTIFICATION

The Chevron Annex did not utilize any new or unique methods of technology during construction. This was a concern during the project because the field office was located a quarter mile west of the site; which made it difficult for the superintendents to keep track of their documents. Additionally, there was a considerable amount of time that was wasted walking between the site and field office. This time could have been utilized better, thus increasing the quality control and supervision of the project. There was also a lack of communication amongst the project team, which could be resolved with the implementation of new and innovative technology in the field.

Due to the potential benefits that are possible with the implementation of technology in the field, it is an idea that should be addressed on this project. To properly determine if this idea is an effective suggestion, a detailed study was performed. This study includes the following:

- Background Information
- Case Studies
- Benefits & Savings
- Cost Evaluation
- Applications
- Summary

BACKGROUND INFORMATION

As technology is becoming more popular in the construction industry, each company is faced with the pressure of integrating new technologies; and whether or not it is going to significantly affect the project. Upon completion, it was determined that the Chevron Annex would have been a great project for Burchick Construction and the other contractors to get their foot in the technological door by implementing technology in the field.

This point can be reinforced by reviewing an article from Engineering News-Record (ENR) that helps describe the popularity and effectiveness of tablet PCs in the construction industry. The article <u>Tablets Take Off in Construction</u> describes the recent attractiveness iPads have been receiving in the field. It briefly focuses on two companies and how they each use the tablet to maximize their company's goals. Tablets provided these users new ways to speed up communication, obtain client approvals, complete inspections, arrange logistics and manage. Although, it is believed that tablet PCs will not replace cell phones and laptops; some believe that they may be one of the enabling devices that allows the industry to leap forward.

In order to gain a better understanding of the technology currently available, a few resources were analyzed. The first reference used for this analysis was a book titled <u>Application of Mobile IT in</u>

Construction (Bowden, 2005). This book provides a full analysis of the use and applications of technology in the construction industry. Additionally, this book uses helpful tables that give a breakdown of the benefits and drawbacks associated with each of the different forms of technology that are proposed. Throughout this book, Bowden touches on the recurring problems associated with contractor rework and the contributing factors (Figure 6). From this figure, it is obvious that something needs to be done to reduce the conflicting information throughout a jobsite.

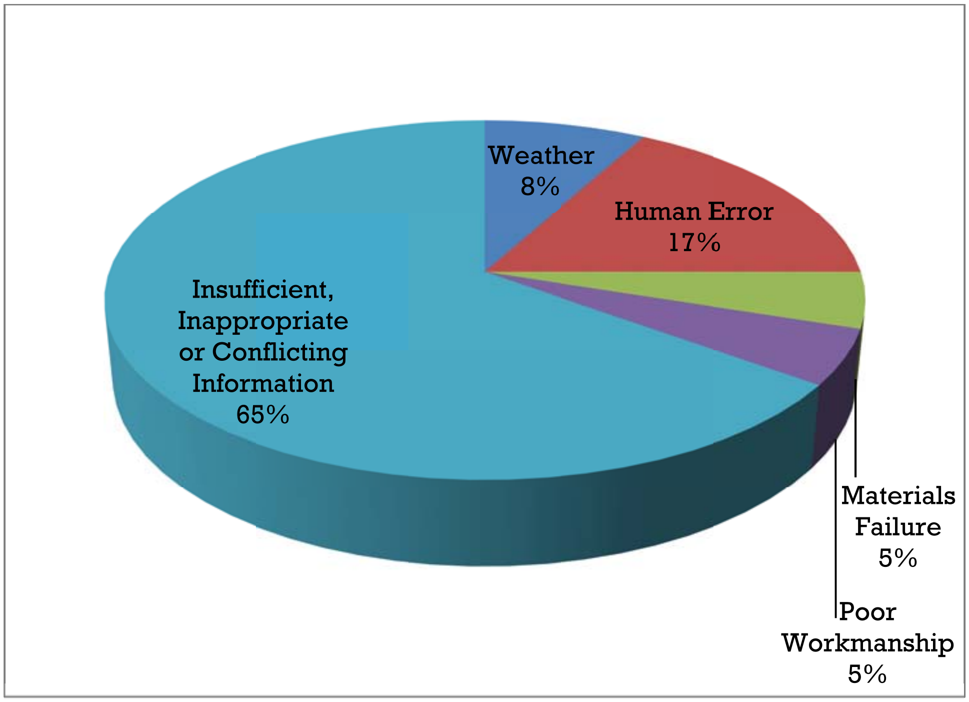


Figure 6 Contributing Factors to Contractor Rework

CASE STUDIES

In order to adequately evaluate a piece of equipment or software, it is essential to review previous projects where the item of interest was used. The problems and solutions developed by the technology can be determined through a variety of case studies. While researching various programs, Vela Systems seemed to be one of the most widely used programs in the industry. After further investigation, Vela Systems included multiple case studies on their website addressing the use of their products and are summarized below.

Case Study 1

The first case study that was reviewed dealt with Balfour Beatty Construction deciding to implement a company-wide, phased use of Vela Systems software and iPads for onsite project management. Initially, Balfour Beatty decided to pilot Vela's field management software and determine the return on investment (ROI) of the software. It was found that there was a reduction of general conditions and overhead, resulting in a ROI of more than 300%. An increase in efficiency and reduced risk was also evident, which was due to the real-time access to the quality and safety aspects of their performance.

Using iPads to support the Vela Mobile system was also suggested. The low cost, long battery life and ease-of-use of iPads make them an essential element for construction management. Protecting the iPads with Otterbox Defender Series cases also makes the tablets able to withstand the rough conditions on the jobsite.

The construction industry's first "all in one" iPad construction application is also provided by Vela Systems. This app includes a document library, checklists for QA/QC, Safety and Commissioning and an issue creation/sign off for tracking any issues while walking in the field. Interestingly, all of these features are available with or without an Internet connection.

This case study also goes into detail on cloud computing and BIM, which are not an area of this study and will not be covered. For more information, please visit Vela Systems' website: www.velasystems.com .

Case Study 2

The second case study that was analyzed focuses on the use of Vela Software on a Suffolk Construction job to increase their efficiency. Suffolk Construction was hired to construct the Liberty Hotel in Boston, Massachusetts. This project was a luxurious hotel that required very detailed and time-consuming communication from the field back to the architects and designers. After being frustrated by the amount of time it took to capture field notes on-site, type the data at the office and then distribute it to all participating parties; co-founder and construction manager, Adam Omansky, felt that there should be less focus on the paperwork and more focus on the actual project.

After researching multiple tablet PCs, Vela chose Motion Computing slate tablet PCs to help support the combination of handwriting and the ability to mark up plans with a pen. Several of Motion tablet's unique features were described, with the main focus being placed on the blend of its performance, ruggedness, lightweight design and affordable price.

After implementation, the end result was that Suffolk's superintendent was able to cut his time of developing meeting minutes in half. Additionally, during a project walk through, several problems were found and the superintendent was able to report the problem in real time. The quality of the electronic output, reports and documents are also superior to the ones Suffolk was using before.

Overall, it was determined that companies using Vela configured Motion tablets see exponential results in the following areas (Vela Systems, 2012):

- Personnel Productivity
- Project Acceleration
- Risk Reduction
- Cost of Quality

Case Study 3

A third case study reviewed on Vela Systems' website involves Bond Brothers, a Massachusetts-based multi-faceted construction company, expanding their use of Vela Systems. Bond Brothers decided to employ Vela Systems' commissioning module on Harvard University's Northwest Lab project. Vela Commissioning tracks systems and equipment as they are delivered, installed, readied for testing and tested. A handover document set is also created by electronically tying all relevant documentation to the specific equipment. This set is then delivered to the owner, speeding up the delivery of the commissioning process (Vela Systems, 2012).

With the use of Vela Systems' mobile field software, the paper side of the construction process is relatively obsolete. Field personnel can use a Tablet PC to view drawings, as well as writing directly on the screen in their own handwriting; which the tablet displays as pen strokes, highlighter marks, or automatically converts to electronic text. Communication of punchlist items were also improved while using Vela Systems. Using a Tablet PC to view drawings, instead of a bunch of 11 x 17 drawings, can assist in the overall orientation within the field.

An example of how easy it is to report problems in the field was also provided in this case study. For instance, if a few windows were not operating properly during inspection; a photo could be taken of the window. The photo could then be downloaded into the system and notes could be written directly on the image. Also, it could be indicated directly on the plans which window does not work and show where the column lines were.

Overall, this case study reinforces the importance of using technology in the field. Also, it shows the wide variety of tasks that can be performed using Vela Systems software and the time and costs savings involved.

BENEFITS & SAVINGS

After reviewing case studies on the applications of mobile technology in the construction industry, it was discovered that the use of technology in the field will eliminate many of the problems associated with paper-based documentation. Decreasing the possibility of human error is an advantage associated with using technology in the field. This is accomplished by reducing the paper-trail involved in transferring information between the field and office. Getting the information directly from the field can also increase the accuracy of the information.

For example, many superintendents wait until the end of the day to record their work reports; which can alter their accuracy. Instead of waiting until the end of the day, superintendents can enter the information directly into the system while observing the work being performed. This can increase the accuracy of the information, while creating a more efficient internal history for the estimating department.

Reducing the number of trips between the site and field office can save a lot of time and money. The superintendent makes an average of five trips per day between the site and field office, while the foreman usually makes at least two, with each trip taking approximately ten minutes. It is also estimated that the superintendent spends an additional three hours a day in the trailer, away from the site. This adds up to three hours and fifty minutes a day the superintendent is not on-site supervising. Likewise, the foremen spend an hour a day away from the site. By decreasing the amount of time the supervisors spend at the field office increases the amount of time they are available to supervise the project and assist workers. This can increase worker productivity, as well as increasing the overall quality of the project.

Without technology, time is also wasted within the company's office. The accountant spends approximately an hour a day transferring the work reports from a faxed copy to the computer, while the project manager spends an hour a day confirming invoices and material quantities. These times can be minimized if the field reports and quantities of materials are recorded directly on site.

COST EVALUATION

When analyzing the costs incurred and potential savings associated with using technology in the field, a significant advantage is found. To support this information, a complete analysis of the labor costs associated with the lack of technology in the field can be found below (Table 1). These unit prices were provided by Burchick Construction, while the durations were observed while on-site. Also, it is important to note that the superintendent and foreman rates have a multiplier of 1.6 applied to them to account for the miscellaneous company and union burden costs.

Worker	Rate	Unit	Hours/Day	Project Days	Total Hours	Total Cost
Superintendent	$ 54.03	$/hr	3.83	486	1,863.00	$ 100,661.62
Foreman	$ 48.80	$/hr	1.00	486	486.00	$ 23,716.80
Accountant	$ 25.00	$/hr	1.00	486	486.00	$ 12,150.00
Project Manager	$ 50.00	$/hr	1.00	486	486.00	$ 24,300.00
					3,321.00	**$ 160,828.42**

Table 1 Costs Associated without Technology in the Field

Additionally, in order to assess the costs involved with adding a new form of technology to the Chevron Annex, a short evaluation of the proposed technologies was performed. From Apple's website, it was determined that the cost of an iPad with a warranty and camera will cost roughly $937 each. Also, an OtterBox protective case would cost $70 each and would help protect the iPad from the rough conditions on the jobsite.

The main costs associated with implementing technology on the Chevron Annex consisted of the Vela Systems software. Vela's software prices are based on the individual project size and duration. The costs associated with purchasing Vela for a project $10 to $29 million and a duration of 24 months would cost $11,064. This includes the use of the software, as well as online support for the entire duration of the project. The training associated with learning this software costs $1,000 for the set up; and an additional $1,500 to help train the end users. The total costs associated with using iPads and Vela for the Chevron Annex are shown below (Table 2).

Technology Type	Cost		Quantity	Total Cost
iPad w/ warranty & camera	$ 937.00		3.00	$ 2,811.00
OtterBox Case	$ 70.00		3.00	$ 210.00
Vela Systems	$ 11,064.00		1.00	$ 11,064.00
Vela Training	$ 2,500.00		1.00	$ 2,500.00
Total				**$ 16,585.00**

Table 2 Estimated Technology Costs

Comparing the costs without technology to the costs of implementing technology, a potential savings of $144,243.42 was found (Table 3). This is an obvious advantage and supports the idea that the Chevron Annex would have been a good job to use technology in the field.

Potential Savings Associated with Technology in the Field	
Costs without Technology	$ 160,828.42
Technology Costs	$ 16,585.00
Potential Savings	**$ 144,243.42**

Table 3 Potential Savings

APPLICATIONS

There were a lot of opportunities that the Chevron Annex would have benefitted from the use of technology in the field. To begin, the overall quality of the project would have increased by reducing the amount of time the superintendents and foremen were away from the project site. By increasing the amount of time each supervisor spends at the job would increase worker productivity, as well as increasing the overall quality of the project.

Another problem that could have been prevented with the use of technology in the field would have been the extensive amount of time it took to complete the punchlists. A main concern of the Construction Manager was the lack of communication during the first phase's punchlist. Items from the first phase's punchlist were still incomplete six months after the phase was completed. This was partly because many of the contractors did not know what items were still open. By using technology to complete the punchlists on the Chevron Annex, the communication delays would have been reduced and the punchlists would have been completed in an appropriate amount of time.

Safety was also a huge concern on the project and could have utilized technology in the field. Safety concerns were repeatedly brought up in meeting, but were slowly resolved by the offending parties. By using a safety inspection software, provided by Vela, the amount of risk on the job could have been reduced. Also, the main safety concerns of the project team could have been recorded and resolved in a more efficient manner.

The commissioning process for the Chevron Annex would have also been a more smooth process with the help of technology. Reports are completed by the software, showing the statuses of all systems and equipment, enabling the commissioning agents and other responsible parties to better manage project status. Also, the commissioning information and linked documents can be created and turned over to the owner in an electronic form. This reduces the time wasted by various parties collecting and compiling the multiple documents related to the commissioning process.

SUMMARY

It is recommended that Burchick Construction purchase Vela Systems software for future projects. This software includes Vela Web, Vela Mobile and Vela Reports. Also, each superintendent, and select foremen, should be given an iPad. Each iPad will include an Otterbox Defender Series case with a shoulder strap, which will increase the durability and mobility of the iPad.

In order to reduce the difficulty related to the learning curves associated with the new software, a training program by Vela's Service and Support Team will be held at Burchick's office. These training sessions will include web-based group sessions targeted to help the end users learn the various forms of technology. This will benefit everyone within the company and will enable Burchick to learn Vela's program, as well as help them in the long run by saving the company a significant amount of money on future projects.

TECHNICAL ANALYSIS 2 – RE-DESIGN/RE-SEQUENCE OF THE FAÇADE

PROBLEM IDENTIFICATION

The installation of the exterior facade caused a number of problems during the construction of the Chevron Annex. Because the roofing and curtainwall contractors were separate prime contractors, difficulties were encountered when figuring out which items were owned by which contractor. In addition, the interdependencies of each of the façade systems created confusion and issues during installation.

Phasing and sequencing of the façade was another problem encountered. A limited number of scaffolding systems were used to install the different façade systems, which created some problems related to space and staging. Countless moves of the scaffolding swings were made due to the limited number of scope meetings and planning sessions.

Additionally, constructing the architectural eyebrow located on the southwest corner of the building consumed much of the schedule and manpower. This feature was built and attached on-site out of structural studs, and the finishing and waterproofing of this item held up other trades on the façade, pushing back the start dates for the façade systems.

Re-sequencing the façade will help decrease the confusion and congestion related to the installation of the façade systems. To properly support this idea, a detailed study was performed. This study includes the following:

- Background Information
- Façade Sequencing
- Schedule Evaluation & Implementation
- Summary

BACKGROUND INFORMATION

To effectively analyze the problems associated with the façade, a complete analysis of the work performed was done. This analysis consisted of multiple interviews with the project team, reviewing project progress photos and studying the original schedule. Within the interview with the project manager, a number of difficulties and obstacles were brought up. These challenges were:

- This was Burchick's first attempt at a large metal panel project and their first attempt at installing terra cotta
- Ensuring that the order was placed properly with adequate quantities of the different components (panels, clips, rails, gaskets, tile pieces/sizes, flashing)
- There was a lack of flow around the building with the different systems

  - The swing scaffolding was constantly being relocated and reset, which was extremely inefficient
- The eyebrow also caused a number of problems
  - Caused problems associated with the swing staging for the exterior façade access, both above and below the eyebrow
- Having a separate curtainwall contractor who was not under Burchick's contractual control complicated matters
- Poor definitions of scope in the documents

In order to make suggestions on how to improve the installation of the exterior façade, a complete review of the actual phasing process needed to be researched. This research first began by contacting Burchick Construction, the general contractor, and asking for progress photos of the entire project. Once these photos were received, they were reviewed and organized to develop a visual aid and schedule of the actual phasing of the exterior (Appendices A & B). The reference breaks down the project by months, with each month showing what each elevation looked like at the beginning of the month.

Before the new phasing of the façade could be developed, a few key pieces of information needed to be obtained. The first piece of information needed related to the scaffolding that was available at the site. The exterior phasing for the Chevron Annex consists of three swing scaffolding stages, each equipped with two motors. Two of these stages have a maximum length of forty feet and the third stage can extend to fifty feet. These stages can be downsized accordingly. Additionally, there will be a total of four crews, two men each, assigned to the façade of the building. These crews will perform all the work necessary to complete the exterior façade of the building.

FAÇADE SEQUENCING

The first step in developing the new façade sequence was to determine the locations of the swings (Appendix C). This minimizes the number of moves for each swing, while increasing the overall efficiency of the exterior sequencing. While the swing locations were being determined, their sequencing was also being decided. It was determined that the installation of the façade would start on the east elevation and finish on the north. The reasoning behind this was because the south and east elevations are the focal point of the building and was a main concern of the University.

Once all of the swing drops were determined, the activities that needed to be performed at each location were analyzed. By utilizing the idea of the last planner, the last swing drop was the first area that was studied at each swing location. The multiple systems were analyzed and all the different activities that needed to be complete to finish the respective area were determined. This was done for all of the different swing drops throughout the façade, keeping in mind the multiple coordination issues related to the various corners and transitions of the systems. Each corner that consisted of terra cotta of metal panels had to be coordinated. This caused each side of the system to be installed simultaneously.

After all of the activities were determined, their durations were calculated. These durations were estimated from personal experience that was gained while observing the actual work being performed on the Chevron Annex. The schedule was then finalized by linking the necessary activities to one another to create a critical path. The final façade sequencing schedule can be found in Appendix D.

SCHEDULE EVALUATION & IMPLEMENTATION

Once the new phasing plan was established, it was compared to the actual schedule created by Burchick Construction. Main differences between the two schedules were discovered and are listed below:

Key Differences:

- The estimated durations differed from the actual durations of the activities being performed
- Eyebrow took up an unexpected amount of time
- There was no initial plan that maximized the efficiency of the swing scaffolds
    - There was no flow maintained around the building
    - Swing scaffolding was moved before the respective area's work was completed

When working on a project that has complex facade systems, it is important to examine all of the systems in extreme detail. Additionally, the scopes of work each contractor is responsible for needs to be determined. This will help reduce confusion related to the interdependencies of the multiple façade systems. Efficient planning will also ensure to the most efficient and practical way of sequencing and constructing these systems. Creating a phasing plan that allowed the construction of the façade to flow smoothly around the perimeter of the building was essential in this analysis.

SUMMARY

After thoroughly analyzing the façade systems used on the Chevron Annex, the following conclusions have been made:

- Proper planning is an essential step in determining the most efficient way to construct a building's system
- Thorough definitions of the scope of work in the documents is important
- Separate prime contractors on a project add additional coordination concerns to the project
    - Multiple coordination and scope review meetings need to be held on a multi-prime project
    - Get all parties involved in creating a schedule
- Knowing how a system works and is installed should be known before beginning the work
- Starting from the end and backtracking can prove to be an effective practice in scheduling
- Take advantage of the on-site knowledge to determine activity durations

TECHNICAL ANALYSIS 3 – COMMISSIONING OF LABORATORY SPACES

PROBLEM IDENTIFICATION

Laboratory spaces have extreme cautions relating to the cleanliness and precision of the areas. The Chevron Annex developed some complications when it came time to turn on the mechanical equipment for the testing and balancing of the systems. The owner insisted on the laboratory spaces being completely dust free before any of the systems could be turned on; however, there were still long lead items that needed to be installed that produced dust and debris. This interrupted the owner's occupancy date, resulting in schedule complications. Additionally, the existing Chevron Tower was in an extreme negative air condition; which tended to suck the dirt from the project into the existing tower, making the job more difficult with cleanliness.

In addition to the above complications, an interview with the project's MEP coordinator, Jeff Stouden, uncovered some more problems. The first issue that was described was that the commissioning agent was contracted directly with the owner and that they did not get involved until the project was already under construction. Another issue related to the commissioning of the building was the lack of site visits by the commissioning agent. It was also pointed out that the commissioning agents that reviewed the submittals and RFI's were not the same personnel who ran the field tests. This caused some problems due to the difference of viewpoints on how the systems should work. The final issue that was brought up by Jeff was that it was often difficult to get the commissioning agents to visit the site.

Within this analysis, a new commissioning schedule will be developed using the last planner method. This new schedule will be compared to the original schedule used on the Chevron Annex. During the comparison, the key areas of discrepancy will be determined. These differences will be analyzed and possible solutions will be proposed. These solutions are only some of the multiple changes that could be performed to help improve the overall efficiency of the commissioning process.

SCHEDULE EVALUATION

The issues discussed above are general issues that could happen on any project, depending on the circumstances. Within this analysis, the last planner method was utilized to develop a detailed schedule relating to the commissioning of the building (Appendix E). With the substantial completion date known, the critical steps and their activities were determined. This was done by working backwards from the substantial completion date, determining what needed to be completed in order to allow the current task to start. This schedule includes all the activities that have an impact on the mechanical equipment start-up.

Once the activities were determined and a new schedule was created, it was compared to the actual commissioning schedule created by Burchick Construction (Appendix F). During the schedule comparison and project team interviews, main differences and problems with the commissioning process were discovered and are listed below:

Key Differences:

- Air Handling Units
- Football Shrouds at Fume Hoods
- Nipple Plenums
- Strobic Fan Start-Up
- Architectural Millwork & Dust-Free Activities
- Above Ceiling Work / Need for Access Above Ceiling
- Laboratory Casework

These key differences were analyzed to determine the contributing factors that caused the discrepancies, while compiling possible solutions. First and foremost, the main problem focused around the air handling units (AHU's). The AHU's were delivered later than expected, which delayed their start-up date. By delaying the start-up date of the AHU's meant that the building would not receive any conditioned air, which was a major concern of this project. This was a main concern because of the significant amount of finished products that were to be installed, most of which required conditioned air.

The architectural millwork in the student desk area was one of the main items affected by the delay of conditioned air throughout the building. The millwork was extremely detailed and precise and any deviation in moisture content would result in the expanding and contracting of the materials. The millwork also required a lot of alterations; causing small amounts of dust from the cutting and fitting of the items. This delayed the strobic fans' start-up date because the laboratory areas needed to be completely dust free to properly test and balance. Additionally, there was a lack of information provided to the contractors that did not adequately define the appropriate cleanliness that was needed to turn on the strobic fans.

The above ceiling work was another contributing factor to the problems experienced during commissioning. The work that was being performed above the ceiling was taking longer than expected, which pushed back the start-up of the mechanical equipment. The reason the above ceiling work affected the mechanical equipment start-up was because the commissioning agent required all ceiling tile to be installed to complete their system evaluations.

The nipple plenums also caused the ceilings to remain open for an extended period of time. The scope of work was not well defined and there was confusion on which contractor owned the work related to this item. Once this scope problem was resolved, the fabrication of the nipple plenums was able to begin; resulting in the ceiling space to then get closed up.

The laboratory casework was another issue relating to the delay of the work. Although the casework was delivered on time, there were multiple changes associated with the casework and lab spaces. Without the casework installed in its entirety, the commissioning of the building was unable to begin. The laboratory casework also involved a number of different custom items that required a significant time to fabricate, deliver and install.

The problems discussed above are only the main problems and concerns that were discovered within the schedule comparison. A number of smaller problems also occurred but it was unclear which party was ultimately responsible because of the lack of detail in the scope of work within the project. The next section discusses possible solutions that could have been implemented on the project to minimize the confusion and difficulty that occurred during the commissioning process on the Chevron Annex.

SOLUTIONS

As discussed above, there were a number of problems that resulted in a confusing and difficult commission process. This section discusses possible solutions to these problems that are related directly to the Chevron Annex.

The delay in the delivery date for the AHU's was a main problem that contributed to many of the problems for the construction of the project. This delivery date and the installation of the AHUs was a critical path item that affected a number of activities throughout the project. In order to minimize the problems that resulted from this delay, a letter could have been written to the Owner stating that this critical path item directly affected the completion date of the project. Also included in this letter should have been the proposal of working overtime to maintain the substantial completion date, requesting approval from the Owner of the extra costs that would be encountered. More than likely, the Owner would have accepted the proposal and extra costs, allowing the possibility of completing the project on time.

If this proposed solution was not accepted by the Owner, prefabrication could have been another possibility to help the project stay on schedule. Any components or systems that had the possibility of being prefabricated should have been. This would allow the components to begin being sized and cut, reducing the amount of time needed to install the items in the field. Prefabricating the mechanical components would limit the amount of time that the ceiling needed to be open and exposed, allowing the testing and balancing to possibly begin on the original date.

Reducing the confusion and difficulties encountered during the end of construction could also been prevented by a more detailed scope of work for the contractors. The information that was provided resulted in confusing and an inadequate amount of risk sharing. The scopes provided did not clearly define the requirements of each party, resulting in repeat work; especially in the final clean up that needed to occur before the testing and balancing of the mechanical equipment could begin.

Finally, the commissioning process could have been simplified by the use of technology in the field. Vela Commissioning tracks systems and equipment as they are delivered, installed, readied for testing and tested. A handover document set is also created by electronically tying all relevant documentation to the specific equipment. This set is then delivered to the owner, speeding up the delivery of the commissioning process (Vela Systems, 2012).

Overall, there were a number of ideas and solutions that could have been implemented to help keep the project on schedule. These solutions were not discovered because of the lack of leadership and coordination that needed to be done throughout the progress meetings. Therefore, it is important to remember that constructing a building is a team effort and everyone involved should work together to construct a building of the highest quality possible.

SUMMARY

After thoroughly analyzing the commissioning process for the Chevron Annex, the following conclusions have been made:

- Get the commissioning agent involved in the project during the design phase so they work hand in hand with the design team to spot possible issues
- Require the commissioning agent to visit the project site routinely
- The same commissioning agent should do the submittal and RFI reviews and then come and do the testing
- The commissioning agent needs to be available when they are schedule
- Start-Up of the AHU's was a critical path item, delaying multiple activities
- An adequate amount of information needs to be provided to inform/define the contractors what is expected of them to be able to turn on the strobic fans
- The commissioning process, as a whole, should be an area of interest throughout the entire project to minimize the number of unforeseen problems
- The commissioning process is affected by all trades

TECHNICAL ANALYSIS 4 – ADDITION OF A GREEN ROOF

PROBLEM IDENTIFICATION

The Chevron Annex's roof consists of a new Thermoplastic-Polyolefin (TPO) system that is placed over protection board on three inch tapered insulation with air barrier and gypsum board sheathing. This is all placed on top of metal decking supported by the building's steel frame. Additionally, the roofing package was bid separately, which caused some complications when installing the transitions and flashing to the façade systems.

