2010

# Thames St. Wharf Office Building

Senior Thesis Final Report
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# Thames St. Wharf Office Building

Baltimore, MD

C. Christopher Bell

Construction management

## Project Team

Owner: Harbor Point Development, LLC
CM: Armada Hoffler Construction
Design Architect: Elkus/manfredi Architects
Architect of Record: Ayers/Saint/Gross Arhictects + Planners
Structural Engineer: Morris & ritchie Associates
Civil Engineer: Rummel, Klepper & Kahl
Foundation Design: Mueser Rutledge Consulting Engineers

## Buildings Stats

Size: ~240,000 SF
8 stories
Cost: total ~ $100 Million
Base Building ~ $23 Million
Construction: Feb. 2007 - Mar. 2010
Delivery: Design-Bid-Build
Other: Project pursuing LEED Silver rating

## Architecture

- Located on the Inner harbor In Baltimore, MD
- Retail on ground Floor
- Office space on floors 1-7
- 8th floor mechanical penthouse
- Wrap around pedestrian promenade
- Glass and brick curtain wall system

## Structure

- One way post-tensioned slabs suported by post-tensioned beams
- Reinforced concrete columns for vertical support
- Shear walls surround both north and south cores
- Roof framing: Wide flange steel columns and beams with 3" metal decking

## Foundation

- Metal pipe piles with reinforced concrete pile caps on top
- Piles under shear wall cap act in tension and compression
- Reinforced concrete pile cap on top of metal sheet pile at water line
- Reinforced concrete ground floor slab supported by pile caps and slab edge turn down beam on pile caps

## Mechanical/Electrical

Floors 1-7 have raised access flooring with ductwork underneath
(2) Energy recovery units
(3) Heat exchangers
(2) Self-Contained AHU's on each floor totaling 375,550 CFM - All 480V, 3 Phase
(2) Main transformers supply main feeders at 4000A 277/480V, 3 phase, 4 wire
(2) Main switchboards both 4000A 277/480, 3 phase, 4 wire
(2) 2000 Kw emergency oil generators

http://www.engr.psu.edu/ae/thesis/portfolios/2010/ccb5018

## Contents

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Dr. Kevin Parfitt
Professor Bob Holland
All of my fellow fifth year students

**…and most of all, my family and friends**

# Executive Summary

This Senior Thesis Final Report is intended to discuss the procedures and findings of three in-depth analyses performed on the Thames St. Wharf Office Building (TSW). This project includes the base building construction of a 277,000 SF seven story office building in downtown Baltimore, MD. A 135,000 SF tenant fit out on floors four through seven of the base building were also included as an addendum to the original construction contract is. The connecting theme between all of the analyses is the benefit of having a more integrated design and construction process.

**Analysis I: Critical Industry Issue, Integrated Project Delivery (IPD)**

The building industry is the only non-farming industry in the United States that has declined in productivity and efficiency over the last 30 years. This is partially due to the way projects are currently being delivered. The design-bid-build delivery method causes people to work against each other on a project to protect their bottom line rather than working with each other for what is in the best interest of the project. Integrated project delivery addresses and corrects this issue. This analysis describes in detail the issues with design-bid-build, how integrated project delivery works, its benefits and drawbacks and the effects of IPD on TSW. The analysis shows that had TSW been delivered using IPD many of the issues that occurred on the project could have been prevented or corrected more easily. Furthermore if IPD was used as the projects delivery method, the project would have been higher quality and completed in less time.

**Analysis II: Façade Evaluation and Redesign**

TSW’s façade is comprised of 95% glazing and the southern façade is almost 99% glazing. This leads to high cooling loads during the summer months as the solar loading on the building increases, increasing the building’s operation costs as well as increasing the size of the mechanical system needed to effectively cool the building. If the project had been delivered with a more integrated design process the mechanical engineer and architect could have worked together to design a more sustainable building. This analysis shows that by switching the glazing to a higher performance glazing the envelope cooling load can be reduced by 26% while only increasing the first cost of the system by 3%. This analysis also includes the MAE study required for the integrated BAE/MAE.

**Analysis III: Mechanical System Evaluation and Redesign**

The mechanical system that was installed in TSW was the most expensive line item in the contract with a cost of $10.2 million, almost 20% of the total project cost. The focus of this analysis was to use the reduced cooling load from Analysis II to reduce the first cost of the mechanical system. This analysis shows that with the smaller cooling load the mechanical system is able to be reduced by $244,000 which more than makes up for the extra costs associated with the higher performance glazing. It also describes how unforeseen design conditions from the owner, tenant and building itself prevented the system size, cost and type from being decreased further.

# 1 Project Overview

## Introduction

The Thames St. Wharf Office Building (TSW) is a core and shell office building being constructed on the Patuxtant River in the Baltimore Inner Harbor. A tenant fit out for 50% of the building was also included as a change order to the original GMP contract for the financial firm Morgan Stanley. The owner is Harbor Point Development, LLC. a subsidiary of H&S properties, a large real estate development firm in the Baltimore area. It is a 277,000 SF office building that has a construction cost of approximately $55 million. The ground floor of the building will be retail and restaurant space, floors 1-3 will be open office and floors 4-7 will be office space for Morgan Stanley. The building also houses an 8th floor mechanical penthouse and open balcony space with access from the 7th floor. The project has a sustainability goal of achieving a LEED® Silver rating. Upon completion TSW will become Morgan Stanley's world headquarters and is therefore being constructed at a very high quality.

Morgan Stanley is currently housed in multiple buildings owned by H&S Properties throughout the Baltimore Metro area and had a desire to consolidate into one convenient location. They approached H&S in the early 2000's about the possibility of having a high quality modern building built for them. This led to the creation of the Thames St. Wharf Building project. There were multiple design and redesign stages culminating in the project that is summarized in this report. TSW is the first in a series of buildings that will be developed by Harbor Point Development, LLC. on this site as well as the empty adjacent lot to the west. This site will eventually hold a parking garage, a hotel and the lot on west will hold athletic fields and the National Lacrosse Hall of Fame. It is part of a city master plan to connect the Baltimore Inner Harbor with the Canton neighborhood located to the east with a scenic walkway along the Patuxtant River.

## Client Information

Harbor Point Development, LLC is a subsidiary of H&S Properties, a development company based out of Baltimore, MD. Harbor Point Development was created as an LLC to protect H&S Properties for liability and financial purposes. It was created for the Harbor Point Project that the Thames St. Wharf Building is a part of. If something was to happen that would result in legal action H&S would not be held liable or financially responsible.

The project is being pursued out of a need that Morgan Stanley had for expansion. They are currently leasing space in multiple properties that H&S owns around Baltimore. Morgan Stanley came to H&S and expressed their need for more space, and it was determined that moving all of Morgan Stanley into one building would be best. Currently Morgan Stanley is only a 50% tenant for the building leaving the rest open for other tenants.

The major concern for the Harbor Point team is that Morgan Stanley is able to move in on time. It is more important for the facility to be operational and ready for move in on time that it is for the project to stay on budget. The project is still a for profit venture though so it has been stressed that on budget is also a major concern. Harbor Point also wants to assure that the quality of the building is as high as it can be when the building is turned over. To ensure that this will happen they are going through a lengthy commissioning process that will test every system in the building to make sure it is working properly.

Harbor Point and H&S hope to keep a strong working relationship with Morgan Stanley and hope that Morgan Stanley expands into more of the building after their scheduled move in date. They also hope that the quality building they are constructing and the effort that they are putting forward to please their client will help them secure other clients to fill this building and in the future for other projects.

**Figure 1.1: Renderings of the Thames St. Wharf Office Building – copyright Ayers/Saint/Gross 2008**

## Project Delivery Method and Project Management

The project is being delivered as a traditional design-bid-build with a CM-at-Risk. This method was chosen due to the amount of time that was available for design and procurement before construction needed to begin. It is also a very familiar delivery system that all of the parties involved are comfortable working in. Some issues did arise with the delivery of the project however and that is why an analysis was done on integrated project delivery and what the effects of changing the delivery system would be.

During the construction phase of TSW Struever Bros. Eccles & Rouse (SBER), the first CM firm selected to construct the building, defaulted on its contract and had to relinquish responsibilities as construction manager. This led to Armada Hoffler (AH) being selected as the new CM firm. They took over all the CM responsibilities on May 1, 2009. The transition between construction management firms went relatively smoothly and work on the project only was only stopped for one week as new contracts were written.

## Organizational Chart

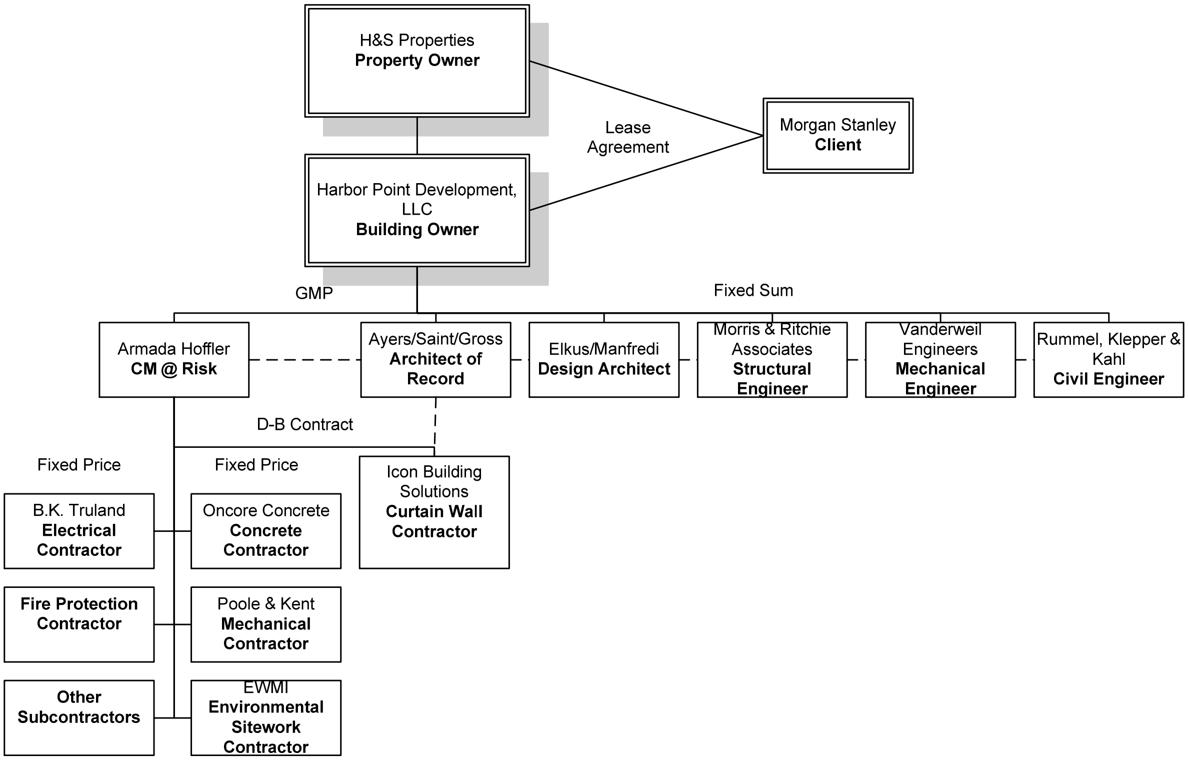


Figure 1.2: TSW Organizational Chart

## Contract Information

Harbor Point LLC holds separate design contracts with each of the design firms and uses ASG as a contact point with all of the designers except Elkus/Manfredi. The contracts with the design firms are basic fixed sum contracts. Harbor Point also holds a GMP contract with Armada Hoffler. It is unclear why SBER was selected originally, but Armada Hoffler was chosen because they are contracted with H&S Properties on a different project in the Baltimore Inner Harbor. When it became apparent that a new CM was going to be needed on the project it was easier to contract with Armada Hoffler than bring in a new CM firm that didn't already have a working relationship with H&S.

Armada Hoffler holds all of the trade subcontractor contracts. All of the subcontractor contracts are fixed price contracts except for the one with ICON, the curtain wall contractor. The curtain wall is being delivered design-build with a design-build contract that is also held by Armada Hoffler.

# 2 Building Design and Construction Overview

## Site Plan of Existing Conditions

*For a copy of the site plan please see Appendix A*

### *Site Location:*

- Located on the Harbor in downtown Baltimore, MD.
- Bordered by public roads on three sides
  - West – Wills St. (to be closed)
  - North – Dock St. (to be closed)
  - Northeast – Caroline St. (to remain open)
- Block St. and Philpot St. run directly through site – Both to be permanently closed
- Thames St. (to remain open) dead ends into Philpot St.

### *Neighboring Properties:*

- Large open plot to the west
- 2 story transfer station off of the northwest corner of the site – far away from construction activities so should not cause any issues
- Ferndale Awning & Fence Company borders the northeast corner of the construction activities. It is a 1 story CMU structure that will be out of reach of the crane swing but will have excavation up to the walls of the structure. Have to be careful not to disturb building foundation.
- Douglas/Myers Maritime Museum is adjacent to the site on the southeast corner along the water. It is a 3 story brick structure that will remain open during construction. Will not be under the crane swing and will not be close to any significant construction activities therefore it should not cause any significant issues.

### *Existing Utilities:*

- Gas, sewer, electric and water run under both Block St. and Philpot St. Electric also runs under the parking lot on the southern half of the site where the building will sit and through the northwest corner of the site. Telecom runs under Block St. and along the northwest edge of the site. Sanitary Sewer also runs along the northwestern edge. An additional water line runs through the northwest corner. The only storm drain onsite is in the drainage ditch in the northeast corner. Municipal storm drains are located along Caroline and Thames St.
- None of the utilities in the southern half of the site will be utilized and will be shut off and removed as needed. The new utilities will be connected to the existing utilities along Block St. and at the end of Thames St.

## *Vicinity Maps*

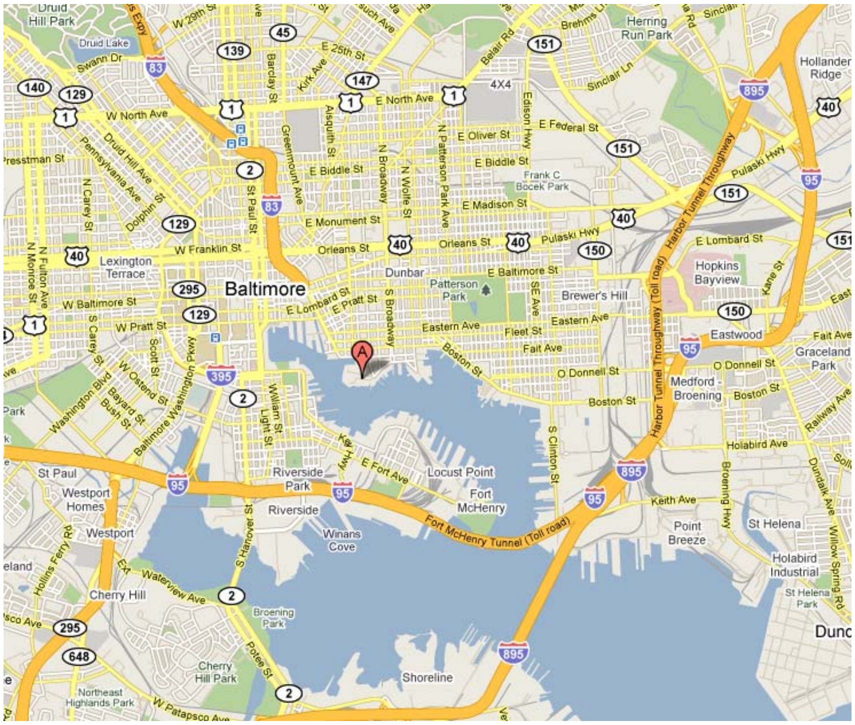


Figure 2.1: Map of downtown Baltimore, MD - http://www.maps.google.com

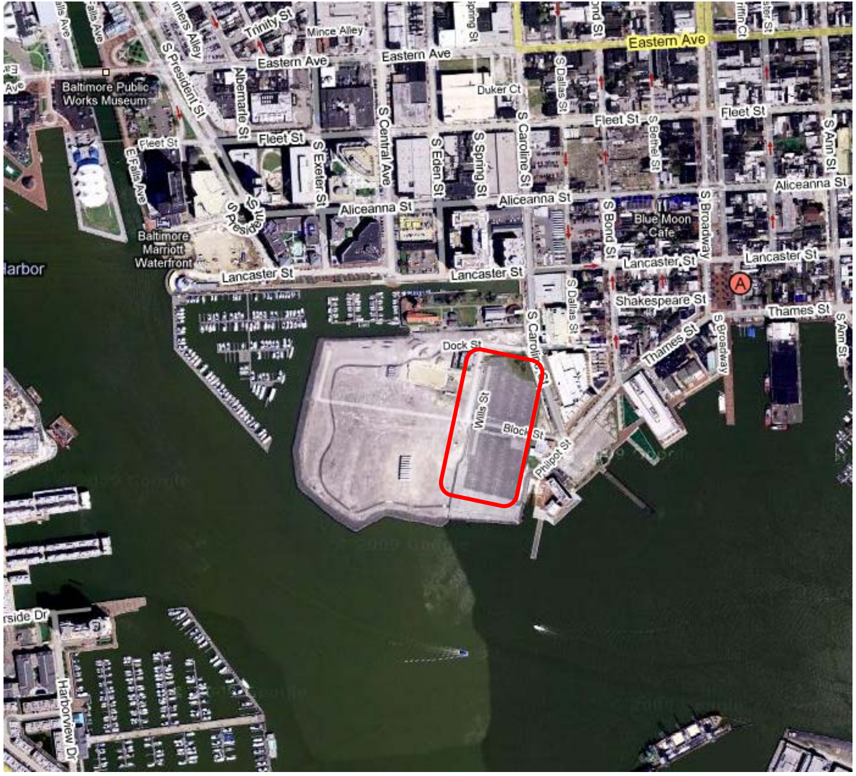


Figure 2.2: Satellite Image of Construction Site -http://www.maps.google.com

## Local Conditions

### *Preferred Methods of Construction:*

- Baltimore, MD has a wide array of steel and standard reinforced concrete and post tensioned concrete structures, so contractors and designers in the area are familiar with all three.
- A PT concrete structure was chosen because it allows for shallower beams over longer spans than the other two systems. This allows for a lower floor-to-floor height while creating a more open floor plan. The weight of the concrete system also reduces vibrations throughout the building.

### *City of Baltimore/Neighborhood Concerns:*

- The City of Baltimore and the local neighborhood required the pile driving for the foundation system to take place during normal working hours due to noise concerns.
- The paved area inside of the limit of disturbance had to be watered multiple times daily while any excavation was taking place to keep dust levels down. This was done because the city did not want contaminated soil particles leaving the site.

### *U.S. Army Corps of Engineers Concerns:*

- Due to the site being adjacent to and extending over the Patuxtant River (Baltimore Inner Harbor) Army Corps guidelines had to be followed.
- Weep holes had to be cut into the sheet pile to allow water to rise and fall in the harbor the way they had before construction. The weep holes also had to be large enough to allow fish to swim through them allowing fish habitats to be preserved.
- Any and all structures or materials placed in the water had to be approved by the Army Corps before they could be set.

### *Construction Parking:*

- Parking is available onsite on the northern section of the site in between the job trailers and the soil stockpile.
- On-site parking is reserved for all CM personnel as well as administrative personnel working in the sub trailers. Laborers are allowed to park on-site only if there is space available.
- Metered parking is available on Caroline St. and a pay lot is available across from the Ferndale Awning Company on Thames St.

### *Soils Report:*

- Site was a small peninsula that was filled beyond original shoreline in the 1800's

- Fill depth ranges from 7-18.5 feet below grade
- Multiple types of sands, silts, clays and rock types below surface
- Bed rock is between 100-121 feet below grade
- Bed rock is an intermediate to medium hard gneiss
- Water level on site ranges from elevation +0.66'-+2.9 feet depending on harbor water levels and location on site

### *Available Recycling and Tipping Fees:*

- Because the project is seeking the LEED on-site recycled materials credit the Armada Hoffler has contracted with a roll off company to use co-mingled dumpsters. The price per pull is $200.

## Building Systems

### *Architectural*

The building is a seven story building with an 8th floor mechanical penthouse. It is mostly on land with the southern tip extending out over the water. The building will eventually become surrounded with a promenade that will allow for foot traffic around the building and will have space for boats to dock. The Ground floor of the building is retail and restaurant spaces along the promenade. The first level will be the main lobby for the offices above and levels two-seven will be office space with Morgan Stanley taking floors 4-7 as previously discussed. There are two main elevator and stair banks in the building, one in the northern half and the second in the southern half both sitting in the center of each area.

**Figure 2.3: TSW Rendering - Copyright 2008 Ayers/Saint/Gross.**

**Figure 2.4: TSW Rendering - Copyright 2008 Ayers/Saint/Gross.**

The building envelope is all glazing on the southern portion of the building and a combination of brick and glazing over the rest. The southern portion of the building was designed completely of glazing to give the building occupants good view of the waterway (Figure 2.3). The rest of the building was designed of brick and glass (Figure 2.4) to match Bond St. Wharf, a turn of the century brick wharf building a block to the south that was recently modernized.

## *Foundation:*

- 4000 psi: used for pile fill under SOG and in marine piles
- 4000 psi: used for SOG, no horizontal formwork was needed; vertical formwork was plywood and rough carpentry.
- 5000 psi: used for marine promenade pile fill
- 5000 psi: used for all pile caps except for shear wall foundations. Formwork type is unknown but believed to be plywood and rough carpentry
- 8000 psi: used for shear wall foundation pile caps
- SOG was pumped, the pile fill and pile caps were placed by crane and bucket.

## *Superstructure:*

- 5000 psi: used for PT slabs and beams, all formed with plywood and rough carpentry. Slabs and beams poured monolithically.
- 5000 psi: used for the majority of columns on levels two and three and for all columns above level three. Reusable flying formwork was used for the square columns and cylindrical cardboard tubes were used for the round columns.
- 8000 psi: used for all columns on the ground and first floors and key columns up to the third floor. Utilized the same formwork as the 5000 psi columns.
- 8000 psi: used for the shear walls. Formed with large reusable flying formwork
- All the slabs and beams were pumped, columns and shear walls were placed by crane and bucket

## *Structural Steel:*

- Wide flange steel beams and girders support a 3", 20G metal roof deck
- Wide flange steel columns support roof beams and girders
- Hollow structural steel members are used as cross bracing to support roof system

## *Mechanical System*

- Each floor has two self packaged air handling units (SCU), one serves the north half of the floor plan and the other serves the south half. Each SCU is housed in its own mechanical room located in the section of building it serves. All the SCU's are variable volume air systems except for the SCU that serves that 1st floor lobby, which is constant volume. Each SCU uses 460V, 3-Phase, 4 wire power and operates at 60 Hz.
- The ground floor and lobby on level one have ceiling mounted duct work for their air distribution systems. The rest of the building is served by under floor ductwork that is pumped to a general location under the floor and then allowed to flow freely throughout the rest of the under-floor system before it moves to the occupied spaces.

- The elevator machine room, security room and telecom roof all have their own AHU's because they are cut off from the rest of the building mechanical systems. All are constant volume and are located in the room that they serve.
- The building utilizes a dry fire suppression system in the loading dock only and a wet fire suppression system throughout the rest of the structure.

### *Electrical System*

- The main building supply comes through two transformers into two switchboards, both rated for 4000A 277/480V, 3 Phase systems. A switchboard and transformer combo for both the north and south sections of the building.
- One 500 kW emergency generator for emergency building systems
- Two 2000 kW emergency generators for tenant spaces with space for an optional third generator.

### *Masonry:*

- 1500 psi CMU blocks are used in the exterior bearing walls above grade. Type N-1 CMU
- 1500 psi CMU blocks are used for non-reinforced interior partition walls. Type S-1 CMU
- 2500 psi grout is used with both types of CMU
- Brick veneer along slab lines and at column lines. Supported by ties linking it directly to the concrete structure.

### *LEED and Project Specific Requirement:*

- Project is looking to achieve a LEED Silver Rating.
- Co-mingled dumpsters are used to aid in recycling.
- Environmental insurance requirements dictate that EWMI must do all excavation into contaminated soil.
- Partial green roof will be installed.
- Under-floor mechanical system (see mechanical system details for additional mechanical system information)
- HVAC system will remain off as long as possible during construction and once it is temporary filters will be used and switched upon turnover.

# 3 Project Logistics

## Project Schedule

*To view a project schedule summary and a more developed schedule please see Appendix B*

The project schedule consists of four main phases: excavation, structure, enclosure and finish. Due to the size of the building phases are able to overlap and each phase begins before the prior one is completely finished. There were some unforeseen issues during the excavation phase that delayed the project for approximately six weeks and caused the concrete contractor to demobilize after they originally mobilized and then remobilize six weeks later. There was also a slight delay in May 2009 when contracts had to be resigned to accommodate the change in construction management firms.

**Table 3.1: Key Project Dates**

| Key Project Dates | |
|---|---|
| SBER NTP | 10/1/2007 |
| Pile Driving Complete | 4/25/2008 |
| Top Out Structure | 11/18/2008 |
| Armada Hoffler NTP | 4/27/2009 |
| Enclosure Complete | 11/23/2009 |
| Temporary C of O | 2/17/2010 |
| Tenant Fit-Out Complete | 3/15/2010 |
| Substantial C of O | 3/9/2010 |
| Final Turnover & Project Completion | 3/15/2010 |

### *Design and Procurement:*

Upon talking with the owner's representative I was informed that the design for the project began schematically in 2003 and was done sporadically until it's completion in late 2006. Intense design took place from late 2005 through late 2006 and that is what is listed on the project schedule summary in Appendix B. Following design completion there was a time gap before procuring a CM for the project. The reasons for the gap are unknown as the representative that I am in contact with was not working on this particular project at that time, and the person who was is no longer employed at Harbor Point Development.

### *Sitework Sequence:*

Before any excavation could take place the existing parking lot had to be demolished. It was only demolished in select spots as needed for construction in order to keep the contaminated soil as covered and undisturbed as possible. After the parking lot was demolished the building footprint was excavated to an elevation six to eight inches below the top of the proposed piles. The piles were then driven; the sequence for the pile driving is unknown. After the piles were driven and cut the site was backfilled with controlled fill, some of which was contaminated soil that was excavated earlier. On top of the controlled fill a layer geotextile fabric was put down followed by a capillary break and then another layer of geotextile fabric. This was done to prevent any contaminants from reaching the surface.

## *Foundation Sequence:*

After all the piles were sunk pile caps were placed on top. Again it is unknown if the pile caps were placed before or after the site was backfilled but due to the environmental concerns and insurance risks for having workers work directly on contaminated soil it is my assumption that the site was backfilled first. The ground floor slab was placed on top of pile caps and grade beams that were also supported by pile caps. All under slab piping was hung from the slab to ensure they wouldn't move if the under-slab fill eroded away.

## *Structural Sequence:*

The superstructure was formed, reinforced and placed from the north to south. Due to the size of each floor slab, each slab was broken into three pours. After each section of slab was poured it cured until it reached a strength of 2500psi (two days on average) before the vertical formwork was stripped and the PT cables were tensioned. After the horizontal formwork was removed vertical re-shoring stayed in place until at least 28 days after the original pour. After a section of slab was formed, but before it was reinforced, all other trades were expected to place all of their embeds and sleeves.

A lot of issues arose during the concrete sequence due to coordination. Certain sleeves were moved or completely omitted and the shop drawings were incorrect resulting in the structural dimensions being too large after the system was poured creating more coordination issues.

## *Façade Sequence:*

The start times for the façade are not known. To my best guess it was not started until a while after the superstructure was completed. I am basing this assumption on the fact that façade installation still had a long remaining duration on 3/16/09. According to the schedule I received from Armada Hoffler the façade sequence was first face brick then windows and then curtain wall in most cases. All four faces of the building were being constructed at approximately the same time. The scaffolding plan for the masonry is unknown as it was completed prior to May 1, 2009. That material hoist for the project is on the west face of the building and will be removed and closed after the elevators are installed.

## *Finish Sequence:*

The finish schedule is typical for the ground level through the 3rd level, and is from ground up. There is no tenant yet on these levels so they are just core and shell construction. First the main floor area is roughed in and the access floor is installed. As crews finish working in the main floor area they move into the core. The core is fully finished and follows the normal sequence of work; MEP rough-in, walls, ceilings, flooring, paint, trim-out. After a crew has finished in the core they move to the next floor and repeat the process.

Levels 4-7 require a tenant fit out. The sequence is still floor wide rough-in and then core but after core comes tenant fit out. After a crew is done in the core they move to the tenant fit out spaces. The work in the tenant space follows the same sequence as the work in the core.

## Site Layout Planning

*To view the site layout plans please view Appendix C*

The site is very large enabling a lot of things to be placed on-site without over cluttering it. It is already separated into a northern and a southern portion by Block St. allowing the site trailers, storage sheds and construction parking to be located away from all construction activities and therefore safe. The northern half of the site plan, site fencing and on-site traffic patterns do not change between each phase of construction.

### *Excavation:*

The site work phase of construction was the shortest phase of construction and had the least number of people involved with it. The entire parking lot in the southern portion of the site did not need to be removed for construction to be successfully completed so it was only demolished in areas that needed to be excavated for underground utilities and pile driving. The soil that was excavated was moved into a segregated section in the northern half of the site plan and separated into two piles. The first pile was for the soils that contained the most contamination and the other pile was for soils that only had a limited amount. The cut off point for each contamination level is not known. The more contaminated soil was to be stored on-site until a disposal facility could be found. The soil with the lower contamination level was also to be stored on-site and used as controlled backfill later in the site work phase. The remaining low contamination soil was then to be disposed of with the high contamination soil. Frac tanks were placed at two locations on site to help gather contaminated particles after a rain and would be removed as they were deemed no longer necessary. No excavation support was needed soil cohesiveness allowed for a step back of 2:1

A separate asphalt dumpster was utilized because the asphalt also had traces of volatile compounds and needed to be disposed of properly. Additionally a commingled dumpster was placed on-site for the remainder of the refuse created. Commingled dumpsters were used to make recycling easier and lower the number of dumpsters needed on-site at one time. If separate dumpsters were used for each material at least four dumpsters would be needed on-site at any one time, at one for each material.

### *Superstructure:*

The superstructure phase was the only phase of the project that utilized a permanent tower crane. It was placed outside the building limits because there was available space and it was easier to erect and dismantle. The exact specifications of the crane are not known but it is known that it covered the entire floor area for L1-PH. The only area of the building that was not under the reach of the tower crane was northern extension on the ground floor. To place the rebar cages for the columns in that area a boom lift was used and concrete was pumped into the formwork.

The rest of the columns in the building were placed using crane and bucket. The floor slabs and shear walls were all placed by pumping. There were two pump locations in the building footprint. Pump Location 1 was used to place the northern 2/3rds of the slabs and the northern shear walls. Pump Location 2 was used for the southern 1/3rd and for the southern shear walls. All reinforcing deliveries were made to the lay down/shakeout area to the west of the building and the days picks would be organized in the staging area to the north of the building.

For the steel construction in the PH the steel contractor brought in their own crawler crane. It was parked in the same location as the tower crane. Again the crane specifications are unknown.

Other notable changes in the site plan are the addition of a dedicated concrete dumpster and another commingled dumpster. A wash out area for the concrete trucks was placed next to concrete dumpster. More personnel are expected on-site during this phase so additional portable toilets are on-site, including some inside the building limits that are lifted from floor-to-floor as work progresses vertically. A temporary power station was also established during this phase. It powers everything needed for construction including the crane. The exact specs of the temporary power system are unknown. Additional material storage trailers were added on the southern half of the site for the mechanical and electrical subcontractors. They were placed in the southern half to limit the distance those subs needed to transport their materials. The northern storage trailers were used mostly for equipment storage.

### *Enclosure:*

The enclosure phase of the project is the phase with the least amount of information available. Scaffolding was used to for both the brickwork and the curtain wall installation. Based on the limited schedule that is available for this phase the assumed work progression is from north-to-south for the masonry, starting on the North and East faces of the building and the curtain wall started in the south and worked north. The curtain wall was stick built and the pieces were light enough to be lifted by one or two people so no cranes were needed. The windows were installed from the inside so no scaffolding was needed.

The tower crane is no longer needed for construction and has been replaced with a man and materials elevator on the south-western corner of the building. There is also a loading dock on the western face of the building in the northern half. During the enclosure phase the soil stockpiles were removed reducing the need for two frac tanks on-site. One was kept just as a safety precaution in case there were severe weather conditions that dictated a need for one. The concrete wash out area was removed and the concrete only dumpster was replaced with a commingled dumpster. The lay down/shakeout area is now a material storage area during this phase.

### *Interior Finish:*

The interior finish phase is the final phase of construction. There are very few changes on the site plan from the enclosure phase. These two phases overlap a significant amount giving reason to the similarities in the site plans. The only major difference is the absence of scaffolding.

All materials that need be stored on-site and protected from the weather are stored inside of the building. There is a lot of empty space inside the building because the floors from the Ground Level through Level 3 are being built as core and shell.

To place the roof mechanical equipment the mechanical subcontractor brought in a crawler crane as well. It was also placed in the same place as the other two cranes had been previously; it was left out of this site plan for clarity. Again the specs for the crane are unknown. To move and install the SCU's on each floor a fork lift was used. The mechanical subcontractor was responsible for the forklift.

## Project Cost Summary

### *Project Cost Breakdown*

**Table 3.2: General Project Costs**

| General Costs | | |
|---|---|---|
| | Cost | Cost/SF |
| Construction Cost (CC)* | $51 Million | $195 |
| Total Cost | $100 Million | $361 |

*Cost breakouts for permitting and fees were unavailable and are included in the construction cost that is reported.

**Table 3.3: Building System Costs Breakdown**

| Building System Costs | | | |
|---|---|---|---|
| System | Cost | Cost/SF | % of CC |
| Concrete Structure | $8.2 Million | $ 29.60 | 15% |
| HVAC | $10 Million | $ 36.10 | 19% |
| Electric | $6.9 Million | $ 24.91 | 13% |
| Misc Metals* | $1.1 Million | $ 3.97 | 2% |
| Masonry | $1.9 Million | $ 6.86 | 4% |
| Curtain Wall | $4.2 Million | $ 15.16 | 8% |

*Misc Metals includes structural steel for Penthouse

### *Parametric Estimate*

| | | | |
|---|---|---|---|
| Total Building Cost: | $39,004,454 | $140.81/SF | 23.5 % Difference |
| Total Project Cost: | $41,495,210 | $151.21/SF | 58.5 % Difference |

This information was compiled using D4 Cost Estimation Software. There was a very limited selection of buildings in D4 to compare to get values comparable to the Thames St. Wharf Building. The total building cost is off by just under 25% percent and this is most likely due to the intensive façade curtain wall system and the expensive mechanical system. The total project cost is most likely off by such a large number because D4 does not include land costs in its total project cost figure. The land values for this project are very high because all of the land needed for the entire Harbor Point Development was included with this project.

## *Square Foot Estimate*

**Table 3.4: RS Means Square Foot Cost Estimate - http://www.meanscostworks.com/**

| Estimate Name: | **Thames St Wharf** |
|---|---|
| Building Type: | **Office, 5-10 Story with Face Brick with Concrete Block Back-up / R/Conc. Frame** |
| Location: | **BALTIMORE, MD** |
| Story Count: | **8** |
| Story Height (L.F.): | **13** |
| Floor Area (S.F.): | **277000** |
| Labor Type: | **Open Shop** |
| Basement Included: | **No** |
| Data Release: | **Year 2007 Quarter 4** |
| Cost Per Square Foot: | **$85.11** |
| Building Cost: | **$23,575,500** |

Costs are derived from a building model with basic components. Scope differences and market conditions can cause costs to vary significantly.

| | % of Total | Cost Per S.F. | Cost |
|---|---|---|---|
| **A Substructure** | 2.70% | $2.26 | $625,500 |
| **B Shell** | 27.60% | $23.50 | $6,510,500 |
| **C Interiors** | 20.40% | $17.39 | $4,817,000 |
| **D Services** | 49.00% | $41.73 | $11,042,500 |
| **E Equipment & Furnishings** | 0.30% | $0.23 | $62,500 |
| **F Special Construction** | 0.00% | $0.00 | $0 |
| **G Building Sitework** | 0.00% | $0.00 | $0 |
| **SubTotal** | 100% | $85.11 | $23,058,000 |
| **Contractor Fees (General Conditions,Overhead,Profit)** | 0.00% | $0.00 | $0 |
| **Architectural Fees** | 0.00% | $0.00 | $0 |
| **User Fees** | 0.00% | $0.00 | $0 |
| **Total Building Cost** | | $85.11 | $23,058,000 |

For complete estimate see Appendix D

The RS Means square foot estimate is off of the actual construction price by just over 50%. This has partially to do with the fee for the contractor and architect. They are not included in the means estimate because the fee percentages for each party were not known but they are included in the actual costs. Another disparity comes from the different façade systems. The means estimate assumes masonry for the whole building and does not include the more expensive curtain wall. Means also does not estimate the mechanical system in this square foot estimate which $10 Million of the actual project costs. The higher end finishes and LEED rating also increase the cost of the actual building over the square foot estimate.

## General Conditions Estimate Summary

Thames St. Wharf Project had a general conditions total of $1,745,462. Bonding was not included in this total because the bond requirements were not fully known and were made more complicated by the change in contractors in May 2009. Had it been included the total cost would most likely be around a million dollars higher. One requirement that the project had that is different than most is two sets of commissioning requirements. The building had to be commissioned to achieve a LEED silver rating but Morgan Stanley also had a requirement for commissioning separate from LEED. Having two sets of commissioning standards caused the construction team to have a very in depth commissioning process raising the cost over the standard.

**Table 3.5: General Conditions Estimate Summary**

| General Conditions Estimate Summary | | | | |
|---|---|---|---|---|
| Item | Quantity | Units | Unit Price | Total |
| Project Management Personnel | 104 | WK | $ 11,100 | $ 1,154,400 |
| Administrative Facilities and Supplies | 104 | WK | $ 320 | $ 33,299 |
| Jobsite Requirements | 104 | WK | $ 1,417 | $ 147,334 |
| Commissioning | 104 | WK | $ 3,606 | $ 375,000 |
| Testing | 104 | WK | $ 341 | $ 35,430 |

To view the complete general conditions estimate please see Appendix E

The general conditions estimate was compiled using RS Means and general conditions costs listed in Justin Wingenfield's Tech II assignment. His assignment was chosen because the building he did his thesis on is similar to The Thames St. Wharf Office Building and located in Washington DC so it is relatively close geographically.

The estimate is based on the ideal 26 month construction schedule. None of the delays are factored into the costs because their durations are unknown separate general. There is also no information available on who was responsible for the delays so it is unknown who is responsible for paying the extra general conditions costs.

A list of assumptions made for the estimate are as follows:

1. All months consist of four (4) weeks
2. Each subcontractor is responsible for their respective permits
3. Each subcontractor is responsible for their own safety equipment

4. Each subcontractor is responsible for clean up at the end of each work day
5. An average of four (4) dumpsters were pulled a week over the duration of the project
6. Each dumpster has the same cost associated per pull
7. All project staff are on-site for the entire project duration
8. Six (6) portable toilets are needed per month over the entire project duration.

## Detailed Structural Systems Estimate Summary

The Thames St. Wharf Office Building consists of a reinforced concrete on metal piles foundation, a post-tensioned concrete superstructure and a structural steel penthouse. The estimates for the foundation and structural steel were created using a complete takeoff of both systems. For the post-tensioned concrete superstructure a take-off was done for Level 4 and used as the average for the other levels. All of the unit prices for the estimate come from RS Means Online using the 2009 cost book with the location factor for Baltimore, MD included. Table 3.6 shows the estimate results summary. For an overview of the estimate take off quantities please refer to Appendix F. The complete take off is not provided due to its length and size.

**Table 3.6: Detailed Structural Estimate Summary**

| Material Costs | | |
|---|---|---|
| Item | Quantity | Total Cost |
| Concrete | 13144 CY | $ 1,597,868 |
| Mild Steel | 13.28 Tons | $ 2,059,134 |
| PT Tendons | 38129 lbs | $ 77,784 |
| Formwork | 403765 SF | $ 1,534,610 |
| Piles | 19769 VLF | $ 655,611 |
| | | |
| Structural Steel | | $737,758.32 |
| | Total | $ 6,662,765 |

For the concrete estimate a major assumption was that all of the columns in the building were 24"x24"X12' with 5000 psi concrete. The majority of the columns in the building are 24"x24"X12' with 5000 psi concrete so this assumption is not far off. It was also assumed that each pile was driven a depth of 64.25 ft. This value was listed in the foundation drawings as the average

Overall the concrete estimate that was developed is off of the actual cost by less than 1%. The actual concrete cost was $8.2 Million. The difference is most likely due to the general conditions costs for the concrete subcontractor and the assumptions that were made in the estimate. A list of assumptions is listed below.

Concrete Estimate Assumptions:

1. The cost of each pile includes concrete being placed inside but does not include reinforcing
2. No reinforcing is epoxy coated
3. Each PT beam contains three (3) tendon bundles containing (4) tendons

4. Crane cost is included in equipment unit costs
5. Open-shop labor

The steel value also seems close to the actual construction cost.  The exact percentage difference is unknown because the structural steel cost that has been reported is combined with the miscellaneous metal cost.  The total misc. metal cost is $1.1 Million.  It stands to reason that the majority of the misc. metal cost is for the structural steel making the estimate provided reasonably accurate.

# 4 Analysis I: Integrated Project Delivery (IPD)

## Background

The construction industry is currently one of the most inefficient industries in the United States. In fact the construction industry is the only non-farm related industry that has declined in productivity since 1964 (Figure 4.1). It is estimated that approximately 30 percent of construction projects do not make their schedule, budget or both. This has occurred for a multitude of reasons, one of the largest being the way projects are delivered. The current design-bid-build (DBB) delivery method causes designers, contractors and subcontractors to work against each other at times as a way to protect themselves against liability.

A survey conducted by the CMAA in 2005 found that 92 percent of owners said architects drawings are typically not sufficient for construction. Additionally it is estimated that 37 percent of the materials used in the construction industry become waste and approximately the same percentage represents the cost of construction that is not value added, meaning that owners are paying for more than a third of a building that they are not receiving.

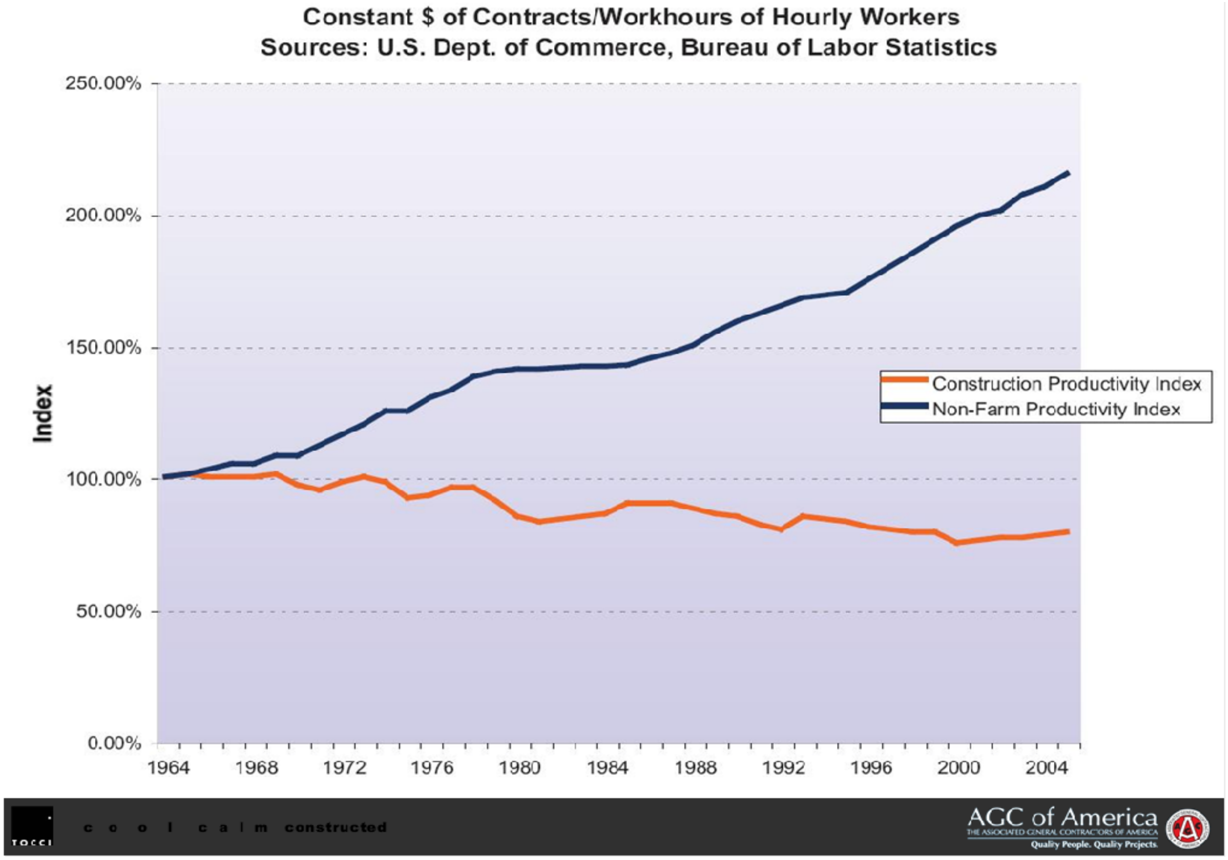


Figure 4.1: (Kenig, Tocci, & Frey, 2009)

## Goal

The goal of this research is to introduce and examine IPD as a way to delivery projects more efficiently and effectively. This is especially important in a down economy where there owners do not have money to waste. The research will focus on the current issues that arise using the DBB delivery method and how they can be remedied using IPD.

## Design-Bid-Build Analysis

As it was stated in the analysis background the design-bid-build delivery method is very inefficient and as times causes all the parties involved in a construction project to work against each other. Firms are unwilling to go out of their way to help each other because they are worried about the possibility of litigation if something goes wrong. Construction management personnel aren't brought onto the project until the bid process and have no significant input into the design. If a CM firm does have a good idea for a way to improve the design of the project it is either too late to include the idea or it requires the design team to spend extra time and money to redo the drawings. This can push the project over the original budget or delay it while the redesign is taking place. Also with the traditional delivery method trade subcontractors that are contacted during preconstruction may save some of their best ideas to use during the formal bid process to gain a competitive edge over their competition.

There is also a lot of waste during the design process between designers that can be prevented. The design teams do not work together on the drawings at the same time causing the design process to become lengthy and drawn out. First the architect designs the building, then hand the drawings to the structural engineer, followed by the MEP and any other design teams that may need to design systems in the building. If all of these designers were able to work off one set of drawings at the same time the design process could be significantly decreased. Additionally all of these groups work independently of each other creating the need for extensive coordination processes to ensure that the building is as constructible as possible. The design teams also have to work off of what the designer before them has done. This may cause one design team to struggle to meet the owner's requests because of the way an earlier system was designed. For example on the Thames St. Wharf Office Building the southern portion of the façade is made entirely of glazing. This caused the mechanical engineer to design a very expensive system to meet the comfort and energy efficiency criteria of the owner. Had these two firms been working together at the start of the project the mechanical engineer would have been able to let the architect know that the large amount of glazing was going to negatively affect the mechanical system and the two could have worked together to come up with a more economical solution.

Even more issues become apparent once the project reaches the construction phase. Designers sometimes intentionally leave things out of the bid documents because they are unsure how exactly a certain detail will work; they don't have enough time to complete everything or simply don't want the liability of designing something incorrectly in the bid documents. Depending on how a projects contract is written, if the design is incorrect and has to be redone the design firm has to pay for the redesign as well as any lost time or increased costs associated with the new design. If they omit certain details the CM will issue an RFI and upon the response a change order may be issued to the owner for the increased cost of the work and the designer will most likely not be liable for the additional cost. Issues also arise between each trade. During the coordination process each trade is solely concerned with what they need to complete and do not generally care about making work easier for anyone else. It even happens where subcontractors rip out work done by other trades so that they can get what they need in place. This is completely detrimental to the whole project. It causes a bad working relationship between the trades and adds additional expense for the rework. A CII study suggests that anywhere up to 10 percent of construction cost is "rework". There are also issues with trades getting in each other's way. Having to work around stored items and equipment as well as around other people can cause the work to progress more slowly than it could if the conditions were optimal.

The final big issues with DBB are change orders and RFI's. RFI's, while they are often needed for the project to be successful can cause a lot of issues. The first issue is that unless an item that needs clarification is caught early enough for the contractor to issue an RFI before the item in question becomes a problem work will most likely have to stop pending the response of the RFI. This can cause work to be done out of sequence or may stop work on the item in question entirely while the RFI is being answered. RFI's may be issued for simple clarifications or for things that were completely omitted from the drawings. As discussed previously designers will sometimes omit things so that they aren't liable for any additional costs from a change order. Designers aren't the only people to blame for change orders though. Many contractors and subcontractors, especially in the economic climate we are facing today omit items from their contract scope to lower their initial costs to complete the work in hopes of winning the bid. For these contractors and subcontractors to complete the work and turn a profit they have to submit change orders. This is where a large amount of subcontractors make their money on projects. Change orders are very detrimental to a project's final budget and schedule. They are expensive ways to get work included into a contract. Figure 4.2 illustrates how the further along a project is the more expensive changes are. This is why it is important to correct as many issues as possible before construction begins.