After looking into the idea of adding a green roof to the Chevron Annex and interviewing Burchick's project manager, it was discovered that the Annex's original design intended on having a green roof. Once this was found out, one of the Architects involved with the project was interviewed; Utkarsh Ghildyal of Renaissance 3 Architects. While talking with Utkarsh, he stated that the owner did not want the additional expense of adding a green roof; so there was no detailed information provided. It was then decided that the initial idea of a green roof would be taken to the next step and a detailed analysis would be performed.

BACKGROUND RESEARCH

Before any changes to the roof design or structure, a better understanding of green roofs was needed. During Utkarsh's interview, he offered a number of suggestions and issues to consider when adding a green roof to a building. First and foremost, the roof would need additional structural reinforcement to take the additional soil load. Also, a root barrier and a thicker layer of waterproofing would need to be considered. More maintenance by the Owner would also be required. Two sources were also suggested by Utkarsh, http://gbapgh.org/ and the city of Portland.

There are a number of benefits associated with the addition of a green roof to a building. As many know, green roofs help reduce the amount of heating and cooling needed. They help reverse the heat island effect, as well as reduce greenhouse gases. Adding a green roof also provides sound insulation and increases the marketability of the building. Green roofs also reduce a building's stormwater runoff, which can reduce the potential for flooding and water contamination. (GBAPGH, 2012)

To assist with compiling information, the sources provided by Utkarsh were first reviewed. The Green Building Alliance (GBA) was extremely helpful in developing an understanding of the layers associated with a green roof. Generally, there are two types of green roofs; extensive and intensive. Extensive green roofs are lighter and less expensive than intensive. They typically weight 10-50 pounds per square foot, as compared to the 80-150 pounds per square foot of an intensive roof. Extensive roofs do not require excessive maintenance and are not intended for use by humans. However, intensive roofs are designed to provide a space of interaction between nature and humans, which increases the loads imposed on the roof. (GBAPGH, 2012)

Regardless of the type of roof, both types consist of four basic layers. The first layer of a green roof is the waterproofing. The waterproofing is used to prevent the penetration of any water into the building. The second layer associated with a green roof is the drainage. The drainage is used to help remove excess water, as well as preventing the potential for leaking and rotting. A growing medium is also essential. The types of medium, mixture and depth of the growing medium depends on the types of plants that are to be living on the green roof. Finally, vegetation is another layer needed for a green roof. The types of plants being installed on a green roof should be non-invasive and native to the region. It is also smart to consider drought and wind-resistant plants.

In addition to these four layers, several specialized layers can be chosen to be added to the design. For instance, a small layer of gravel can be placed on the drainage layer to provide extra drainage. Also, if wind is an issue, a wind erosion layer can be added to the growing medium layer to prevent the wind from blowing soil off of the roof.

The layers and detailing of a green roof is a critical step in the design process. The more layers chosen for the roof can place additional loads on the roof and structure, which will result in a need to increase the structure. Additionally, the drainage associated with the addition of a green roof needs to be analyzed.

PROPOSED DESIGN

When considering adding a green roof to a building, there are a number of items that need to be considered. First off, the primary function of the green roof needs to be determined. Since the Chevron Annex's roof will be accessible for human use, an intensive roof will be chosen over an extensive one.

Once an intensive green roof was chosen, the design and detailing of the green roof needed to be developed. With the help of American Hydrotech, Inc.'s website and literature, a typical shallow intensive green roof design was able to be developed (Figure 7).

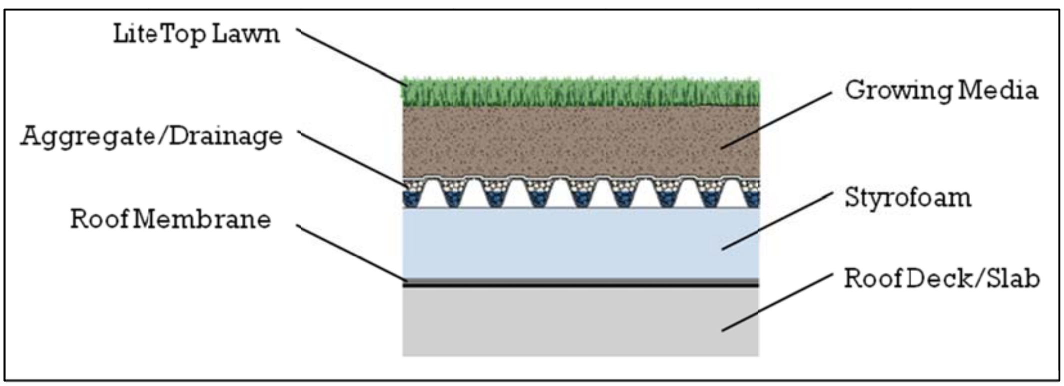


Figure 7 Standard Lawn Assembly *Courtesy of American Hydrotech, Inc.*

In addition to the considerations previously discussed, the drainage associated with the addition of the green roof needs to be considered. Also, the only point of access to the roof is through a roof hatch. By adding an intensive green roof to the Chevron Annex, the main purpose is for use by the building's users. This cannot be accomplished with a roof hatch, so it is proposed that a new access point be created at the connection between the Chevron Annex's roof and the existing Chevron Tower's 10th floor. This would require the removal of the women's toilet in the Chevron Tower and a door be added at the transition point. A plan view of the proposed green roof can be found in Appendix G. The plan view shows the proposed green roof layout and its components. Keeping the layout simple, the green roof system uses only grass and concrete pavers. The pavers are placed around the entire perimeter of the roof and are two feet wide. The rest of the roof is covered in grass and is completely accessible to humans.

INSTALLATION PROCEDURE

Due to the complexity of a green roof system, the installation is a crucial part of the overall performance of the system. To assist with the installation, steps for the installation of the green roof were developed and are described below (Figure 8). (Hydrotech, 2012)

Activity Name
Leak Test
Root Stop - Loose Lay
Insulation - Loose Lay
Gardendrain 30 - Loose Lay
Fill Gardendrain w/ Aggregate
SystemFilter
Hardscape Elements & Pavers
Lite Top Growing Media
Erosion Control Blanket
Roll GardMat & Stake in Place
Misc. Plantings

Figure 8 Steps Associated with the Installation of a Green Roof

The first step involved with constructing a green roof is to install the roofing membrane, making sure all the membrane termination points are located above the eventual level of the soil and vegetation. This membrane consists of one coat at 90 mils into which Hydrotech's Flex Flash is embedded. A second coat of the membrane is then installed at 125 mils with the Hydroflex 30 being rolled directly into the membrane while still warm to ensure good adhesion.

Once the membrane and Hydroflex 30 are installed, a leak test is to be performed to ensure a water-tight seal. After the membrane is approved, the Root Stop can be installed. The Root Stop is to be laid loosely over the previous layer, extending it full height to cover all flashing and lapping adjacent sheets five feet in order to protect against the lateral growth of roots.

Next, the insulation is to be laid loosely over the root barrier that was just previously installed. The thickness of the insulation should be predetermined, based on the desired R-value. Also, cut the foam at all drain locations and ensure proper fitting around all penetrations. After installing the insulation, the drainage component of the system needs to be put in place. The Gardendrain 30 material is to be loose laid over the entire roof deck, with the aeration holes facing up, cutting over all drains and to fit around all penetrations.

The next step involved with installing the green roof system is to fill the Gardendrain panels with Hydrotech's LiteTop Expanded Aggregate. Once this is complete, the SystemFilter filter fabric is to be placed over the Gardendrain and lapped at least twelve inches to ensure complete coverage; preventing the soil from washing out through the system.

After the filter fabric is installed, it is then time to install any of the hardscape elements that are incorporated in the design; which can be built directly on the drainage elements. Also, any stone and/or paver ballasts required for wind resistance are to be installed at this point.

Hydrotech's Lite Top growing media is then installed after the hardscape elements. After the growing media is spread to the desired thickness, an erosion control blanket is put in place. Hydrotech's GardMat is rolled out over the growing media and staked into place. Finally, once all the previous steps are completed, the various plantings can be put into place.

MAINTENANCE

Properly designing and installing a green roof system are both essential in creating an efficient and beautiful architectural feature. However, a green roof is a living system that needs a certain amount of attention and care throughout its lifetime in order to allow it to remain active. This enforces the importance of giving the green roof proper amounts of maintenance over time. Without maintenance, weeds will invade the area and various areas of the roof can become overgrown.

By properly planning for the amount of maintenance required, the overall amount needed can be simplified and reduced. However, it is important to note, that reduced maintenance does not mean no maintenance. The amount of maintenance a green roof needs can be broken down into three segments:

- Removing unwanted plants
- Mowing, trimming, pruning
- Irrigation

The seeds of many unwanted plants and weeds can be brought to the green roof by birds or wind. These seeds can create many unwanted plants and weeds throughout the roof and need to be removed. The recommended method of removing these plants is to remove them physically by hand. Although tedious, it reduces the amount of digging needed, as well as decrease the damage to the underlying components.

Also, grass lawn landscapes require regular mowing and cutting. The trees and shrubs throughout the roof should also be trimmed and pruned. This helps keep an aesthetically friendly environment, while keeping the trees and shrubs healthy.

It is also important to determine the adequate amount of irrigation a green roof system needs. The types of vegetation used within the system are usually well adapted and may only require a small amount of irrigating. However, the frequency of watering will depend mainly on the types of vegetation that is planted on the roof, as well as the intensity of the local climate.

Overall, it is important to take care and maintain the green roof after installation. Careful planning of the green roof system is important in reducing the amount of maintenance required. This can be done by ensuring the correct choice and depth of the growing medium. Additionally, correct detailing and proper irrigation are important in minimizing the frequency of maintenance required by a green roof.

STRUCTURAL BREADTH

Replacing the existing TPO roof with a green roof significantly changes the loads imposed on the structure. An analysis of the columns and roof structure (Figure 9) was performed to determine if any of the existing steel members required resizing. In order to evaluate the current structure, the new loads from the green roof system need to be determined. The additional loadings created by the shallow intensive green roof include (Hydrotech, 2012):

- Total Roof Dead Load – 90 psf
- Total Roof Live Load – 100 psf

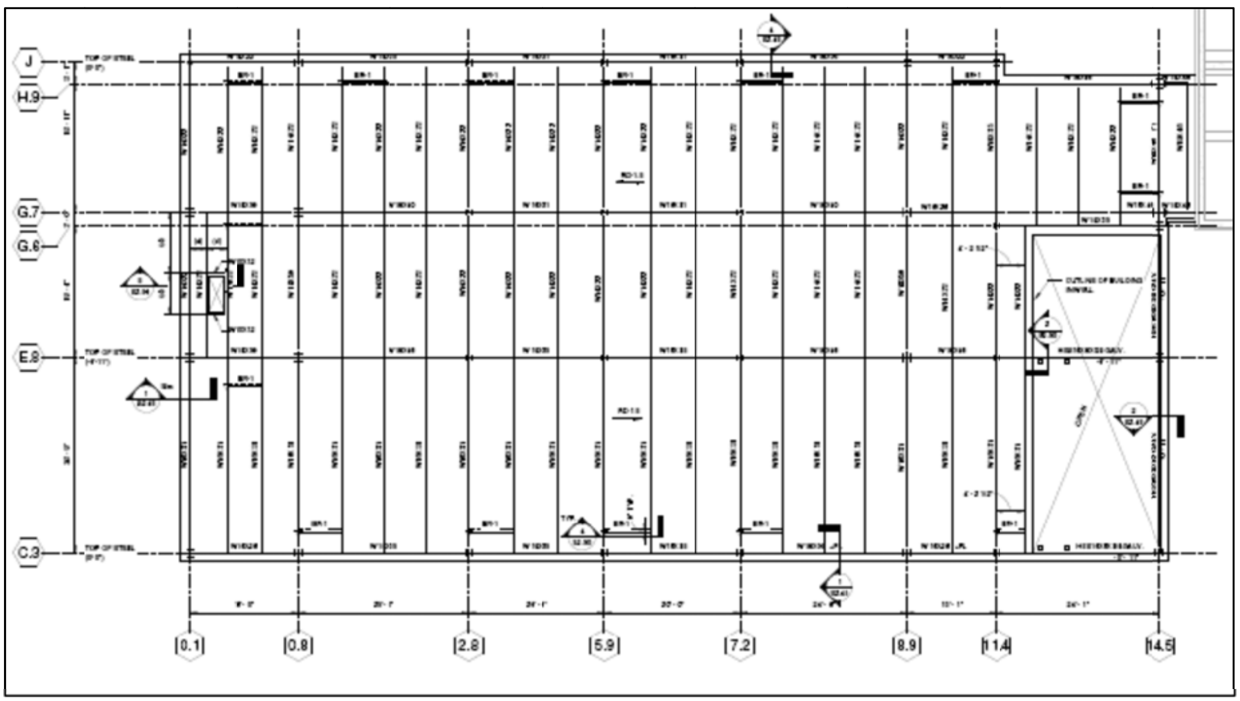


Figure 9 Original Roof Structure

Once these loads were determined, the columns were then analyzed. Six different columns were selected to perform calculations (Figure 10), determining if their sizes would still withstand the additional loading. Of these six columns, only one of them needed to be resized, shown in **RED**, and was done so by referring to the AISC Steel Construction Manual.

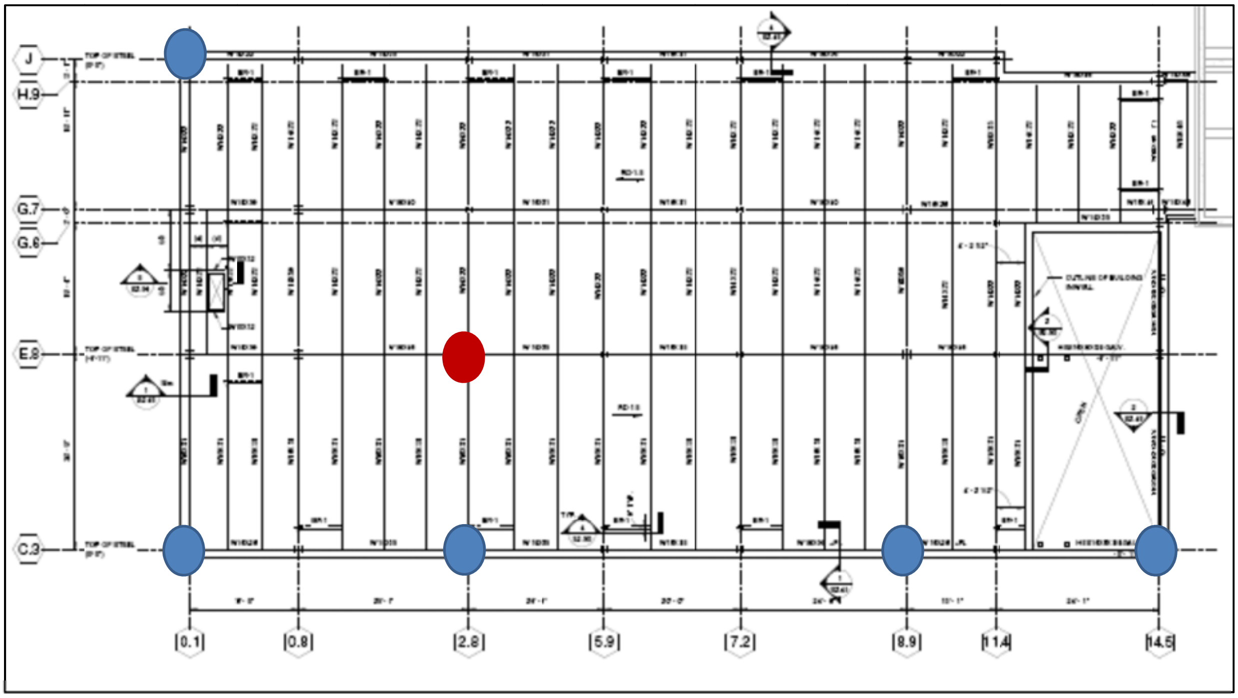


Figure 10 Selected Columns for Analysis

After the columns were analyzed, the beams were then inspected. Three different bays were typical throughout the structure and were assumed to be pin-pin connections. These three bays were analyzed (Figure 11), determining the minimum beam sizes that would be adequate for this structure and these sizes were then compared to the current beams, adjusting as needed. Finally, the girders were evaluated for adequacy. Three girders were selected to be inspected (Figure 12), two of which required resizing, shown in **RED**. A summary of the structural members that required re-sizing can be found in Table 4 below and complete hand calculations performed for this breadth can be found in Appendix H.

STRUCTURAL MEMBERS REQUIRING RE-SIZING		
Member	**Original Size**	**Adjusted Size**
Column <E.8-2.8>	W10 x 60	W10 x 88
Girder <7.2-8.9>, <E.8>	W18 x 46	W24 x 62
Girder <0.2-2.8>, <C.3>	W18 x 35	W21 x 44

Table 4 Structural Members Requiring Re-Sizing

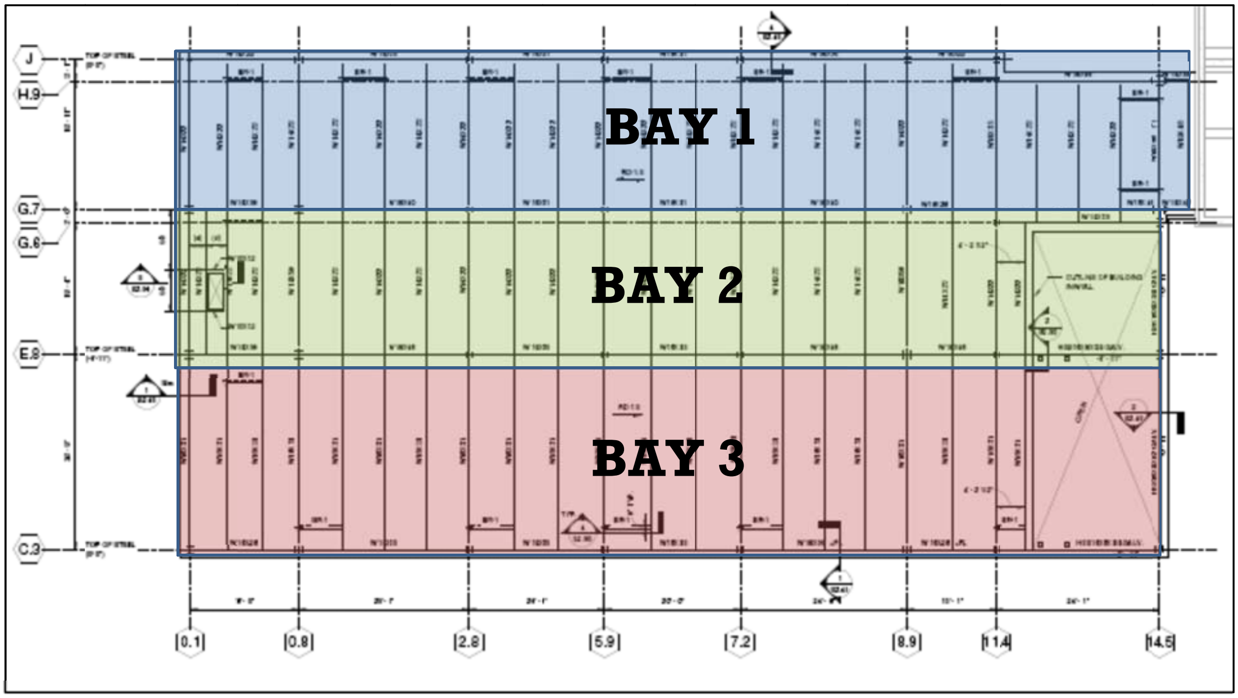


Figure 11 Selected Bays for Analysis

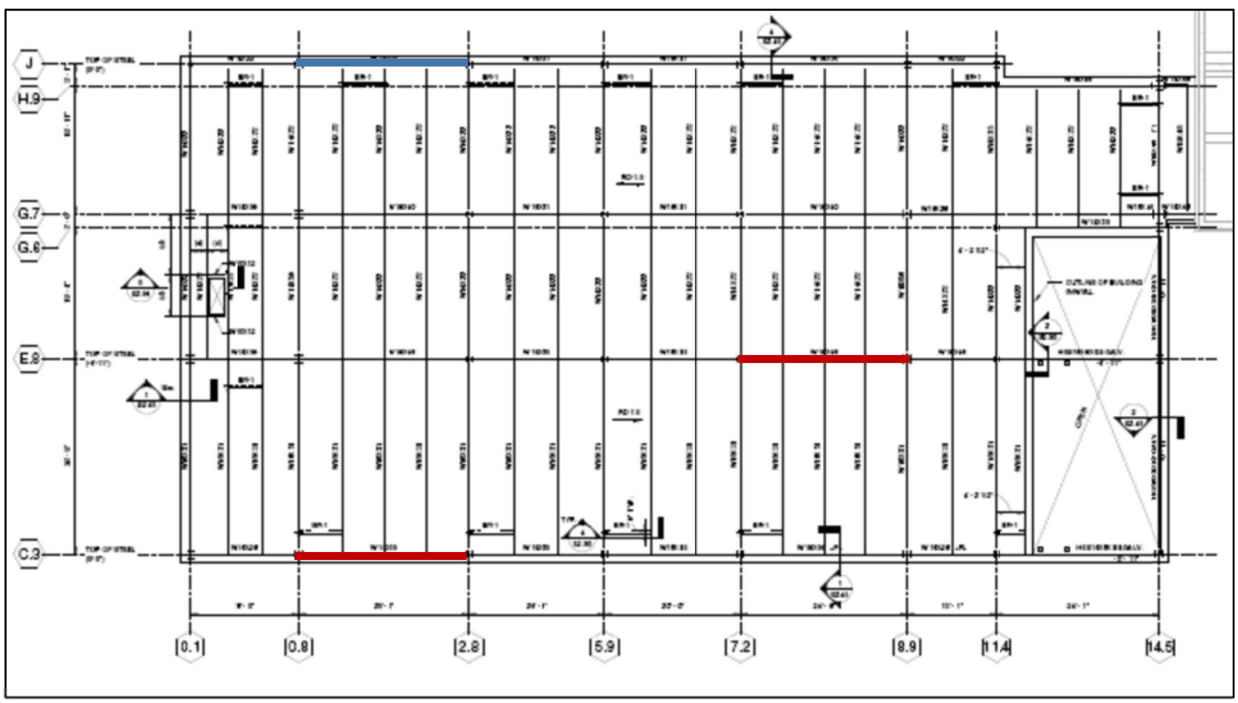


Figure 12 Selected Girders for Analysis

MECHANICAL BREADTH

Adding a green roof to the Chevron Annex provides multiple benefits including:

- Stormwater Management
- Longer life for the roof membrane
- Lower Energy Costs
- Reduction of the Urban Heat Island Effect
- Habitat for Urban Wildlife
- Amenity Value, Aesthetics, and Marketing

When determining the wide variety of benefits provided by a green roof, the reduction in heat flow was a major contributor. Concepts learned in AE 310 Fundamentals of HVAC and ME 201Introduction to Thermal Science will be used to analyze the benefits provided by a green roof. The main concept used within this breadth is heat loss and the concepts associated with it. The heat loss associated with the proposed green roof will be calculated and compared to the original TPO roof design.

The first step in calculating the building's heat loss is to determine all the materials that compose each of the roofing systems. The R-value of each of each material was also determined. (R-Value is the measure of thermal resistance within a certain material.) These materials and values are summarized below (Figure 13 & 14).

Original Roof	
Material	R-Value
TPO Roof Membrane System	0.05
Protection Board - 1/4"	0.28
3" Rigid Insulation	15.00
Air/Vapor Barrier Barrier	0.01
Cover Board - 5/8"	0.67
Decking & Concrete	0.43
Total (BTU/hr)	**16.44**

Figure 13 Original Roof R-Values

Proposed Green Roof	
Material	R-Value
LiteTop Lawn	2.85
SystemFilter	0.10
Gardendrain 30	0.15
STYROFOAM	15.00
Root Stop/Hydroflex 30	0.05
MM6125	0.70
Decking & Concrete	0.43
Total (BTU/hr)	**19.28**

Figure 14 Proposed Green Roof R-Values

After each system's total R-value was calculated, the total change in temperature between the interior and exterior of the building was determined. With the R-Values and change in temperatures now known, the heat loss of the building can be calculated. The heat loss associated with a building can be calculated by Equation 1 and are summarized in Figure 15.

$$\text{Building Heat Loss} = \frac{\text{Total Surface Area}}{\text{Surface Area R-Value}} \times \text{Change in Temperature}$$

The following units are associated with the terms in Equation 1:

- Building Heat Loss $= \frac{BTUs}{Hr}$
- Total Surface Area = Square Feet
- R-Value $= \frac{Ft^2 x\ °F \times Hr}{BTU}$
- Change in Temperature = °F

Roof Heat Loss Comparison				
Roof	**Square Footage**	**R-Value**	**Summer Heat Loss**	**Winter Heat Loss**
Original Roof	10,500	16.44	2,746.35	24,142.34
Green Roof	10,500	19.28	2,341.80	20,586.10
Difference			**404.55**	**3,556.24**

Figure 15 Roof Heat Loss Comparison

Figure 8 above is a comparison of the heat losses associated with the two different roof types. As expected, the green roof reduces the amount of heat loss experienced by the building. The heat loss in the summer is minimal, while the winter heat loss is much larger. This is due to the greater difference between the inside and outside temperatures.

After analyzing the heat loss experienced by the Chevron Annex, it was observed that there is a minimal difference between to heat transfer (14.7%). Due to this undesired outcome, the vegetated roof heat flow will be further investigated.

After investigation, the above breadth focuses on R-Value and the resistance to heat flow. However, to effectively analyze the benefits associated with a green roof the heat flow needs to be researched. Green roofs are a living building system that is constantly operating. The plants within the green roof collect, process and release energy to stay living and functioning. Additionally, they manage heat through a number of different ways: evaporation, reflection, convection and thermal mass (Figure 16). The detailed information and calculations involved with these types of heat flow are beyond the scope of this breadth and will not be discussed.

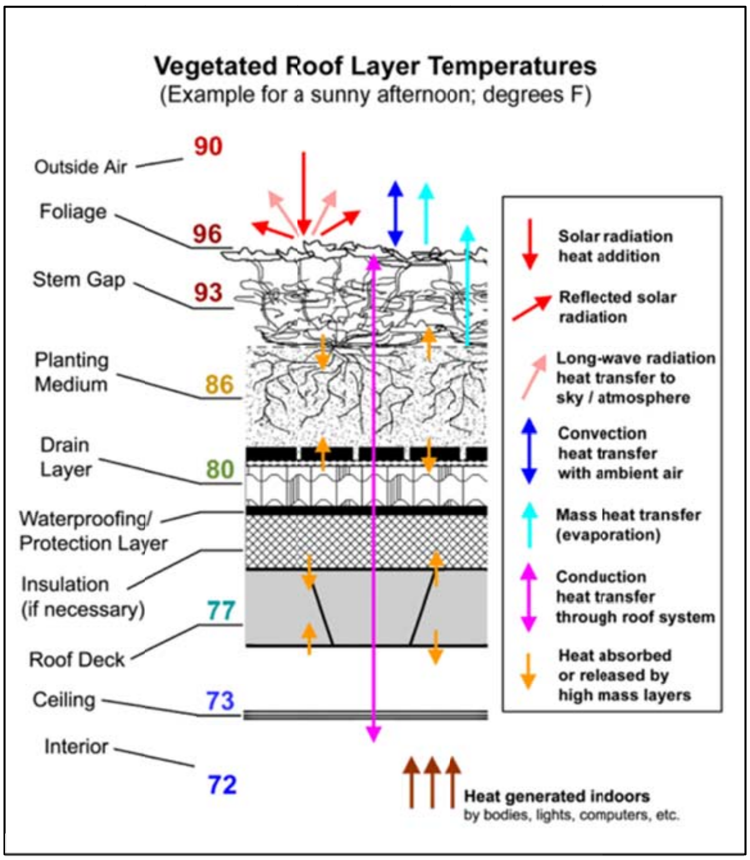


Figure 16 Vegetated Roof Heat Flow

SUMMARY

After thoroughly analyzing the addition of a green roof to the Chevron Annex, the following conclusions have been made:

- Green roofs have multiple benefits including:
  - Reverse the heat island effect
  - Reduce greenhouse gases
  - Provides sound insulation
  - Reduce a building's stormwater runoff
- A green roof requires additional structural reinforcement to take the additional loads
- A green roof is a living system and requires a carefully planned maintenance procedure
- Installing a green roof is a major concern to ensure proper performance
- Green roofs manage heat through a number of ways:
  - Evaporation
  - Reflection
  - Convection
  - Thermal mass

APPENDIX A – ACTUAL PHASING VISUAL

The following visual is a representation of the actual progress involved with the installation of the exterior façade for the Chevron Annex.

The photos shown below dictate what the Chevron Annex's building elevation looked like at the beginning of the month and the short summary describes the work that was performed that month.

East

January 2011

Install Exterior Sheathing (started Oct 2010)

February 2011

Started Windows & Curtainwall

March 2011

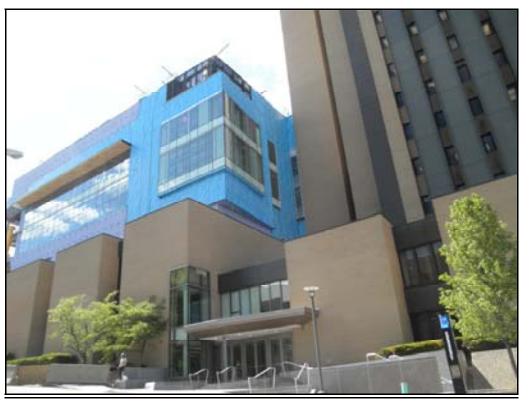
Continued Windows & Curtainwall
Started Sheet Air Barrier

April 2011

Continued Air Barrier
Started Exterior Building Louvers

May 2011

Continued Air Barrier



June 2011

Started Exterior Wall Insulation
Started Metal Wall Panels
Started Terra Cotta

July 2011

Continued Exterior Wall Insulation
Continued Metal Wall Panels
Continued Terra Cotta

August 2011

Started Insulation and Metal Wall Panels @ Existing Ashe Roof

September 2011

Continued Insulation and Metal Wall Panels @ Existing Ashe Roof

South

January 2011

Finished Exterior Sheathing (started Oct 2010)
Start Windows & Curtainwall
Started Sheathing & Roofing Eyebrow

February 2011

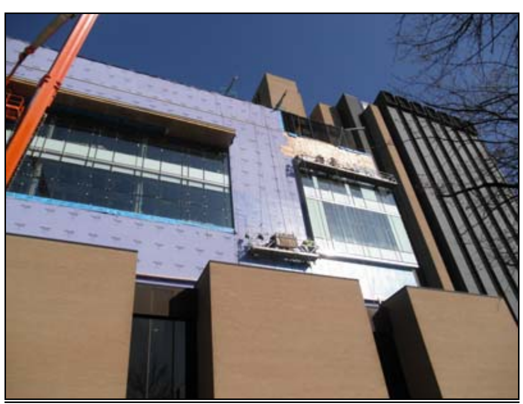
Continued Windows & Curtainwall
Continued Sheathing & Roofing Eyebrow

March 2011

Continued Sheathing & Roofing Eyebrow

April 2011

Continued Sheathing & Roofing Eyebrow
Started Sheet Air Barrier
Started Exterior Building Louvers



May 2011

Continued Sheathing & Roofing Eyebrow
Continued Sheet Air Barrier

June 2011

Finished Sheathing & Roofing Eyebrow
Continued Sheet Air Barrier
Started Exterior Wall Insulation

July 2011

Finished Sheet Air Barrier
Continued Exterior Wall Insulation
Started Terra Cotta

August 2011

Finished Exterior Wall Insulation
Finished Terra Cotta
Started Metal Wall Panels
Started Sunshade Devices

September 2011

Started Insulation & Metal Wall Panels @ Existing Ashe Roof

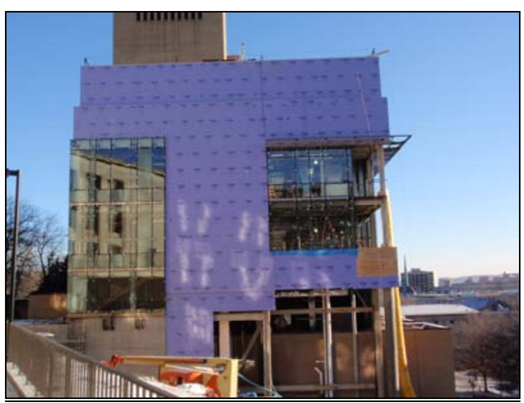
West

January 2011

Exterior Sheathing – Completed in December 2010
Started Windows & Curtainwall

February 2011

Finished Windows & Curtainwall
Started Sheathing & Roofing Eyebrow



March 2011

Continued Sheathing & Roofing Eyebrow

April 2011

Continued Sheathing & Roofing Eyebrow

May 2011

Continued Sheathing & Roofing Eyebrow
Started Sheet Air Barrier

June 2011

Finished Sheathing & Roofing Eyebrow
Finished Sheet Air Barrier

July 2011

Started Exterior Wall Insulation
Started Terra Cotta

August 2011

Continued Exterior Wall Insulation
Finished Terra Cotta
Started Metal Wall Panels
Started Sunshade Devices

September 2011

Finished Exterior Wall Insulation
Finished Metal Wall Panels

North

January 2011

Exterior Sheathing – Finished December 2010
Windows & Curtainwall – Finished December 2010

February 2011

March 2011

Started Exterior Building Louvers

April 2011

Started Sheet Air Barrier

May 2011

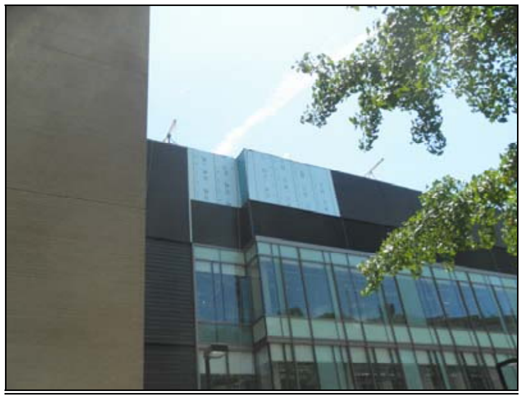
Finished Sheet Air Barrier
Started Exterior Wall Insulation
Started Metal Wall Panels

June 2011

Continued Exterior Wall Insulation
Continued Metal Wall Panels

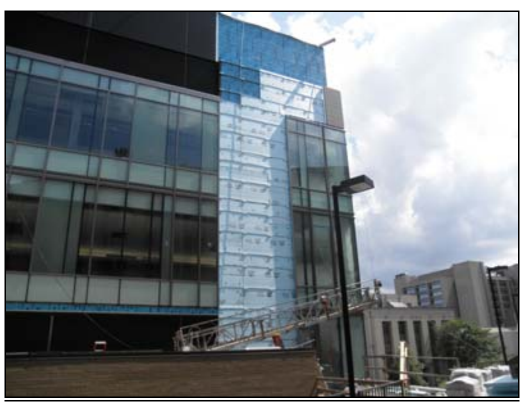
July 2011

Continued Exterior Wall Insulation
Finished Metal Wall Panels
Started Terra Cotta



August 2011

Finished Exterior Wall Insulation
Finished Terra Cotta

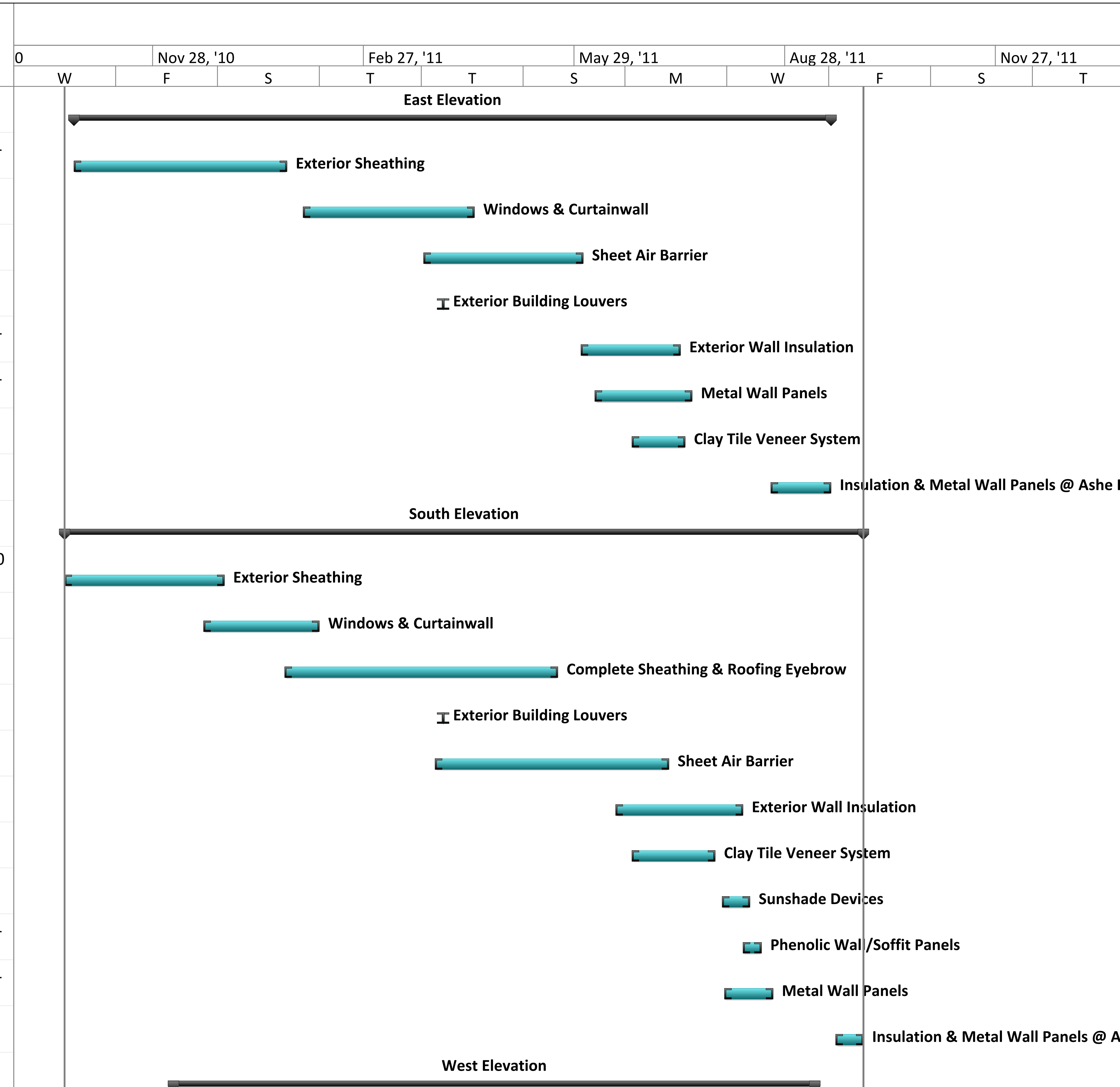


APPENDIX B – ACTUAL FAÇADE SCHEDULE

The following schedule is a representation of the actual activities and durations involved with the installation of the exterior façade for the Chevron Annex.

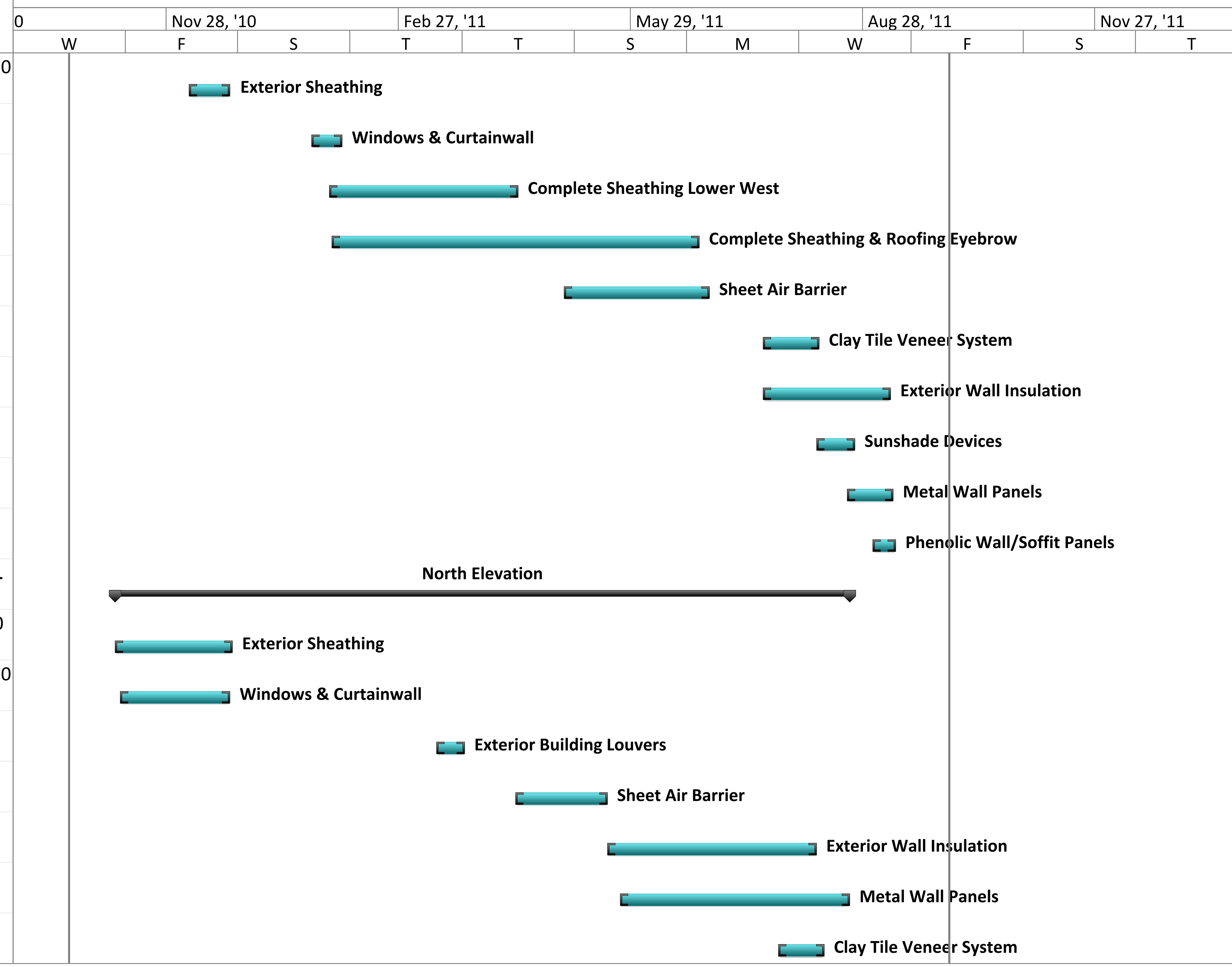
University of Pittsburgh
Chevron Annex
Actual Facade Phasing

ID		Task Mode	Task Name	Duration	Start	Finish
1			**East Elevation**	**235 days**	**Mon 10/25/10**	**Fri 9/16/11**
2			Exterior Sheathing	66 days	Mon 10/25/10	Mon 1/24/11
3			Windows & Curtainwall	54 days	Tue 2/1/11	Fri 4/15/11
4			Sheet Air Barrier	49 days	Fri 3/25/11	Wed 6/1/11
5			Exterior Building Louvers	1 day	Sat 4/2/11	Sat 4/2/11
6			Exterior Wall Insulation	31 days	Wed 6/1/11	Wed 7/13/11
7			Metal Wall Panels	30 days	Tue 6/7/11	Mon 7/18/11
8			Clay Tile Veneer System	17 days	Thu 6/23/11	Fri 7/15/11
9			Insulation & Metal Wall Panels @ Ashe Roof	20 days	Mon 8/22/11	Fri 9/16/11
10			**South Elevation**	**247 days**	**Thu 10/21/10**	**Fri 9/30/11**
11			Exterior Sheathing	49 days	Thu 10/21/10	Tue 12/28/10
12			Windows & Curtainwall	36 days	Mon 12/20/10	Mon 2/7/11
13			Complete Sheathing & Roofing Eyebrow	86 days	Mon 1/24/11	Sat 5/21/11
14			Exterior Building Louvers	1 day	Sat 4/2/11	Sat 4/2/11
15			Sheet Air Barrier	73 days	Wed 3/30/11	Fri 7/8/11
16			Exterior Wall Insulation	39 days	Thu 6/16/11	Tue 8/9/11
17			Clay Tile Veneer System	26 days	Thu 6/23/11	Thu 7/28/11
18			Sunshade Devices	10 days	Mon 8/1/11	Fri 8/12/11
19			Phenolic Wall/Soffit Panels	6 days	Wed 8/10/11	Wed 8/17/11
20			Metal Wall Panels	15 days	Tue 8/2/11	Mon 8/22/11
21			Insulation & Metal Wall Panels @ Ashe Roof	10 days	Mon 9/19/11	Fri 9/30/11
22			**West Elevation**	**199 days**	**Tue 12/7/10**	**Fri 9/9/11**



University of Pittsburgh
Chevron Annex
Actual Facade Phasing

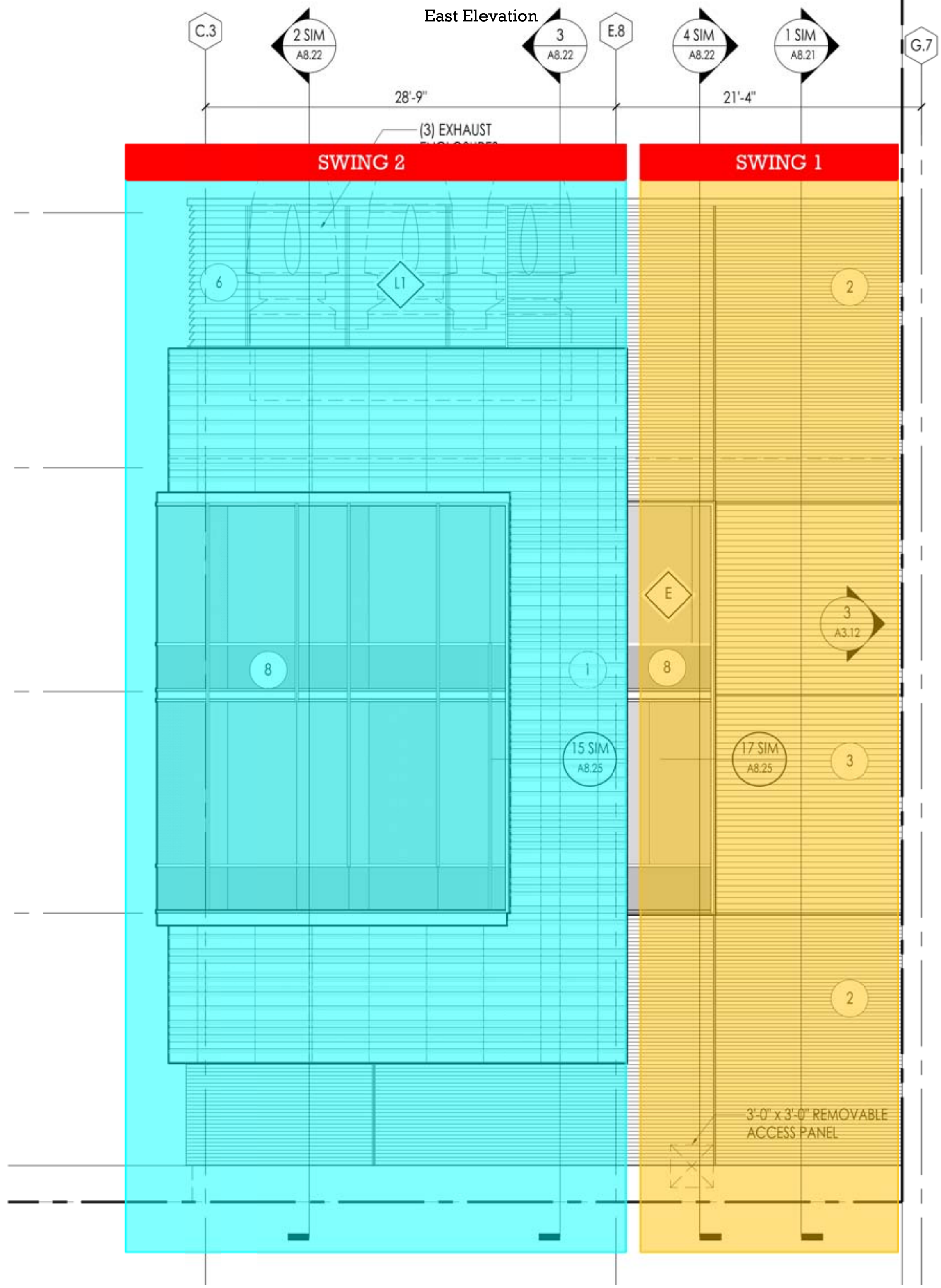
ID	Task Mode	Task Name	Duration	Start	Finish
23		Exterior Sheathing	12 days	Tue 12/7/10	Wed 12/22/10
24		Windows & Curtainwall	10 days	Mon 1/24/11	Fri 2/4/11
25		Complete Sheathing Lower West	54 days	Mon 1/31/11	Thu 4/14/11
26		Complete Sheathing & Roofing Eyebrow	104 days	Tue 2/1/11	Fri 6/24/11
27		Sheet Air Barrier	41 days	Tue 5/3/11	Tue 6/28/11
28		Clay Tile Veneer System	16 days	Wed 7/20/11	Wed 8/10/11
29		Exterior Wall Insulation	36 days	Wed 7/20/11	Wed 9/7/11
30		Sunshade Devices	11 days	Wed 8/10/11	Wed 8/24/11
31		Metal Wall Panels	14 days	Mon 8/22/11	Thu 9/8/11
32		Phenolic Wall/Soffit Panels	7 days	Thu 9/1/11	Fri 9/9/11
33		**North Elevation**	**206 days**	**Mon 11/8/10**	**Mon 8/22/11**
34		Exterior Sheathing	34 days	Mon 11/8/10	Thu 12/23/10
35		Windows & Curtainwall	31 days	Wed 11/10/10	Wed 12/22/10
36		Exterior Building Louvers	9 days	Mon 3/14/11	Thu 3/24/11
37		Sheet Air Barrier	26 days	Thu 4/14/11	Thu 5/19/11
38		Exterior Wall Insulation	58 days	Fri 5/20/11	Tue 8/9/11
39		Metal Wall Panels	64 days	Wed 5/25/11	Mon 8/22/11
40		Clay Tile Veneer System	14 days	Tue 7/26/11	Fri 8/12/11



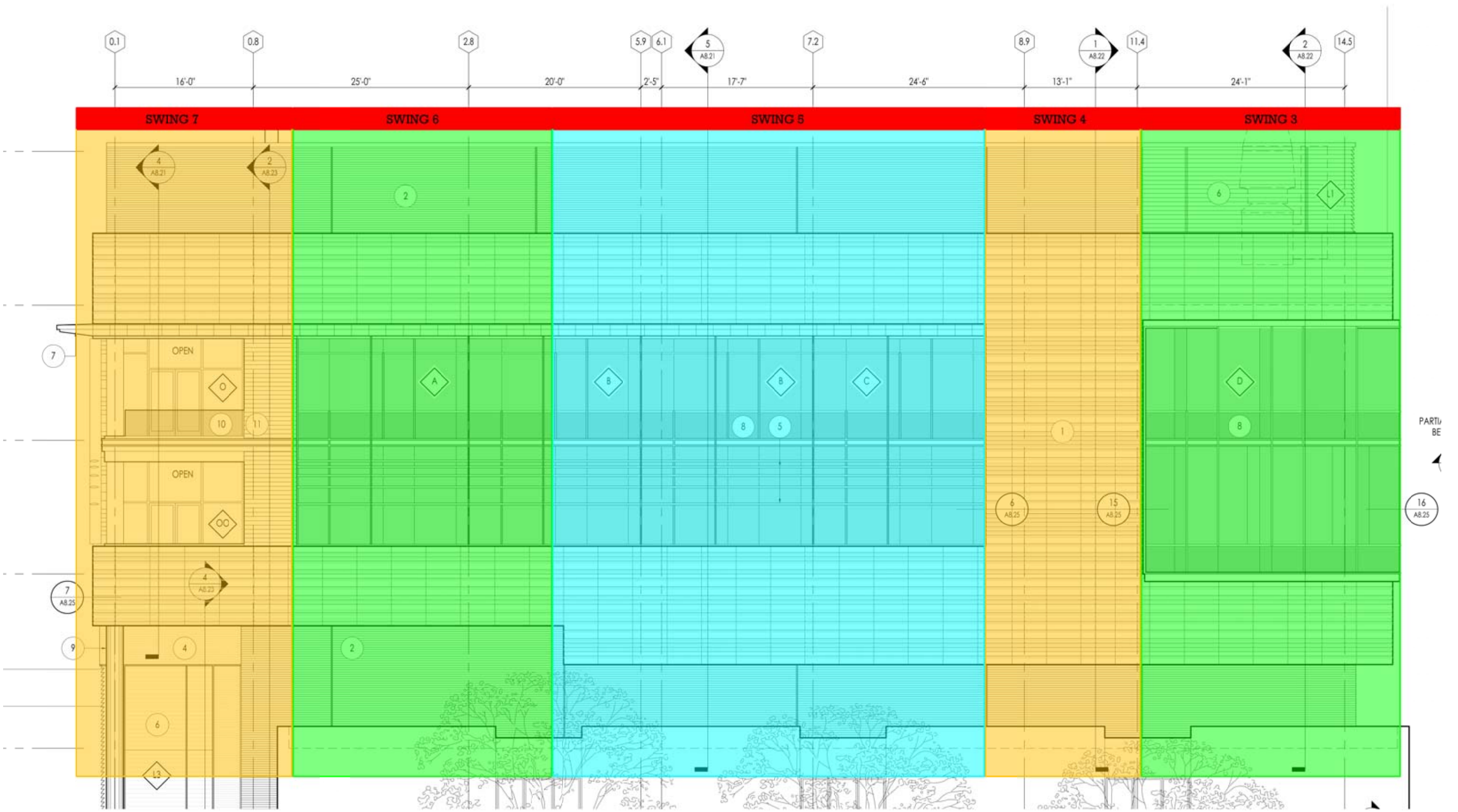
APPENDIX C – SWING SCAFFOLDING LOCATIONS

The following visual shows the swing scaffolding locations involved with the installation of the exterior façade for the Chevron Annex.