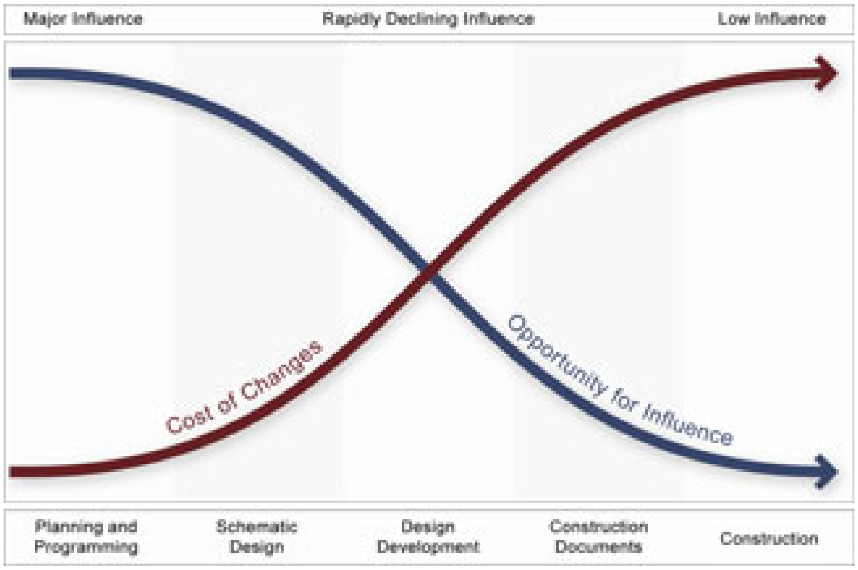


Figure 4.2: Cost of Changes vs. Opportunity for Influence (Cherry & Petronis, 2009)

It has also been found that the contractual relationships between each of the parties involved in a project causes strain. The CM holds individual contracts with each subcontractor while the owner holds all of the design contracts and uses the architect as a communication point. This places difficult lines of communication between each party. For a trade subcontractor to get an answer from a design engineer an RFI needs to be sent from the trade subcontractor to the CM who sends it to the Architect who then forwards it to the design engineer. This information then has to go back through all of those parties to reach the subcontractor. Having to pass through all of the different parties lengthens the amount of time the process takes and increases the chance that information may become lost or convoluted in the transition.

For the Cardinal Glennon Children's Hospital the Alberici Constructors construction management team asked all of their subcontractors what makes their work unproductive. There were a lot of responses most based around issues stemming from the DBB delivery method. They cited things like having a selection by lowest price, which caused them to staff cheaper, lower quality people on projects, changes in the design after the project started, work that was completed out of sequence and needing information and decisions. All of these are symptoms of not having a design that is not complete and done in an integrated fashion and each person looking out for their own best interests and not the best interests of the project as a whole.

## Integrated Project Delivery

### Overview

Integrated Project Delivery or IPD is not a brand new approach for delivering a project but it is starting to gain momentum throughout the country as a successful way to deliver a project that gives the owner the most "bang for the buck". The major difference between IPD and the standard design-bid-build delivery method with a GMP contract is the way all of the parties are contracted with each other. With IPD the owner, designers, and construction manager all sign one contract. This contract has the effect of making the entire project team one entity that is supposed to "share" the risks and rewards on the project. Signing one contract also causes the team members to work together as a team. The idea behind it is that each member now works for what is best for the project and not what is best for them. Chuck Thompson, FAIA, FCMAA sums it up when he says, "The inspiring vision of IPD is that of a seamless project team, not portioned by economic self interest of contractual silos of responsibility, but a collection of companies with a mutual responsibility to help one another meet an owner's goals."

### Cost

These team members are brought on early in the project, hopefully as early as schematic design and work together to come up with the project scope and budget. The reason for bringing them on as early as possible is to get everyone's expertise to the table before anything is designed. Figure 4.3 shows the level of influence a decision has on the final cost of the project as the

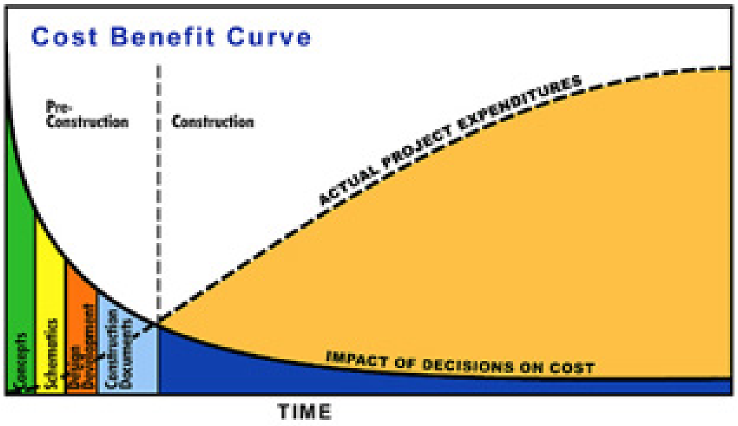
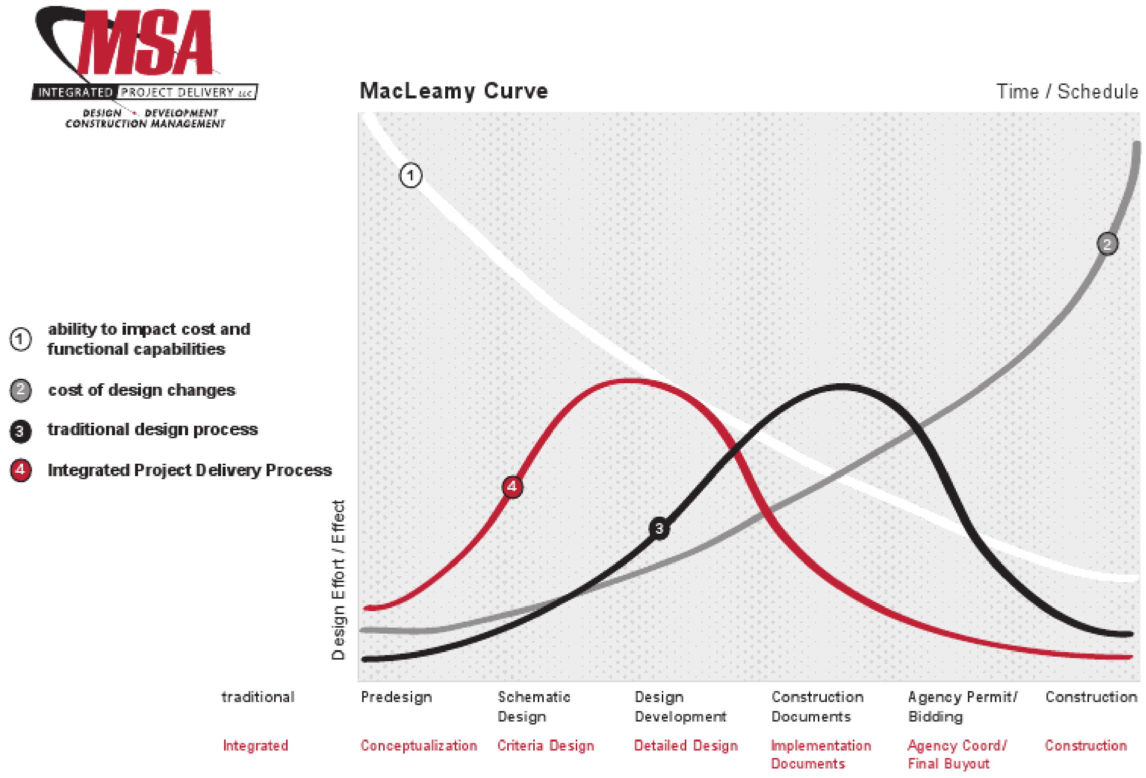


Figure 4.3: Impact of Decisions on Total Cost vs. Time (Kerr, 2010)

design and time progress. It shows that the earlier a decision is made the greater effect it has on the total cost of the project. This shows why it is so imperative for all the necessary parties to be one the project as early as possible. Figure 4.4, the Macleamy Curve, shows how the different design processes between IPD and DBB affect the cost of the project. With IPD more important decisions are made earlier on in the project and by the time the design reaches the construction documents stage the design is mostly finalized.



*Introduced in the Construction Users Roundtable's "Collaboration, Integrated Information, and the Project Lifecycle in Building Design and Construction and Operation" (WP-1202, August, 2004)", the "MacLeamy Curve" illustrates the advantages of Integrated Project Delivery.*

**Figure 4.4: MacLeamy Curve (MacLeamy, 2004)**

This doesn't mean IPD delivers a less expensive product than DBB. What it does mean though, according to Patrick Duke a program director at KLMK group, a healthcare facilities management firm that has experience building with IPD, is that owners are able a higher quality building with IPD for the same price of a lower quality building delivered with the traditional method. He says that bringing everyone on earlier in the project enables the team to come up with a better cost model early on enabling the team to make more effective decisions. Knowing how much money is going to be spent on each item earlier enables the team to include less "padding" when they estimate the cost of the building. And since they don't have to put extra money into the cost of each item in the form of a contingency there is more available to use for more or higher quality systems or better finishes. This makes it good for all types of building projects. In late 2008 Autodesk completed its new AEC

Headquarters using IPD. After the project's completion they determined that by using IPD they were able to incorporate improvements to the project valued at 7.5 percent of the base construction budget from savings generated by the IPD process. And according to John Tocci, the Founder and CEO of the CM firm that constructed the Autodesk Headquarters, "in general, savings are proportional to building density." IPD is beneficial for all types of owners. It enables owners with very fixed budgets to stretch their money as far as possible and get more for each dollar spent. It is also profitable for speculative owners. For the same initial investment they are able to get a higher quality product compared with DBB. Having a higher quality building then makes it easier to market the building which can then command a higher sale price or rental values.

### Contracting

As it was briefly discussed above the IPD contract is the basis for most of the differences between it and DBB but also where the most confusion can take place. There are a few different contracts available for IPD; the most popular are the AIA IPD contract, which is currently being revised, and the Consensusdocs 300 IPD contract. Sutter Health, one of the first owners in the United States to have a project that was delivered with integrated project delivery developed their own contract to suit their needs. While all of the contracts have slight differences they are at their cores, the same. They all require the owner, the architect and construction manager to sign the same contract, making each one responsible to the next. Additionally as engineering design firms and subcontractors are brought on the board they sign adjoining agreements effectively making them team members.

With everyone working under the same contract, everyone's goals become aligned. This means that each firm isn't working to reach its own bottom line but instead to make sure the project is successful as a whole. The way the contract is set up, if the project fails, everyone fails. This does away with the issue of firms focusing solely on their part of the project, and instead working on the whole project. Michael Tardiff of Grunley Construction made the statement; "Shared risk/shared reward means that if a problem comes up on a project, the focus of the team is on finding a solution rather than assigning blame for the problem. So it instantly eliminates a lot of 'defensive documentation' and changes the focus of the parties from protecting themselves to solving problems and getting the project done." That 'defensive documentation' contributes to the approximately 37 percent of construction cost that is not value added with the old methods of construction. It wastes the time and energy of the project team members and contributes nothing to the overall project.

IPD also does away with the GMP contract. It instead uses a target cost contract. What this means is that as the project and estimates become more refined the total cost of the project becomes more apparent. Once the design of hits a certain point, to be defined by the owner, a final estimate is created and from that estimate the target cost for the project is created. The goal of the project team is to stay at or below that target cost. This makes some owners nervous at first because it does not 'guarantee' a price like a GMP contract does. In reality GMP contracts don't 'guarantee' a final contract price either. On the surface they do but once change orders are factored in, and almost all DBB projects have a change order at some point, the GMP cost rises to incorporate that change order. With the target cost contract actual final cost has to remain below the target cost. If it does not the extra costs are split up among the major project team members based on how the risk was allocated in the contract. Integrated project delivery contracts stipulate that there will no non-discretionary change orders. This means that the cost that has been agreed upon will be the end cost unless all parties agree to add scope to the project. According to Patrick Duke most of the owners he deals with feel that on paper the risk with IPD looks higher than with DBB but in reality there is less risk for the owner using IPD.

Risk and reward allocation with IPD are where the most confusion occurs with the contract. Ideally compensation and risk should be allocated to each party based on the level of value they add to the project. KLMK awards compensation and incentives based on project risk. While everyone is splitting the risk to some degree they have noticed that most of the risk is still on the owner, for the simple reason that they are financing everything. This means that the incentives clause in the contract generally awards more to the owner for any savings on the project. Mr. Duke also said the incentives clause in the contract is the biggest “hang up” when it comes to writing the contract. It becomes very difficult to get all of the parties to agree on it. In his experience that is the part that people want to decide on first and that creates difficulties with the rest of the contract. So what they have decided to do is create the scope, preliminary budget and have the contract signed before they even discuss incentives. Then after everything else is completed and risk has been allocated it is much easier to get the team to agree. Mr. Duke also said that the incentives clause has been overdone and that people who are doing IPD for the monetary benefits are missing the point of the delivery method. He says that the completion of a successful project should be the first goal and when that is reached monetary gains will follow.

### Communication

With everyone on the project team being connected by the same contract the lines of communication become a lot more open and effective. Any questions or issues can go directly from one party to another without having to work through the entire project hierarchy. On some of the projects that have been completed thus far all of the designers worked in one room together making communication even easier. If all a person has to do to have a question answered is walk across the room and have a face-to-face conversation collaboration becomes a lot easier. And with the advent of building information modeling (BIM) this has become even easier. With all of the designers working on the same model coordination becomes much easier and more efficient. When a conflict arises as each of the systems is designed they can be solved on the spot. With all of the designers in question in the same room working at the same time everyone can discuss the best options and come up with a viable solution. And this can be done as the design progresses, and not at the end of the design phase like DBB. As the previous graphs show, the earlier changes can be made the better.

Teams aren’t always able to have everyone work in the same location for multiple different reasons. For the Sutter Medical Center Castro Valley (SMCCV) project this was exactly the case. To remedy the situation they held large meetings at least biweekly to go over the design and address any possible issues. Technology was available that enabled those that could not physically be there to remotely connect to the meeting and see what was taking place and participate whenever needed. In these meetings they would go room by room examining each detail and asking questions on anything that needed clarification. With everyone present, and the model up on large screens in the front of the room getting answers was instantaneous and things that needed to be changed were corrected immediately. Of the issues that were cited by subcontractors on the Cardinal Glennon project they said people walking out of meetings in agreement but then going and doing their own thing anyway. Having meetings where more than discussion takes place alleviates that issue.

A case study on the SMCCV project and IPD was completed by Dr. Lachmi Khemlani, the founder and editor of AECbytes.com and while she was attending one of the project meetings as an issue arose. The structural engineer had to change some of the beams in the building for permitting reasons, and thinking that the changes were minor they did not inform the rest of the project team of the changes. During the meeting, which the structural firm was not present for, the other designers noticed that the model had changed and that there were new conflicts in the space being reviewed. They were using NavisWorks which allowed them to color code all of the changes and realized that beams had been moved, others were made deeper and a few more were added. The changes to the beams caused conflicts with the MEP systems and architecture of the space. The project team immediately called the structural designers who were able to instantly connect to the meeting online and the issues were discussed. After discussing the issue it was determined that the best course of action was to try and make all of the beams as shallow as possible to accommodate the other systems. The structural team then began to work on the change and fully resolved the issue. Had the team members not held frequent meetings, or if it technology wasn't as advanced, allowing people that weren't in attendance to participate, this issue could have grown into a large problem once construction had started. With DBB this issue may have come up in coordination meetings if 3-D coordination was used. If not though it is very likely that this issue would have been encountered during construction and work would have had to stop while a solution was found. A solution that would most likely resulted in a change order raising the price of the project.

**Figure 4.5: Meeting room for SMCCV project team (Lachmi Khemlani, 2009)**

The issue that came up in the SMCCV project meeting did highlight the fact that there is no substitute for good communication. While the issue was caught and resolved had the structural design team talked with the rest of the project team members before changing the structure like they are supposed to there would have been no issue. The more communication that takes place between all of the parties involved in a project, the fewer issues there generally occur. This is why Mr. Duke recommends bringing on as many people as possible, as early as possible in the project. Even, and sometimes especially, trade subcontractors. Subcontractors are the ones that have to construct everything so the better their knowledge of what needs to be done the more effective they are. If they are able to sit in the design meetings and ask questions about the building, and bring up things that could become potentially difficult in the field they will be better able to successfully construct the project.

### Schedule

IPD has a large effect on the total project schedule and is able to shrink it in both the design and construction phases. The elimination of all the rework in the design phase eliminates all of the extra time needed to do the rework. And with all of the designers being able to design together at the same time no one has to sit around idly waiting for someone else to finish their part of the design. IPD generally has a greater intensity and higher team involvement during the early phases of design. This enables the design to get done quick and higher levels of coordination to occur earlier speeding up construction. The high intensity does cause people to dedicate their time to one project though instead of the current practice working on multiple projects at the same time. When each team member is only able to work on one project at a time they know that project inside and out creating a better product.

The construction document phase of the project is also shortened because everything is already designed and coordination has been completed. With IPD CD phase is only supposed to show how the design will be implemented, the design should be complete before this phase starts. And if the project is using BIM, which is highly recommended for all IPD projects, the BIM model should be able to be used to create the construction documents further speeding up the process.

The construction phase will also be faster using integrated project delivery. With all of the efforts that were put into the design, the constant meetings and the ongoing coordination most of the kinks in the project will have been worked out before construction even starts. Subcontractor familiarity with the project also relates to a decreased schedule. While the differences aren’t completely quantifiable Mr. Duke stated that he has noticed that the subs are able to complete their work in less time. They have already asked questions about many of the things they need to know and many of the potential issues have been resolved they don’t have to stop working to wait for a response to an RFI. Each subcontractor also knows what they others need to do. This allows each trade to stay out of the way of another. And because everyone is working for what is best for the project they are willing to help each other out whenever possible and don’t rip out work that is in their way if it can be avoided.

The increased coordination and design allows more items to be prefabricated than ever before. Prefab items are generally long lead items and if the design isn’t completed until right before the bid documents are sent out, contractors don’t have enough time to weigh the benefits of prefabrication, design and then order all of the pieces necessary. This is especially true for curtain all contractors. Curtain wall contracts are generally done as design-build (D/B) and aren’t awarded until after the design is completed and a CM has been selected. This leaves them with very little time to decide on the best way to implement the architects design. They have to take the information given and design the curtain wall in a constructible way, order all of the components necessary and then erect the wall all in a tight schedule. If they are on the project during the design phase they have enough time to find the best way to construct the curtain wall and have plenty of time to order any necessary components. They are also able to sit down with the architect and structural engineer and design a system that works best with the building. This is also true of mechanical contractors. They are also generally awarded on a design-build basis. If they are able to design before construction starts and are able to have their ideas represented early on they have more time to order all of the correct components and schedule things more effectively.

Another schedule reduction benefit of having everyone on board early is that all of the subcontractors are there as the schedule is being created. They are able to provide input and are able to discuss things together. Each subcontractor is going to know how quickly they can actually complete each task better than the construction manager will be. They also know how well they are able to work around the other trades and can help with the sequencing, helping things flow more fluently.

## Integrated Project Delivery for Thames St. Wharf Office Building

The Thames St. Wharf Office Building could have benefitted by being delivered with integrated project delivery. Many of the issues that occurred were a result of the design process and then unsuccessful coordination. One of the things that Marco Greenburg, the Harbor Point representative I have been in contact with, said that he would do if the project was started over again is manage the design process better. With IPD multiple parties would have been monitoring the design throughout the whole process and a large amount of the issues that plagued the project would have been caught. One of the things about the design that caused issues was having a design architect and then an architect of record. Having two different architecture firms work on different parts of the building caused a lot of conflict when the building went into construction. The first firm only designed the exterior of the building and when it came to detailing a smaller firm was responsible. Having the ideas of one person translated through a second so that a third can construct it creates a lot of communication issues. Had IPD been used one architect would have worked on the project the whole way through and communication would have been much simpler and more effective.

The design process also took multiple years to complete and was redone multiple times. One of the reasons it was redone is because after the first design was completed the owners decided to make the project a LEED project. With IPD when the preliminary budget and scope were created the owner could have seen how much money was available to make the project a LEED project and could have decided earlier. All of the rework extended the length and cost of the design and translated into no value added costs for Harbor Point. With IPD they would have been able to reduce the no value added costs and translated them into more efficient or higher quality systems in the building.

Scope was also added after the base building design and estimate were compiled. It is unknown if this scope was added because the original estimate was lower than expected or it was realized after the original design that more was needed. An estimated $6 million was added to the original project scope. With IPD that extra could have been added earlier and as the graphs above show the earlier things are added and changes are made the less they cost. This means for that same $6 million H&S and Morgan Stanley could have gotten more or they could have saved themselves money on the additions. The tenant fit out was also included as a different contract and add on. The major reason this project was started was as a new home for Morgan Stanley. Knowing this, it would have been more beneficial for the tenant design to be included as part of the original contract and design. If this had been the case then the tenant fit out may have been less expensive or of a higher quality. The reason it was added later though is unknown.

A more integrated design could have potentially lowered the costs of some of the building systems. The large glass façade on the southern portion increases the cooling loads on the building during the summer months and causes glare in the work space all throughout the year. With an integrated design multiple parties could have weighed the pros and cons of changing the system and could have designed one that is more beneficial for the building as a whole. Instead an expensive mechanical system and manually operated shades were included in the building to combat the effects of the curtain wall.

There was also a large issue with RFI's and change orders on the project. To date there are over 400 RFI's and multiple change orders. Change order data is unavailable because the owner does not want to share it with the public. All of these RFI's slowed the project down and caused a lot of issues between all of the parties on the project. People that were working on the project were dreading going to work each day because project meetings and at times the job-site in general were very hostile environments. Blame was constantly being thrown from one person to another and nothing was being accomplished. Absolutely everything on the project needed to be documented by everyone at all times to avoid litigation and fault. With IPD all of the parties involved would have been working together to complete the project instead of blaming each other and wasting time arguing. RFI's also took almost three weeks to be returned at certain times during the project. Each RFI had to go through the entire project hierarchy and get filed in everyone's system which takes time. In the case of the sheet metal contractor for an RFI to be answered it had to go through four different parties, and then back through all of those parties. This caused delays and increases the chance that an error can take place with the answer of the RFI. Using this system is a lot like a group of kids playing 'telephone'. By the time the original message gets back to the first person it has been completely distorted. With IPD, the subcontractors would have been able to contact the design firms directly to get answers to their questions. It is also likely that these questions would have been sorted out before construction even started.

Coordination and shop drawings were also an issue on TSW. Coordination was taking place while construction was ongoing. Coordination for the systems that interacted with the concrete structure was taking place the week before the floor in question was going to be poured. This caused a lot of issues with shop drawings. If there was a conflict with anything the concrete contractor had at most one week to correct their shop drawings and have them go through the project hierarchy and then get back to the people onsite before a floor was poured. This is not a reasonable amount of time and caused multiple areas. A few times the show drawings came from the concrete subcontractor on the same day that the floor in question was being poured. Then after it went through the review process certain dimensions or other issues would have to be corrected but it was too late, the structure had been poured. This is why the structure was two inches to large in certain areas. With IPD coordination would have taken place before the construction documents were even created and would have completely alleviated this issue. Shop drawings would also be easier to create because the team would have been able to use the BIM model to create the shop drawings saving a lot of time.

Finally prefabrication could have saved some time on the TSW project. The curtain wall was a stick built system that had the curtain wall contractor been given enough time they could have been built as a unitized system in some places. This would have saved time on the schedule and would have made the building water tight earlier on. The earlier the building is water tight the earlier work can begin on the interior of the building. The quicker a project can be completed, the sooner a client can move in and the owner can generate rent. Until a building is complete and has tenants the owner has to pay for all of the building costs, which increases the soft costs on the project and lengthens the owners return on investment.

## Conclusion & Recommendations

Integrated project delivery is an innovative and promising way to deliver projects in the future. It is not the perfect solution to all of the problems stemming from the current project delivery methods but it is a giant step in the right direction. Making the project as a whole more important than any particular party involved is the way it should be. The idea that one party can profit on a project that as a whole wasn't delivered successfully doesn't make sense, and IPD does away with that. Had TSW been delivered using IPD the end product may have been of a higher quality, completed sooner and the people working on the project could have had a better working experience.