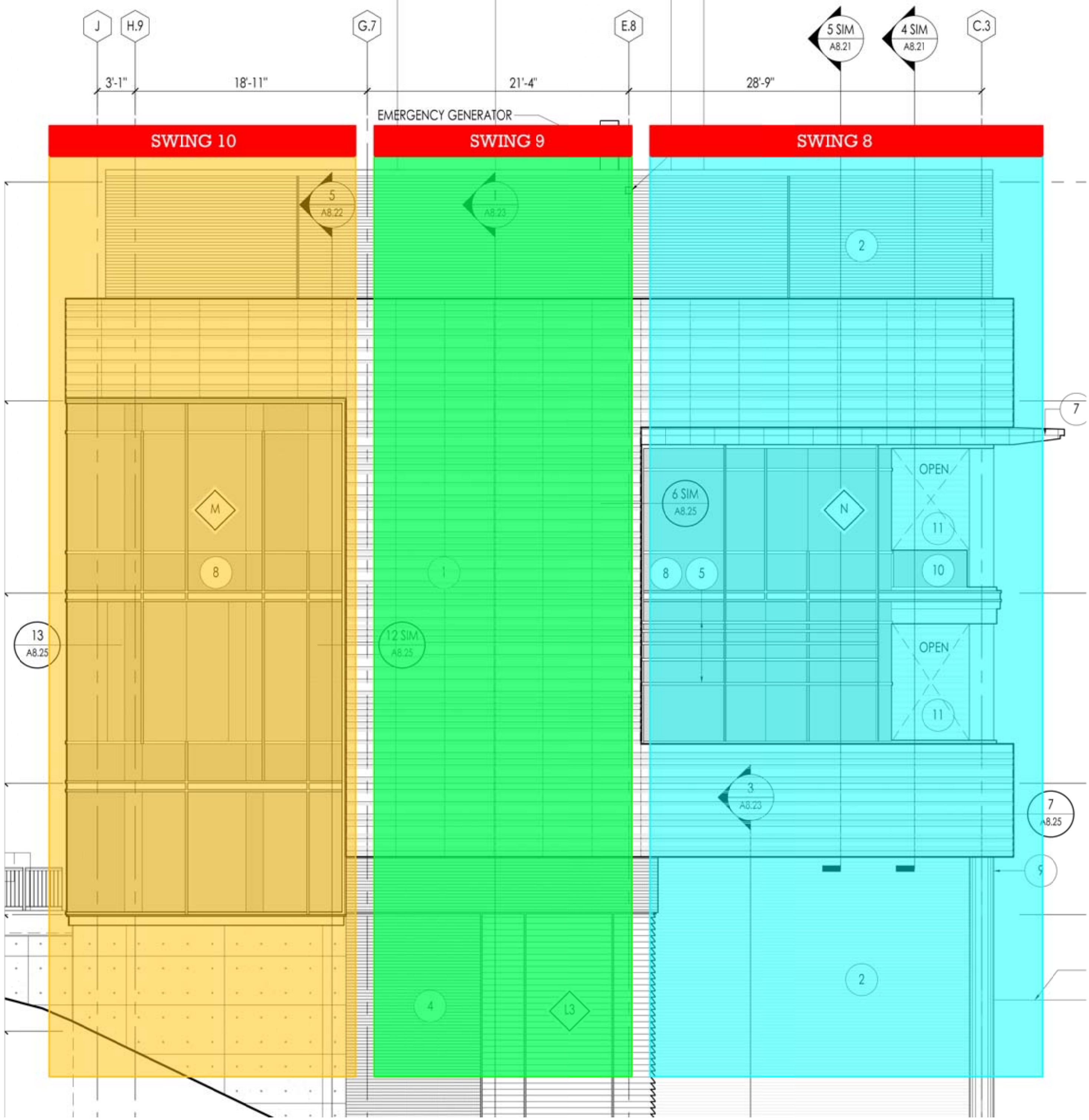
East Elevation



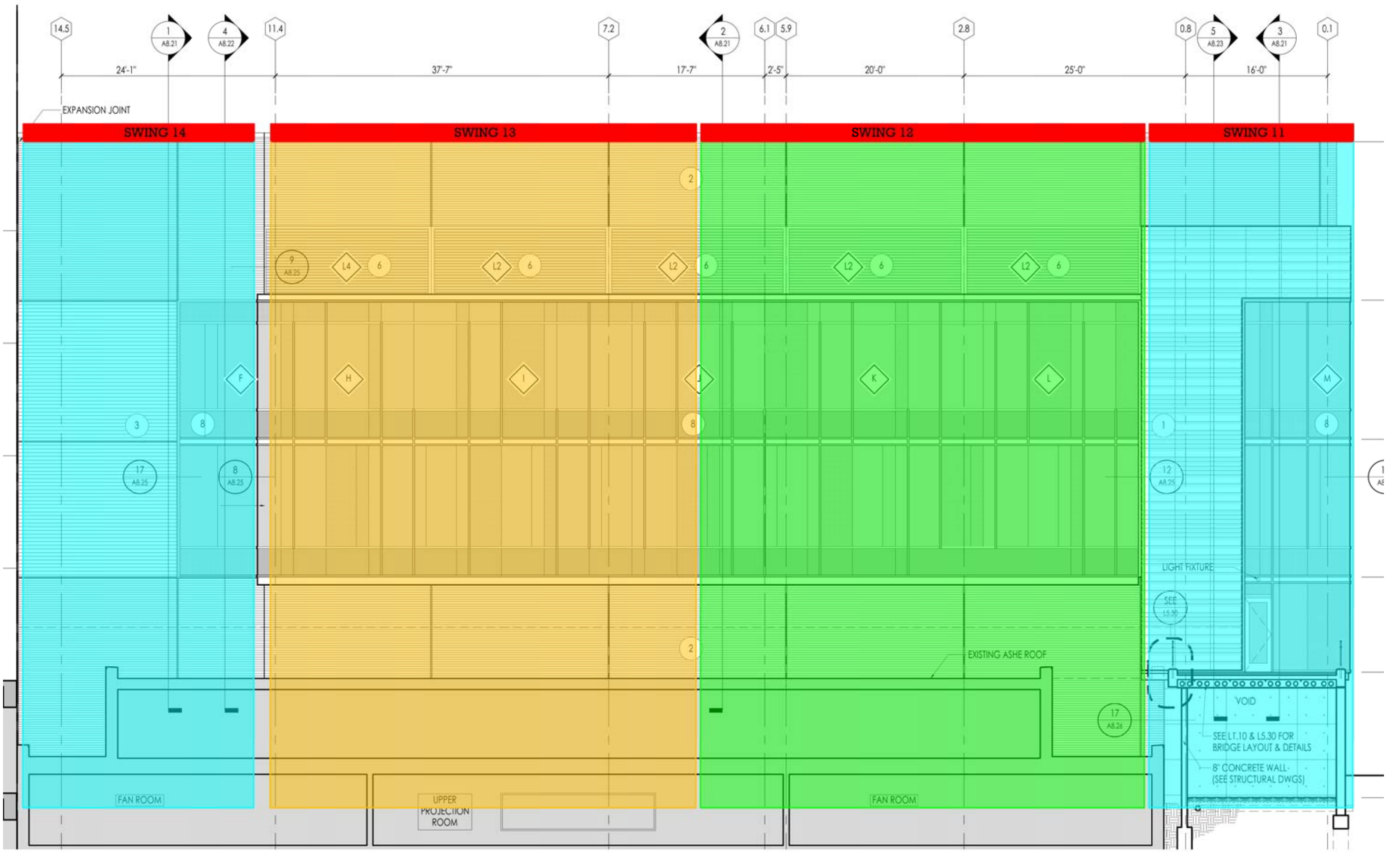
South Elevation



West Elevation



North Elevation

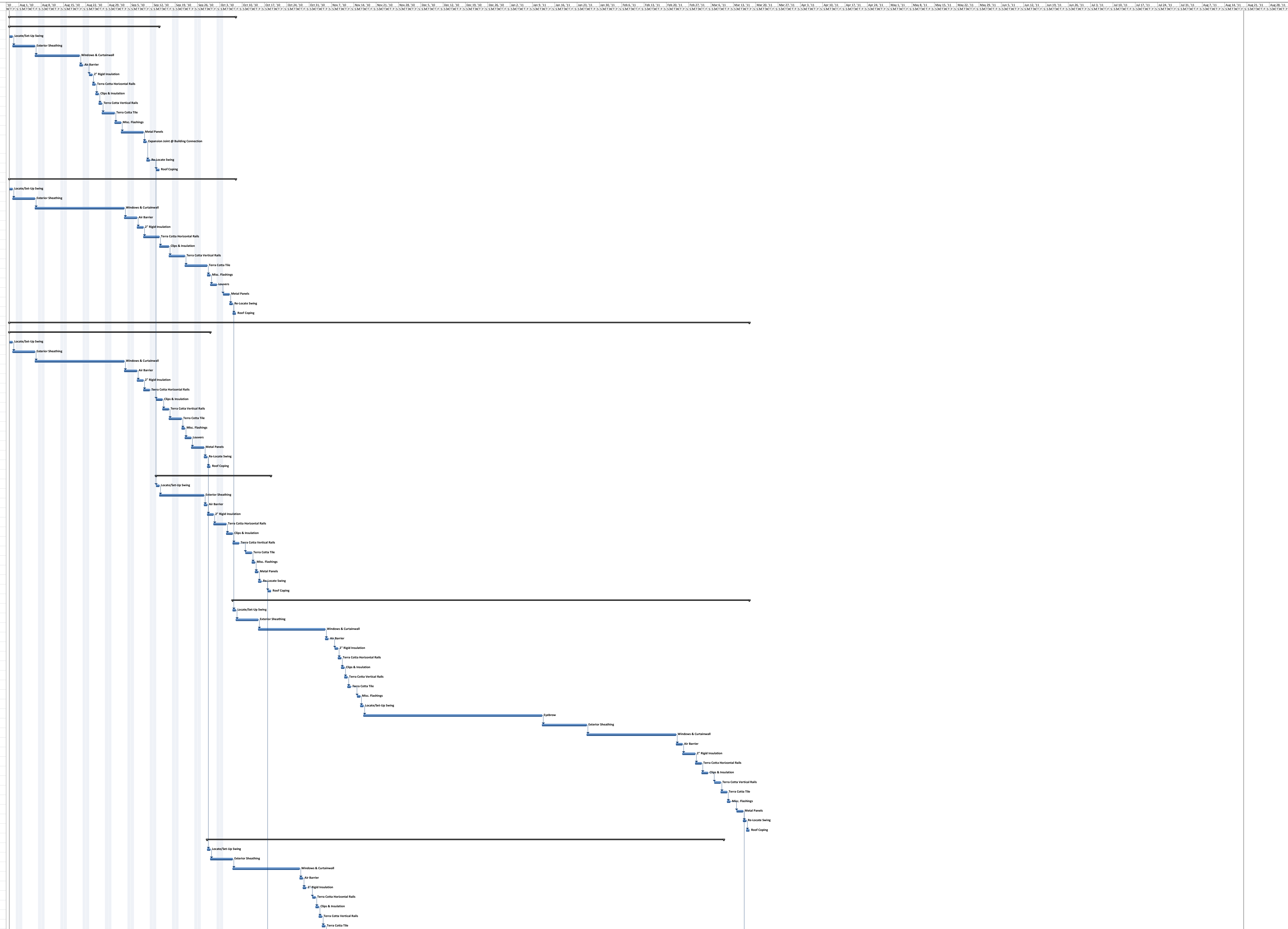


APPENDIX D – NEW FAÇADE SCHEDULE

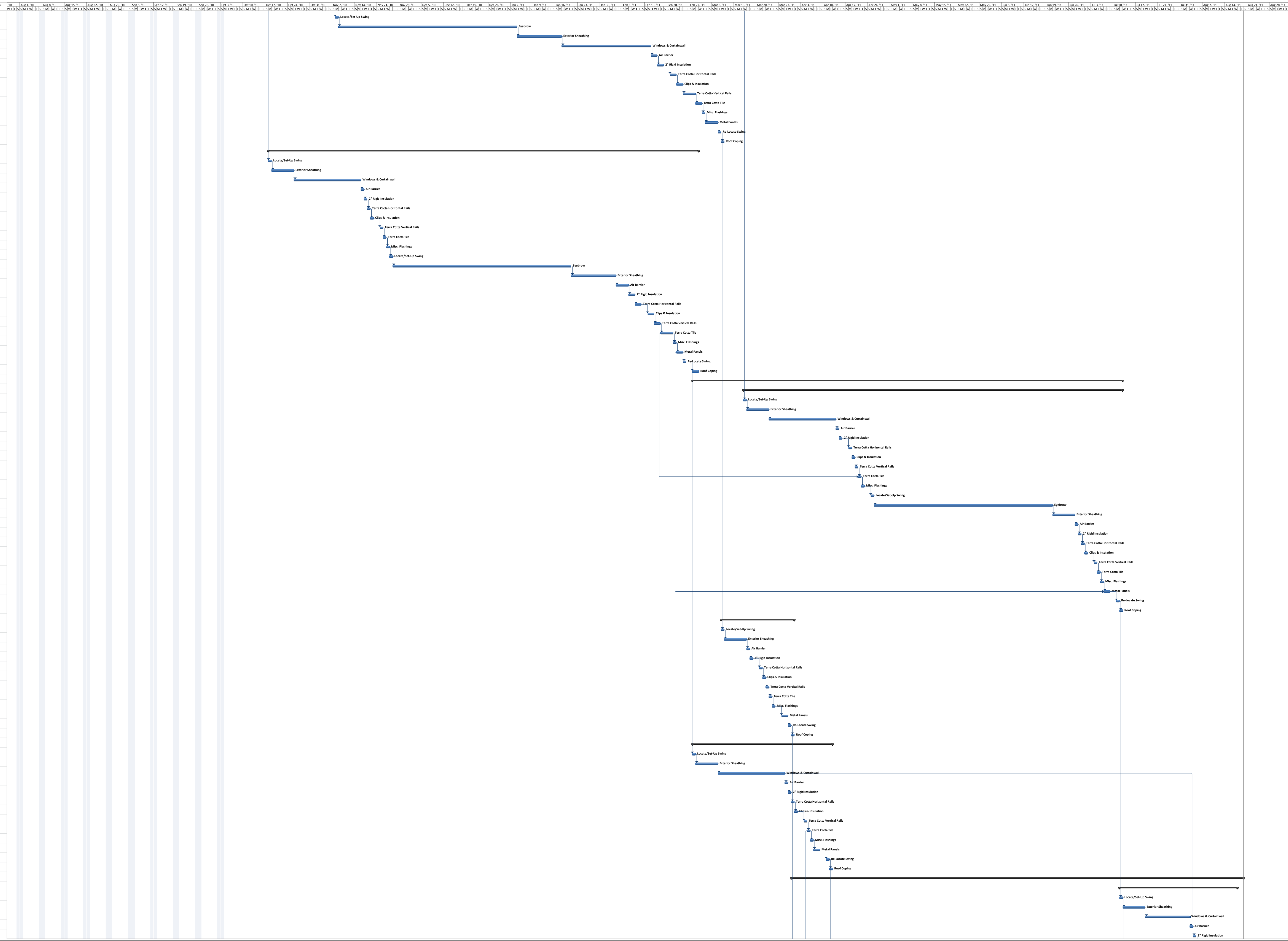
The following schedule is a new schedule for the installation of the exterior facade for the Chevron Annex.

University of Pittsburgh
Chevron Annex
New Exterior Facade Schedule

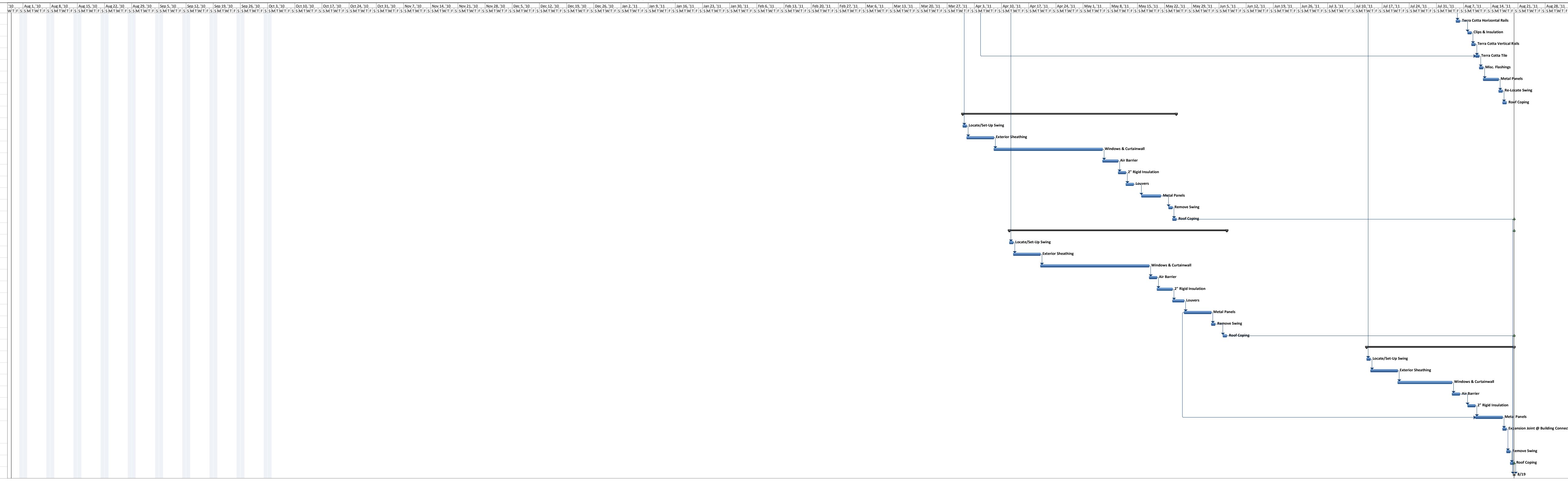
ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	Successors	Resource Names
1			**East Elevation**	**51 days**	**Thu 7/29/10**	**Thu 10/7/10**			
2			**Swing 1**	**33 days**	**Thu 7/29/10**	**Mon 9/13/10**			
3			Locate/Set-Up Swing	1 day	Thu 7/29/10	Thu 7/29/10		4	
4			Exterior Sheathing	5 days	Fri 7/30/10	Thu 8/5/10	3	5	
5			Windows & Curtainwall	10 days	Fri 8/6/10	Thu 8/19/10	4	6	
6			Air Barrier	1 day	Fri 8/20/10	Fri 8/20/10	5	7	
7			2" Rigid Insulation	1 day	Mon 8/23/10	Mon 8/23/10	6	8	
8			Terra Cotta Horizontal Rails	1 day	Tue 8/24/10	Tue 8/24/10	7	9	
9			Clips & Insulation	1 day	Wed 8/25/10	Wed 8/25/10	8	10	
10			Terra Cotta Vertical Rails	1 day	Thu 8/26/10	Thu 8/26/10	9	11	
11			Terra Cotta Tile	2 days	Fri 8/27/10	Mon 8/30/10	10	12	
12			Misc. Flashings	2 days	Tue 8/31/10	Wed 9/1/10	11	13	
13			Metal Panels	5 days	Thu 9/2/10	Wed 9/8/10	12	14	
14			Expansion Joint @ Building Connection	1 day	Thu 9/9/10	Thu 9/9/10	13	15	
15			Re-Locate Swing	1 day	Fri 9/10/10	Fri 9/10/10	14	16,49	
16			Roof Coping	1 day	Mon 9/13/10	Mon 9/13/10	15		
17			**Swing 2**	**51 days**	**Thu 7/29/10**	**Thu 10/7/10**			
18			Locate/Set-Up Swing	1 day	Thu 7/29/10	Thu 7/29/10		19	
19			Exterior Sheathing	5 days	Fri 7/30/10	Thu 8/5/10	18	20	
20			Windows & Curtainwall	20 days	Fri 8/6/10	Thu 9/2/10	19	21	
21			Air Barrier	2 days	Fri 9/3/10	Mon 9/6/10	20	22	
22			2" Rigid Insulation	2 days	Tue 9/7/10	Wed 9/8/10	21	23	
23			Terra Cotta Horizontal Rails	3 days	Thu 9/9/10	Mon 9/13/10	22	24	
24			Clips & Insulation	3 days	Tue 9/14/10	Thu 9/16/10	23	25	
25			Terra Cotta Vertical Rails	3 days	Fri 9/17/10	Tue 9/21/10	24	26	
26			Terra Cotta Tile	5 days	Wed 9/22/10	Tue 9/28/10	25	27	
27			Misc. Flashings	1 day	Wed 9/29/10	Wed 9/29/10	26	28	
28			Louvers	2 days	Thu 9/30/10	Fri 10/1/10	27	29	
29			Metal Panels	2 days	Mon 10/4/10	Tue 10/5/10	28	30	
30			Re-Locate Swing	1 day	Wed 10/6/10	Wed 10/6/10	29	31,62	
31			Roof Coping	1 day	Thu 10/7/10	Thu 10/7/10	30		
32			**South Elevation**	**166 days**	**Thu 7/29/10**	**Thu 3/17/11**			
33			**Swing 3**	**45 days**	**Thu 7/29/10**	**Wed 9/29/10**			
34			Locate/Set-Up Swing	1 day	Thu 7/29/10	Thu 7/29/10		35	
35			Exterior Sheathing	5 days	Fri 7/30/10	Thu 8/5/10	34	36	
36			Windows & Curtainwall	20 days	Fri 8/6/10	Thu 9/2/10	35	37	
37			Air Barrier	2 days	Fri 9/3/10	Mon 9/6/10	36	38	
38			2" Rigid Insulation	2 days	Tue 9/7/10	Wed 9/8/10	37	39	
39			Terra Cotta Horizontal Rails	2 days	Thu 9/9/10	Fri 9/10/10	38	40	
40			Clips & Insulation	2 days	Mon 9/13/10	Tue 9/14/10	39	41	
41			Terra Cotta Vertical Rails	2 days	Wed 9/15/10	Thu 9/16/10	40	42	
42			Terra Cotta Tile	2 days	Fri 9/17/10	Mon 9/20/10	41	43	
43			Misc. Flashings	1 day	Tue 9/21/10	Tue 9/21/10	42	44	
44			Louvers	2 days	Wed 9/22/10	Thu 9/23/10	43	45	
45			Metal Panels	2 days	Fri 9/24/10	Mon 9/27/10	44	46	
46			Re-Locate Swing	1 day	Tue 9/28/10	Tue 9/28/10	45	47,87	
47			Roof Coping	1 day	Wed 9/29/10	Wed 9/29/10	46		
48			**Swing 4**	**26 days**	**Mon 9/13/10**	**Mon 10/18/10**			
49			Locate/Set-Up Swing	1 day	Mon 9/13/10	Mon 9/13/10	15	50	
50			Exterior Sheathing	10 days	Tue 9/14/10	Mon 9/27/10	49	51	
51			Air Barrier	1 day	Tue 9/28/10	Tue 9/28/10	50	52	
52			2" Rigid Insulation	2 days	Wed 9/29/10	Thu 9/30/10	51	53	
53			Terra Cotta Horizontal Rails	2 days	Fri 10/1/10	Mon 10/4/10	52	54	
54			Clips & Insulation	2 days	Tue 10/5/10	Wed 10/6/10	53	55	
55			Terra Cotta Vertical Rails	2 days	Thu 10/7/10	Fri 10/8/10	54	56	
56			Terra Cotta Tile	2 days	Mon 10/11/10	Tue 10/12/10	55	57	
57			Misc. Flashings	1 day	Wed 10/13/10	Wed 10/13/10	56	58	
58			Metal Panels	1 day	Thu 10/14/10	Thu 10/14/10	57	59	
59			Re-Locate Swing	1 day	Fri 10/15/10	Fri 10/15/10	58	60,112	
60			Roof Coping	1 day	Mon 10/18/10	Mon 10/18/10	59		
61			**Swing 5**	**116 days**	**Thu 10/7/10**	**Thu 3/17/11**			
62			Locate/Set-Up Swing	1 day	Thu 10/7/10	Thu 10/7/10	30	63	
63			Exterior Sheathing	5 days	Fri 10/8/10	Thu 10/14/10	62	64	
64			Windows & Curtainwall	15 days	Fri 10/15/10	Thu 11/4/10	63	65	
65			Air Barrier	1 day	Fri 11/5/10	Fri 11/5/10	64	66	
66			2" Rigid Insulation	1 day	Mon 11/8/10	Mon 11/8/10	65	67	
67			Terra Cotta Horizontal Rails	1 day	Tue 11/9/10	Tue 11/9/10	66	68	
68			Clips & Insulation	1 day	Wed 11/10/10	Wed 11/10/10	67	69	
69			Terra Cotta Vertical Rails	1 day	Thu 11/11/10	Thu 11/11/10	68	70	
70			Terra Cotta Tile	1 day	Fri 11/12/10	Fri 11/12/10	69	71	
71			Misc. Flashings	1 day	Mon 11/15/10	Mon 11/15/10	70	72	
72			Locate/Set-Up Swing	1 day	Tue 11/16/10	Tue 11/16/10	71	73	
73			Eyebrow	40 days	Wed 11/17/10	Tue 1/11/11	72	74	
74			Exterior Sheathing	10 days	Wed 1/12/11	Tue 1/25/11	73	75	
75			Windows & Curtainwall	20 days	Wed 1/26/11	Tue 2/22/11	74	76	
76			Air Barrier	2 days	Wed 2/23/11	Thu 2/24/11	75	77	
77			2" Rigid Insulation	2 days	Fri 2/25/11	Mon 2/28/11	76	78	
78			Terra Cotta Horizontal Rails	2 days	Tue 3/1/11	Wed 3/2/11	77	79	
79			Clips & Insulation	2 days	Thu 3/3/11	Fri 3/4/11	78	80	
80			Terra Cotta Vertical Rails	2 days	Mon 3/7/11	Tue 3/8/11	79	81	
81			Terra Cotta Tile	2 days	Wed 3/9/11	Thu 3/10/11	80	82	
82			Misc. Flashings	1 day	Fri 3/11/11	Fri 3/11/11	81	83	
83			Metal Panels	2 days	Mon 3/14/11	Tue 3/15/11	82	84,137	
84			Re-Locate Swing	1 day	Wed 3/16/11	Wed 3/16/11	83	85	
85			Roof Coping	1 day	Thu 3/17/11	Thu 3/17/11	84		
86			**Swing 6**	**116 days**	**Wed 9/29/10**	**Wed 3/9/11**			
87			Locate/Set-Up Swing	1 day	Wed 9/29/10	Wed 9/29/10	46	88	
88			Exterior Sheathing	5 days	Thu 9/30/10	Wed 10/6/10	87	89	
89			Windows & Curtainwall	15 days	Thu 10/7/10	Wed 10/27/10	88	90	
90			Air Barrier	1 day	Thu 10/28/10	Thu 10/28/10	89	91	
91			2" Rigid Insulation	1 day	Fri 10/29/10	Fri 10/29/10	90	92	
92			Terra Cotta Horizontal Rails	1 day	Mon 11/1/10	Mon 11/1/10	91	93	
93			Clips & Insulation	1 day	Tue 11/2/10	Tue 11/2/10	92	94	
94			Terra Cotta Vertical Rails	1 day	Wed 11/3/10	Wed 11/3/10	93	95	
95			Terra Cotta Tile	1 day	Thu 11/4/10	Thu 11/4/10	94	96	
96			Misc. Flashings	1 day	Fri 11/5/10	Fri 11/5/10	95	97	



ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	Successors	Resource Names
97			Locate/Set-Up Swing	1 day	Mon 11/8/10	Mon 11/8/10	96	98	
98			Eyebrow	40 days	Tue 11/9/10	Mon 1/3/11	97	99	
99			Exterior Sheathing	10 days	Tue 1/4/11	Mon 1/17/11	98	100	
100			Windows & Curtainwall	20 days	Tue 1/18/11	Mon 2/14/11	99	101	
101			Air Barrier	2 days	Tue 2/15/11	Wed 2/16/11	100	102	
102			2" Rigid Insulation	2 days	Thu 2/17/11	Fri 2/18/11	101	103	
103			Terra Cotta Horizontal Rails	2 days	Mon 2/21/11	Tue 2/22/11	102	104	
104			Clips & Insulation	2 days	Wed 2/23/11	Thu 2/24/11	103	105	
105			Terra Cotta Vertical Rails	2 days	Fri 2/25/11	Mon 2/28/11	104	106	
106			Terra Cotta Tile	2 days	Tue 3/1/11	Wed 3/2/11	105	107	
107			Misc. Flashings	1 day	Thu 3/3/11	Thu 3/3/11	106	108	
108			Metal Panels	2 days	Fri 3/4/11	Mon 3/7/11	107	109	
109			Re-Locate Swing	1 day	Tue 3/8/11	Tue 3/8/11	108	110,161	
110			Roof Coping	1 day	Wed 3/9/11	Wed 3/9/11	109		
111			**Swing 7**	**97 days**	**Mon 10/18/10**	**Tue 3/1/11**			
112			Locate/Set-Up Swing	1 day	Mon 10/18/10	Mon 10/18/10	59	113	
113			Exterior Sheathing	5 days	Tue 10/19/10	Mon 10/25/10	112	114	
114			Windows & Curtainwall	15 days	Tue 10/26/10	Mon 11/15/10	113	115	
115			Air Barrier	1 day	Tue 11/16/10	Tue 11/16/10	114	116	
116			2" Rigid Insulation	1 day	Wed 11/17/10	Wed 11/17/10	115	117	
117			Terra Cotta Horizontal Rails	1 day	Thu 11/18/10	Thu 11/18/10	116	118	
118			Clips & Insulation	1 day	Fri 11/19/10	Fri 11/19/10	117	119	
119			Terra Cotta Vertical Rails	1 day	Mon 11/22/10	Mon 11/22/10	118	120	
120			Terra Cotta Tile	1 day	Tue 11/23/10	Tue 11/23/10	119	121	
121			Misc. Flashings	1 day	Wed 11/24/10	Wed 11/24/10	120	122	
122			Locate/Set-Up Swing	1 day	Thu 11/25/10	Thu 11/25/10	121	123	
123			Eyebrow	40 days	Fri 11/26/10	Thu 1/20/11	122	124	
124			Exterior Sheathing	10 days	Fri 1/21/11	Thu 2/3/11	123	125	
125			Air Barrier	2 days	Fri 2/4/11	Mon 2/7/11	124	126	
126			2" Rigid Insulation	2 days	Tue 2/8/11	Wed 2/9/11	125	127	
127			Terra Cotta Horizontal Rails	2 days	Thu 2/10/11	Fri 2/11/11	126	128	
128			Clips & Insulation	2 days	Mon 2/14/11	Tue 2/15/11	127	129	
129			Terra Cotta Vertical Rails	2 days	Wed 2/16/11	Thu 2/17/11	128	130	
130			Terra Cotta Tile	2 days	Fri 2/18/11	Mon 2/21/11	129	131,145SS	
131			Misc. Flashings	1 day	Tue 2/22/11	Tue 2/22/11	130	132	
132			Metal Panels	2 days	Wed 2/23/11	Thu 2/24/11	131	133,157SS	
133			Re-Locate Swing	1 day	Fri 2/25/11	Fri 2/25/11	132	134,174	
134			Roof Coping	2 days	Mon 2/28/11	Tue 3/1/11	133		
135			**West Elevation**	**97 days**	**Mon 2/28/11**	**Tue 7/12/11**			
136			**Swing 8**	**85 days**	**Wed 3/16/11**	**Tue 7/12/11**			
137			Locate/Set-Up Swing	1 day	Wed 3/16/11	Wed 3/16/11	83	138	
138			Exterior Sheathing	5 days	Thu 3/17/11	Wed 3/23/11	137	139	
139			Windows & Curtainwall	15 days	Thu 3/24/11	Wed 4/13/11	138	140	
140			Air Barrier	1 day	Thu 4/14/11	Thu 4/14/11	139	141	
141			2" Rigid Insulation	1 day	Fri 4/15/11	Fri 4/15/11	140	142	
142			Terra Cotta Horizontal Rails	1 day	Mon 4/18/11	Mon 4/18/11	141	143	
143			Clips & Insulation	1 day	Tue 4/19/11	Tue 4/19/11	142	144	
144			Terra Cotta Vertical Rails	1 day	Wed 4/20/11	Wed 4/20/11	143	145	
145			Terra Cotta Tile	1 day	Thu 4/21/11	Thu 4/21/11	144,130SS	146	
146			Misc. Flashings	1 day	Fri 4/22/11	Fri 4/22/11	145	147	
147			Locate/Set-Up Swing	1 day	Mon 4/25/11	Mon 4/25/11	146	148	
148			Eyebrow	40 days	Tue 4/26/11	Mon 6/20/11	147	149	
149			Exterior Sheathing	5 days	Tue 6/21/11	Mon 6/27/11	148	150	
150			Air Barrier	1 day	Tue 6/28/11	Tue 6/28/11	149	151	
151			2" Rigid Insulation	1 day	Wed 6/29/11	Wed 6/29/11	150	152	
152			Terra Cotta Horizontal Rails	1 day	Thu 6/30/11	Thu 6/30/11	151	153	
153			Clips & Insulation	1 day	Fri 7/1/11	Fri 7/1/11	152	154	
154			Terra Cotta Vertical Rails	1 day	Mon 7/4/11	Mon 7/4/11	153	155	
155			Terra Cotta Tile	1 day	Tue 7/5/11	Tue 7/5/11	154	156	
156			Misc. Flashings	1 day	Wed 7/6/11	Wed 7/6/11	155	157	
157			Metal Panels	2 days	Thu 7/7/11	Fri 7/8/11	132SS,156	158	
158			Re-Locate Swing	1 day	Mon 7/11/11	Mon 7/11/11	157	159,189	
159			Roof Coping	1 day	Tue 7/12/11	Tue 7/12/11	158		
160			**Swing 9**	**17 days**	**Wed 3/9/11**	**Thu 3/31/11**			
161			Locate/Set-Up Swing	1 day	Wed 3/9/11	Wed 3/9/11	109	162	
162			Exterior Sheathing	5 days	Thu 3/10/11	Wed 3/16/11	161	163	
163			Air Barrier	1 day	Thu 3/17/11	Thu 3/17/11	162	164	
164			2" Rigid Insulation	1 day	Fri 3/18/11	Fri 3/18/11	163	165	
165			Terra Cotta Horizontal Rails	1 day	Mon 3/21/11	Mon 3/21/11	164	166	
166			Clips & Insulation	1 day	Tue 3/22/11	Tue 3/22/11	165	167	
167			Terra Cotta Vertical Rails	1 day	Wed 3/23/11	Wed 3/23/11	166	168	
168			Terra Cotta Tile	1 day	Thu 3/24/11	Thu 3/24/11	167	169	
169			Misc. Flashings	1 day	Fri 3/25/11	Fri 3/25/11	168	170	
170			Metal Panels	2 days	Mon 3/28/11	Tue 3/29/11	169	171	
171			Re-Locate Swing	1 day	Wed 3/30/11	Wed 3/30/11	170	172,203	
172			Roof Coping	1 day	Thu 3/31/11	Thu 3/31/11	171		
173			**Swing 10**	**32 days**	**Mon 2/28/11**	**Tue 4/12/11**			
174			Locate/Set-Up Swing	1 day	Mon 2/28/11	Mon 2/28/11	133	175	
175			Exterior Sheathing	5 days	Tue 3/1/11	Mon 3/7/11	174	176	
176			Windows & Curtainwall	15 days	Tue 3/8/11	Mon 3/28/11	175	177,191FF	
177			Air Barrier	1 day	Tue 3/29/11	Tue 3/29/11	176	178	
178			2" Rigid Insulation	1 day	Wed 3/30/11	Wed 3/30/11	177	179	
179			Terra Cotta Horizontal Rails	1 day	Thu 3/31/11	Thu 3/31/11	178	180	
180			Clips & Insulation	1 day	Fri 4/1/11	Fri 4/1/11	179	181	
181			Terra Cotta Vertical Rails	1 day	Mon 4/4/11	Mon 4/4/11	180	182	
182			Terra Cotta Tile	1 day	Tue 4/5/11	Tue 4/5/11	181	183,197SS	
183			Misc. Flashings	1 day	Wed 4/6/11	Wed 4/6/11	182	184	
184			Metal Panels	2 days	Thu 4/7/11	Fri 4/8/11	183	185	
185			Re-Locate Swing	1 day	Mon 4/11/11	Mon 4/11/11	184	186,213	
186			Roof Coping	1 day	Tue 4/12/11	Tue 4/12/11	185		
187			**North Elevation**	**102 days**	**Thu 3/31/11**	**Fri 8/19/11**			
188			**Swing 11**	**27 days**	**Tue 7/12/11**	**Wed 8/17/11**			
189			Locate/Set-Up Swing	1 day	Tue 7/12/11	Tue 7/12/11	158	190,223	
190			Exterior Sheathing	5 days	Wed 7/13/11	Tue 7/19/11	189	191	
191			Windows & Curtainwall	10 days	Wed 7/20/11	Tue 8/2/11	190,176FF	192	
192			Air Barrier	1 day	Wed 8/3/11	Wed 8/3/11	191	193	
193			2" Rigid Insulation	1 day	Thu 8/4/11	Thu 8/4/11	192	194	



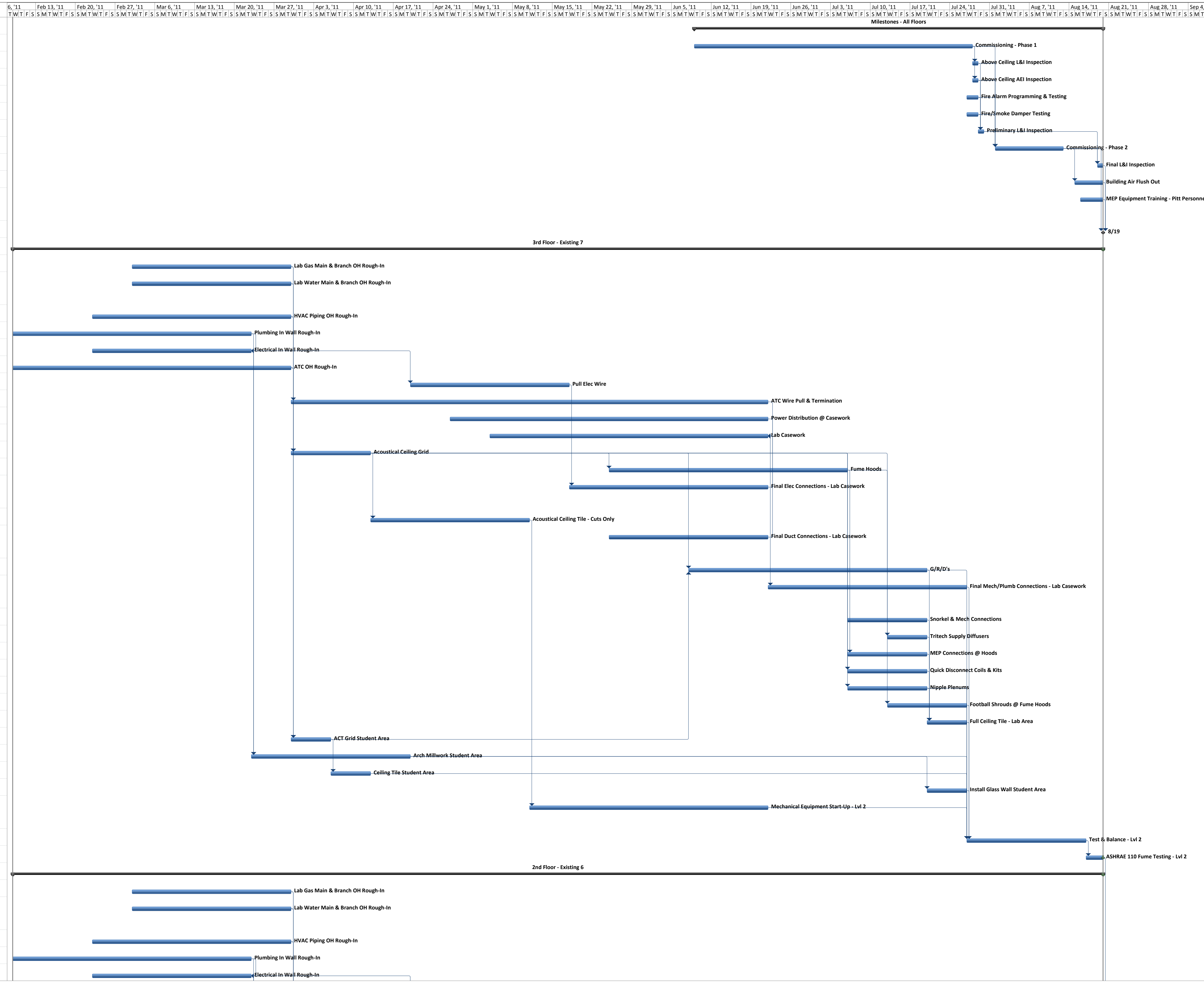
ID	Indicators	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Successors	Resource Names
194			Terra Cotta Horizontal Rails	1 day	Fri 8/5/11	Fri 8/5/11	193	195	
195			Clips & Insulation	1 day	Mon 8/8/11	Mon 8/8/11	194	196	
196			Terra Cotta Vertical Rails	1 day	Tue 8/9/11	Tue 8/9/11	195	197	
197			Terra Cotta Tile	1 day	Wed 8/10/11	Wed 8/10/11	196,182SS	198	
198			Misc. Flashings	1 day	Thu 8/11/11	Thu 8/11/11	197	199	
199			Metal Panels	2 days	Fri 8/12/11	Mon 8/15/11	198	200	
200			Re-Locate Swing	1 day	Tue 8/16/11	Tue 8/16/11	199	201	
201			Roof Coping	1 day	Wed 8/17/11	Wed 8/17/11	200		
202			**Swing 12**	**39 days**	**Thu 3/31/11**	**Tue 5/24/11**			
203			Locate/Set-Up Swing	1 day	Thu 3/31/11	Thu 3/31/11	171	204	
204			Exterior Sheathing	5 days	Fri 4/1/11	Thu 4/7/11	203	205	
205			Windows & Curtainwall	20 days	Fri 4/8/11	Thu 5/5/11	204	206	
206			Air Barrier	2 days	Fri 5/6/11	Mon 5/9/11	205	207	
207			2" Rigid Insulation	2 days	Tue 5/10/11	Wed 5/11/11	206	208	
208			Louvers	2 days	Thu 5/12/11	Fri 5/13/11	207	209	
209			Metal Panels	5 days	Mon 5/16/11	Fri 5/20/11	208	210	
210			Remove Swing	1 day	Mon 5/23/11	Mon 5/23/11	209	211	
211			Roof Coping	1 day	Tue 5/24/11	Tue 5/24/11	210	232	
212			**Swing 13**	**40 days**	**Tue 4/12/11**	**Mon 6/6/11**			
213			Locate/Set-Up Swing	1 day	Tue 4/12/11	Tue 4/12/11	185	214	
214			Exterior Sheathing	5 days	Wed 4/13/11	Tue 4/19/11	213	215	
215			Windows & Curtainwall	20 days	Wed 4/20/11	Tue 5/17/11	214	216	
216			Air Barrier	2 days	Wed 5/18/11	Thu 5/19/11	215	217	
217			2" Rigid Insulation	2 days	Fri 5/20/11	Mon 5/23/11	216	218	
218			Louvers	3 days	Tue 5/24/11	Thu 5/26/11	217	219	
219			Metal Panels	5 days	Fri 5/27/11	Thu 6/2/11	218	220,228SS	
220			Remove Swing	1 day	Fri 6/3/11	Fri 6/3/11	219	221	
221			Roof Coping	1 day	Mon 6/6/11	Mon 6/6/11	220	232	
222			**Swing 14**	**28 days**	**Wed 7/13/11**	**Fri 8/19/11**			
223			Locate/Set-Up Swing	1 day	Wed 7/13/11	Wed 7/13/11	189	224	
224			Exterior Sheathing	5 days	Thu 7/14/11	Wed 7/20/11	223	225	
225			Windows & Curtainwall	10 days	Thu 7/21/11	Wed 8/3/11	224	226	
226			Air Barrier	2 days	Thu 8/4/11	Fri 8/5/11	225	227	
227			2" Rigid Insulation	2 days	Mon 8/8/11	Tue 8/9/11	226	228	
228			Metal Panels	5 days	Wed 8/10/11	Tue 8/16/11	227,219SS	229	
229			Expansion Joint @ Building Connection	1 day	Wed 8/17/11	Wed 8/17/11	228	230	
230			Remove Swing	1 day	Thu 8/18/11	Thu 8/18/11	229	231	
231			Roof Coping	1 day	Fri 8/19/11	Fri 8/19/11	230	232	
232	✓		Substantial Completion	0 days	Fri 8/19/11	Fri 8/19/11	231,221,211		



APPENDIX E – NEW COMMISSIONING SCHEDULE

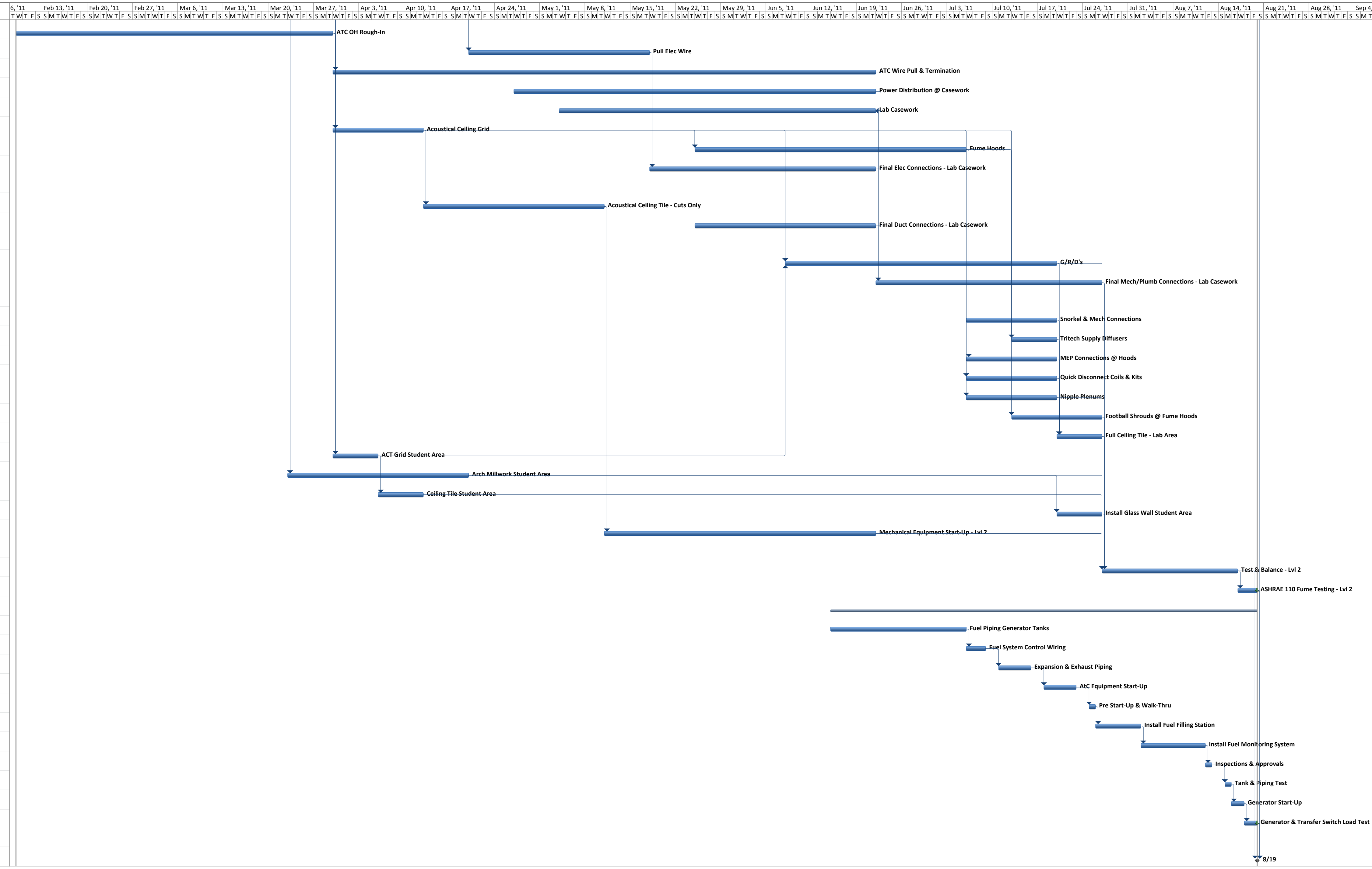
The following schedule is a new schedule for the commissioning process for the Chevron Annex.

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	Successors	Resource Names
1			**Milestones - All Floors**	**52 days**	**Thu 6/9/11**	**Fri 8/19/11**			
2			Commissioning - Phase 1	35 days	Thu 6/9/11	Wed 7/27/11		3,4,8	
3			Above Ceiling L&I Inspection	1 day	Thu 7/28/11	Thu 7/28/11	2	7,8	
4			Above Ceiling AEI Inspection	1 day	Thu 7/28/11	Thu 7/28/11	2	7,8	
5			Fire Alarm Programming & Testing	2 days	Wed 7/27/11	Thu 7/28/11		7,8	
6			Fire/Smoke Damper Testing	2 days	Wed 7/27/11	Thu 7/28/11		7,8	
7			Preliminary L&I Inspection	1 day	Fri 7/29/11	Fri 7/29/11	3,4,5,6	9,8	
8			Commissioning - Phase 2	10 days	Mon 8/1/11	Fri 8/12/11	2,3,4,5,6,7	9,12,10	
9			Final L&I Inspection	1 day	Fri 8/19/11	Fri 8/19/11	8,7	12	
10			Building Air Flush Out	5 days	Mon 8/15/11	Fri 8/19/11	8	12	
11			MEP Equipment Training - Pitt Personnel	4 days	Tue 8/16/11	Fri 8/19/11		12	
12			Substantial Completion	0 days	Fri 8/19/11	Fri 8/19/11	10,9,8,11		
13			**3rd Floor - Existing 7**	**138 days**	**Wed 2/9/11**	**Fri 8/19/11**			
14			Lab Gas Main & Branch OH Rough-In	20 days	Wed 3/2/11	Tue 3/29/11		24,38	
15			Lab Water Main & Branch OH Rough-In	20 days	Wed 3/2/11	Tue 3/29/11		24,38	
16			HVAC Piping OH Rough-In	25 days	Wed 2/23/11	Tue 3/29/11		24,38	
17			Plumbing In Wall Rough-In	30 days	Wed 2/9/11	Tue 3/22/11		18FF,39	
18			Electrical In Wall Rough-In	20 days	Wed 2/23/11	Tue 3/22/11	17FF	20,39	
19			ATC OH Rough-In	35 days	Wed 2/9/11	Tue 3/29/11		21,24,38	
20			Pull Elec Wire	20 days	Wed 4/20/11	Tue 5/17/11	18	26	
21			ATC Wire Pull & Termination	60 days	Wed 3/30/11	Tue 6/21/11	19	23FF	
22			Power Distribution @ Casework	40 days	Wed 4/27/11	Tue 6/21/11		23FF	
23			Lab Casework	35 days	Wed 5/4/11	Tue 6/21/11	22FF,26FF,28FF,	30	
24			Acoustical Ceiling Grid	10 days	Wed 3/30/11	Tue 4/12/11	14,15,16,19	27,29,32,35,34,25	
25			Fume Hoods	30 days	Wed 5/25/11	Tue 7/5/11	24	33,36	
26			Final Elec Connections - Lab Casework	25 days	Wed 5/18/11	Tue 6/21/11	20	23FF	
27			Acoustical Ceiling Tile - Cuts Only	20 days	Wed 4/13/11	Tue 5/10/11	24	42	
28			Final Duct Connections - Lab Casework	20 days	Wed 5/25/11	Tue 6/21/11		23FF	
29			G/R/D's	30 days	Wed 6/8/11	Tue 7/19/11	24,38	37,43	
30			Final Mech/Plumb Connections - Lab Casework	25 days	Wed 6/22/11	Tue 7/26/11	23	43	
31			Snorkel & Mech Connections	10 days	Wed 7/6/11	Tue 7/19/11		37	
32			Tritech Supply Diffusers	5 days	Wed 7/13/11	Tue 7/19/11	24	37	
33			MEP Connections @ Hoods	10 days	Wed 7/6/11	Tue 7/19/11	25	37	
34			Quick Disconnect Coils & Kits	10 days	Wed 7/6/11	Tue 7/19/11	24	37	
35			Nipple Plenums	10 days	Wed 7/6/11	Tue 7/19/11	24	37,43	
36			Football Shrouds @ Fume Hoods	10 days	Wed 7/13/11	Tue 7/26/11	25	43	
37			Full Ceiling Tile - Lab Area	5 days	Wed 7/20/11	Tue 7/26/11	29,31,32,33,34,	43	
38			ACT Grid Student Area	5 days	Wed 3/30/11	Tue 4/5/11	14,15,16,19	29,40	
39			Arch Millwork Student Area	20 days	Wed 3/23/11	Tue 4/19/11	17,18	43,41	
40			Ceiling Tile Student Area	5 days	Wed 4/6/11	Tue 4/12/11	38	43	
41			Install Glass Wall Student Area	5 days	Wed 7/20/11	Tue 7/26/11	39	43	
42			Mechanical Equipment Start-Up - Lvl 2	30 days	Wed 5/11/11	Tue 6/21/11	27	43	
43			Test & Balance - Lvl 2	15 days	Wed 7/27/11	Tue 8/16/11	29,30,35,36,37,	44	
44			ASHRAE 110 Fume Testing - Lvl 2	3 days	Wed 8/17/11	Fri 8/19/11	43	89	
45			**2nd Floor - Existing 6**	**138 days**	**Wed 2/9/11**	**Fri 8/19/11**			
46			Lab Gas Main & Branch OH Rough-In	20 days	Wed 3/2/11	Tue 3/29/11		56,70	
47			Lab Water Main & Branch OH Rough-In	20 days	Wed 3/2/11	Tue 3/29/11		56,70	
48			HVAC Piping OH Rough-In	25 days	Wed 2/23/11	Tue 3/29/11		56,70	
49			Plumbing In Wall Rough-In	30 days	Wed 2/9/11	Tue 3/22/11		50FF,71	
50			Electrical In Wall Rough-In	20 days	Wed 2/23/11	Tue 3/22/11	49FF	52,71	



University of Pittsburgh
Chevron Annex
New Commissioning

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	Successors	Resource Names
51			ATC OH Rough-In	35 days	Wed 2/9/11	Tue 3/29/11		53,56,70	
52			Pull Elec Wire	20 days	Wed 4/20/11	Tue 5/17/11	50	58	
53			ATC Wire Pull & Termination	60 days	Wed 3/30/11	Tue 6/21/11	51	55FF	
54			Power Distribution @ Casework	40 days	Wed 4/27/11	Tue 6/21/11		55FF	
55			Lab Casework	35 days	Wed 5/4/11	Tue 6/21/11	54FF,58FF,60FF,	62	
56			Acoustical Ceiling Grid	10 days	Wed 3/30/11	Tue 4/12/11	46,47,51,48	59,61,64,67,66,57	
57			Fume Hoods	30 days	Wed 5/25/11	Tue 7/5/11	56	65,68	
58			Final Elec Connections - Lab Casework	25 days	Wed 5/18/11	Tue 6/21/11	52	55FF	
59			Acoustical Ceiling Tile - Cuts Only	20 days	Wed 4/13/11	Tue 5/10/11	56	74	
60			Final Duct Connections - Lab Casework	20 days	Wed 5/25/11	Tue 6/21/11		55FF	
61			G/R/D's	30 days	Wed 6/8/11	Tue 7/19/11	56,70	69,75	
62			Final Mech/Plumb Connections - Lab Casework	25 days	Wed 6/22/11	Tue 7/26/11	55	75	
63			Snorkel & Mech Connections	10 days	Wed 7/6/11	Tue 7/19/11		69	
64			Tritech Supply Diffusers	5 days	Wed 7/13/11	Tue 7/19/11	56	69	
65			MEP Connections @ Hoods	10 days	Wed 7/6/11	Tue 7/19/11	57	69	
66			Quick Disconnect Coils & Kits	10 days	Wed 7/6/11	Tue 7/19/11	56	69	
67			Nipple Plenums	10 days	Wed 7/6/11	Tue 7/19/11	56	69,75	
68			Football Shrouds @ Fume Hoods	10 days	Wed 7/13/11	Tue 7/26/11	57	75	
69			Full Ceiling Tile - Lab Area	5 days	Wed 7/20/11	Tue 7/26/11	63,64,65,66,67,	75	
70			ACT Grid Student Area	5 days	Wed 3/30/11	Tue 4/5/11	46,47,48,51	72,61	
71			Arch Millwork Student Area	20 days	Wed 3/23/11	Tue 4/19/11	49,50	75,73	
72			Ceiling Tile Student Area	5 days	Wed 4/6/11	Tue 4/12/11	70	75	
73			Install Glass Wall Student Area	5 days	Wed 7/20/11	Tue 7/26/11	71	75	
74			Mechanical Equipment Start-Up - Lvl 2	30 days	Wed 5/11/11	Tue 6/21/11	59	75	
75			Test & Balance - Lvl 2	15 days	Wed 7/27/11	Tue 8/16/11	67,68,69,71,73,	89,76	
76			ASHRAE 110 Fume Testing - Lvl 2	3 days	Wed 8/17/11	Fri 8/19/11	75	89	
77			**Emergency Generator**						
78			Fuel Piping Generator Tanks	15 days	Wed 6/15/11	Tue 7/5/11		79	
79			Fuel System Control Wiring	3 days	Wed 7/6/11	Fri 7/8/11	78	80	
80			Expansion & Exhaust Piping	5 days	Mon 7/11/11	Fri 7/15/11	79	81	
81			AtC Equipment Start-Up	5 days	Mon 7/18/11	Fri 7/22/11	80	82	
82			Pre Start-Up & Walk-Thru	1 day	Mon 7/25/11	Mon 7/25/11	81	83	
83			Install Fuel Filling Station	5 days	Tue 7/26/11	Mon 8/1/11	82	84	
84			Install Fuel Monitoring System	8 days	Tue 8/2/11	Thu 8/11/11	83	85	
85			Inspections & Approvals	1 day	Fri 8/12/11	Fri 8/12/11	84	86	
86			Tank & Piping Test	1 day	Mon 8/15/11	Mon 8/15/11	85	87	
87			Generator Start-Up	2 days	Tue 8/16/11	Wed 8/17/11	86	88	
88			Generator & Transfer Switch Load Test	2 days	Thu 8/18/11	Fri 8/19/11	87	89	
89	✓		Substantial Completion	0 days	Fri 8/19/11	Fri 8/19/11	76,75,88,44		



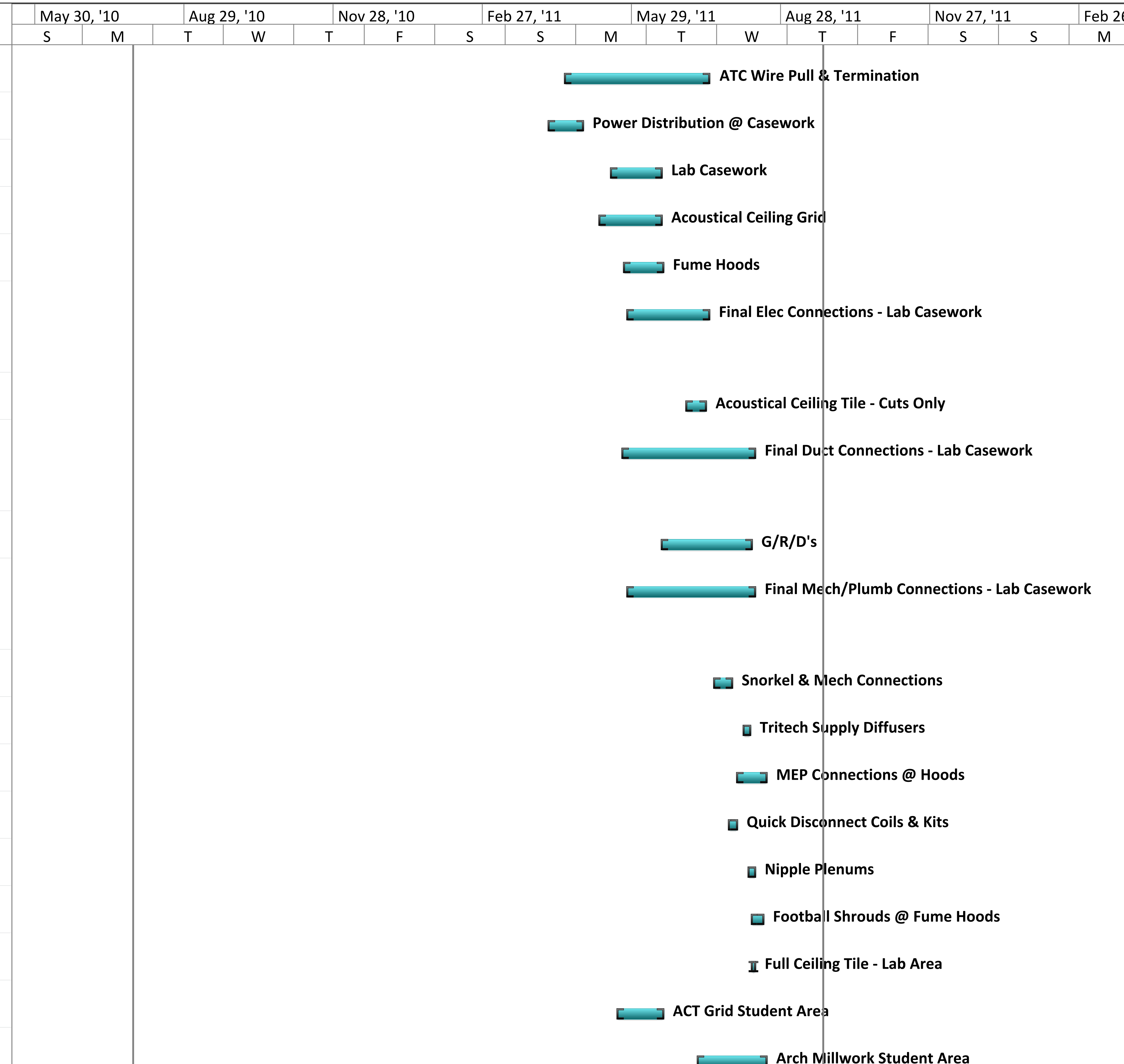
APPENDIX F – ACTUAL COMMISSIONING SCHEDULE

The following schedule is a representation of the actual activities and durations involved with the commissioning process for the Chevron Annex.

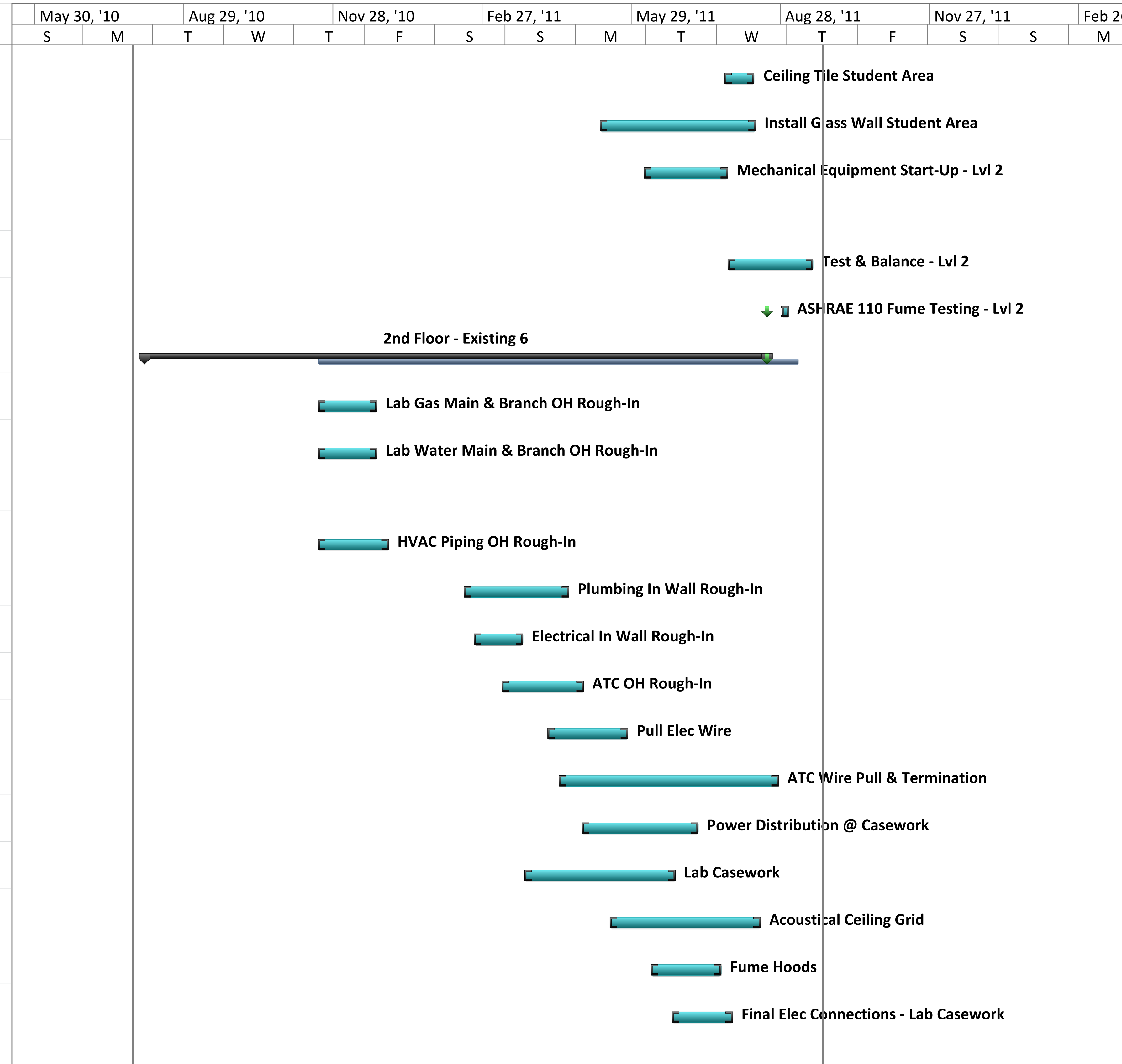
University of Pittsburgh
Chevron Annex
Actual Commissioning

ID		Task Mode	Task Name	Duration	Start	Finish
1			**Milestones - All Floors**	**15 days**	**Mon 8/1/11**	**Fri 8/19/11**
2			Commissioning - Phase 1	15 days	Mon 6/27/11	Fri 7/15/11
3			Above Ceiling L&I Inspection	1 day	Mon 7/11/11	Mon 7/11/11
4			Above Ceiling AEI Inspection	3 days	Mon 7/18/11	Wed 7/20/11
5			Fire Alarm Programming & Testing	2 days	Mon 8/8/11	Tue 8/9/11
6			Fire/Smoke Damper Testing	2 days	Thu 8/11/11	Fri 8/12/11
7			Preliminary L&I Inspection	1 day	Thu 8/18/11	Thu 8/18/11
8			Substantial Completion	0 days	Fri 8/19/11	Fri 8/19/11
9			Commissioning - Phase 2	10 days	Mon 8/22/11	Fri 9/2/11
10			Final L&I Inspection	7 days	Fri 9/2/11	Mon 9/12/11
11			Building Air Flush Out	2 days	Fri 9/16/11	Mon 9/19/11
12			MEP Equipment Training - Pitt Personnel	4 days	Mon 9/19/11	Thu 9/22/11
13			**3rd Floor - Existing 7**	**131 days**	**Fri 3/18/11**	**Fri 9/16/11**
14			Lab Gas Main & Branch OH Rough-In	81 days	Wed 8/11/10	Wed 12/1/10
15			Lab Water Main & Branch OH Rough-In	11 days	Fri 11/19/10	Fri 12/3/10
16			HVAC Piping OH Rough-In	46 days	Fri 10/8/10	Fri 12/10/10
17			Plumbing In Wall Rough-In	49 days	Wed 2/16/11	Mon 4/25/11
18			Electrical In Wall Rough-In	15 days	Mon 3/14/11	Fri 4/1/11
19			ATC OH Rough-In	35 days	Tue 3/1/11	Mon 4/18/11
20			Pull Elec Wire	39 days	Mon 4/4/11	Thu 5/26/11

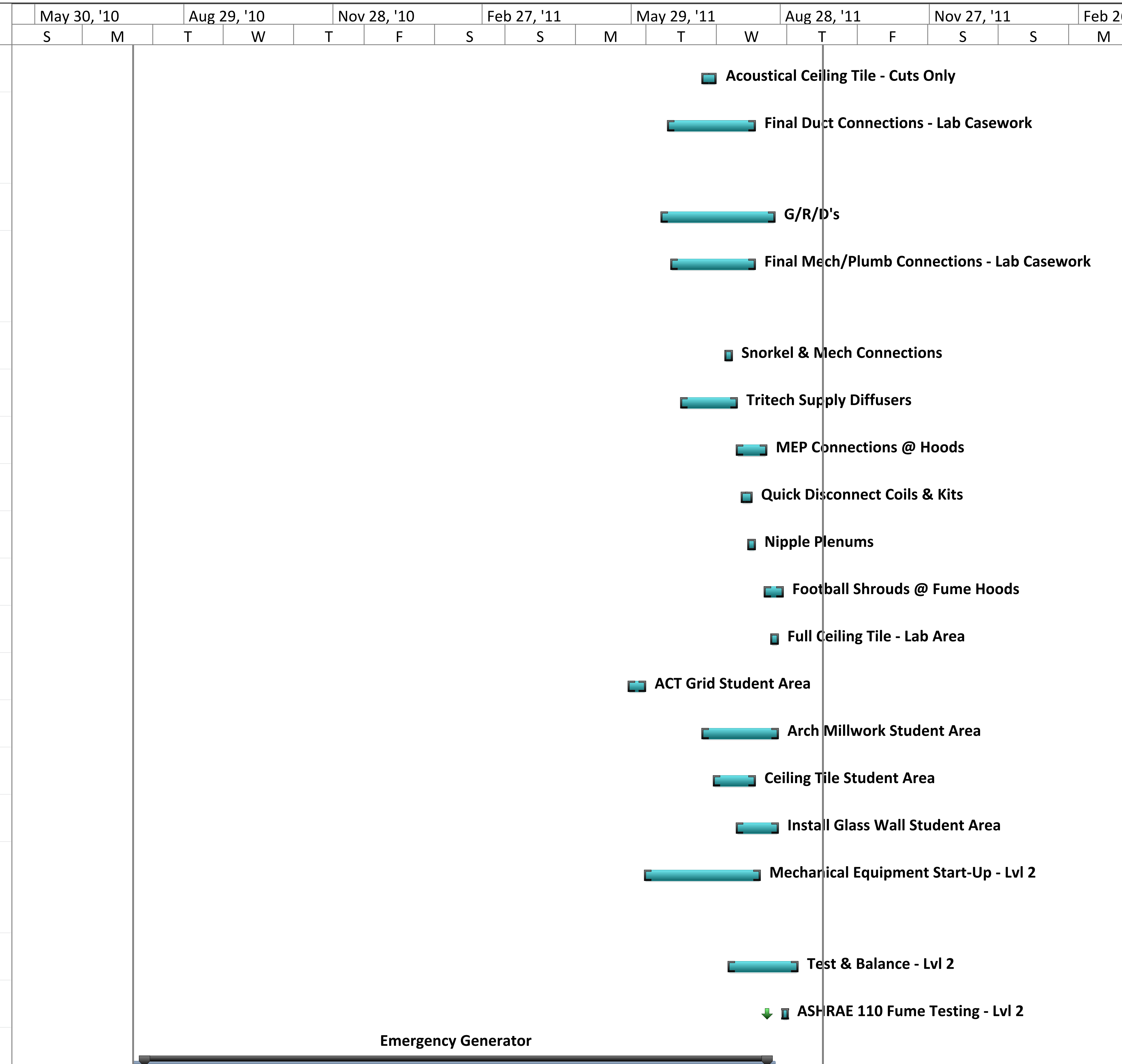
ID	Task Mode	Task Name	Duration	Start	Finish
21		ATC Wire Pull & Termination	65 days	Mon 4/18/11	Fri 7/15/11
22		Power Distribution @ Casework	16 days	Fri 4/8/11	Fri 4/29/11
23		Lab Casework	24 days	Mon 5/16/11	Thu 6/16/11
24		Acoustical Ceiling Grid	29 days	Mon 5/9/11	Thu 6/16/11
25		Fume Hoods	19 days	Tue 5/24/11	Fri 6/17/11
26		Final Elec Connections - Lab Casework	37 days	Thu 5/26/11	Fri 7/15/11
27		Acoustical Ceiling Tile - Cuts Only	9 days	Fri 7/1/11	Wed 7/13/11
28		Final Duct Connections - Lab Casework	60 days	Mon 5/23/11	Fri 8/12/11
29		G/R/D's	40 days	Thu 6/16/11	Wed 8/10/11
30		Final Mech/Plumb Connections - Lab Casework	57 days	Thu 5/26/11	Fri 8/12/11
31		Snorkel & Mech Connections	10 days	Mon 7/18/11	Fri 7/29/11
32		Tritech Supply Diffusers	3 days	Fri 8/5/11	Tue 8/9/11
33		MEP Connections @ Hoods	15 days	Mon 8/1/11	Fri 8/19/11
34		Quick Disconnect Coils & Kits	4 days	Wed 7/27/11	Mon 8/1/11
35		Nipple Plenums	5 days	Mon 8/8/11	Fri 8/12/11
36		Football Shrouds @ Fume Hoods	6 days	Wed 8/10/11	Wed 8/17/11
37		Full Ceiling Tile - Lab Area	3 days	Wed 8/10/11	Fri 8/12/11
38		ACT Grid Student Area	21 days	Fri 5/20/11	Fri 6/17/11
39		Arch Millwork Student Area	31 days	Fri 7/8/11	Fri 8/19/11



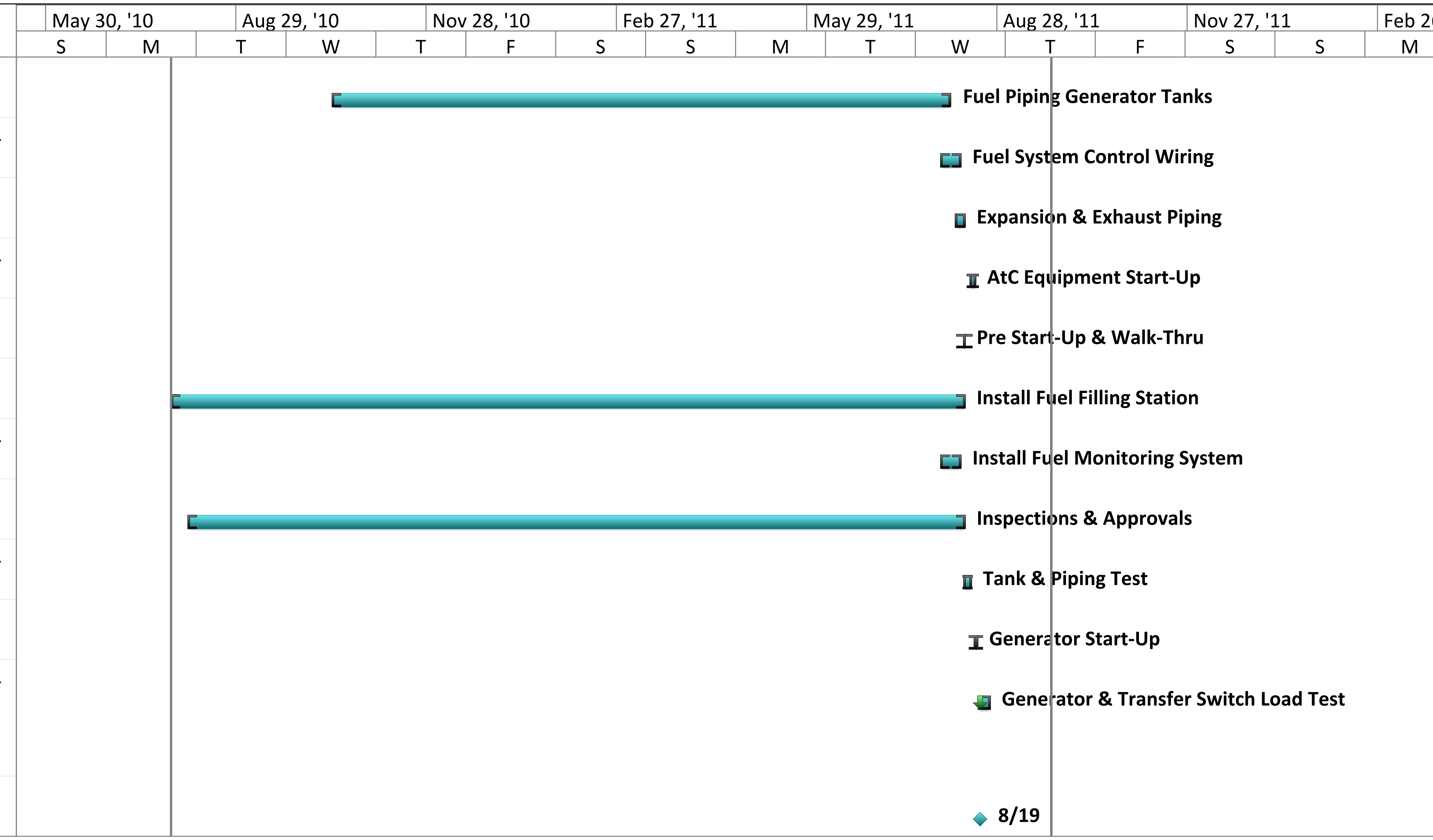
ID		Task Mode	Task Name	Duration	Start	Finish
40			Ceiling Tile Student Area	14 days	Mon 7/25/11	Thu 8/11/11
41			Install Glass Wall Student Area	69 days	Tue 5/10/11	Fri 8/12/11
42			Mechanical Equipment Start-Up - Lvl 2	37 days	Mon 6/6/11	Tue 7/26/11
43			Test & Balance - Lvl 2	38 days	Wed 7/27/11	Fri 9/16/11
44			ASHRAE 110 Fume Testing - Lvl 2	4 days	Mon 8/29/11	Thu 9/1/11
45			**2nd Floor - Existing 6**	**272 days**	**Thu 8/5/10**	**Fri 8/19/11**
46			Lab Gas Main & Branch OH Rough-In	26 days	Fri 11/19/10	Fri 12/24/10
47			Lab Water Main & Branch OH Rough-In	26 days	Fri 11/19/10	Fri 12/24/10
48			HVAC Piping OH Rough-In	31 days	Fri 11/19/10	Fri 12/31/10
49			Plumbing In Wall Rough-In	46 days	Wed 2/16/11	Wed 4/20/11
50			Electrical In Wall Rough-In	22 days	Tue 2/22/11	Wed 3/23/11
51			ATC OH Rough-In	36 days	Fri 3/11/11	Fri 4/29/11
52			Pull Elec Wire	35 days	Fri 4/8/11	Thu 5/26/11
53			ATC Wire Pull & Termination	96 days	Fri 4/15/11	Fri 8/26/11
54			Power Distribution @ Casework	51 days	Fri 4/29/11	Fri 7/8/11
55			Lab Casework	66 days	Fri 3/25/11	Fri 6/24/11
56			Acoustical Ceiling Grid	66 days	Mon 5/16/11	Mon 8/15/11
57			Fume Hoods	31 days	Fri 6/10/11	Fri 7/22/11
58			Final Elec Connections - Lab Casework	27 days	Thu 6/23/11	Fri 7/29/11



ID	ℹ	Task Mode	Task Name	Duration	Start	Finish
59			Acoustical Ceiling Tile - Cuts Only	7 days	Mon 7/11/11	Tue 7/19/11
60			Final Duct Connections - Lab Casework	40 days	Mon 6/20/11	Fri 8/12/11
61			G/R/D's	50 days	Thu 6/16/11	Wed 8/24/11
62			Final Mech/Plumb Connections - Lab Casework	38 days	Wed 6/22/11	Fri 8/12/11
63			Snorkel & Mech Connections	5 days	Mon 7/25/11	Fri 7/29/11
64			Tritech Supply Diffusers	25 days	Tue 6/28/11	Mon 8/1/11
65			MEP Connections @ Hoods	15 days	Mon 8/1/11	Fri 8/19/11
66			Quick Disconnect Coils & Kits	5 days	Thu 8/4/11	Wed 8/10/11
67			Nipple Plenums	5 days	Mon 8/8/11	Fri 8/12/11
68			Football Shrouds @ Fume Hoods	8 days	Thu 8/18/11	Mon 8/29/11
69			Full Ceiling Tile - Lab Area	5 days	Mon 8/22/11	Fri 8/26/11
70			ACT Grid Student Area	7 days	Fri 5/27/11	Mon 6/6/11
71			Arch Millwork Student Area	35 days	Mon 7/11/11	Fri 8/26/11
72			Ceiling Tile Student Area	20 days	Mon 7/18/11	Fri 8/12/11
73			Install Glass Wall Student Area	20 days	Mon 8/1/11	Fri 8/26/11
74			Mechanical Equipment Start-Up - Lvl 2	51 days	Mon 6/6/11	Mon 8/15/11
75			Test & Balance - Lvl 2	31 days	Wed 7/27/11	Wed 9/7/11
76	!		ASHRAE 110 Fume Testing - Lvl 2	4 days	Mon 8/29/11	Thu 9/1/11
77			**Emergency Generator**	**272 days**	**Thu 8/5/10**	**Fri 8/19/11**