Integrated project delivery hasn't been perfected yet though. Only a select few buildings have been completed using IPD around the country so IPD is still a work in progress. AIA is currently working on its third version of an IPD contract. The last revision was completed in late 2009, and is already out of date. More still has to be done to correct the uneven risk allocation between all the parties and a better job has to be done to inform building owners of the lower risk levels associated with IPD.

Additionally while IPD can benefit most projects not every owner is ready for it. To use IPD to deliver a project the owner needs to have a lot of trust. They need to trust that giving up the right to sue will result in a better project. Phil Bernstein, the VP of building industry strategy and relations for Autodesk, made the statement, "As an owner, I'm taking a leap of faith that the design and construction process will perform so much better without the threat of litigation that I'm giving up the right to sue. But for me as an owner, having been through enough projects, I knew two things: One, I take a risk [with a non-IPD project] because I ultimately have to clean up any problems anyway; and two, litigation is the least efficient way to resolve a matter. It takes forever."

Owners also can't be looking for the lowest price available. They have to be looking for the best product. If the focus is entirely on first cost then IPD is probably not the best way to deliver a product. IPD's value becomes apparent after a project has been completed. IPD also can't be used by owners that need "hard bid" contracts like government bodies or anything that gets government funding. There is no hard bid with IPD, only target cost estimates.

To gain more steam in the building industry owners are going to have to become more aware of the delivery method. Currently the idea is rapidly increasing popularity with A/E's and CM's but it much slower with owners. The market will also most likely have to improve. People are generally unwilling to take new risks when there is less money available to make those risks with. Also owners are currently of the opinion that because contractors need work that sending a project out to bid that they will be able to get exceptionally low costs for their projects. Mr. Duke stated that when the focus turns from first cost to building quality and performance IPD will become wildly popular.

It is recommended that any owner that wants a high quality building with the least amount of stress they should utilize IPD. Once IPD becomes popular the efficiency of the construction industry as a whole will improve. Hopefully IPD becomes popular sooner rather than later and becomes an option for project delivery that all owners consider when they are trying to decide how they want their project to be carried out.

# 5 Analysis II: Façade Evaluation & Redesign: MAE Study

## Background

The Thames St. Wharf Office Building has a large glass façade on the southern portion of the building that is in direct sunlight throughout the entire year (Figure 5.1). The design intent was to give the building a modern appearance while giving the building occupants a large view of the Patuxtant River from the Baltimore Inner Harbor to the Key Bridge. This downside of the curtain wall though is that the solar gain creates large cooling loads during the summer months and the direct sunlight may cause a large amount of glare inside the space making the working conditions difficult. Brandon Harwick, the mechanical engineer for the building, stated that the envelope cooling load on the building contributes 42 percent of the total cooling load. To remedy this situation the mechanical system had to be designed to effectively cool the building from the excess heat, making the system more expensive than it otherwise would have been. Additionally shading systems needed to be put in place to increase user comfort in the space. The more expensive mechanical system takes money away from other portions of the project that could be improved and the shading system defeats the purpose of giving the occupants a good view because once the shades are pulled the building occupants are not able to see outside anymore.

Figure 5.1: Rendering of the Thames St. Wharf Office Building - copyright Ayers/Saint/Gross 2008

## Goal

The goal of the façade redesign is to reduce the cooling load on the building so that there is potential to have a less expensive mechanical system. A secondary goal is to reduce the glare in the space making the space more comfortable and usable for the occupants. It is also important that the redesign keeps the architectural integrity of the building.

## Existing Curtain Wall

The existing curtain wall covers the entire southern façade and approximately 90 feet on the southern portions of both the east and west façades. The curtain wall type is YCW 750 IG by YKK AP American Inc. (Figure 5.2). It is a stick built curtain wall system with aluminum mullions and can be either inside or outside glazed. The curtain wall and all of the window sections are the same curtain wall type. The large curtain wall is outside glazed with double sided structural silicone to eliminate the vertical mullions while the windows are inside glazed. The curtain wall is broken into approximately 28' sections, each separated by a 13" insulated metal panel. There is also a 13"

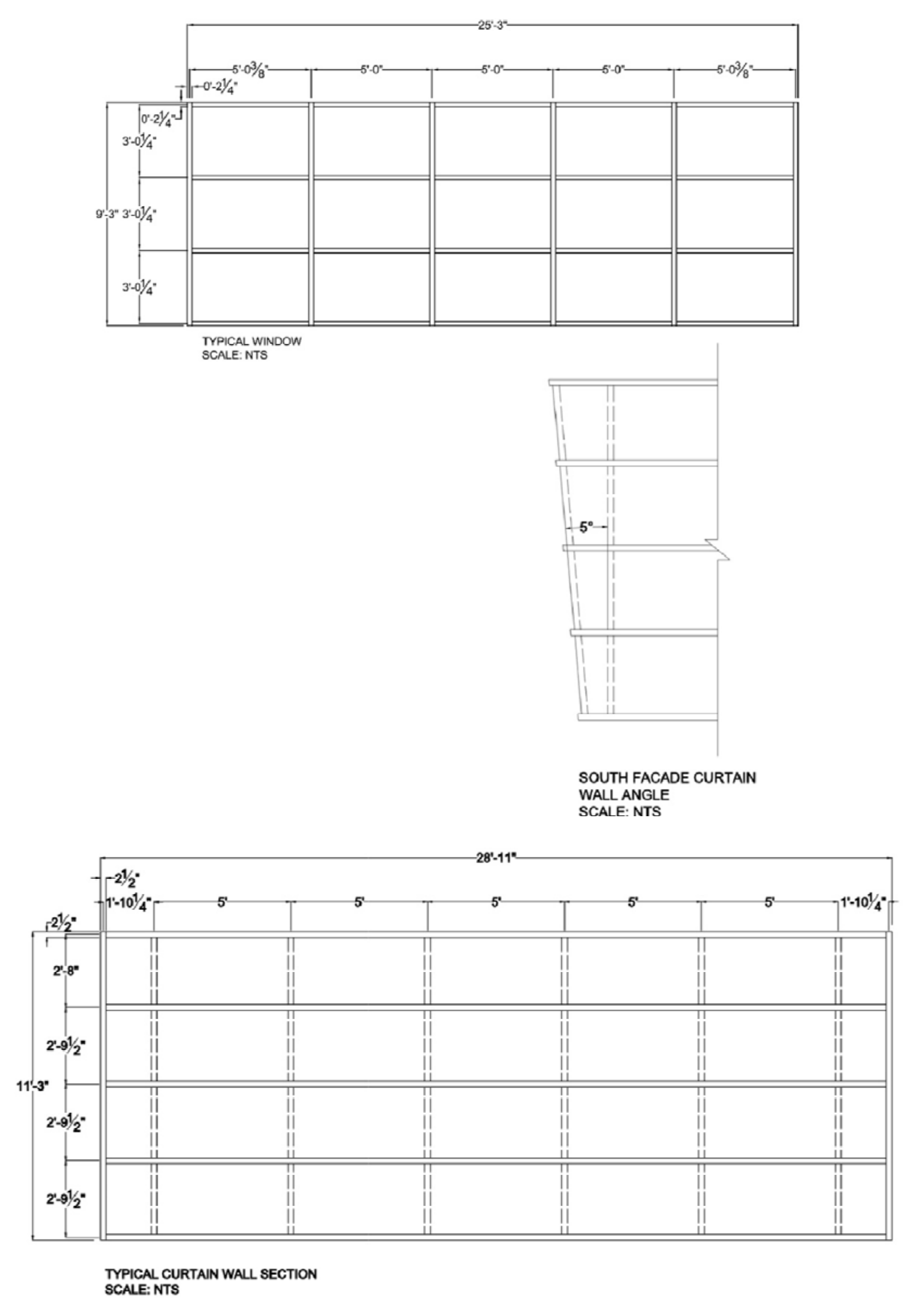
Figure 5.2: YCW 750 IG Curtain Wall - (YKK AP American Inc., 2008)

metal spandrel panel separating each floor. The ground floor and level one are vertical on all three façades, consist of larger glazing pieces and are separated by clear spandrel glass. Levels two through six consist of identical curtain wall with the southern face sloped at a five degree angle away from the building (Figure 5.3). Level seven is stepped back approximately 30 feet and opens up onto a roof level courtyard. The window sections extend from the top of the raised access floor to the underside of the next floor slab. The brick is used as a spandrel section and covers the concrete curbs that support the curtain wall and hide the under floor systems.

All of the glazing on the building is Solarban® 70XL by PPG Industries, Inc. and is either heat strengthened or tempered depending on its location. After researching different types of glazing Solarbon® 70XL proves to be one of the best IGU's on the market. The "Starphire"® tint level was chosen for the TSW project. It is the most transparent tint of 70XL with a visible light transmission of 63 percent. Please see Table 5.1 for Solarban® 70XL "Starphire"® product data. Having each floor identical after level one simplified the installation of the curtain wall. Each window section on the building was also identical, further simplifying installation. The majority of the lites in the building were also of the same size. Each section consisted of mainly 57.75" wide lites that were consistent between each section. Having standard sizes throughout the building made it easier and quicker to install because the installers did not have to stop to figure out where each piece of glazing went because they are mostly interchangeable. All of the mullions for the curtain wall are 2.5" wide and 7" deep. All of the window mullions, including the seventh floor, are all 2.25"X7". To view the curtain wall elevations please see Appendix G

**Table 5.1 – Solarban® 70XL Product Data - PPG Inudstries, Inc.**

| Solarban® 70XL (2) Starphire® | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | U-Value | | R-Value | SHGC | Glass Surface Temperature (F) | | Reflectance (%) | | Transmittance (%) | | | Shading Coefficient | Relative Heat Gain | LSG |
| | Wint. | Sum. | | | Wint. | Sum. | Vis. | Solar | Visi. | Solar | UV | | | |
| Common 1-1/2" Glass Packages | | | | | | | | | | | | | | |
| Solarban® 70XL (2) Starphire® | 0.28 | 0.26 | 3.7 | 0.27 | UNK | UNK | 12 | 52 | 64 | 25 | 6 | 0.32 | UNK | 2.37 |



5.3 - Curtain Wall Details

### Performance

Even though the glazing only lets 63 percent of the visible light through a lot of light and radiant light energy still enter the building. This is because glazing covers almost the entire usable interior space. The brick only used in spandrel locations and only covers places where the concrete structure would be visible from the exterior. The cooling load generated through the façade was calculated for the 1% design conditions as defined by ASHRAE. The exterior design temperature is 90.9 °F and the summer interior design condition is 75 °F as specified by the mechanical engineer. Vanderweil Engineers used an envelope design load of 3 W/ft$^2$ which is 10.23 Btu/hr-ft$^2$ and a design area of 48,000 ft$^2$ per floor to calculate the total façade cooling load on the building. This resulted in an envelope cooling load of approximately 491,040 Btu/hr (40.9 tons of refrigeration) per floor and occurs at 5:00 PM. To view the results of the mechanical calculations please see Appendix H. Only the results are posted due to the size and length of the calculations.

The light levels in the space are extremely high near the windows when they are in direct contact with the sun. Figure 5.4 graphs the illuminance levels across a typical floor plan on the December 21 at 5:00 PM. This date was chosen as the graph point because it is when the sun will be the lowest in the sky while the building is occupied. The maximum value is 1653 Fc, which is an extremely high value. At this point the day lighting would be too intense and glare on any computer screens would make it extremely difficult to read them. Shading would most likely have to be pulled at this level to make the space comfortable to work in. The average value is 232 Fc which is still quite a bit higher than the 30 Fc recommended for office space. This value is distorted though because of the high values near the western windows.

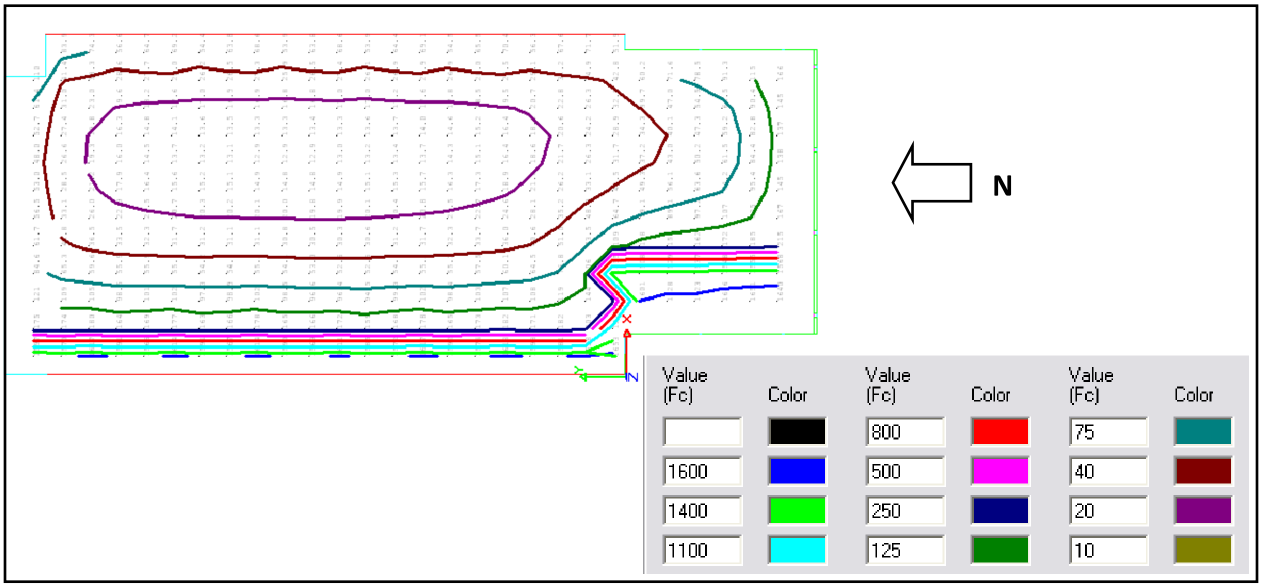


Figure 5.4: Graph of Day Lighting Illuminance Levels on a Typical Floor Plan through Current Glazing- December 21, 5:00pm

### Cost

The total cost for the curtain wall and windows was $2.79 million before overhead and profit were added for both the curtain wall subcontractor and the construction manager. The curtain wall covers 31,914 ft$^2$ of the building's façade and costs $70/ft$^2$. This brings the total value for the curtain wall to $2.23 million. The windows have a total area of 18,445 ft$^2$ and cost $30/ft$^2$ making the total cost of the windows just over $550,000. There is a total of 47,923 ft$^2$ of glazing on the entire building. The PPG Solarban® 70XL has a square foot cost of $8.50, making the total cost of the glazing used on the building $407,000. Table 5.2 shows the cost breakdown for the windows and curtain wall while table 5.3 shows the glazing cost.

**Table 5.2: Curtain Wall & Window Cost Breakdown**

| Proposed Curtain Wall | | | |
|---|---|---|---|
| | Area (SF) | Cost/SF | Cost |
| North | 2,464 | $ 70 | $ 172,480 |
| South | 10,884 | $ 70 | $ 761,880 |
| East | 8,118 | $ 70 | $ 568,260 |
| West | 10,448 | $ 70 | $ 731,360 |
| Subtotal | 31,914 | | $ 2,233,980 |
| **Proposed Windows** | | | |
| | Area (SF) | Cost/SF | Cost |
| North | 5,016 | $ 30 | $ 150,480 |
| South | 270 | $ 30 | $ 8,100 |
| East | 10,354 | $ 30 | $ 310,617 |
| West | 2,805 | $ 30 | $ 84,144 |
| Subtotal | 18,445 | | $ 553,341 |
| Total | 50,359 | | $ 2,787,321 |

**Table 5.3: Glazing Total Cost**

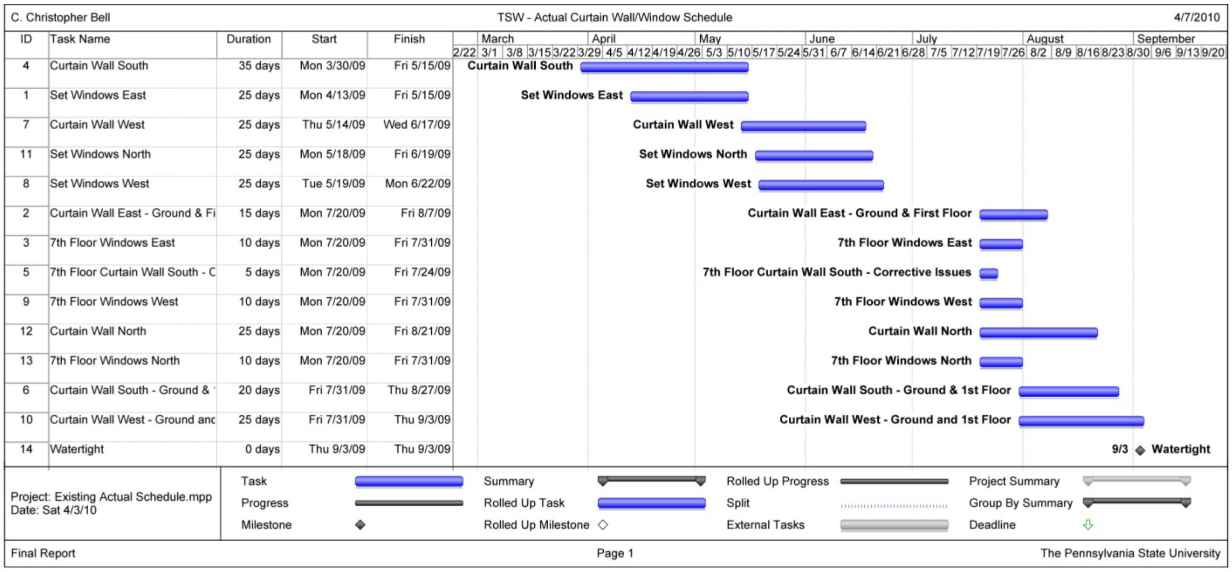
| Glazing | | | |
|---|---|---|---|
| | Area (SF) | Cost/SF | Cost |
| Glazing | 47,923 | $ 8.5 | $ 407,346 |

### Schedule

There were multiple issues on TSW that affected the projects schedule, and the curtain wall was not immune to these issues. The windows for the seventh floor and the curtain walls on the ground floor were delayed almost a month because of the issues that occurred with the concrete structure. As was discussed previously the structure was built correctly per the shop drawings but the shop drawings did not match the structural drawings exactly in all places. This caused some of the concrete curbs that supported the curtain wall on the ground & first floors and windows on the seventh to be 2" too tall. This didn't allow the curtain wall to fit in and as a result work had to be delayed on the curtain wall in those locations while the concrete had to be chipped out where the curtain wall supports needed to be placed (Figure 5.6). The beams that support the roof running north-south were also 2" to long causing a conflict with the south curtain wall the seventh floor (Figure 5.7). To correct this issue curtain wall pieces had to be trimmed around the beams. It was not possible to chip away the ends of the beams because they are post-tensioned concrete and the tendon caps were right on the edge of the beams. While the issues were being corrected curtain wall work had to stop. The delay took so long because the issues with the structure were not noticed until the curtain wall contractor arrived on-site and attempted to fit the wall in place and was unable. Before any corrections could be made the issue had to go through the lengthy RFI process that was previously discussed as well further delaying any action. Because of the delays six activities all started on the same day to make up for the time lost due to the delay. Fortunately the curtain wall was not on the critical path and the increased man power prevented the delay from causing the entire project to be delayed. Figure 5.8 is a representation of the curtain wall schedule the way it actually occurred, and Figure 5.9 is a theoretical depiction of the schedule had no delays taken place. The work is spaced more evenly to reduce the amount of man power and materials that was needed on-site at any given time. This would reduce site congestion and allow all of the trades to work faster and easier.

**Figure 5.5: Chipped Concrete Curtain Wall Support Curb**

**Figure 5.6: 7th Floor PT Beams/Curtain Wall Conflict**



C. Christopher Bell — TSW - Actual Curtain Wall/Window Schedule — 4/7/2010

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 4 | Curtain Wall South | 35 days | Mon 3/30/09 | Fri 5/15/09 |
| 1 | Set Windows East | 25 days | Mon 4/13/09 | Fri 5/15/09 |
| 7 | Curtain Wall West | 25 days | Thu 5/14/09 | Wed 6/17/09 |
| 11 | Set Windows North | 25 days | Mon 5/18/09 | Fri 6/19/09 |
| 8 | Set Windows West | 25 days | Tue 5/19/09 | Mon 6/22/09 |
| 2 | Curtain Wall East - Ground & Fi | 15 days | Mon 7/20/09 | Fri 8/7/09 |
| 3 | 7th Floor Windows East | 10 days | Mon 7/20/09 | Fri 7/31/09 |
| 5 | 7th Floor Curtain Wall South - C | 5 days | Mon 7/20/09 | Fri 7/24/09 |
| 9 | 7th Floor Windows West | 10 days | Mon 7/20/09 | Fri 7/31/09 |
| 12 | Curtain Wall North | 25 days | Mon 7/20/09 | Fri 8/21/09 |
| 13 | 7th Floor Windows North | 10 days | Mon 7/20/09 | Fri 7/31/09 |
| 6 | Curtain Wall South - Ground & | 20 days | Fri 7/31/09 | Thu 8/27/09 |
| 10 | Curtain Wall West - Ground anc | 25 days | Fri 7/31/09 | Thu 9/3/09 |
| 14 | Watertight | 0 days | Thu 9/3/09 | Thu 9/3/09 |

Project: Existing Actual Schedule.mpp
Date: Sat 4/3/10

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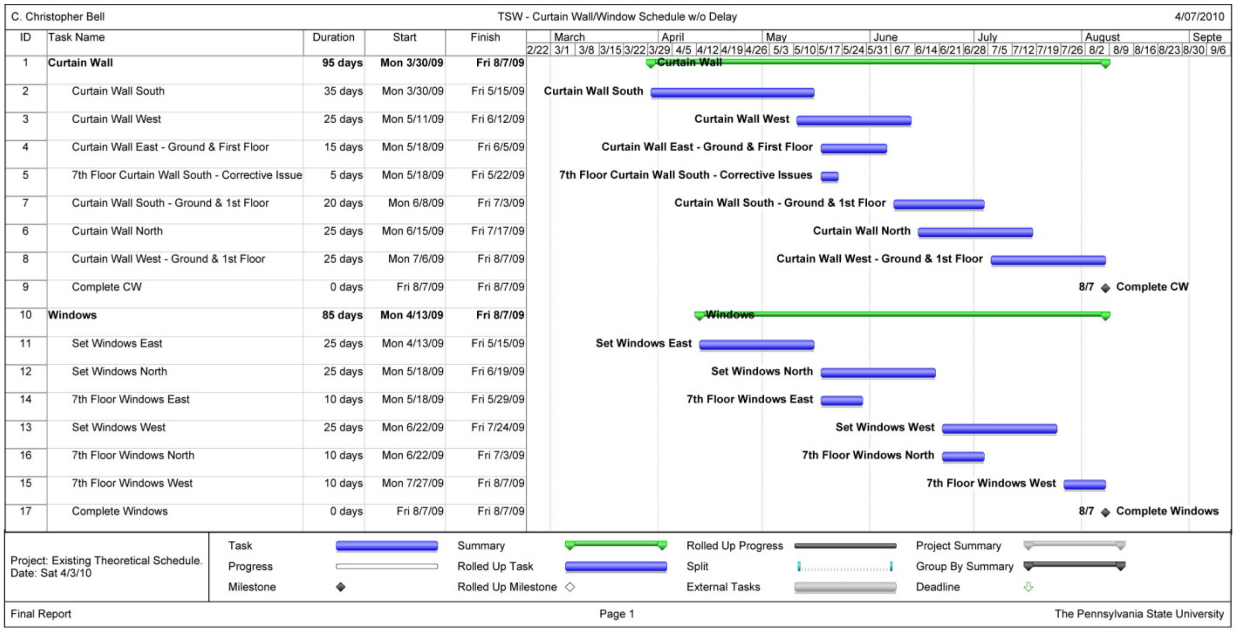
Figure 5.7: Curtain Wall Schedule - Actual



C. Christopher Bell — TSW - Curtain Wall/Window Schedule w/o Delay — 4/07/2010

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | **Curtain Wall** | **95 days** | **Mon 3/30/09** | **Fri 8/7/09** |
| 2 | Curtain Wall South | 35 days | Mon 3/30/09 | Fri 5/15/09 |
| 3 | Curtain Wall West | 25 days | Mon 5/11/09 | Fri 6/12/09 |
| 4 | Curtain Wall East - Ground & First Floor | 15 days | Mon 5/18/09 | Fri 6/5/09 |
| 5 | 7th Floor Curtain Wall South - Corrective Issue | 5 days | Mon 5/18/09 | Fri 5/22/09 |
| 7 | Curtain Wall South - Ground & 1st Floor | 20 days | Mon 6/8/09 | Fri 7/3/09 |
| 6 | Curtain Wall North | 25 days | Mon 6/15/09 | Fri 7/17/09 |
| 8 | Curtain Wall West - Ground & 1st Floor | 25 days | Mon 7/6/09 | Fri 8/7/09 |
| 9 | Complete CW | 0 days | Fri 8/7/09 | Fri 8/7/09 |
| 10 | **Windows** | **85 days** | **Mon 4/13/09** | **Fri 8/7/09** |
| 11 | Set Windows East | 25 days | Mon 4/13/09 | Fri 5/15/09 |
| 12 | Set Windows North | 25 days | Mon 5/18/09 | Fri 6/19/09 |
| 14 | 7th Floor Windows East | 10 days | Mon 5/18/09 | Fri 5/29/09 |
| 13 | Set Windows West | 25 days | Mon 6/22/09 | Fri 7/24/09 |
| 16 | 7th Floor Windows North | 10 days | Mon 6/22/09 | Fri 7/3/09 |
| 15 | 7th Floor Windows West | 10 days | Mon 7/27/09 | Fri 8/7/09 |
| 17 | Complete Windows | 0 days | Fri 8/7/09 | Fri 8/7/09 |

Project: Existing Theoretical Schedule.
Date: Sat 4/3/10

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Figure 5.8: Curtain Wall Schedule without Delays

## Proposed Curtain Wall

Multiple different options were proposed at the beginning of the analysis but were then removed for various reasons. The first proposal was to change the southern curtain wall from all glazing to brick a brick and glazing combination like the rest of the building. After an initial study of this option it was determined that hand laid brick cannot be supported at a five degree angle which it would need to be on the southern face of the building.