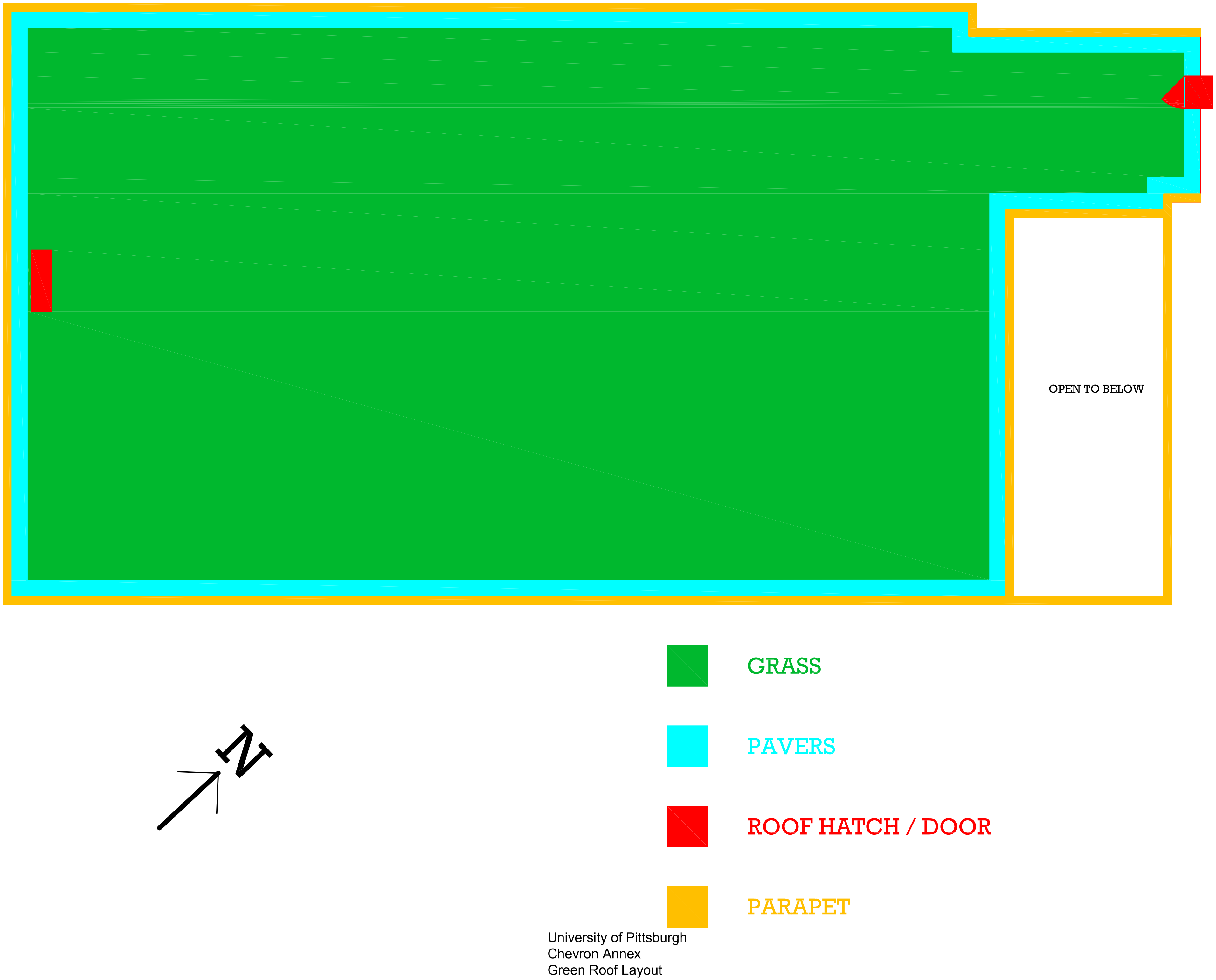


ID		Task Mode	Task Name	Duration	Start	Finish
78			Fuel Piping Generator Tanks	212 days	Thu 10/14/10	Fri 8/5/11
79			Fuel System Control Wiring	8 days	Mon 8/1/11	Wed 8/10/11
80			Expansion & Exhaust Piping	5 days	Mon 8/8/11	Fri 8/12/11
81			AtC Equipment Start-Up	3 days	Mon 8/15/11	Wed 8/17/11
82			Pre Start-Up & Walk-Thru	1 day	Fri 8/12/11	Fri 8/12/11
83			Install Fuel Filling Station	272 days	Thu 7/29/10	Fri 8/12/11
84			Install Fuel Monitoring System	8 days	Mon 8/1/11	Wed 8/10/11
85			Inspections & Approvals	266 days	Fri 8/6/10	Fri 8/12/11
86			Tank & Piping Test	2 days	Fri 8/12/11	Mon 8/15/11
87			Generator Start-Up	2 days	Wed 8/17/11	Thu 8/18/11
88			Generator & Transfer Switch Load Test	4 days	Fri 8/19/11	Wed 8/24/11
89			Substantial Completion	0 days	Fri 8/19/11	Fri 8/19/11



APPENDIX G – PROPOSED GREEN ROOF LAYOUT

The following is a simplified plan view of the proposed green roof for the Chevron Annex.


OPEN TO BELOW
N
GRASS
PAVERS
ROOF HATCH / DOOR
PARAPET
University of Pittsburgh
Chevron Annex
Green Roof Layout

APPENDIX H – STRUCTURAL BREADTH HAND CALCULATIONS

The following calculations were performed to analyze the structural integrity of the Chevron Annex when a green roof is added.

DESIGN LOADS

	LIVE LOADS	DEAD LOADS	4" TOPPING
LOBBIES →	100 psf	85 psf	
LABS →	60 psf	100 psf	155 psf
STAIRS & CORRIDORS →	100 psf	85 psf	
STORAGE →	150 psf	100 psf	
COMPUTER CLASSROOMS →	60 psf	100 psf	155 psf
OFFICE →	60 psf	100 psf	155 psf
PENTHOUSE →	150 psf	135 psf	

ROOF LIVE LOAD ⇒ 30 psf

ROOF DEAD LOAD → 30 psf

FLAT-ROOF SNOW LOAD ⇒ 28 psf

LEVEL 5/ROOF - VARIES

INTERMEDIATE 1071'-6"

LEVEL 4/PH 1063'-6"

LEVEL 3 1047'-10"

LEVEL 2 1032'-4"

PLAZA 1021'-7½"

ASHE ROOF 1012'-1½"

BRACING LEVEL 1002'-0"

GENERATOR 991'-9½"

LEVEL M1 982'-8"

LEVEL 1 970'-0"

SHALLOW INTENSIVE GREEN ROOF

LIVE LOAD = 100 psf

DEAD LOAD = 60 psf

TOTAL ROOF DEAD LOAD = 30 + 60 = 90 psf

DESIGN LOADS

	LIVE LOADS	DEAD LOADS	4" TOPPING
LOBBIES →	100 psf	85 psf	
LABS →	60 psf	100 psf	155 psf
STAIRS & CORRIDORS →	100 psf	85 psf	
STORAGE →	150 psf	100 psf	
COMPUTER CLASSROOMS →	60 psf	100 psf	155 psf
OFFICE →	60 psf	100 psf	155 psf
PENTHOUSE →	150 psf	135 psf	

ROOF LIVE LOAD ⇒ 30 psf

ROOF DEAD LOAD → 30 psf

FLAT-ROOF SNOW LOAD ⇒ 28 psf

LEVEL 5/ROOF - VARIES

INTERMEDIATE 1071'-6"

LEVEL 4/PH 1063'-6"

LEVEL 3 1047'-10"

LEVEL 2 1032'-4"

PLAZA 1021'-7½"

ASHE ROOF 1012'-1½"

BRACING LEVEL 1002'-0"

GENERATOR 991'-9½"

LEVEL M1 982'-8"

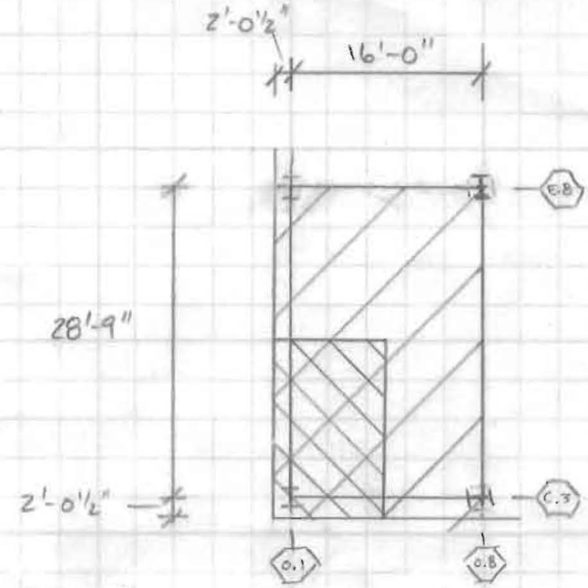
LEVEL 1 970'-0"

SHALLOW INTENSIVE GREEN ROOF

LIVE LOAD = 100 psf

DEAD LOAD = 60 psf

TOTAL ROOF DEAD LOAD = 30 + 60 = 90 psf



TRIBUTARY AREA $= \left[\left(\frac{16}{2}\right) + 2'\text{-}0\tfrac{1}{2}''\right] \times \left[\left(\frac{28'\text{-}9''}{2}\right) + 2'\text{-}0\tfrac{1}{2}''\right]$

$= 165 \text{ ft}^2$

INFLUENCE AREA $= (16 + 2'\text{-}0\tfrac{1}{2}'') \times (28'\text{-}9'' + 2'\text{-}0\tfrac{1}{2}'')$

$= 556 \text{ ft}^2 > 400 \text{ ft}^2$ ⇒ LIVE LOAD REDUCTION

$LL_{RED} = 0.25 + \frac{15}{\sqrt{KA_T}}$

$= 0.25 + \frac{15}{\sqrt{(556)}}$ ⇒ $\boxed{0.886 = LL_{RED}}$

LEVEL 5 / ROOF

$P_D = (90\text{psf})(165) = 14.9K$ $P_L = (100\text{psf})(165) = 16.5K$

LEVEL 4

$P_D = (135\text{psf}) \times (165) = 22.3K$ $P_L = (150\text{psf})(165)(0.886) = 21.9K$

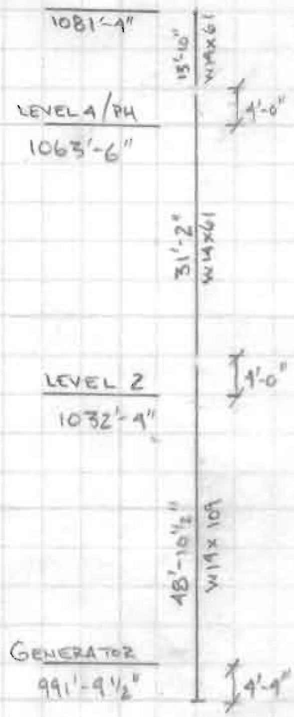
LEVEL 3

$P_D = (85\text{psf}) \times (165) = 14.1K$ $P_L = (100)(165)(0.886) = 14.6K$

LEVEL 2

$P_D = (85\text{psf})(165) = 14.1K$ $P_L = (100')(165)(0.886) = 14.6K$

LOAD CASE 5 ⇒ 1.2D + 1.6L + 0.2 S



$P_{u_1} = 1.2(14.9) + 1.6(16.5)$

$P_{u_1} = 44.3$ Kips

$P_{u_2} = P_{u_1} + 1.2(22.3 + 14.1) + 1.6(21.9 + 14.6)$

$P_{u_2} = 146.4$ Kips

$P_{u_3} = P_{u_2} + 1.2(14.1) + 1.6(14.6)$

$P_{u_3} = 186.7$ Kips

COLUMN 1

EFFECTIVE LENGTH $KL_{EFF,x} = 1.0(13'\text{-}10") = 13'\text{-}10"$ → BRACED @ 13'-10" IN Y-DIRECTION

$KL_{EFF,x} = \frac{KL}{(r_x/r_y)} = \frac{13'\text{-}10"}{2.44} = 5.67 < 13'\text{-}10"$

$KL_{EFF,y} = 13'\text{-}10"$ → USE 14' ⇒ $\phi P_n = 571$ Kip

CHECK ⇒ $\frac{KL}{r_x} = \frac{1.0(13'\text{-}10")}{5.98} = 2.31 \leq 200$ $\frac{KL}{r_y} = \frac{1.0(13'\text{-}10")}{2.44} = 5.67 \leq 200$

COLUMN 2

$KL_{EFF,y} = 1.0(31'\text{-}2") = 31'\text{-}2"$ → BRACED @ 31'-2"

$KL_{EFF,x} = \frac{31'\text{-}2"}{2.44} = 12.8'$ ⇒ USE $KL_{EFF,y} = \frac{31'\text{-}2"}{2} = 15.6$ FT ⇒ $\phi P_n = 514K$

CHECK ⇒ $\frac{KL}{r_x} = \frac{1.0(31'\text{-}2")}{5.98} = 5.21 \leq 200$ $\frac{KL}{r_y} = \frac{1.0(31'\text{-}2")}{2.44} = 12.78 \leq 200$

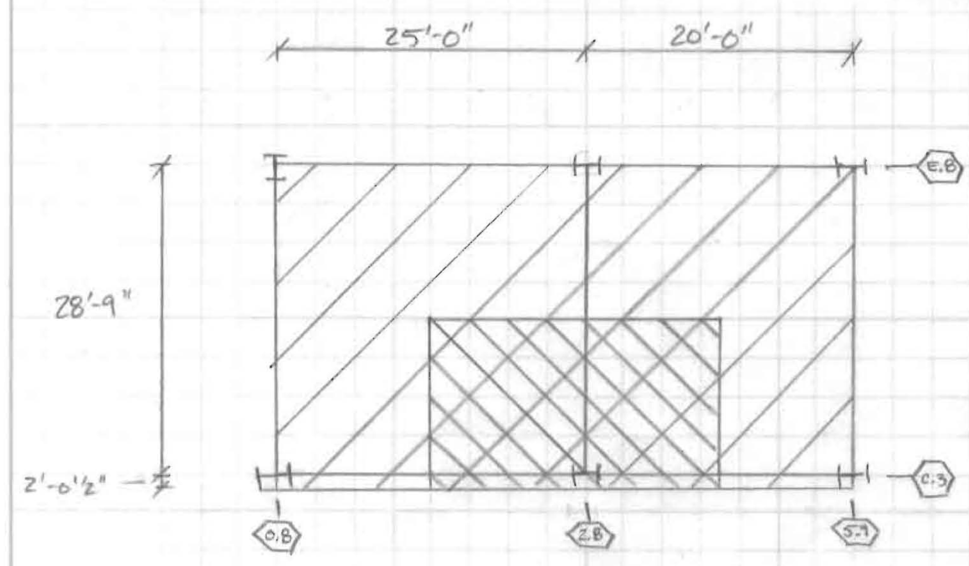
COLUMN 3

$KL_{EFF,y} = 1.0(48'\text{-}10\tfrac{1}{2}") = 48'\text{-}10\tfrac{1}{2}"$ → BRACED @ 48'-10½" ⇒ 40'

$KL_{EFF,x} = \frac{KL}{(r_x/r_y)} = \frac{48'\text{-}10\tfrac{1}{2}"}{1.67} = 29.27'$ ⇒

$\phi P_n = 437$ Kips

CHECK ⇒ $\frac{KL}{r_x} = \frac{1.0(48'\text{-}10\tfrac{1}{2}")}{6.22} = 7.86 \leq 200$ $\frac{KL}{r_y} = \frac{1.0(48'\text{-}10\tfrac{1}{2}")}{3.73} = 13.1 \leq 200$



$\text{TRIBUTARY AREA} = \left[\left(\frac{25+20}{2}\right)\right] \times \left[\left(\frac{28'\text{-}9''}{2}\right) + 2'\text{-}0\tfrac{1}{2}''\right] = 370\ ft^2$

$\text{INFLUENCE AREA} = (25+20) \times (28'\text{-}9'' + 2'\text{-}0\tfrac{1}{2}'') = 1386\ ft^2 > 400$
$\Rightarrow LL_{RED}$

$LL_{RED} = 0.25 + \frac{15}{\sqrt{KA_T}}$

$= 0.25 + \frac{15}{\sqrt{1386}} \Rightarrow \boxed{0.653 = LL_{RED}}$

LEVEL 5 / ROOF

$P_D = (90) \times (370) = 33.3K$ $\quad$ $P_L = (100psf) \times (370) = 37K$

LEVEL 4

$P_D = (135psf) \times (370ft^2) = 50K$ $\quad$ $P_L = (150psf) \times (370ft^2) = (55.5K) \times (0.653)$
$= 36.3K$

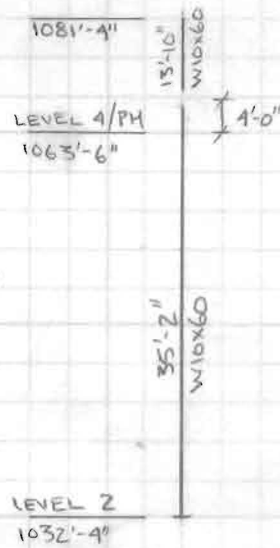
LEVEL 3

$P_D = (100psf) \times (370ft^2) = 37K$ $\quad$ $P_L = (60psf) \times (370ft^2) = (22.2K) \times (0.653)$
$= 14.5K$

LEVEL 2

$P_D = (100psf) \times (370ft^2) = 37K$ $\quad$ $P_L = 14.5K$

LOAD CASE 5 ⇒ $1.2D + 1.6L + 0.2S$



$P_{u(1)} = 1.2(33.3) + 1.6(37)$

$P_{u(1)} = 99.2$ Kips

$P_{u(2)} = P_{u(1)} + 1.2(50 + 37 + 37) + 1.6(36.3 + 14.5 + 14.5)$

$P_{u(2)} = 352.5$ Kips

COLUMN 1

$KL_{EFF,x} = 1.0(13'\text{-}10") = 13'\text{-}10"$ → BRACED @ 13'-10" IN Y-DIRECTION

$KL_{EFF,x} = \frac{KL}{(r_x/r_y)} = \frac{13'\text{-}10"}{(1.71)} = 8.09 \le 13'\text{-}10"$

$KL_{EFF,y} = 13'\text{-}10"$ → USE 14' ⇒ $\phi P_n = 583$ Kips

CHECK ⇒ $\frac{KL}{r_x} = \frac{1.0(13'\text{-}10")}{4.39} = 3.15 \le 200$ $\frac{KL}{r_y} = \frac{1.0(13'\text{-}10")}{2.88} = 4.8 \le 200$

COLUMN 2

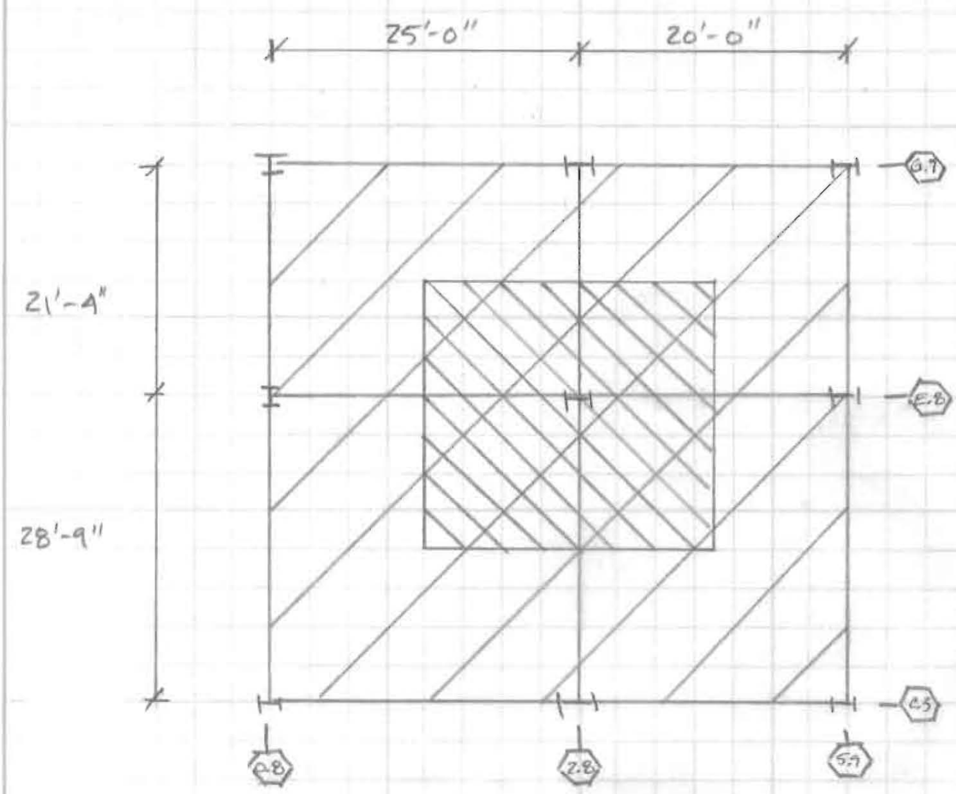
$KL_{EFF,x} = 1.0(35'\text{-}2") = 35'\text{-}2"$ → BRACED @ 35'-2"

$KL_{EFF,x} = \frac{35'\text{-}2"}{1.71} = 20.57'$ $KL_{EFF,y} = \frac{35'\text{-}2"}{2} = 17.6$ FT

⇓ 22'

$\phi P_n = 368$ Kips

CHECK ⇒ $\frac{KL}{r_x} = \frac{1.0(35'\text{-}2")}{4.39} = 8.01 \le 200$ $\frac{KL}{r_y} = \frac{1.0(35'\text{-}2")}{2.88} = 12.21 \le 200$



TRIBUTARY AREA $= \left(\frac{25+20}{2}\right) \times \left(\frac{21'\text{-}4'' + 28'\text{-}9''}{2}\right) = 564\ ft^2$

INFLUENCE AREA $= (25+20) \times (21'\text{-}4'' + 28'\text{-}9'') = 2254\ ft^2 > 400\ ft^2$ LL_{RED}

$LL_{RED} = 0.25 + \frac{15}{\sqrt{KA_T}}$

$= 0.25 + \frac{15}{\sqrt{2254}} \Rightarrow$ $\boxed{0.566 = LL_{RED}}$

LEVEL 5/ROOF

$P_D = (90psf) \times (564ft^2) = 50.8K$ $P_L = (100psf) \times (564ft^2) = 56.4K$

LEVEL 4

$P_D = (135psf) \times (564) = 76.2K$ $P_L = (150psf) \times (564) = (84.6K)(0.566)$
$= 47.9K$

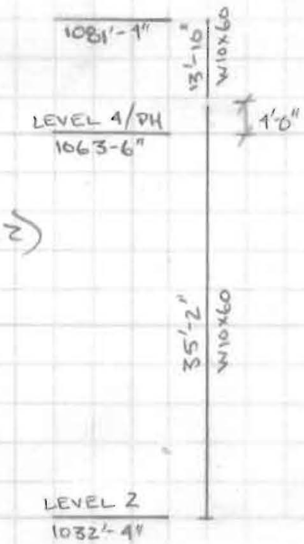
LEVEL 3

$P_D = (100psf) \times (564) = 56.4K$ $P_L = (60psf) \times (564) = (33.9K)(0.566)$
$= 19.2K$

LEVEL 2

$P_D = 56.4K$ $P_L = 19.2K$

LOAD CASE 5 ⇒ $1.2D + 1.6L + 0.2S$



$P_{u(1)} = 1.2(50.8) + 1.6(56.4)$

$P_{u(1)} = 151.2$ Kips

$P_{u(2)} = P_{u(1)} + 1.2(76.2 + 56.4 + 56.4) + 1.6(47.9 + 19.2 + 19.2)$

$P_{u(2)} = 516.1$ Kips

COLUMN 1

(SAME CALCULATIONS AS COLUMN <C.3 - 2.8>)

$\phi P_n = 583$ Kips

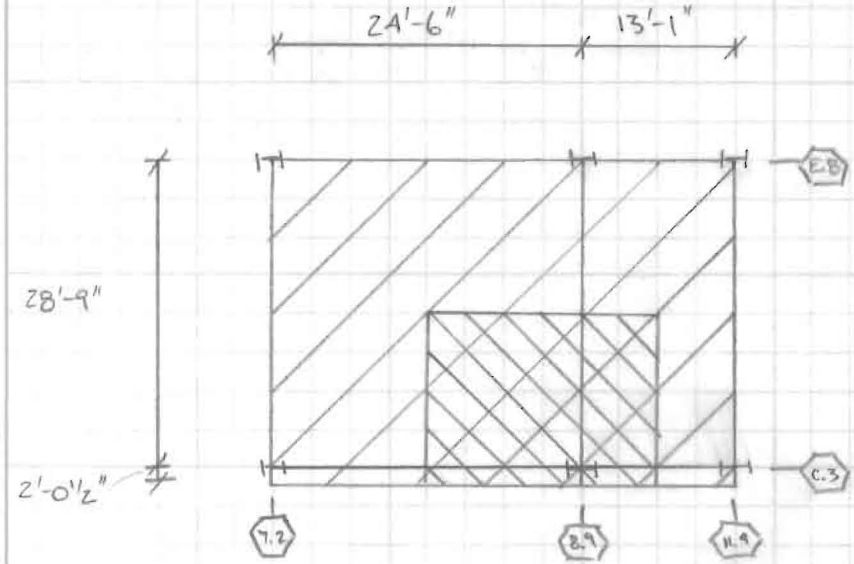
COLUMN 2

(SAME CALCULATIONS AS COLUMN <C.3 - 2.8>)

$\phi P_n = 368 \text{ Kips} < 516.1 \text{ Kips}$

RE-SIZE ⇒ USE W10x88

$\phi P_n = 560$ Kips



$$\text{TRIBUTARY AREA} = \left(\frac{24'\text{-}6" + 13'\text{-}1"}{2}\right) \times \left[\left(\frac{28'\text{-}9"}{2}\right) + 2'\text{-}0\tfrac{1}{2}"\right] = 552\ ft^2$$

$$\text{INFLUENCE AREA} = (24'\text{-}6" + 13'\text{-}1") \times (28'\text{-}9" + 2'\text{-}0\tfrac{1}{2}")$$

$$= 1158\ ft^2 > 400\ ft^2 \Rightarrow LL_{RED}$$

$$LL_{RED} = 0.25 + \frac{15}{\sqrt{KA_T}}$$

$$= 0.25 + \frac{15}{\sqrt{1158}} \Rightarrow \boxed{0.691 = LL_{RED}}$$

LEVEL 5/ROOF

$P_D = (90psf) \times (552ft^2) = 49.7K$ $\qquad$ $P_L = (100psf) \times (552ft^2) = 55.2K$

LEVEL 4

$P_D = (135psf) \times (552\ ft^2) = 74.5K$ $\qquad$ $P_L = (150)(552) = (82.8K)(0.691) = 57.3K$

LEVEL 3

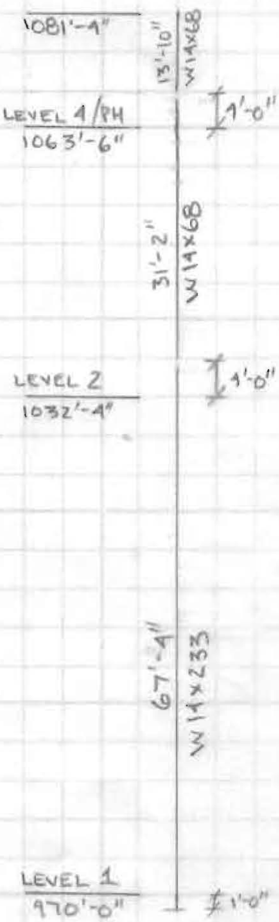
$P_D = (100psf) \times (552\ ft^2) = 55.2K$ $\qquad$ $P_L = (60)(552) = (33.1K)(0.691) = 22.9K$

LEVEL 2

$P_D = 55.2K$ $\qquad$ $P_L = 22.9K$

(NO PG. 10/14)

LOAD CASE 5 ⇒ 1.2D + 1.6L + 0.2S



$P_{u(1)} = 1.2(49.7) + 1.6(55.2)$

$P_{u(1)} = 148$ Kips

$P_{u(2)} = P_{u(1)} + 1.2(74.5 + 55.2) + 1.6(57.3 + 22.9)$

$P_{u(2)} = 432$ Kips

$P_{u(3)} = P_{u(2)} + 1.2(55.2) + 1.6(22.9)$

$P_{u(3)} = 534.9$ Kips

COLUMN 1

$KL_{EFF,x} = 1.0(13'\text{-}10") = 13'\text{-}10"$ → BRACED @ 13'-10" IN Y-DIRECTION

$KL_{EFF,x} = \frac{KL}{(r_x/r_y)} = \frac{13'\text{-}10"}{2.44} = 5.67 < 13'\text{-}10"$

$KL_{EFF,y} = 13'\text{-}10"$ → USE 14' ⇒ $\phi P_n = 640$ Kips

CHECK ⇒ $\frac{KL}{r_x} = \frac{1.0(13'\text{-}10")}{6.01} = 2.3 \le 200 \ge \frac{KL}{r_y} = \frac{1.0(13'\text{-}10")}{2.46} = 5.62$

COLUMN 2

$KL_{EFF,x} = 1.0(31'\text{-}2") = 31'\text{-}2"$ → BRACED @ 31'-2"

$KL_{EFF_x} = \frac{KL}{(r_x/r_y)} = \frac{31'\text{-}2"}{2.44} = 12.78'$ ⇒ USE $KL_{EFF,y} = \frac{31'\text{-}2"}{2} = 15.6'$ ⇒ $\phi P_n = 577$ Kip

CHECK ⇒ $\frac{KL}{r_x} = \frac{1.0(31'\text{-}2")}{6.01} = 5.19 \le 200 \ge \frac{KL}{r_y} = \frac{1.0(31'\text{-}2")}{2.46} = 12.67$

COLUMN 3

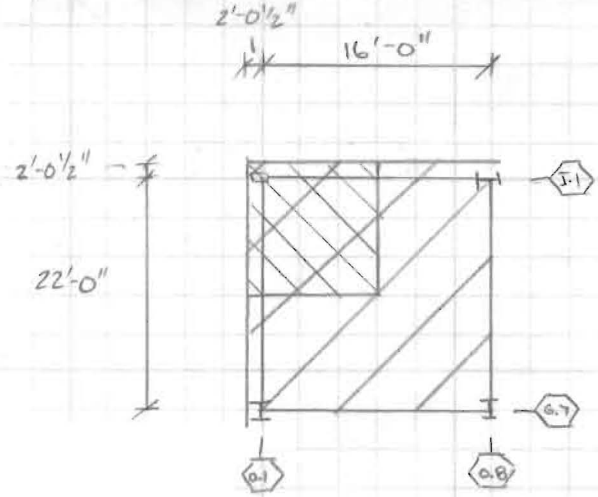
$KL_{EFF,x} = 1.0(67'\text{-}4") = 67'\text{-}4"$ → BRACED @ ~40'

$\phi P_n = 1130$ Kips

CHECK ⇒ $\frac{KL}{r_x} = \frac{1.0(67'\text{-}4")}{6.63} = 10.16 \le 200$

$\frac{KL}{r_y} = \frac{1.0(67'\text{-}4")}{4.10} = 16.4 \le 200$

(40 PG 10/14)



TRIBUTARY AREA $= \left[\left(\frac{16}{2}\right) + 2'\text{-}0\tfrac{1}{2}''\right] \times \left[\left(\frac{22}{2}\right) + 2'\text{-}0\tfrac{1}{2}''\right] = 131\ ft^2$

INFLUENCE AREA $= (16' + 2'\text{-}0\tfrac{1}{2}'') \times (22' + 2'\text{-}0\tfrac{1}{2}'') = 434\ ft^2 > 400\ ft^2$ LL_{RED}

$$LL_{RED} = 0.25 + \frac{15}{\sqrt{KA_T}}$$

$$= 0.25 + \frac{15}{\sqrt{434}} \Rightarrow \boxed{0.97 = LL_{RED}}$$

LEVEL 5 / ROOF

$P_D = (90psf) \times (131 ft^2) = 11.8K$ $\quad P_L = (100psf) \times (131 ft^2) = 13.1K$

LEVEL 4

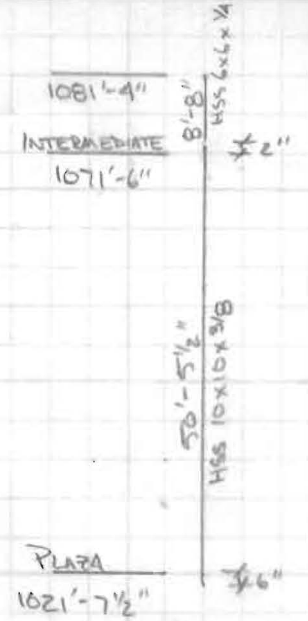
$P_D = (85psf)(131 ft^2) = 11.2K$ $\quad P_L = (100psf)(131 ft^2)(0.97) = 12.7K$

LEVEL 3

$P_D = (85)(131 ft^2) = 11.2K$ $\quad P_L = 12.7K$

LEVEL 2

$P_D = 11.2K$ $\quad P_L = 12.7K$



LOAD CASE 5 ⇒ $1.2D + 1.6L + 0.2S$

$P_{u_1} = 1.2(11.8) + 1.6(13.1)$

$P_{u_1} = 35.1$ Kips

$P_{u_2} = P_{u_1} + 1.2(11.2+11.2+11.2) + 1.6(12.7+12.7+12.7)$

$P_{u_2} = 136.4$ Kips

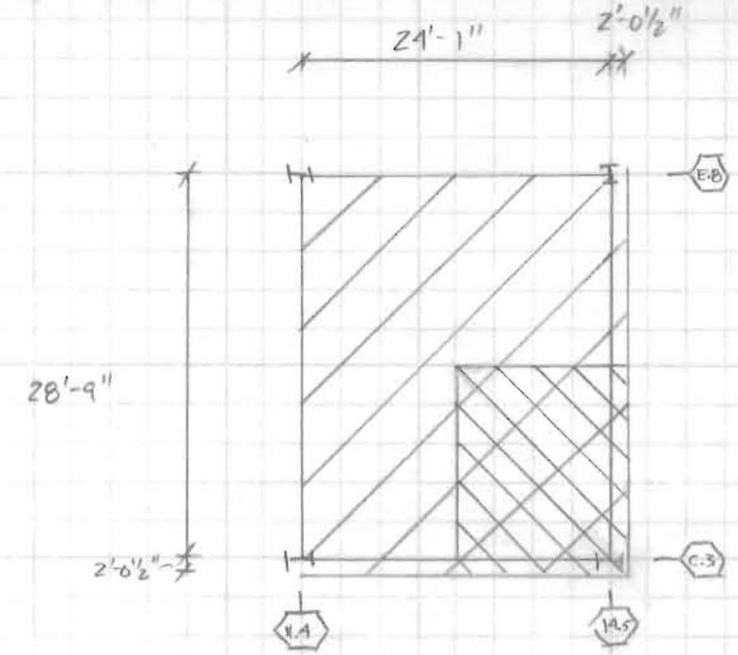
COLUMN 1

HSS 6x6x¼ @ 9' ⇒ $\phi P_n = 188$ Kips

COLUMN 2

HSS 10x10x⅜ @ $\frac{50'-5\frac{1}{2}"}{4} = 12.6'$

13' ⇒ $\phi P_n = 491$ Kips



TRIBUTARY AREA = $\left[\left(\frac{24'-1''}{2}\right) + 2'-0\tfrac{1}{2}''\right] * \left[\left(\frac{28'-9''}{2}\right) + 2'-0\tfrac{1}{2}''\right]$

$= 232\ ft^2$

INFLUENCE AREA = $(24'-1'' + 2'-0\tfrac{1}{2}'') * (28'-9'' + 2'-0\tfrac{1}{2}'')$

$= 805\ ft^2 > 400\ ft^2 \Rightarrow LL_{RED}$

$LL_{RED} = 0.25 + \frac{15}{\sqrt{KA_T}}$

$= 0.25 + \frac{15}{\sqrt{805}} \Rightarrow$ **$0.779 = LL_{RED}$**

LEVEL 5/ROOF

$P_D = (90psf)*(232ft^2) = 20.9K$ $P_L = (100psf)*(232ft^2) = 23.2K$

LEVEL 4

$P_D = (135psf)*(232ft^2) = 31.3K$ $P_L = (150psf)(232ft^2)(0.779)$
$P_L = 27.1K$

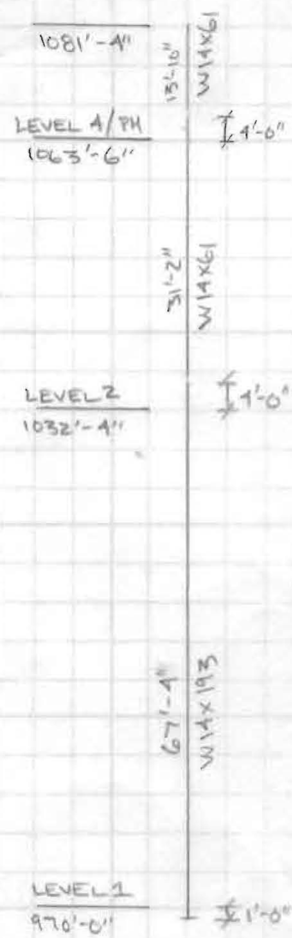
LEVEL 3

$P_D = (100psf)*(232ft^2) = 23.2K$ $P_L = (60psf)(232ft^2)(0.779)$
$P_L = 10.9K$

LEVEL 2

$P_D = 23.2K$ $P_L = 10.9K$

Load Case 5 ⇒ $1.2D + 1.6L + 0.2S$



$P_{u_{①}} = 1.2(20.9) + 1.6(23.2)$

$P_{u_{①}} = 62.2$ Kips

$P_{u_{②}} = P_{u_{①}} + 1.2(31.3 + 23.2) + 1.6(27.1 + 10.9)$

$P_{u_{②}} = 188.4$ Kips

$P_{u_{③}} = P_{u_{②}} + 1.2(23.2) + 1.6(10.9)$

$P_{u_{③}} = 233.7$ Kips

Column 1

(Same calculations as Column <C.3-0.1>)

$\phi P_n = 571$ Kip

Column 2

(Same calculations as Column <C.3-0.1>)

$\phi P_n = 514$ Kip

Column 3

(Same calculations as Column <C.3-0.1>)

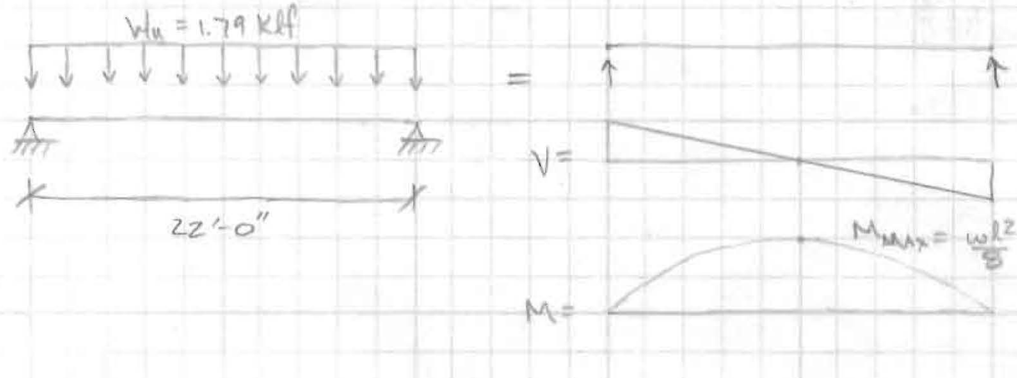
$\phi P_n = 437$ Kip

Robert Mroskey	Beam Calculations	22'-0" Span (6.7 - J)

$W_u = (1.2D + 1.6L)$ TRIB WIDTH

MAX SPACING = 6'-8"

$W_u = \left[1.2(90) + 1.6(100) \right] \times 6'\text{-}8'' \Rightarrow \boxed{1787\ plf = W_u}$



$M_{MAX} = \frac{w l^2}{8} = \frac{(1.79\ klf)(22'\text{-}0'')^2}{8} \Rightarrow \boxed{109\ ft\text{-}K = M_{MAX}}$

① $M_u = F_y Z \Rightarrow (109)(12) = 50(z)$

FROM TABLE 3-2 IN STEEL MANUAL

$Z = 26.16\ in^3$

$\Rightarrow$ USE W12x22 $\Rightarrow Z_x = 29.3\ in^3$

② $\Delta_{LL} = \frac{l}{240} = \frac{(22)12}{240} = 1.1''$

$\Delta_{TL} = \frac{l}{180} = \frac{(22)12}{180} = 1.47''$

③ $\Delta_{LL} = 1.1 = \frac{5 w l^4}{384 EI}$

$\Delta_{TL} = 1.47 = \frac{5 w_{TL} l^4}{384 EI}$

$1.1 = \frac{5(0.67\ klf)(22)^4(1728)}{384(29{,}000)\ I}$

$1.47 = \frac{5(0.60\ klf)(22)^4(1728)}{384(29{,}000)\ I}$

$I_x = 110.7\ in^4$

$I_x = 74.2\ in^4$

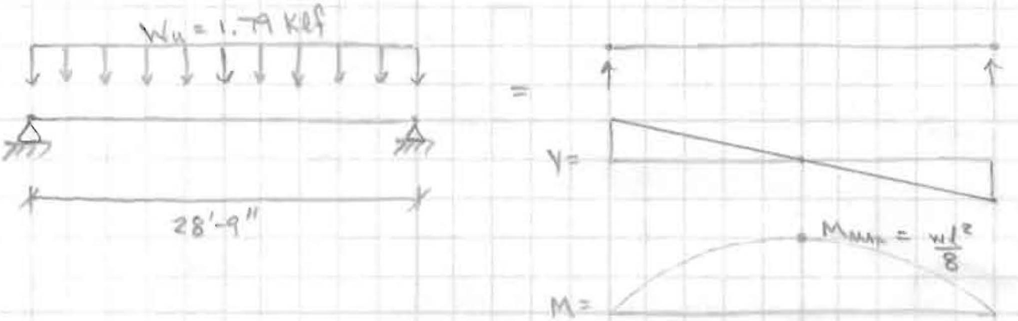
FROM TABLE 3-3, $\Rightarrow$ USE W12x19

$\Rightarrow$ CHOOSE W12x22 FOR MINIMUM BEAM SIZE

Robert Mroskey	Beam Calculations	28'-9" Span (C.3-E.8)

$W_u = (1.2D + 1.6L)$ Trib Width Max Spacing = 6'-8"

$W_u = [1.2(90) + 1.6(100)] \times 6'\text{-}8" \Rightarrow$ **1787 plf = W_u**



$M_{max} = \frac{wl^2}{8} = \frac{(1.79\ klf)(28'\text{-}9")^2}{8} \Rightarrow$ **185 ft-K = M_{max}**

① $M_u = F_y Z \Rightarrow (185\ ft\text{-}k)(12) = 50\ (z)$

$Z = 44.4\ in^3$

From Table 3-2 in Steel Manual $\Rightarrow$ Use W14x30 $\Rightarrow Z_x = 47.3\ in^3$

② $\Delta_{LL} = \frac{l}{240} = \frac{(28'\text{-}9")(12)}{240} = 1.44"$ | $\Delta_{TL} = \frac{l}{180} = \frac{(28'\text{-}9")(12)}{180} = 1.92"$

③ $\Delta_{LL} = 1.44" = \frac{5 W_{LL} l^4}{384 EI}$ | $\Delta_{TL} = 1.92" = \frac{5 W_{TL} l^4}{384 EI}$

$1.44 = \frac{5(0.67)(28'\text{-}9")^4(1728)}{384(29,000)\ I}$ | $1.92" = \frac{5(0.60)(28'\text{-}9")^4(1728)}{384(29,000)\ I}$

$I_x = 246.6\ in^4$ | $I = 165.7\ in^4$

From Table 3-3, $\Rightarrow$ Use W16x26 minimum

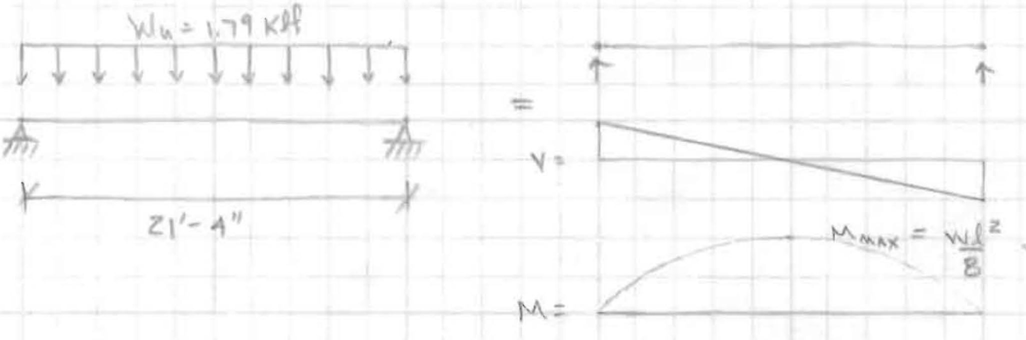
$\Rightarrow$ Choose W14x30 for minimum beam size

ROBERT MROSKEY	BEAM CALCULATIONS	21'-4" SPAN (E.8 - G.7)

$W_u = (1.2D + 1.6L)$ TRIB WIDTH

MAX SPACING = 6'-8"

$W_u = [1.2(90) + 1.6(100)] \times 6'\text{-}8'' \Rightarrow$ **1787 plf = W_u**



$M_{MAX} = \frac{wl^2}{8} = \frac{(1.79\,Klf)(21'\text{-}4'')^2}{8} \Rightarrow$ **109 ft·K = M_{MAX}**

① $M_u = F_y Z \Rightarrow (109\,ft{\cdot}K)(12) = 50(Z)$

FROM TABLE 3-2 IN STEEL MANUAL

$Z = 26.16\,in^3$

$\Rightarrow$ USE W12x22 $\Rightarrow Z_x = 29.3\,in^3$

② $\Delta_{LL} = \frac{l}{240} = \frac{(21.33')(12)}{240} = 1.07''$

$\Delta_{TL} = \frac{l}{180} = \frac{(21.33)(12)}{180} = 1.42''$

③ $\Delta_{LL} = 1.07 = \frac{5 W_{LL} l^4}{384 EI}$

$1.07 = \frac{5(0.67)(21.33)^4(1728)}{384(29{,}000) I}$

$I_x = 100.6\,in^4$

$\Delta_{TL} = 1.42 = \frac{5 W_{TL} l^4}{384 EI}$

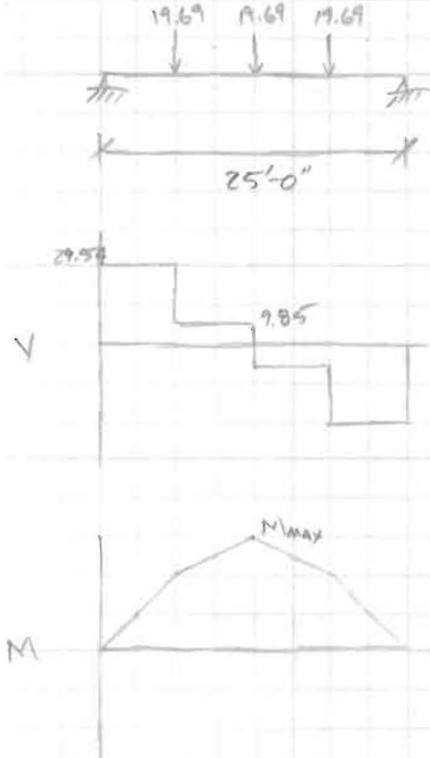
$1.42 = \frac{5(0.67)(21.33)^4(1728)}{384(29{,}000) I}$

$I_x = 75.82\,in^4$

FROM TABLE 3-3, $\Rightarrow$ USE W12x19

$\Rightarrow$ CHOOSE W12x22 FOR MINIMUM BEAM SIZE

22'-0" SPAN ⇒ (1.79)(22'-0") ÷ 2 = 19.69 Kips



$P_{LIVE} = 9.7$
$P_{DEAD} = 6.4$
} 16.1

$A_{①} = (29.54)(6.25) = 185$

$A_{②} = (9.85)(6.25) = 61.6$

$M_{MAX} = 185 + 61.6 = 246.6$ ft-K

$$\frac{l}{240} = 1.25 = \Delta_{MAX} = \frac{(0.05)Pl^3}{3EI_x} = \frac{(0.05)(16.1)(25')^3(1728)}{3(29,000)I_x} \Rightarrow I_x = 199.9 \text{ IN}^4$$

⇒ W14x22 FROM TABLE 3-3 IN STEEL MANUAL

$$\frac{l}{360} = 0.83 = \Delta_{MAX} = \frac{(0.05)(9.7)(25)^3(1728)}{3(29,000)I_x} \Rightarrow I_x = 181.4 \text{ IN}^4$$

⇒ W14x22

$$M_u = F_y Z \Rightarrow \frac{(246.6)(12)}{0.9} = 50Z$$

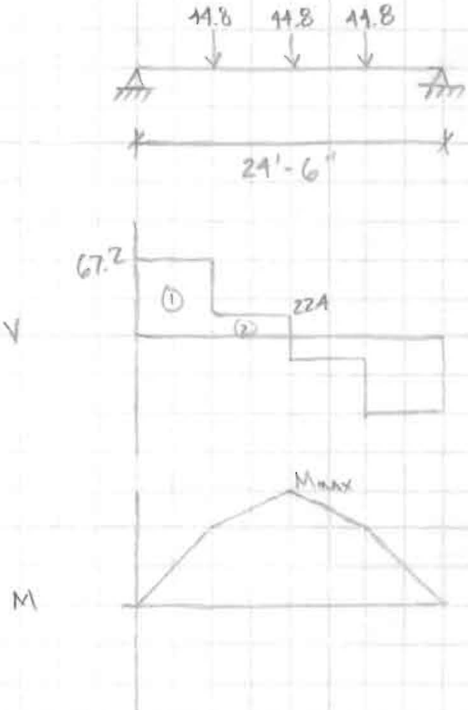
$Z = 65.76 \text{ IN}^3$

CHOOSE W18x35

$I_x = 510 \text{ IN}^4 > 199.9 \text{ IN}^4$

$> 181.4 \text{ IN}^4$

21'-4" Span ⇒ (1.79 klf)(21'-4") ÷ 2 = 19.1 Kips
28'-9" Span ⇒ (1.79 klf)(28'-9") ÷ 2 = 25.7 Kips
} 44.8 Kips



$P_{LIVE} = 9.7 + 7.2 = 16.9$ Kips
$P_{DEAD} = 6.4 + 8.6 = 15.0$ Kips
} 31.9

$A_① = (6.125)(67.2) = 411.6$

$A_② = (6.125)(22.4) = 137.2$

$M_{MAX} = 411.6 + 137.2 = 548.8$ ft.K

$M_u = F_y Z \Rightarrow \frac{(548.8)(12)}{0.9} = 50\,Z$
$\Rightarrow Z = 146.3\ \text{in}^3$

$\frac{l}{240} = 1.225 = \Delta_{max} = \frac{(0.05)Pl^3}{3EI_x} = \frac{(0.05)(31.9)(24'\text{-}6")^3(1728)}{3(29{,}000)I_x} \Rightarrow I_x = 380\ \text{in}^4$

⇒ W18x35 from Table 3-3 in Steel Manual

$\frac{l}{360} = 0.82 = \Delta_{max} = \frac{(0.05)(16.9)(24'\text{-}6")^3(1728)}{3(29{,}000)I_x} \Rightarrow I_x = 301\ \text{in}^4$

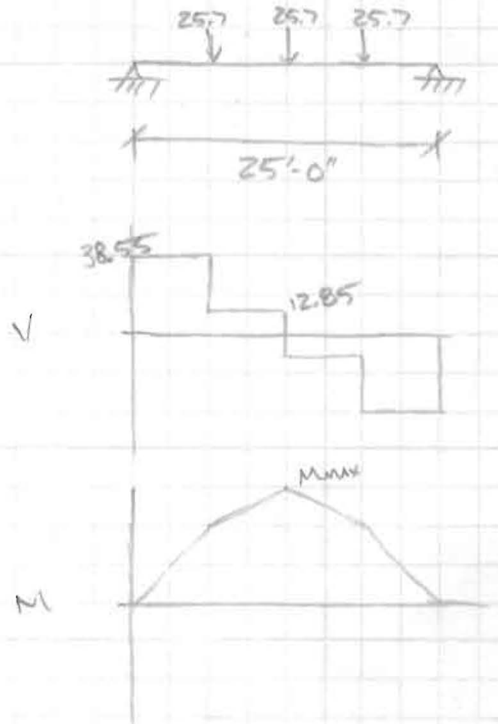
⇒ W16x31

Choose W24x62 $\quad I_x = 1550\ \text{in}^4$

⇓

1550 > 380
> 301

28'-9" Span ⇒ $(1.79)(28'\text{-}9") \div 2 = 25.7$ Kips



$P_{LIVE} = 9.7$
$P_{DEAD} = 6.4$ } 16.1

$A_{①} = (38.55)(6.25) = 241$

$A_{②} = (12.85)(6.25) = 80.3$

$M_{MAX} = 241 + 80.3 = 321.3$

$$\frac{l}{240} = 1.25 = \Delta_{MAX} = \frac{(0.05)Pl^3}{3EI_x} = \frac{(0.05)(16.1)(25)^3(1728)}{3(29{,}000)} \Rightarrow I_x = 199.9 \text{ in}^4$$

⇒ W14x22 from Table 3-3 in Steel Manual

$$\frac{l}{360} = 0.83 = \Delta_{MAX} = \frac{(0.05)(9.7)(25)^3(1728)}{3(29{,}000)I_x} \Rightarrow I_x = 181.4 \text{ in}^4$$

⇒ W14x22

$$M_u = F_y Z \Rightarrow \frac{(321.3)(12)}{0.9} = 50Z$$

$$Z = 85.68$$

Choose W21x44

$I_x = 843 \text{ in}^4 > 199.9 \text{ in}^4$

$> 181.4 \text{ in}^4$

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