The second proposed option was to use precast panels in place of hand laid brick for the redesign but this also presented constructability challenges. First being that the angle of the southern face made it extremely difficult to place the panels. A crane from the side of the building would not be able to freely swing the lower panels into place without having the cables hit the building structure above. Precast panels are also extremely heavy so finding a way to swing them into place from the interior of the building would have been extremely difficult. The water below the southern façade also posed issues for this idea. It removed the possibility of hoisting the panels into position from below.

The third option considered was to combine either insulated metal panels or insulating opaque glazing with transparent glazing. Opaque glazing was decided to be a more viable option than insulated metal panels because the glazing could fit into the current curtain wall. If metal panels had been selected the aesthetic of the curtain wall would change and may cause it to look 'tacky' and not fitting for the world headquarters of a large financial firm. Using metal panels would also create more transitions in the wall system which would increase the chance of an error being made during installation decreasing the performance of the system. After studying the thermal performance of the opaque and clear glazing combination system it was determined that the performance enhancements weren't high enough. The cooling load was only dropped by about half of a ton per floor and it only had an effect on the southern half of the building. The majority of the building façade remained the same and therefore the cooling load in most of the building was unaffected. It also did nothing to stop the glare in the spaces. The southern façade was still mostly transparent glazing and allowed a lot of light in that would negatively affect the work space.

The fourth and final option that was considered after talking with Mr. Harwick of Vanderweil Engineers was to change all of the glazing in the building to one that had a lower shading coefficient. This allows the curtain wall itself to remain the YCW 750 IG so the aesthetic of the building remains mostly unchanged. The only difference aesthetically will be that less light passes through the windows making them appear slightly darker from the outside. After reviewing the different glazing options available, SeriousGlass SG 8 57/24-150 from Serious Materials was chosen. All of the values for the SG 8 are listed in Table 5.4. As can be seen all of the values for the RG 8 are lower than the PPG Solarban® 70XL that was used on the original curtain wall.

**Table 5.4 - SeriousGlass SG 8 51/24-150 data sheet - http://www.seriouswindows.com/Serious_Glass_Brochure.pdf**

| SeriousGlass SG 8 51/24-150 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Product | U-Value | | R-Value | SHGC | Glass Surface Temperature (F) | | Reflectance (%) | | | Transmittance (%) | | | Shading Coefficient | Relative Heat Gain | LSG |
| | Wint. | Sum. | | | Wint. | Sum. | Vis-Out | Vis-In | Solar | Vis. | Solar | UV | | | |
| Common 1-1/2" Glass Packages | | | | | | | | | | | | | | | |
| SG 8 51/24-150 | 0.13 | 0.13 | 7.7 | 0.24 | 62 | 82.3 | 13 | 16 | 37 | 57 | 22 | <1 | 0.28 | 57.4 | 2.36 |

### Performance

The new façade cooling load on the building was calculated to be 491,520 Btu/hr (30.14 tons of refrigeration) per floor and occurs at 5:00 pm. This is a savings of approximately 129,851 Btu/hr (10.82 tons of refrigeration) per floor. To view the mechanical calculations please see Appendix H.

To calculate the difference in the cooling load between the two curtain wall systems the cooling load was hand calculated for both the original and proposed systems and compared to the actual cooling load calculated by Vanderweil. The original envelope load was calculated to ensure that the proposed envelope calculations could be accurately compared to the actual load. Errors occurred in the hand calculations for the original curtain wall and therefore the same errors were carried through when calculating the proposed curtain wall load. To remedy this and ensure and accurate comparison of the values, the percent difference was taken between the original and proposed façade cooling loads. Then the known façade load that was calculated by Vanderweil was multiplied by the percent difference between the two calculated values. This resulted in a final Btu/hr difference between the current and proposed façades that relates to the actual values (Table 5.5). The errors most likely derived from inexperience with complicated mechanical calculations which led to important mechanical load data being omitted.

**Table 5.5: Facade Cooling Load Differences - Original vs. Proposed**

| Façade Cooling Load Differences | | | | | | |
|---|---|---|---|---|---|---|
| | Original Enclosure Load - Actual | Original Envelope Load - Calculated | Proposed Enclosure Load - Calculated | % Reduction | Load Difference Original-Actual vs. % Difference | Adjusted Proposed Façade Load |
| Btu/hr | 491,520 | 31,622 | 23,268 | 26% | 129,851 | 361,669 |
| Tons | 40.96 | 2.64 | 1.94 | 26% | 10.82 | 30.14 |

The proposed glazing has a lower transmittance than the current and only lets 57% of the visible light through as opposed the 63% that the current glazing allows. A visible transmittance of 0.57 still allows enough light pass through that there isn't a noticeable tint to the window. If the glazing's transmittance value is too low it makes the building occupants feel like the weather is always overcast. This can have an adverse effect on the moral and productivity of the people inside. It can make people feel the effects of seasonal depression even though they are getting a lot of day light and it is sunny outside.

Figure 5.10 graphs the luminance levels on a typical floor plan on December 21 at 5:00pm with the proposed glazing. The maximum is 1509 Fc which is down from 1653 Fc for the original glazing. The average for the proposed glazing is 211.61 Fc which is also lower than the average for the original glazing. The shades will still probably need to be pulled down to block the direct sunlight from affecting the work space.

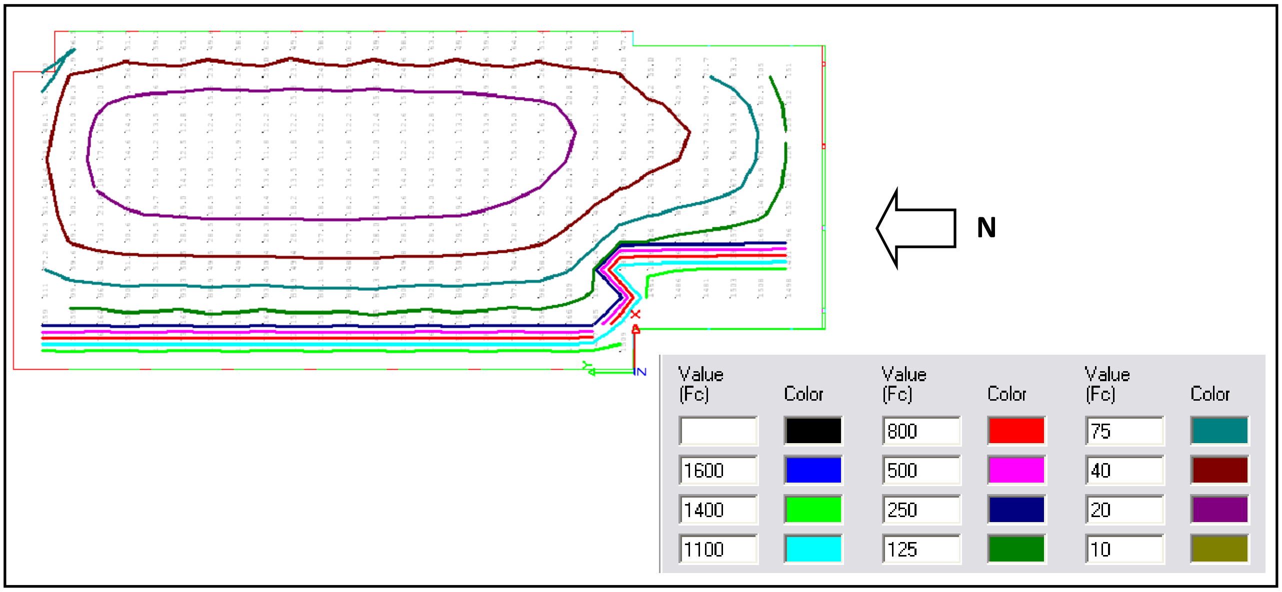

**Figure 5.9: Graph of Day Lighting Luminance Levels on a Typical Floor Plan through Proposed Glazing- December 21, 5:00pm**

### Cost*

*All costs associated with SeriousGlass products are based off a rough estimate conducted by a SeriousGlass dealer over the phone and therefore aren't exact and are not binding SF costs.

The higher performing SG 8 costs \$10/ft$^2$ compared to the Solarbon® 70XL cost of \$8.50/ft$^2$, which increases the cost of the entire system. The change increases the cost of the system \$72,000 bringing the total from \$2.79 million to \$2.86 million. This makes the total contract value for the curtain wall and windows \$4.69 million up from \$4.57 million, an increase of \$118,000. The curtain wall cost becomes \$71.43/ft$^2$ and the window cost becomes \$31.43/ft$^2$ bringing their costs to \$2.3 million and \$580,000 respectively. Table 5.6 shows the cost breakdown for the proposed changes and table 5.8 shows the cost comparisons between the two systems. Unfortunately the energy efficiency of the mechanical system and energy consumption values for the building were not made available so a dollar savings on the cooling load reduction could not be calculated. Additionally because those values could not be calculated the payback period for the proposed changes could not be calculated either. It is expected that the payback period will be relatively short due the small increase in cost versus rising utility costs.

Table 5.6: Proposed Curtain & Window Cost Breakdown

| Proposed Curtain Wall | | | |
|---|---|---|---|
| | Area (SF) | Cost/SF | Cost |
| North | 2,464 | $ 71.43 | $ 175,997 |
| South | 10,884 | $ 71.43 | $ 777,416 |
| East | 8,118 | $ 71.43 | $ 579,848 |
| West | 10,448 | $ 71.43 | $ 746,274 |
| Subtotal | 31,914 | | $ 2,279,536 |
| **Propsed Windows** | | | |
| | Area (SF) | Cost/SF | Cost |
| North | 5,016 | $ 31.43 | $ 157,640 |
| South | 270 | $ 31.43 | $ 8,485 |
| East | 10,354 | $ 31.43 | $ 325,396 |
| West | 2,805 | $ 31.43 | $ 88,148 |
| Subtotal | 18,445 | | $ 579,670 |
| Total | 50,359 | | $ 2,859,205 |

Table 5.7: Proposed Glazing Total Cost

| Proposed Glazing | | | |
|---|---|---|---|
| | Area (SF) | Cost/SF | Cost |
| Glazing | 47,923 | $ 10.0 | $ 479,230 |

Table 5.8: Comparison of Original Costs vs. Proposed Costs

| Cost Comparison | | | | | | |
|---|---|---|---|---|---|---|
| | Original Cost/SF | Original Total | Proposed Cost/SF | Proposed Total | Difference | % Addition |
| Glazing | $ 8.50 | $ 407,346 | $ 10 | $ 479,230 | $ 71,885 | 15.0% |
| Curtain Wall | $ 70 | $ 2,233,980 | $ 70.00 | $ 2,279,536 | $ 45,556 | 2.0% |
| Windows | $ 30 | $ 553,341 | $ 30.00 | $ 579,670 | $ 26,329 | 4.5% |
| Subtotal | | $ 2,787,321 | | **$ 2,859,205** | **$ 71,885** | **2.5%** |
| Total System Cost Including O&P | | $ 4,315,917 | | **$ 4,427,223** | **$ 111,306** | **2.5%** |
| Total Construction Contract Value | | $ 54,321,902 | | **$ 54,441,133** | **$ 119,231** | **0.22%** |

### Schedule

The curtain wall itself remains the same and only the glazing was changed. Due to this the schedule for the curtain wall remains unchanged. Installation procedures for the SG 8 glazing are the same as they are for the Solarban® 70XL. The windows will be glazed from the interior just like the current glazing and therefore will not take any longer to install. Lighting levels in the space were also decreased from an average of

## Conclusions & Recommendations

Though the current building enclosure is relatively high performing it does not perform as well as the proposed system. Changing the glazing from the Solarbon® 70XL to the SeriousGlass SG 8 increases the curtain walls performance by 26% while only increasing the cost of the system by 2.5% and the cost of the total project by 0.22%. Unfortunately the energy consumption data for TSW was not available for this study so the payback period for the change in glazing could not be calculated. Changing the system did not increase the schedule at all as was originally expected when the idea of changing the building façade was considered. Changing the glazing also decreased the lighting levels in the space from 232 Fc to 212 Fc, making the space more comfortable for the building occupants.

Based on this analysis SeriousGlass SG 8 51/24-150 is the recommended glazing type. The cost increase is miniscule compared to the total cost of the project and justifiable expense for the improved performance benefits.

## MAE Analysis

The integrated BAE/MAE requirement for the senior capstone project was met by utilizing key concepts learned in two graduate level courses to conduct the second analysis; *Façade Evaluation & Redesign.*

**AE 597D: Sustainable Building Methods** was a course with a focus on sustainable design techniques and materials. The major topics that were discussed during this course and implemented in this analysis are the effects of building orientation and the benefits of different façade systems. Research conducted during this course led to improved knowledge of different research techniques for finding sustainable building systems. All of the above mentioned topics were instrumental in the study and subsequent redesign of the curtain wall for the Thames St. Wharf Office Building.

**AE 542: Building Science Enclosure and Design** was the second graduate level course that contributed to this analysis. It was a course on all aspects of building enclosures including different façade types, load calculations, constructability and lighting issues. The main concepts from this course that were utilized in the evaluation and redesign of the façade were the load calculations and constructability issues.

## Analysis III: Mechanical System Redesign*

### *Note Regarding Analysis

The information needed to conduct this analysis was not obtained until late in the overall process of compiling this report and therefore a complete examination of the subject matter proposed within was not possible. Therefore the work within is not fully completed and is only preliminary. Some cost data for this analysis was never successfully obtained and therefore the cost data section is not complete.

When this analysis was proposed the details of the Morgan Stanley tenant fit-out were unavailable and therefore were not incorporated into the decision for this proposal. The information on the tenant fit out did not become available until very late in the overall process. This did not leave enough time complete as thorough and examination as was desired. Prior to receiving the information about the tenant fit out it was assumed that the majority of the cooling load was through the façade but after talking with the mechanical engineer and mechanical subcontractor it became apparent that this was not the case. Morgan Stanley has such high requirements and redundant systems like a data center because this building is a scaled down version of a data center. It houses secure information in large servers throughout the building that need to be on and connected with the New York Stock Exchange (NYSE) and Morgan Stanley branch offices around the world at all times. If the building were to lose power at any time during the day there is the potential that millions of dollars could be lost. Morgan Stanley was also given an option to lease the rest of the space in TSW so the owners decided to provide the same mechanical system throughout the entire building incase Morgan Stanley exercised the option.

### Background

The current mechanical system is the most expensive line item on the project. The total cost of the system is approximately $10.2 million dollars which is almost 20 percent of the total $54.3 million building cost. This is closer to the cost of a mechanical system for a data center and not an office building. The system consists (16) Mammoth custom order self contained air handling units (SCU), with two located on each floor. There are two (2) 36 ton SCU's and (14) 50 ton SCU's. These SCU's are exceptionally energy efficient and help the building reach its goal of 17.5% energy efficiency gaining four LEED points. All of the ductwork for the system is run under the raised access floor. The air is then pumped through under floor ductwork into empty space under the floor where it is then flows into the occupied spaces. This system offers a lot of controllability for the building occupants but comes at an expensive price tag. There are multiple sensors and controls in the system that contribute to the high price tag. The system also has two energy recovery units, three VAV air handling units, three cooling towers and three heat exchangers along with multiple pumps and VAV boxes. Only the SCU's are the focus of this analysis.

### Goal

The goal behind redesigning the mechanical system is to keep the performance and controllability goals of the owner and design team while reducing the cost. By using the performance improvements from the redesigned curtain wall in Analysis II it is hoped that enough money can be saved on the reduction of the mechanical system to justify any extra expense on the curtain wall. A secondary goal of this analysis is to discover if decreasing the size of the HVAC system will decrease the installation cost and schedule.

## Current Mechanical System

### Loads

The façade load on the building only consisted of approximately 42 percent of the total cooling load on the building. The other 58% comes from the equipment in the building, the building occupants and the lighting. Morgan Stanley had a design requirement of 3.5 W/ft$^2$ (11.9 Btu/hr-ft$^2$-°F) which according to Brandon Harwick is about double the wattage/ft$^2$ that Vanderweil generally uses for office buildings. The reason the equipment load is so high is because MS has servers in the building that communicate constantly with the stock exchange in New York and therefore are always on and generating heat. This was unknown when the original proposal to reduce the cooling load in the building by changing the façade was considered and is the reason that a data center style mechanical system was specked for the building. The mechanical engineers also used a design load of 1 W/ft$^2$ (3.41 Btu/hr-ft$^2$-°F) per person and 2 W/ft$^2$ (6.82 Btu/hr-ft$^2$-°F) for the lighting. The design area was 34,000 ft$^2$. When multiplied by the cooling load factors (CLF) for each respective load type found in the Heating and Cooling of Buildings CD-Rom the non-façade cooling load is 667,814 Btu/hr (55.7 tons of refrigeration) per floor and occurs at 5:00 PM. When the non-façade cooling loads are added with the cooling loads from the façade over a 24 hour period the design load becomes 1,158,854 Btu/hr (96.6 tons of refrigeration) per floor and occurs at 5:00PM. This became the design parameter when sizing the mechanical system. The system was also sized with a value of 1.4 CFM/ft$^2$, which makes the total CFM per floor 47,600 CFM.

To incorporate the two SCU's per floor the design loads need to be halved making the design load for each SCU is 579,427 Btu/hr (48.3 tons of refrigeration) and 23,300 CFM which was rounded to 24,000 CFM. To make installation and ordering of the system cheaper the same unit was specked for each floor. This meant that the ductwork for each floor was identical as well, and all the mechanical subcontractor had to do differently between the floors was adjust the CFM output on each unit to meet the requirements in each space. The load on each floor is not split evenly across the entire floor plan and is higher in the southern portion than the northern portion due to the southern façade. To make it so the same SCU could be specked in all locations the southern SCU covers less area than the northern one. The split between the SCU's is 19,000 ft$^2$ for the northern SCU and 15,000 ft$^2$ for the southern SCU. To view the non-enclosure mechanical loads please see Appendix I.

**Table 5.9: TSW Cooling Load Summary**

| Cooling Load Summary | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Occupants | Lighting | Equipment | Total Non-Envelope | Envelope | Total | Total per SCU |
| Btu/hr | 103,187 | 199,417 | 365,211 | 667,815 | 491,040 | 1,158,855 | 579,427 |
| Tons Cooling | 8.6 | 16.6 | 30.4 | 55.7 | 40.9 | 96.6 | 48.3 |
| % of Total | 9% | 17% | 32% | 58% | 42% | | |

### Cost

The total cost of the mechanical system was just under $10.19 million. This price includes all of the necessary equipment and installation as well as subcontractor O&P. Based off of values from RS Means a mark-up of 30% for the mechanical subcontractor is assumed. After factoring out the fees the unit cost for the system becomes $7.84 million. The total cost of all the SCU's was just over $1.37 million before mark-up. With a total tonnage of 772 tons this equates to $1777.29/ton of SCU. After subtracting the SCU's from the total cost the rest of the system costs approximately $6.47 million. The cost and spec information for all of the equipment except the SCU's wasn't made available and is therefore out of the scope of this analysis. Labor costs for the under floor system were also unavailable for proprietary reasons and RS Means does not have values for under floor ductwork. After speaking with the mechanical engineer and the project manager for the mechanical subcontractor labor costs for this project were high.

Table 5.10: TSW Mechanical System Cost Breakdown

| Mechanical System Cost Breakdown | |
|---|---|
| Total Cost | $ 10,194,691 |
| Mechanical Sub O&P (30%) | $ 2,352,621 |
| Subtotal (Unit Cost) | $ 7,842,070 |
| SCU Cost | $ 1,372,069 |
| Unit Cost w/o SCU's | $ 6,470,001 |

### Schedule

The total schedule for the mechanical system took 171 days. It began 5/25/2009 and was completed 1/14/2010. To view the mechanical schedule please see Appendix J. The general sequence was to first layout the ductwork, place it, place the mechanical equipment and then hook up all the equipment. This sequence began with level 4 and progressed through level 7 then after level 7 it went to the ground level through level 3. It started on level 4 because that is where the tenant fit-out began so the ductwork needed to be placed so that the access floor could be installed and the rest of so the rest of the floor could progress. Had the mechanical system been started from the ground floor the entire project schedule would have been extended due to the extra time needed for the tenant fit-out on the fourth-seventh levels. For the building core the sequence was: install MEP riser, place SCU's and then rough-in the bathroom duct. The MEP riser started on the ground level and then progressed sequentially through level 7, while placing the SCU's and roughing-in the bathroom duct started on level 1 and progressed through 7 with the ground floor units being placed in the middle.

## Proposed Mechanical System

### Load

The same non-façade loads that were used to calculate the original cooling load were used for this calculation as well. The number of occupants and equipment load in the space are values that are required by ASHRAE and the building owner respectively. The only non-façade load that could potentially change is the lighting load. More lighting may need to be added to the space to counteract the reduction in natural lighting entering the space but ass was stated previously the lumen levels throughout the floor remained above the 30 foot candles needed for office lighting so any increase in lighting in the space was determined to be negligible for this study. The lighting load does have the potential to be decreased by occupancy sensors and automatic solar shading but that beyond the scope of this analysis and is therefore not taken into consideration. The only change in the cooling load comes from the reduction of the envelope load. When the proposed façade load is added to the non-enclosure loads the total load becomes 1,029,484 Btu/hr (85.79 tons of refrigeration). This is an 11% reduction from the original design load. The total CFM for the system remained the same because the air change requirements remained the same.

Table 5.11: TSW Proposed Cooling Summary

| Proposed Cooling Load Summary per Floor | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Occupants | Lighting | Equipment | Total Non-Envelope | Envelope | Total | Total per SCU |
| Btu/hr | 103,187 | 199,417 | 365,211 | 667,815 | 361,669 | 1,029,484 | 514,742 |
| Tons Cooling | 8.60 | 16.62 | 30.43 | 55.65 | 30.14 | 85.79 | 42.90 |
| % of Total | 10% | 19% | 35% | 65% | 35% | 100% | 50% |

Table 5.12: Cooling Load Comparison - Original vs. Proposed

| Cooling Load Comparison Original vs. Proposed | | | | | |
|---|---|---|---|---|---|
| | Original Cooling Load | Proposed Cooling Load | Total Savings per Floor | Savings per SCU | % Reduction |
| Btu/hr | 1,158,855 | 1,029,484 | 129,371 | 64,685.50 | 11% |
| Tons Cool | 96.57 | 85.79 | 10.78 | 5.39 | 11% |

### Cost

After learning about the extensive mechanical requirements for the project it was determined that using a typical VAV system would not be practical. For this reason it was decided to use the same Mammoth units currently specified for the project. After speaking with the mechanical engineer he said that it that multiplying the new tonnage per SCU by the unit cost of $1777.29 per ton would provide and accurate cost estimate. For the (14) identical SCU's on levels 1-7 the cost per SCU is $76,423 and for the two smaller SCU's on the ground floor the cost is $56,873. This makes the total cost of the proposed SCU's $1.18 million. This is a reduction from the original cost of almost 14%.

Table 5.13: Proposed SCU Cost vs. Original SCU Cost

| SCU Cost Breakdown | | | | | | | |
|---|---|---|---|---|---|---|---|
| SCU # | Original Size (Tons) | Proposed Size (Tons) | Cost/Ton | Original Cost | Proposed Cost | Difference | % Difference |
| 0.1 | 36 | 32 | $ 1,777.29 | $ 63,982 | $ 56,873 | $ 7,109 | 11% |
| 0.2 | 36 | 32 | $ 1,777.29 | $ 63,982 | $ 56,873 | $ 7,109 | 11% |
| 1.1 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 1.2 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 2.1 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 2.2 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 3.1 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 3.1 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 4.1 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 4.2 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 5.1 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 5.2 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 6.1 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 6.2 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 7.1 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| 7.2 | 50 | 43 | $ 1,777.29 | $ 88,865 | $ 76,423 | $ 12,441 | 14% |
| Total | 772 | 666 | | $ 1,372,068 | $ 1,183,675 | $ 188,393 | 13.7% |

When savings from the reduction of SCU's is added to the together with the rest of the system and subcontractor overhead and profit are taken into account the total system cost is $9.95 million. This is a savings of approximately $245,000 which is 2.4% of the original mechanical system cost. This contributes to a 0.26% savings on the total building cost after the increased curtain wall cost is factored in.

**Table 5.14: Proposed Mechanical System Cost Breakdown**

| Proposed Mechanical System Cost | |
|---|---|
| System Unit Cost w/o SCU's | $ 6,470,001 |
| Proposed SCU Cost | $ 1,183,675 |
| Subtotal | $ 7,653,676 |
| Mechanical Sub O&P | $ 2,296,103 |
| Total Proposed Cost | $ 9,949,779 |
| Original Cost | $ 10,194,691 |
| Savings | $ 244,912 |
| Percent Savings | 2.4% |
| Proposed Total Building Cost* (Including CM O&P) | $ 54,178,783 |
| Original Building Total (Including CM O&P) | $ 54,321,902 |
| Total Savings | $ 143,119 |
| Total Percent Savings | 0.26% |

*Includes adjusted curtain wall cost from the previous analysis

### Schedule

The schedule for the proposed mechanical system remains the same as the one for the original system. The reduction of the SCU's did not lead to a reduction in duct size for the space so the durations for duct layout and installation remain unchanged. After speaking with the mechanical subcontractor it will take the same amount of time to install the smaller SCU's as it does for the larger ones, the only difference is that smaller SCU's will be slightly easier to get into place.

### Additional Proposals

To further reduce the total cost of the mechanical system additional options were considered. One option considered was to consolidate the two SCU per floor system into a one SCU per floor system. This would reduce the amount of time needed to set, install, test and balance the system. It would also create more leasable floor space because only one mechanical room per floor would be needed. The more leasable space per floor the more the owner could charge for rent increasing the project's profit margins.

After examining this options it was determined that using only one unit would decrease the overall controllability in each of the spaces throughout the building. The temperature gradients between the north and south portions of the building create varied cooling requirements throughout the day. Additionally the air speed in the ducts would also need to be increased at the unit to properly pump conditioned air throughout the entire floor. This has the potential of creating unwanted noise in the space and would require more insulation or other sound attenuating materials to absorb the noise. Increasing the insulation would increase the cost of the ductwork and length of time needed to install it. The additional ductwork needed to carry the conditioned air throughout the space would also most likely increase the duration for ductwork layout and installation. Finally using a single unit would increase the duct size around the unit. The ductwork can only be a maximum of 22" tall to fit under the raised access floor that is 24" off the concrete slab. This means that the ductwork would have to get wider and would cause conflicts with the other systems that need to run under the floor.

A second option that was examined was switching from an under floor system to a more traditional over head system. Overhead ductwork is generally quicker to install because the sheet metal contractors are more familiar with it. Under floor systems are still relatively rare outside of data centers and therefore a large portion of sheet metal contractors do not have a lot of experience installing them. Under floor ductwork causes issues while it is being installed because before the access floor is installed the ductwork is exposed and is an obstruction as workers try and work around it. When the ducts are overhead workers can move around more freely increasing the speed of installation. Quicker installation would save on labor costs as well as free space throughout the building for other trades. The mechanical system is also on the critical path for the project so decreasing the total mechanical schedule creates potential to decrease the total project schedule saving on general conditions costs.

Moving the ductwork into the ceiling has various drawbacks though. Loss of individual controllability can be issue with overhead systems because occupants aren't able to reach vents and diffusers to manually open or close them. With access floors the diffusers and vents are in the floor and are therefore easily accessible and can be opened or closed by anyone. The structure of this particular building also creates issues for overhead ductwork. The large PT beams make it difficult to efficiently run ductwork throughout the building. The ducts would have to bend under the beams which would increase the friction losses in the system. To remedy this, the velocity of the air being pumped would have to increase and as discussed before this could create noise issues. Finally to move the ductwork overhead either the access floor would need to be removed or the floor to ceiling height would need to be decreased to accommodate the ductwork as it passed under the beams. If the access floor was removed, which is the most logical option for both cost and architectural reasons, all of the systems under the floor would also need to be placed overhead creating possible coordination issues.

## Conclusions & Recommendations

The original mechanical system in this building is very advanced and well designed and all of the parties involved with it did a very good job with the constraints that were placed on them. There was no noticeable way to improve the system that was in place and that is why the same system was used for the proposed system. Using the improved performance benefits generated by replacing the glazing in the previous analysis though the overall cost of the mechanical system was able to be reduced by $244,912. After including the increased cost associated with the new glazing the total contract value is still decreased by $143,118 which immediately justifies changing the glazing. The first cost of this mechanical system was able to be reduced without sacrificing any of the controllability or comfort requirements of the building owners.

Based on this analysis it is recommended to reduce the size of the mechanical system if the curtain wall and window glazing is changed. If the glazing is not changed than the load does not change and to reduce the mechanical systems cost a different system will need to be designed.

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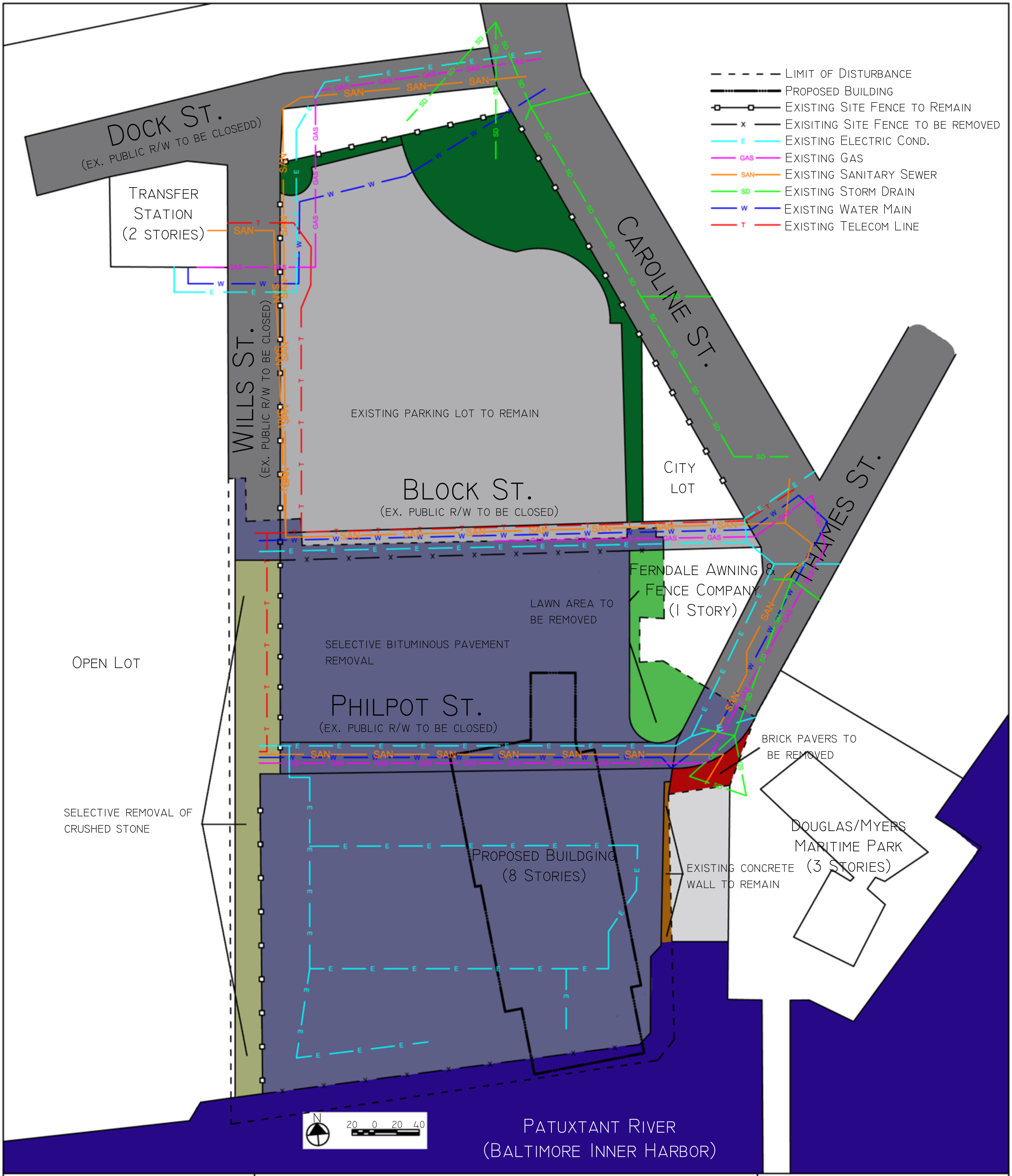
# Appendix A: Site Plan of Existing Conditions

| Chris Bell | Thames St. Wharf Office Building<br>Baltimore, MD | Satelite Image of Site plan |
|---|---|---|

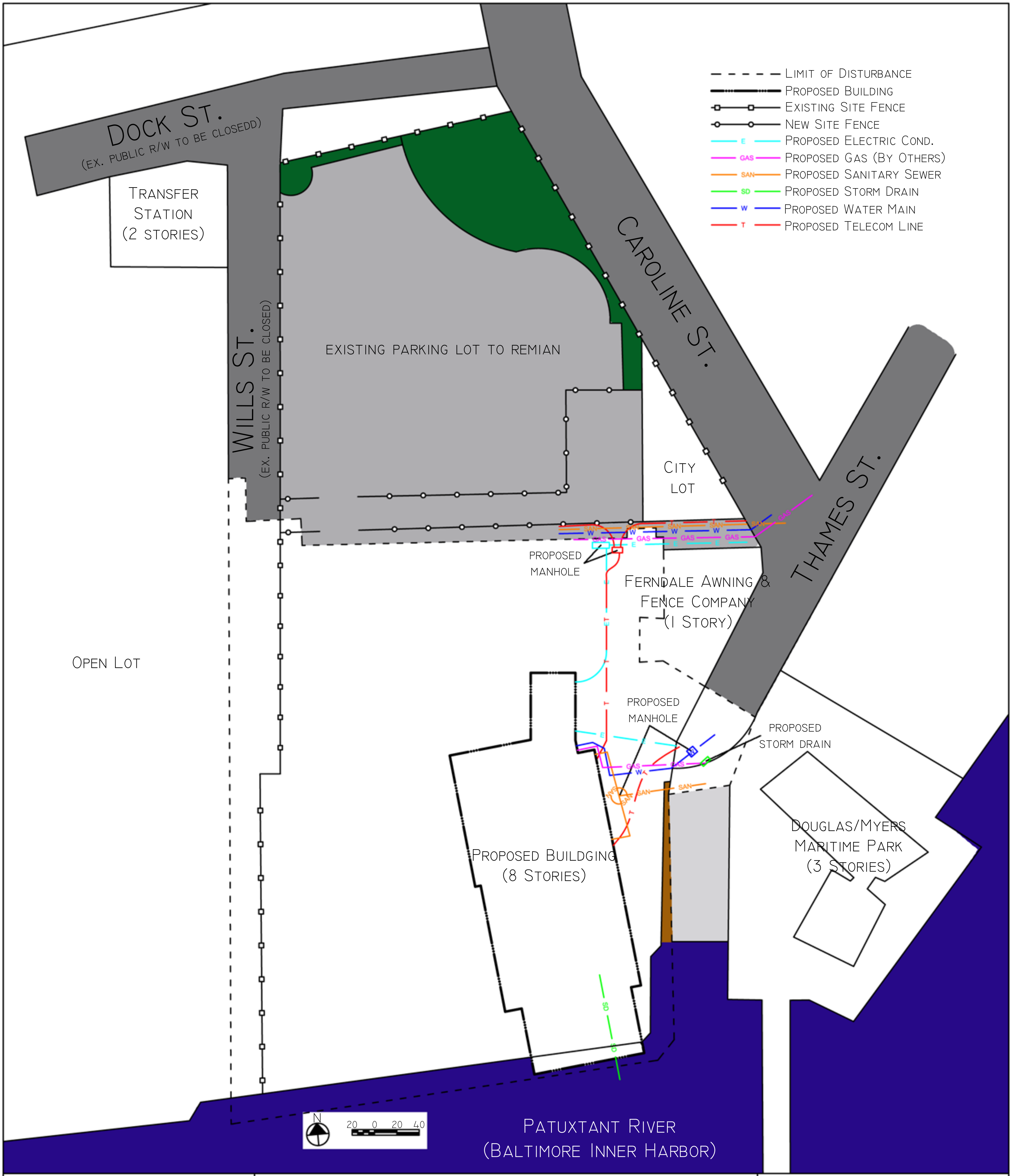


Chris Bell

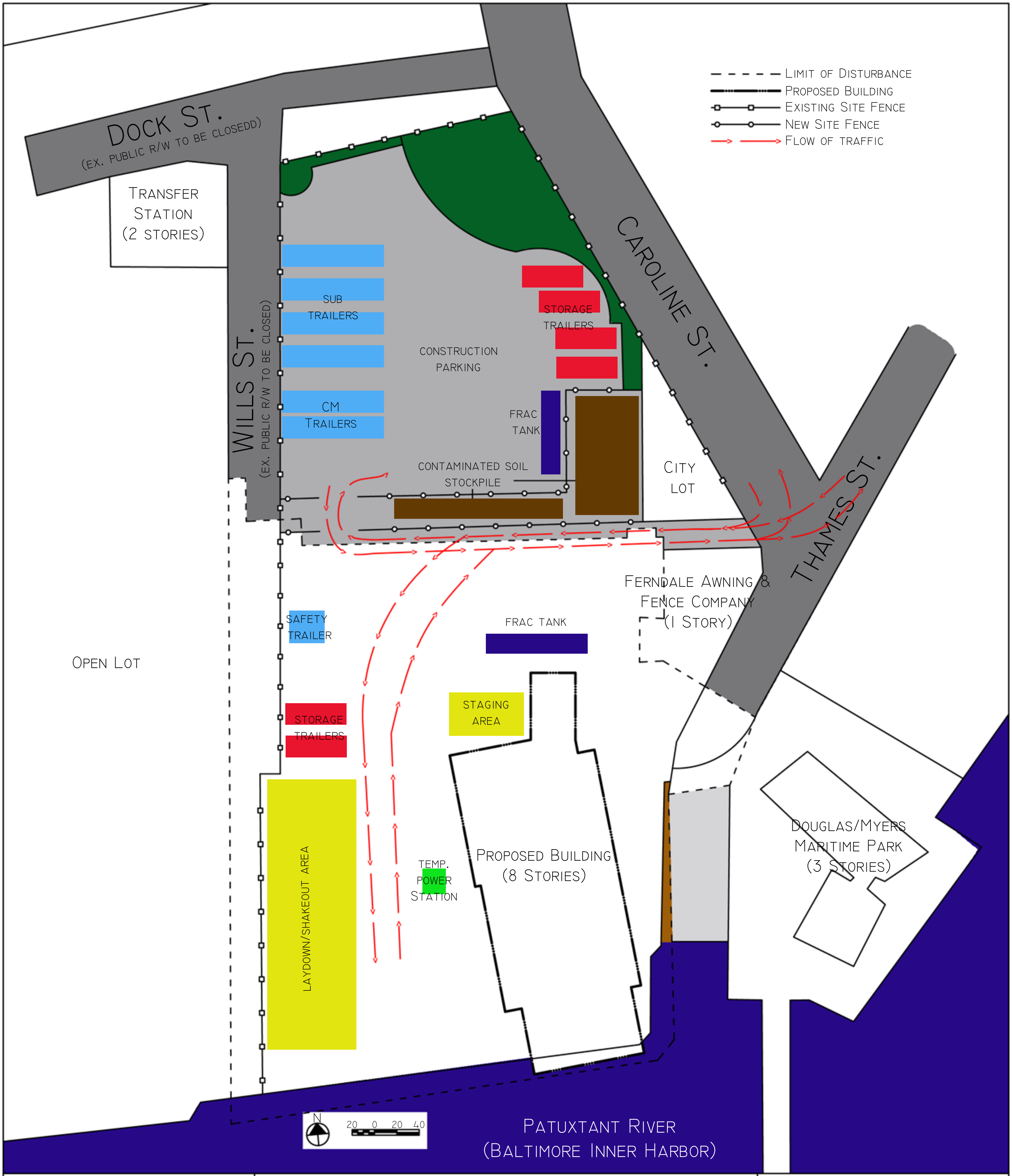
# Thames St. Wharf Office Building

Baltimore, MD

Existing Site Plan



| Chris Bell | Thames St. Wharf Office Building<br>Baltimore, MD | Site Plan with Proposed Utilities |
|---|---|---|



Chris Bell

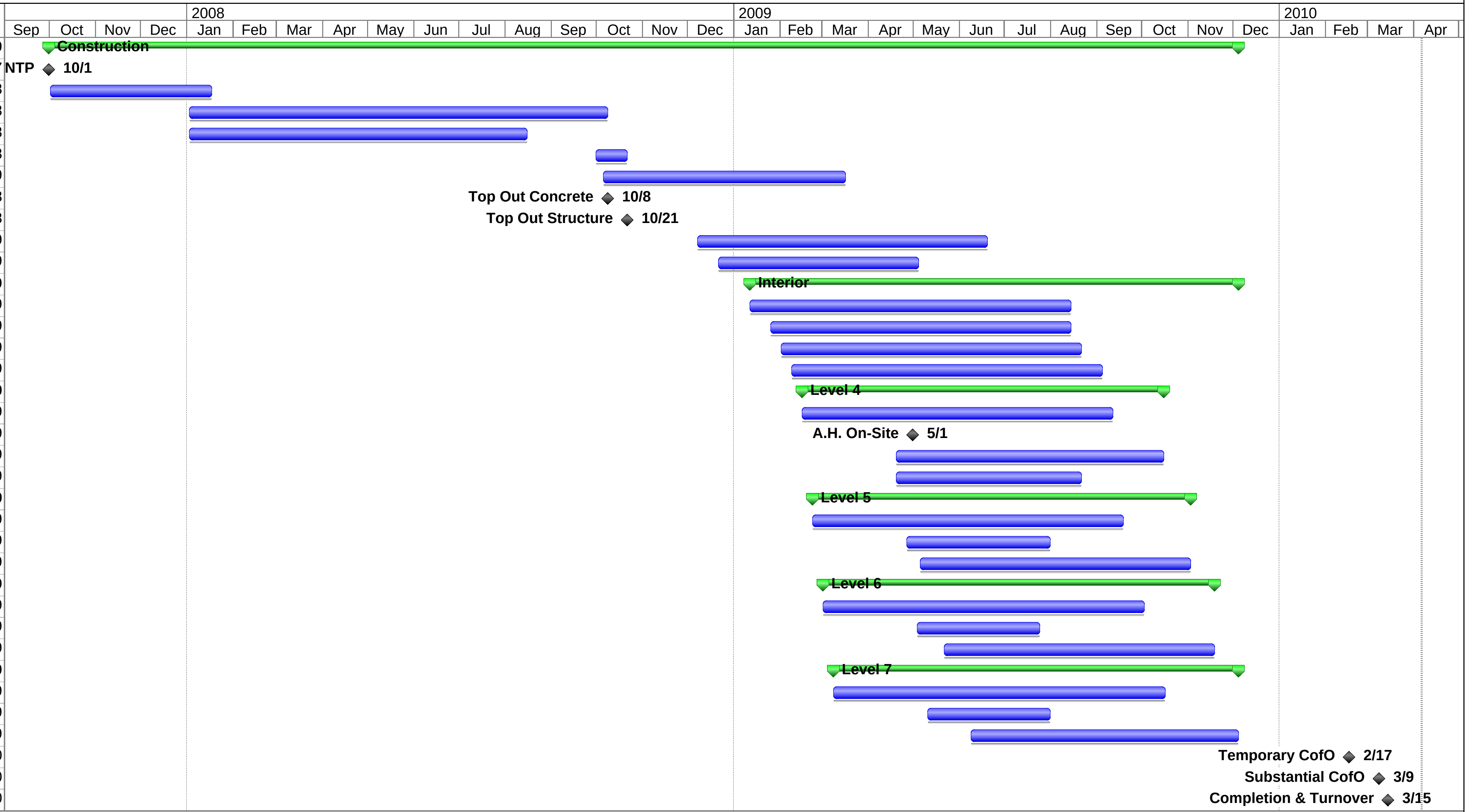
Thames St. Wharf Office Building

Baltimore, MD

Site Plan with Temp. Facilities

# Appendix B: Project Schedules

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | **Construction** | **570 days** | **Mon 10/1/07** | **Fri 12/4/09** |
| 2 | NTP | 0 days | Mon 10/1/07 | Mon 10/1/07 |
| 3 | Sitework | 78 days | Tue 10/2/07 | Thu 1/17/08 |
| 4 | Concrete | 200 days | Thu 1/3/08 | Wed 10/8/08 |
| 6 | Base Building MEP | 162 days | Thu 1/3/08 | Fri 8/15/08 |
| 7 | Steel | 15 days | Wed 10/1/08 | Tue 10/21/08 |
| 9 | Masonry | 116 days | Mon 10/6/08 | Mon 3/16/09 |
| 5 | Top Out Concrete | 0 days | Wed 10/8/08 | Wed 10/8/08 |
| 8 | Top Out Structure | 0 days | Tue 10/21/08 | Tue 10/21/08 |
| 10 | Curtain Wall | 140 days | Mon 12/8/08 | Fri 6/19/09 |
| 11 | Windows | 96 days | Mon 12/22/08 | Mon 5/4/09 |
| 12 | **Interior** | **235 days** | **Mon 1/12/09** | **Fri 12/4/09** |
| 13 | Ground Floor | 155 days | Mon 1/12/09 | Fri 8/14/09 |
| 14 | Level 1 | 145 days | Mon 1/26/09 | Fri 8/14/09 |
| 15 | Level 2 | 145 days | Mon 2/2/09 | Fri 8/21/09 |
| 16 | Level 3 | 150 days | Mon 2/9/09 | Fri 9/4/09 |
| 17 | **Level 4** | **174 days** | **Mon 2/16/09** | **Thu 10/15/09** |
| 18 | Floor Wide | 150 days | Mon 2/16/09 | Fri 9/11/09 |
| 19 | A.H. On-Site | 0 days | Fri 5/1/09 | Fri 5/1/09 |
| 20 | Tenant Fit Out | 129 days | Mon 4/20/09 | Thu 10/15/09 |
| 21 | Central Command/IDF Room | 90 days | Mon 4/20/09 | Fri 8/21/09 |
| 22 | **Level 5** | **181 days** | **Mon 2/23/09** | **Mon 11/2/09** |
| 23 | Floor Wide | 150 days | Mon 2/23/09 | Fri 9/18/09 |
| 24 | Central Command/ IDF Room | 70 days | Mon 4/27/09 | Fri 7/31/09 |
| 25 | Tenant Fit Out | 129 days | Wed 5/6/09 | Mon 11/2/09 |
| 26 | **Level 6** | **188 days** | **Mon 3/2/09** | **Wed 11/18/09** |
| 27 | Floor Wide | 155 days | Mon 3/2/09 | Fri 10/2/09 |
| 28 | Central Command/ IDF Room | 60 days | Mon 5/4/09 | Fri 7/24/09 |
| 29 | Tenant Fit Out | 129 days | Fri 5/22/09 | Wed 11/18/09 |
| 30 | **Level 7** | **195 days** | **Mon 3/9/09** | **Fri 12/4/09** |
| 31 | Floor Wide | 160 days | Mon 3/9/09 | Fri 10/16/09 |
| 32 | Central Command/ IDF Room | 60 days | Mon 5/11/09 | Fri 7/31/09 |
| 33 | Tenant Fit Out | 129 days | Tue 6/9/09 | Fri 12/4/09 |
| 36 | Temporary CofO | 0 days | Wed 2/17/10 | Wed 2/17/10 |
| 34 | Substantial CofO | 0 days | Tue 3/9/10 | Tue 3/9/10 |
| 35 | Completion & Turnover | 0 days | Mon 3/15/10 | Mon 3/15/10 |



Project: Detailed Schedule Condensed
Date: Tue 4/6/10

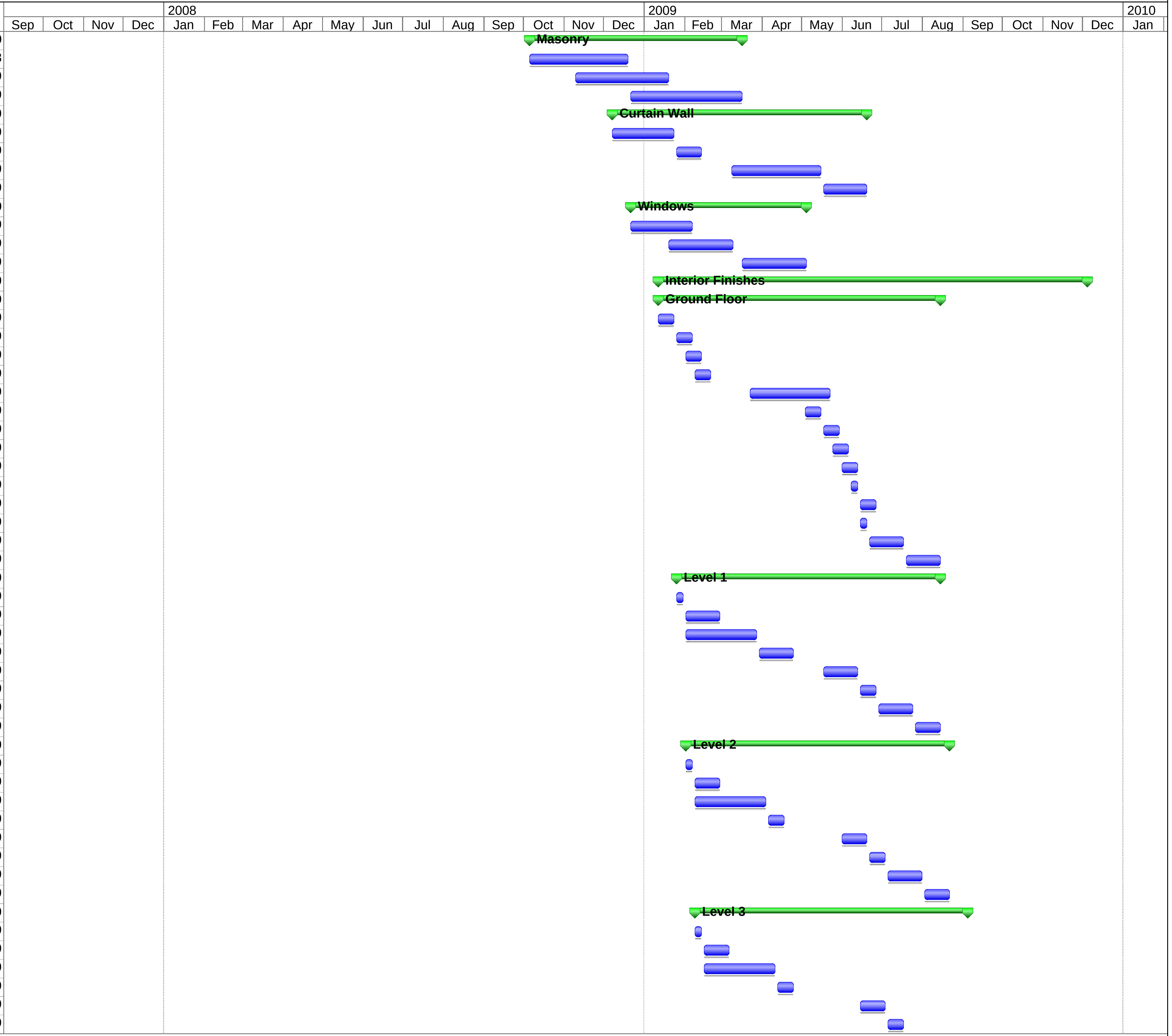
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Task | ▬ | Milestone | ◆ | Rolled Up Task | ▬ | Rolled Up Progress | ▬ | External Tasks | ▬ | Group By Summary | ▬ |
| Progress | ▭ | Summary | ▬ | Rolled Up Milestone | ◇ | Split | ┆ | Project Summary | ▬ | Deadline | ⇩ |

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | **Construction** | **570 days** | **Mon 10/1/07** | **Fri 12/4/09** |
| 2 | NTP | 0 days | Mon 10/1/07 | Mon 10/1/07 |
| 3 | **Sitework** | **97 days** | **Tue 10/2/07** | **Wed 2/13/08** |
| 4 | Demo Existing Parking Lot | 12 days | Tue 10/2/07 | Wed 10/17/07 |
| 5 | Excavation | 10 days | Thu 10/18/07 | Wed 10/31/07 |
| 6 | Pile Driving | 45 days | Thu 11/1/07 | Wed 1/2/08 |
| 7 | Underground Utilities | 20 days | Thu 1/3/08 | Wed 1/30/08 |
| 8 | Back Fill | 10 days | Thu 1/31/08 | Wed 2/13/08 |
| 9 | **Superstructure** | **209 days** | **Thu 1/3/08** | **Tue 10/21/08** |
| 10 | **Concrete** | **200 days** | **Thu 1/3/08** | **Wed 10/8/08** |
| 11 | Erect Tower Crane | 9 days | Thu 1/3/08 | Tue 1/15/08 |
| 12 | Pile Caps | 25 days | Thu 1/3/08 | Wed 2/6/08 |
| 14 | Ground Floor Columns & Walls | 30 days | Thu 1/10/08 | Wed 2/20/08 |
| 13 | SOG | 20 days | Mon 2/4/08 | Fri 2/29/08 |
| 15 | 1st Floor Beams & Slab | 22 days | Thu 2/21/08 | Fri 3/21/08 |
| 16 | 1st Floor Columns & Walls | 15 days | Thu 2/28/08 | Wed 3/19/08 |
| 17 | 2nd Floor Beams & Slab | 19 days | Thu 3/20/08 | Tue 4/15/08 |
| 18 | 2nd Floor Columns & Walls | 15 days | Thu 3/27/08 | Wed 4/16/08 |
| 30 | 1st Floor Curbs | 3 days | Wed 4/16/08 | Fri 4/18/08 |
| 19 | 3rd Floor Beams & Slab | 19 days | Thu 4/17/08 | Tue 5/13/08 |
| 20 | 3rd Floor Columns and Walls | 15 days | Thu 4/24/08 | Wed 5/14/08 |
| 31 | 2nd Floor Curbs | 3 days | Wed 5/14/08 | Fri 5/16/08 |
| 21 | 4th Floor Beams & Slab | 19 days | Thu 5/15/08 | Tue 6/10/08 |
| 22 | 4th Floor Columns & Walls | 15 days | Thu 5/22/08 | Wed 6/11/08 |
| 32 | 3rd Floor Curbs | 3 days | Wed 6/11/08 | Fri 6/13/08 |
| 23 | 5th Floor Beams & Slab | 19 days | Thu 6/12/08 | Tue 7/8/08 |
| 24 | 5th Floor Columns & Walls | 15 days | Thu 6/19/08 | Wed 7/9/08 |
| 33 | 4th Floor Curbs | 3 days | Wed 7/9/08 | Fri 7/11/08 |
| 25 | 6th Floor Beams & Slab | 19 days | Thu 7/10/08 | Tue 8/5/08 |
| 26 | 6th Floor Columns & Walls | 15 days | Thu 7/17/08 | Wed 8/6/08 |
| 34 | 5th Floor Curbs | 3 days | Wed 8/6/08 | Fri 8/8/08 |
| 27 | 7th Floor Beams & Slab | 19 days | Thu 8/7/08 | Tue 9/2/08 |
| 28 | 7th Floor Columns & Walls | 15 days | Thu 8/14/08 | Wed 9/3/08 |
| 35 | 6th Floor Curbs | 3 days | Wed 9/3/08 | Fri 9/5/08 |
| 29 | Penthouse Beams & Slab | 19 days | Thu 9/4/08 | Tue 9/30/08 |
| 36 | 7th Floor Curbs | 3 days | Wed 10/1/08 | Fri 10/3/08 |
| 37 | Dismantle Tower Crane | 3 days | Mon 10/6/08 | Wed 10/8/08 |
| 38 | **Base Building MEP** | **157 days** | **Thu 1/10/08** | **Fri 8/15/08** |
| 39 | Ground Floor Electrical Sleeves | 1 day | Thu 1/10/08 | Thu 1/10/08 |
| 40 | Ground Floor Plumbing Sleeves | 1 day | Thu 1/10/08 | Thu 1/10/08 |
| 41 | Ground Floor Sprinkler Sleeves | 1 day | Thu 1/10/08 | Thu 1/10/08 |
| 42 | 1st Floor Sleeves | 1 day | Fri 2/29/08 | Fri 2/29/08 |
| 43 | 2nd Floor Sleeves | 1 day | Fri 3/28/08 | Fri 3/28/08 |
| 44 | 3rd Floor Sleeves | 1 day | Fri 4/25/08 | Fri 4/25/08 |
| 45 | 4th Floor Sleeves | 1 day | Fri 5/23/08 | Fri 5/23/08 |
| 46 | 5th Floor Sleeves | 1 day | Fri 6/20/08 | Fri 6/20/08 |
| 47 | 6th Floor Sleeves | 1 day | Fri 7/18/08 | Fri 7/18/08 |
| 48 | 7th Floor Sleeves | 1 day | Fri 8/15/08 | Fri 8/15/08 |
| 49 | PH Sleeves | 1 day | Fri 8/15/08 | Fri 8/15/08 |
| 50 | **Steel** | **15 days** | **Wed 10/1/08** | **Tue 10/21/08** |
| 51 | Penthouse Columns | 5 days | Wed 10/1/08 | Tue 10/7/08 |
| 52 | Penthouse Beams | 5 days | Wed 10/8/08 | Tue 10/14/08 |
| 53 | Penthouse Decking | 5 days | Wed 10/15/08 | Tue 10/21/08 |
| 54 | **Enclosure** | **185 days** | **Mon 10/6/08** | **Fri 6/19/09** |

Project: Detailed Schedule.mpp
Date: Tue 4/6/10

Task
Progress
Milestone ◆
Summary
Rolled Up Task
Rolled Up Milestone ◇
Rolled Up Progress
Split
External Tasks
Project Summary
Group By Summary
Deadline ⇩

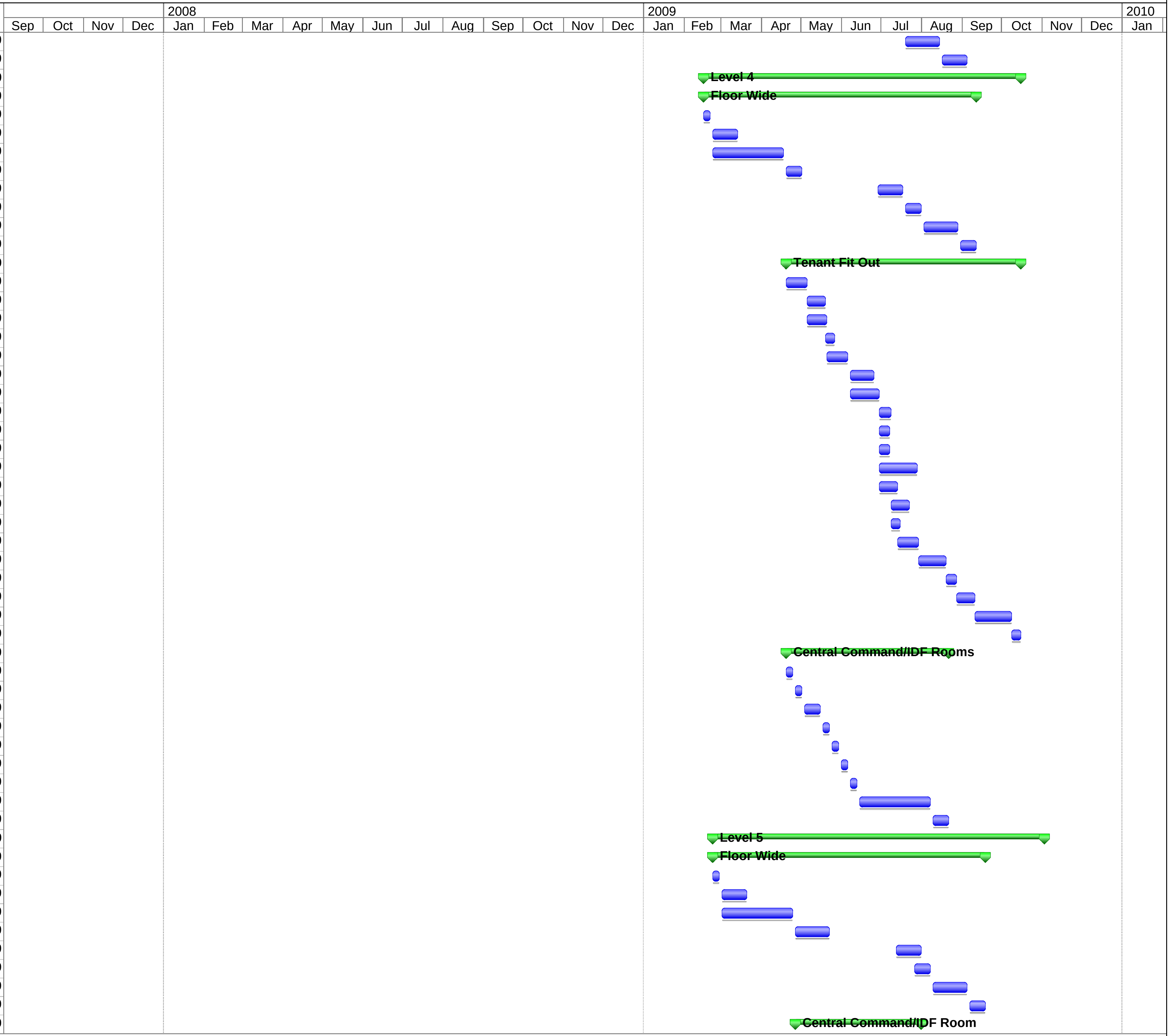
| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 55 | **Masonry** | **116 days** | **Mon 10/6/08** | **Mon 3/16/09** |
| 56 | Brick & Sills East | 55 days | Mon 10/6/08 | Fri 12/19/08 |
| 57 | Brick & Sills North | 51 days | Mon 11/10/08 | Mon 1/19/09 |
| 58 | Brick & Sills West | 61 days | Mon 12/22/08 | Mon 3/16/09 |
| 63 | **Curtain Wall** | **140 days** | **Mon 12/8/08** | **Fri 6/19/09** |
| 64 | Curtain Wall South | 35 days | Mon 12/8/08 | Fri 1/23/09 |
| 66 | Curtain Wall East | 15 days | Mon 1/26/09 | Fri 2/13/09 |
| 65 | Curtain Wall West | 50 days | Mon 3/9/09 | Fri 5/15/09 |
| 67 | Curtain Wall North | 25 days | Mon 5/18/09 | Fri 6/19/09 |
| 59 | **Windows** | **96 days** | **Mon 12/22/08** | **Mon 5/4/09** |
| 60 | Windows East | 35 days | Mon 12/22/08 | Fri 2/6/09 |
| 62 | Windows North | 35 days | Tue 1/20/09 | Mon 3/9/09 |
| 61 | Windows West | 35 days | Tue 3/17/09 | Mon 5/4/09 |
| 68 | **Interior Finishes** | **235 days** | **Mon 1/12/09** | **Fri 12/4/09** |
| 69 | **Ground Floor** | **155 days** | **Mon 1/12/09** | **Fri 8/14/09** |
| 70 | MEP Riser | 10 days | Mon 1/12/09 | Fri 1/23/09 |
| 71 | Plumbing Rough In | 10 days | Mon 1/26/09 | Fri 2/6/09 |
| 72 | Sprinkler Rough In | 10 days | Mon 2/2/09 | Fri 2/13/09 |
| 73 | Electrical Rough In | 10 days | Mon 2/9/09 | Fri 2/20/09 |
| 78 | Frame, Finish & Paint - Core | 45 days | Mon 3/23/09 | Fri 5/22/09 |
| 74 | Duct Layout | 10 days | Mon 5/4/09 | Fri 5/15/09 |
| 75 | Install Access Floor | 10 days | Mon 5/18/09 | Fri 5/29/09 |
| 79 | Plumbing Trim Out - Core | 10 days | Mon 5/25/09 | Fri 6/5/09 |
| 76 | Duct Installation | 10 days | Mon 6/1/09 | Fri 6/12/09 |
| 80 | Electrical Trim - Core | 5 days | Mon 6/8/09 | Fri 6/12/09 |
| 77 | Set Mechanical Eqpt. | 10 days | Mon 6/15/09 | Fri 6/26/09 |
| 81 | HVAC Trim - Core | 5 days | Mon 6/15/09 | Fri 6/19/09 |
| 82 | MEP Connections to Eqpt | 20 days | Mon 6/22/09 | Fri 7/17/09 |
| 83 | Testing & Commissioning | 20 days | Mon 7/20/09 | Fri 8/14/09 |
| 84 | **Level 1** | **145 days** | **Mon 1/26/09** | **Fri 8/14/09** |
| 85 | MEP Riser | 5 days | Mon 1/26/09 | Fri 1/30/09 |
| 86 | Plumbing, Sprinkler, Electrical Rough In | 20 days | Mon 2/2/09 | Fri 2/27/09 |
| 91 | Frame, Finish & Paint - Core | 40 days | Mon 2/2/09 | Fri 3/27/09 |
| 92 | Trim Out - Core | 20 days | Mon 3/30/09 | Fri 4/24/09 |
| 87 | Duct Layout & Install | 20 days | Mon 5/18/09 | Fri 6/12/09 |
| 88 | Install Access Floor | 10 days | Mon 6/15/09 | Fri 6/26/09 |
| 89 | MEP Connections to Eqpt | 20 days | Mon 6/29/09 | Fri 7/24/09 |
| 90 | Testing & Commissioning | 15 days | Mon 7/27/09 | Fri 8/14/09 |
| 93 | **Level 2** | **145 days** | **Mon 2/2/09** | **Fri 8/21/09** |
| 94 | MEP Riser | 5 days | Mon 2/2/09 | Fri 2/6/09 |
| 95 | Plumbing, Sprinkler, Electrical Rough In | 15 days | Mon 2/9/09 | Fri 2/27/09 |
| 98 | Frame, Finish & Paint - Core | 40 days | Mon 2/9/09 | Fri 4/3/09 |
| 99 | Trim Out - Core | 10 days | Mon 4/6/09 | Fri 4/17/09 |
| 96 | Duct Layout & Install | 15 days | Mon 6/1/09 | Fri 6/19/09 |
| 97 | Install Access Floor | 10 days | Mon 6/22/09 | Fri 7/3/09 |
| 100 | MEP Connections to Eqpt | 20 days | Mon 7/6/09 | Fri 7/31/09 |
| 101 | Testing & Commissioning | 15 days | Mon 8/3/09 | Fri 8/21/09 |
| 102 | **Level 3** | **150 days** | **Mon 2/9/09** | **Fri 9/4/09** |
| 103 | MEP Riser | 5 days | Mon 2/9/09 | Fri 2/13/09 |
| 104 | Plumbing, Sprinkler, Electrical Rough In | 15 days | Mon 2/16/09 | Fri 3/6/09 |
| 107 | Frame, Finish & Paint - Core | 40 days | Mon 2/16/09 | Fri 4/10/09 |
| 108 | Trim Out - Core | 10 days | Mon 4/13/09 | Fri 4/24/09 |
| 105 | Duct Layout & Install | 15 days | Mon 6/15/09 | Fri 7/3/09 |
| 106 | Install Access Floor | 10 days | Mon 7/6/09 | Fri 7/17/09 |



Project: Detailed Schedule.mpp
Date: Tue 4/6/10

Task
Progress
Milestone ◆
Summary
Rolled Up Task
Rolled Up Milestone ◇
Rolled Up Progress
Split
External Tasks
Project Summary
Group By Summary
Deadline ⇩

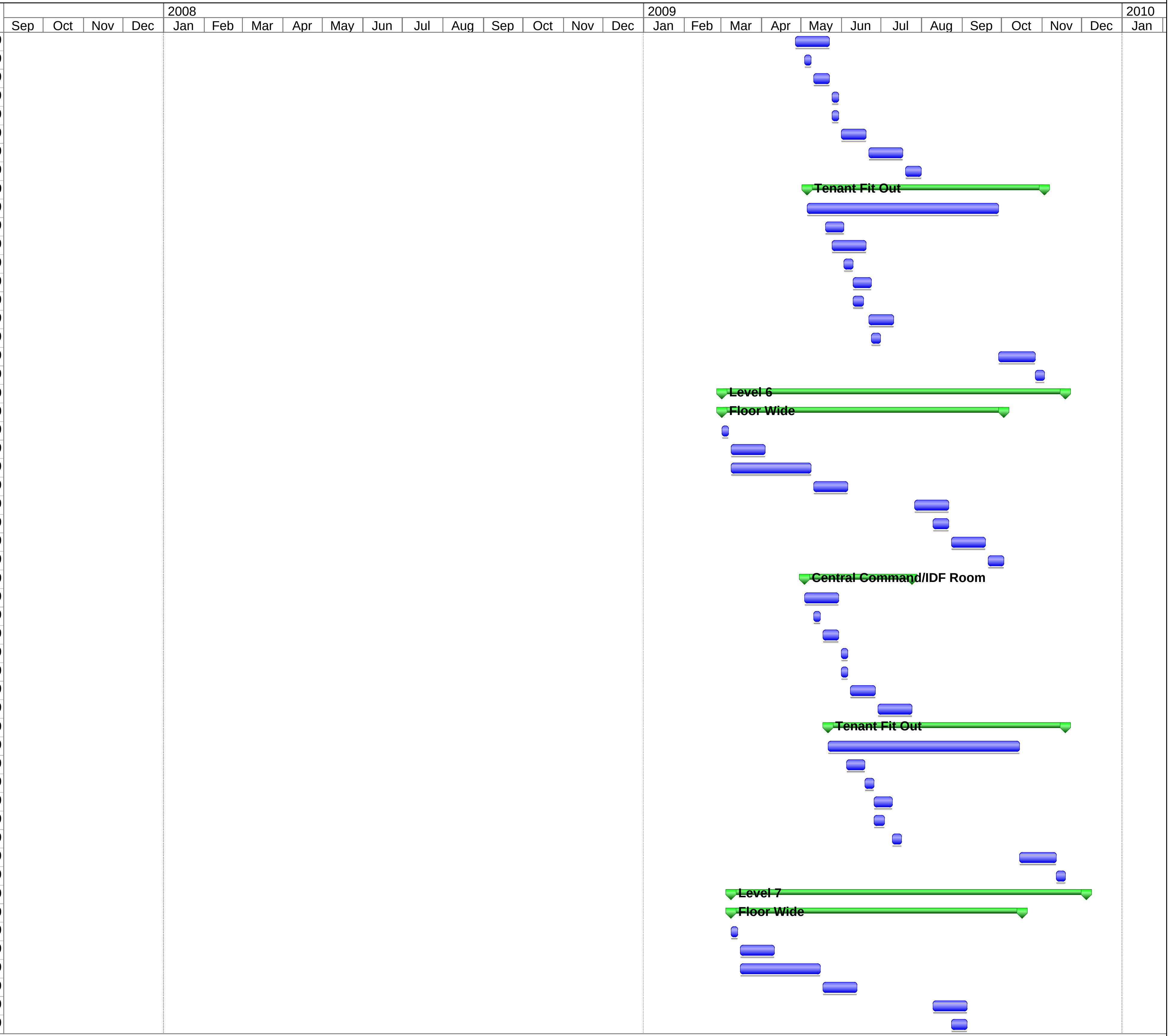
| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 109 | MEP Connections to Eqpt | 20 days | Mon 7/20/09 | Fri 8/14/09 |
| 110 | Testing & Commissioning | 15 days | Mon 8/17/09 | Fri 9/4/09 |
| 111 | **Level 4** | **174 days** | **Mon 2/16/09** | **Thu 10/15/09** |
| 112 | **Floor Wide** | **150 days** | **Mon 2/16/09** | **Fri 9/11/09** |
| 113 | MEP Riser | 5 days | Mon 2/16/09 | Fri 2/20/09 |
| 114 | Plumbing, Sprinkler, Electrical Rough In | 15 days | Mon 2/23/09 | Fri 3/13/09 |
| 117 | Frame, Finish & Paint - Core | 40 days | Mon 2/23/09 | Fri 4/17/09 |
| 118 | Trim Out - Core | 10 days | Mon 4/20/09 | Fri 5/1/09 |
| 115 | Duct Layout & Install | 15 days | Mon 6/29/09 | Fri 7/17/09 |
| 116 | Install Access Floor | 10 days | Mon 7/20/09 | Fri 7/31/09 |
| 119 | MEP Connections to Eqpt | 20 days | Mon 8/3/09 | Fri 8/28/09 |
| 120 | Testing & Commissioning | 10 days | Mon 8/31/09 | Fri 9/11/09 |
| 121 | **Tenant Fit Out** | **129 days** | **Mon 4/20/09** | **Thu 10/15/09** |
| 122 | Frame Type G Walls | 12 days | Mon 4/20/09 | Tue 5/5/09 |
| 123 | Install Underfloor Electrical | 10 days | Wed 5/6/09 | Tue 5/19/09 |
| 124 | Frame Ceilings | 11 days | Wed 5/6/09 | Wed 5/20/09 |
| 126 | Rough In Ceiling MEP - E Lobby | 5 days | Wed 5/20/09 | Tue 5/26/09 |
| 125 | Frame Type R Walls | 12 days | Thu 5/21/09 | Fri 6/5/09 |
| 127 | Prep & Install Terrazzo Floor | 14 days | Mon 6/8/09 | Thu 6/25/09 |
| 128 | Hang & Finish Drywall | 16 days | Mon 6/8/09 | Mon 6/29/09 |
| 129 | Hang Ceiling Grid | 7 days | Tue 6/30/09 | Wed 7/8/09 |
| 131 | Install Linear Diffusers | 6 days | Tue 6/30/09 | Tue 7/7/09 |
| 132 | Install Base & Trim | 6 days | Tue 6/30/09 | Tue 7/7/09 |
| 134 | Install Millwork | 21 days | Tue 6/30/09 | Tue 7/28/09 |
| 135 | Install Frames | 10 days | Tue 6/30/09 | Mon 7/13/09 |
| 130 | Install Sprinkler Piping | 10 days | Thu 7/9/09 | Wed 7/22/09 |
| 133 | Install Light Fixtures | 5 days | Thu 7/9/09 | Wed 7/15/09 |
| 136 | Install Doors & Hardware | 12 days | Tue 7/14/09 | Wed 7/29/09 |
| 137 | Prime & Paint | 15 days | Thu 7/30/09 | Wed 8/19/09 |
| 138 | Drop Ceiling Tiles | 6 days | Thu 8/20/09 | Thu 8/27/09 |
| 139 | Install Carpet | 10 days | Fri 8/28/09 | Thu 9/10/09 |
| 140 | Punchlist & Walkthrough | 20 days | Fri 9/11/09 | Thu 10/8/09 |
| 141 | Tenant FF&E | 5 days | Fri 10/9/09 | Thu 10/15/09 |
| 142 | **Central Command/IDF Rooms** | **90 days** | **Mon 4/20/09** | **Fri 8/21/09** |
| 143 | Frame Walls | 5 days | Mon 4/20/09 | Fri 4/24/09 |
| 144 | Rough In MEP | 5 days | Mon 4/27/09 | Fri 5/1/09 |
| 145 | Hang & Finish Drywall | 10 days | Mon 5/4/09 | Fri 5/15/09 |
| 146 | Paint Walls | 5 days | Mon 5/18/09 | Fri 5/22/09 |
| 147 | Waterproof | 5 days | Mon 5/25/09 | Fri 5/29/09 |
| 148 | Install Access Floor | 5 days | Mon 6/1/09 | Fri 6/5/09 |
| 149 | Underfloor Duct Work | 5 days | Mon 6/8/09 | Fri 6/12/09 |
| 150 | Set Eqpt & Fit Out | 40 days | Mon 6/15/09 | Fri 8/7/09 |
| 151 | Install Cable | 10 days | Mon 8/10/09 | Fri 8/21/09 |
| 152 | **Level 5** | **181 days** | **Mon 2/23/09** | **Mon 11/2/09** |
| 153 | **Floor Wide** | **150 days** | **Mon 2/23/09** | **Fri 9/18/09** |
| 154 | MEP Riser | 5 days | Mon 2/23/09 | Fri 2/27/09 |
| 155 | Plumbing, Sprinkler, Electrical Rough In | 15 days | Mon 3/2/09 | Fri 3/20/09 |
| 160 | Frame, Finish & Paint - Core | 40 days | Mon 3/2/09 | Fri 4/24/09 |
| 161 | Trim Out - Core | 20 days | Mon 4/27/09 | Fri 5/22/09 |
| 156 | Duct Layout & Install | 15 days | Mon 7/13/09 | Fri 7/31/09 |
| 159 | Install Access Floor | 10 days | Mon 7/27/09 | Fri 8/7/09 |
| 157 | MEP Connections to Eqpt | 20 days | Mon 8/10/09 | Fri 9/4/09 |
| 158 | Testing & Commissioning | 10 days | Mon 9/7/09 | Fri 9/18/09 |
| 173 | **Central Command/IDF Room** | **70 days** | **Mon 4/27/09** | **Fri 7/31/09** |



Project: Detailed Schedule.mpp
Date: Tue 4/6/10

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Task | ▬ | Milestone | ◆ | Rolled Up Task | ▬ | Rolled Up Progress | ▬ | External Tasks | ▬ | Group By Summary | ▬ |
| Progress | ▭ | Summary | ▬ | Rolled Up Milestone | ◇ | Split | ┆ | Project Summary | ▬ | Deadline | ⇩ |

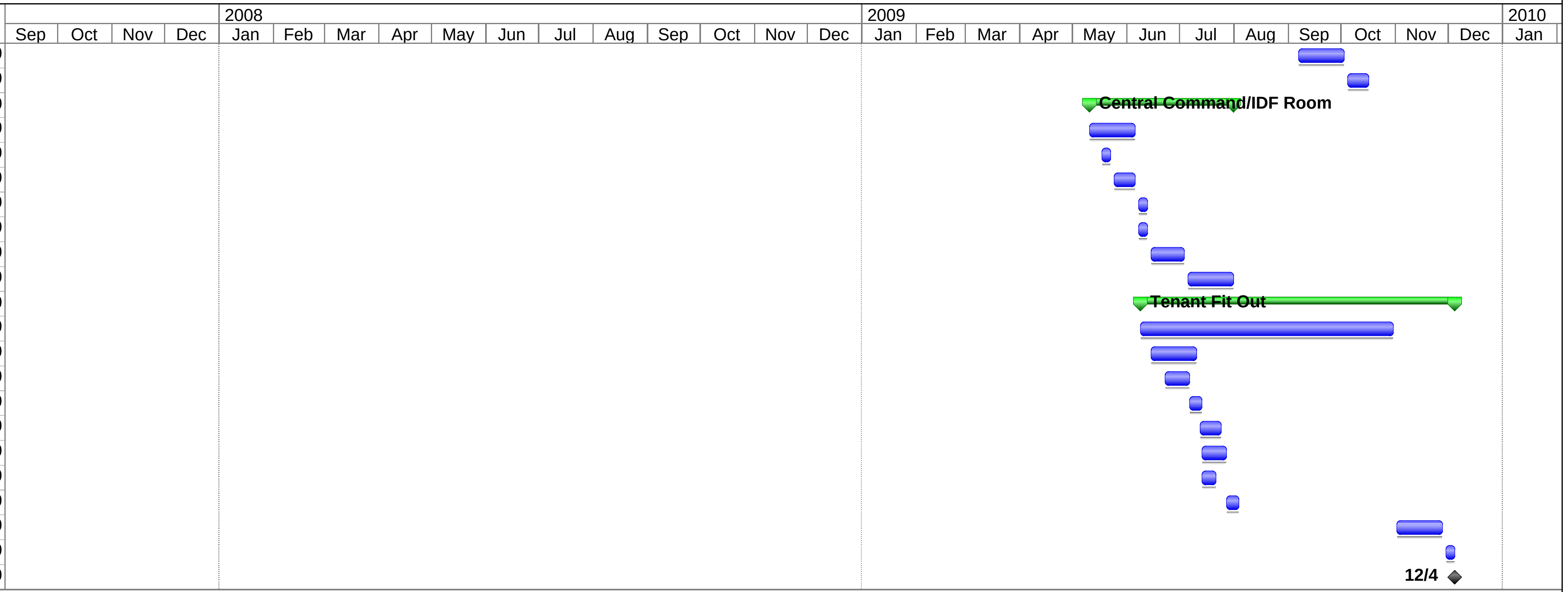
| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 174 | Frame, Finish & Paint Walls | 20 days | Mon 4/27/09 | Fri 5/22/09 |
| 175 | Rough In MEP | 5 days | Mon 5/4/09 | Fri 5/8/09 |
| 176 | Cable Risers | 10 days | Mon 5/11/09 | Fri 5/22/09 |
| 177 | Install Access Floor | 5 days | Mon 5/25/09 | Fri 5/29/09 |
| 178 | Under Floor Ductwork | 5 days | Mon 5/25/09 | Fri 5/29/09 |
| 179 | Rough In & Install Cable | 15 days | Mon 6/1/09 | Fri 6/19/09 |
| 180 | Set Eqpt. And Fit Out | 20 days | Mon 6/22/09 | Fri 7/17/09 |
| 181 | Commission | 10 days | Mon 7/20/09 | Fri 7/31/09 |
| 162 | **Tenant Fit Out** | **129 days** | **Wed 5/6/09** | **Mon 11/2/09** |
| 163 | Frame & Finish Floors/Ceiling/Walls | 104 days | Wed 5/6/09 | Mon 9/28/09 |
| 164 | Install Underfloor Electric | 10 days | Wed 5/20/09 | Tue 6/2/09 |
| 171 | MEP Connections to Eqpt | 20 days | Mon 5/25/09 | Fri 6/19/09 |
| 165 | Rough In MEP - E Lobby | 5 days | Wed 6/3/09 | Tue 6/9/09 |
| 166 | Run Sprinker Pipe | 10 days | Wed 6/10/09 | Tue 6/23/09 |
| 167 | Install Diffusers | 6 days | Wed 6/10/09 | Wed 6/17/09 |
| 172 | Testing & Commissioning | 15 days | Mon 6/22/09 | Fri 7/10/09 |
| 168 | Install Light Fixtures | 5 days | Wed 6/24/09 | Tue 6/30/09 |
| 169 | Punchlist & Walkthrough | 20 days | Tue 9/29/09 | Mon 10/26/09 |
| 170 | Tenant FF&E | 5 days | Tue 10/27/09 | Mon 11/2/09 |
| 182 | **Level 6** | **188 days** | **Mon 3/2/09** | **Wed 11/18/09** |
| 183 | **Floor Wide** | **155 days** | **Mon 3/2/09** | **Fri 10/2/09** |
| 184 | MEP Riser | 5 days | Mon 3/2/09 | Fri 3/6/09 |
| 185 | Plumbing, Sprinkler, Electrical Rough In | 20 days | Mon 3/9/09 | Fri 4/3/09 |
| 190 | Frame, Finish & Paint - Core | 45 days | Mon 3/9/09 | Fri 5/8/09 |
| 191 | Trim Out - Core | 20 days | Mon 5/11/09 | Fri 6/5/09 |
| 186 | Duct Layout & Install | 20 days | Mon 7/27/09 | Fri 8/21/09 |
| 189 | Install Access Floor | 10 days | Mon 8/10/09 | Fri 8/21/09 |
| 187 | MEP Connections to Eqpt | 20 days | Mon 8/24/09 | Fri 9/18/09 |
| 188 | Testing & Commissioning | 10 days | Mon 9/21/09 | Fri 10/2/09 |
| 201 | **Central Command/IDF Room** | **60 days** | **Mon 5/4/09** | **Fri 7/24/09** |
| 202 | Frame, Finish & Paint Walls | 20 days | Mon 5/4/09 | Fri 5/29/09 |
| 203 | Rough In MEP | 5 days | Mon 5/11/09 | Fri 5/15/09 |
| 204 | Cable Risers | 10 days | Mon 5/18/09 | Fri 5/29/09 |
| 205 | Install Access Floor | 5 days | Mon 6/1/09 | Fri 6/5/09 |
| 206 | Under Floor Ductwork | 5 days | Mon 6/1/09 | Fri 6/5/09 |
| 207 | Rough In & Install Cable | 15 days | Mon 6/8/09 | Fri 6/26/09 |
| 208 | Set Eqpt. And Fit Out | 20 days | Mon 6/29/09 | Fri 7/24/09 |
| 192 | **Tenant Fit Out** | **129 days** | **Fri 5/22/09** | **Wed 11/18/09** |
| 193 | Frame & Finish Floors/Ceiling/Walls | 104 days | Fri 5/22/09 | Wed 10/14/09 |
| 194 | Install Underfloor Electric | 10 days | Fri 6/5/09 | Thu 6/18/09 |
| 195 | Rough In MEP - E Lobby | 5 days | Fri 6/19/09 | Thu 6/25/09 |
| 196 | Run Sprinker Pipe | 10 days | Fri 6/26/09 | Thu 7/9/09 |
| 197 | Install Diffusers | 6 days | Fri 6/26/09 | Fri 7/3/09 |
| 200 | Install Light Fixtures | 5 days | Fri 7/10/09 | Thu 7/16/09 |
| 198 | Punchlist & Walkthrough | 20 days | Thu 10/15/09 | Wed 11/11/09 |
| 199 | Tenant FF&E | 5 days | Thu 11/12/09 | Wed 11/18/09 |
| 209 | **Level 7** | **195 days** | **Mon 3/9/09** | **Fri 12/4/09** |
| 210 | **Floor Wide** | **160 days** | **Mon 3/9/09** | **Fri 10/16/09** |
| 211 | MEP Riser | 5 days | Mon 3/9/09 | Fri 3/13/09 |
| 212 | Plumbing, Sprinkler, Electrical Rough In | 20 days | Mon 3/16/09 | Fri 4/10/09 |
| 217 | Frame, Finish & Paint - Core | 45 days | Mon 3/16/09 | Fri 5/15/09 |
| 218 | Trim Out - Core | 20 days | Mon 5/18/09 | Fri 6/12/09 |
| 213 | Duct Layout & Install | 20 days | Mon 8/10/09 | Fri 9/4/09 |
| 216 | Install Access Floor | 10 days | Mon 8/24/09 | Fri 9/4/09 |



Project: Detailed Schedule.mpp
Date: Tue 4/6/10

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Task | ▬ | Milestone | ◆ | Rolled Up Task | ▬ | Rolled Up Progress | ▬ | External Tasks | ▬ | Group By Summary | ▬ |
| Progress | ▭ | Summary | ▬ | Rolled Up Milestone | ◇ | Split | ┆ | Project Summary | ▬ | Deadline | ⇩ |

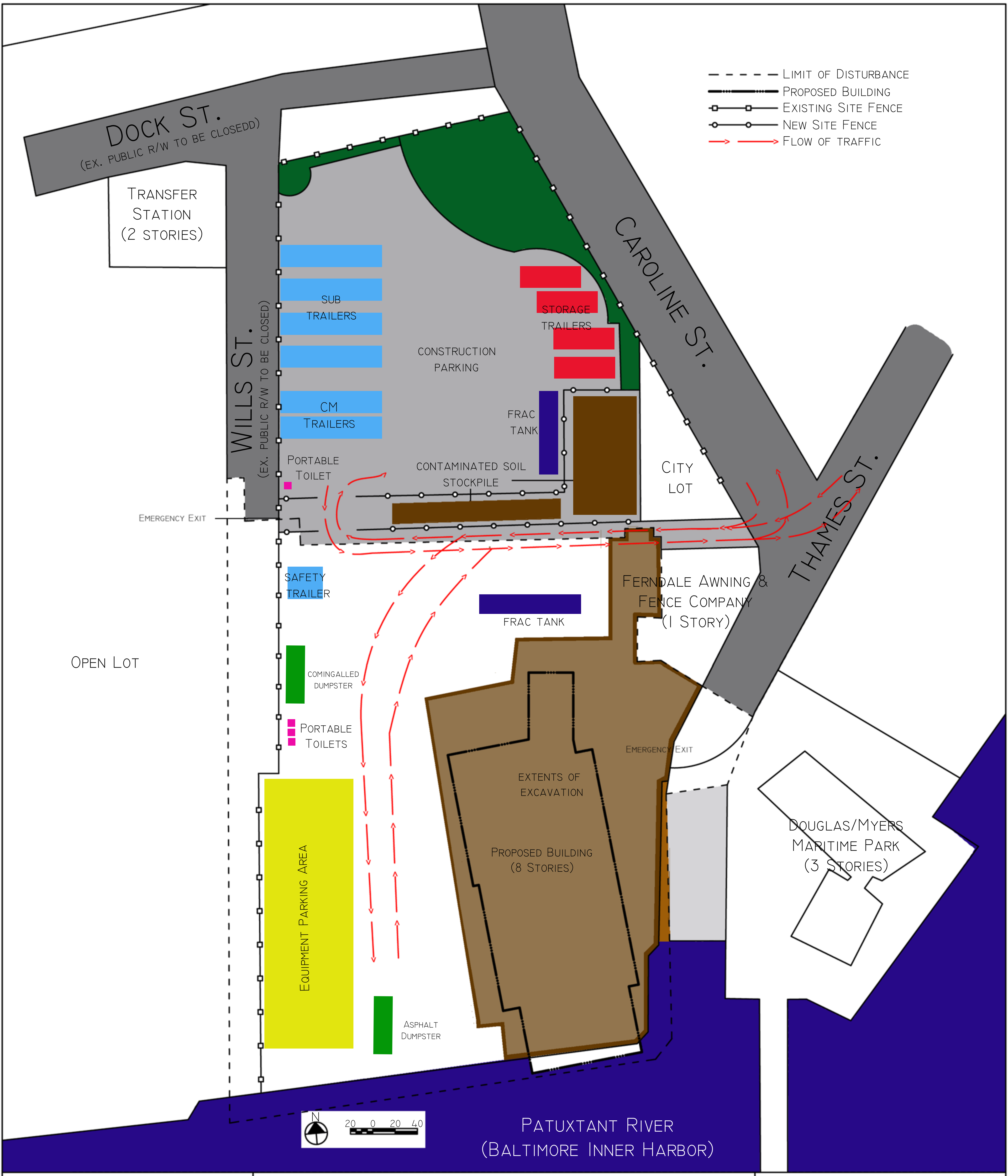
| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 214 | MEP Connections to Eqpt | 20 days | Mon 9/7/09 | Fri 10/2/09 |
| 215 | Testing & Commissioning | 10 days | Mon 10/5/09 | Fri 10/16/09 |
| 230 | **Central Command/IDF Room** | **60 days** | **Mon 5/11/09** | **Fri 7/31/09** |
| 231 | Frame, Finish & Paint Walls | 20 days | Mon 5/11/09 | Fri 6/5/09 |
| 232 | Rough In MEP | 5 days | Mon 5/18/09 | Fri 5/22/09 |
| 233 | Cable Risers | 10 days | Mon 5/25/09 | Fri 6/5/09 |
| 234 | Install Access Floor | 5 days | Mon 6/8/09 | Fri 6/12/09 |
| 235 | Under Floor Ductwork | 5 days | Mon 6/8/09 | Fri 6/12/09 |
| 236 | Rough In & Install Cable | 15 days | Mon 6/15/09 | Fri 7/3/09 |
| 237 | Set Eqpt. And Fit Out | 20 days | Mon 7/6/09 | Fri 7/31/09 |
| 219 | **Tenant Fit Out** | **129 days** | **Tue 6/9/09** | **Fri 12/4/09** |
| 220 | Frame & Finish Floors/Ceiling/Walls | 104 days | Tue 6/9/09 | Fri 10/30/09 |
| 228 | MEP Connections to Eqpt | 20 days | Mon 6/15/09 | Fri 7/10/09 |
| 221 | Install Underfloor Electric | 10 days | Tue 6/23/09 | Mon 7/6/09 |
| 222 | Rough In MEP - E Lobby | 5 days | Tue 7/7/09 | Mon 7/13/09 |
| 229 | Testing & Commissioning | 10 days | Mon 7/13/09 | Fri 7/24/09 |
| 223 | Run Sprinker Pipe | 10 days | Tue 7/14/09 | Mon 7/27/09 |
| 224 | Install Diffusers | 6 days | Tue 7/14/09 | Tue 7/21/09 |
| 227 | Install Light Fixtures | 5 days | Tue 7/28/09 | Mon 8/3/09 |
| 225 | Punchlist & Walkthrough | 20 days | Mon 11/2/09 | Fri 11/27/09 |
| 226 | Tenant FF&E | 5 days | Mon 11/30/09 | Fri 12/4/09 |
| 238 | Substantial Completion | 0 days | Fri 12/4/09 | Fri 12/4/09 |



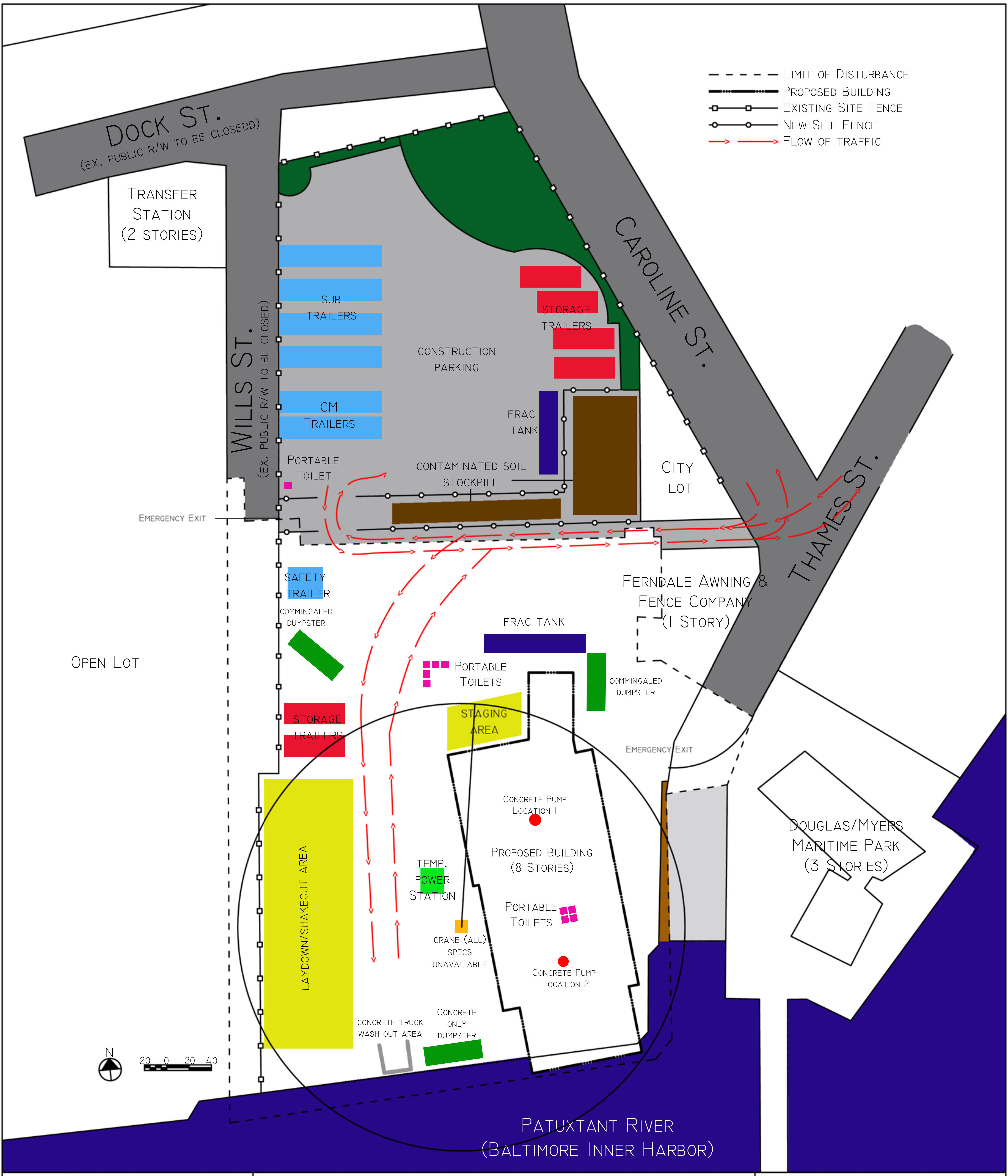
Project: Detailed Schedule.mpp
Date: Tue 4/6/10

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Task | ▬ | Milestone | ◆ | Rolled Up Task | ▬ | Rolled Up Progress | ▬ | External Tasks | ▬ | Group By Summary | ▬ |
| Progress | ▭ | Summary | ▬ | Rolled Up Milestone | ◇ | Split | ┆ | Project Summary | ▬ | Deadline | ⇩ |

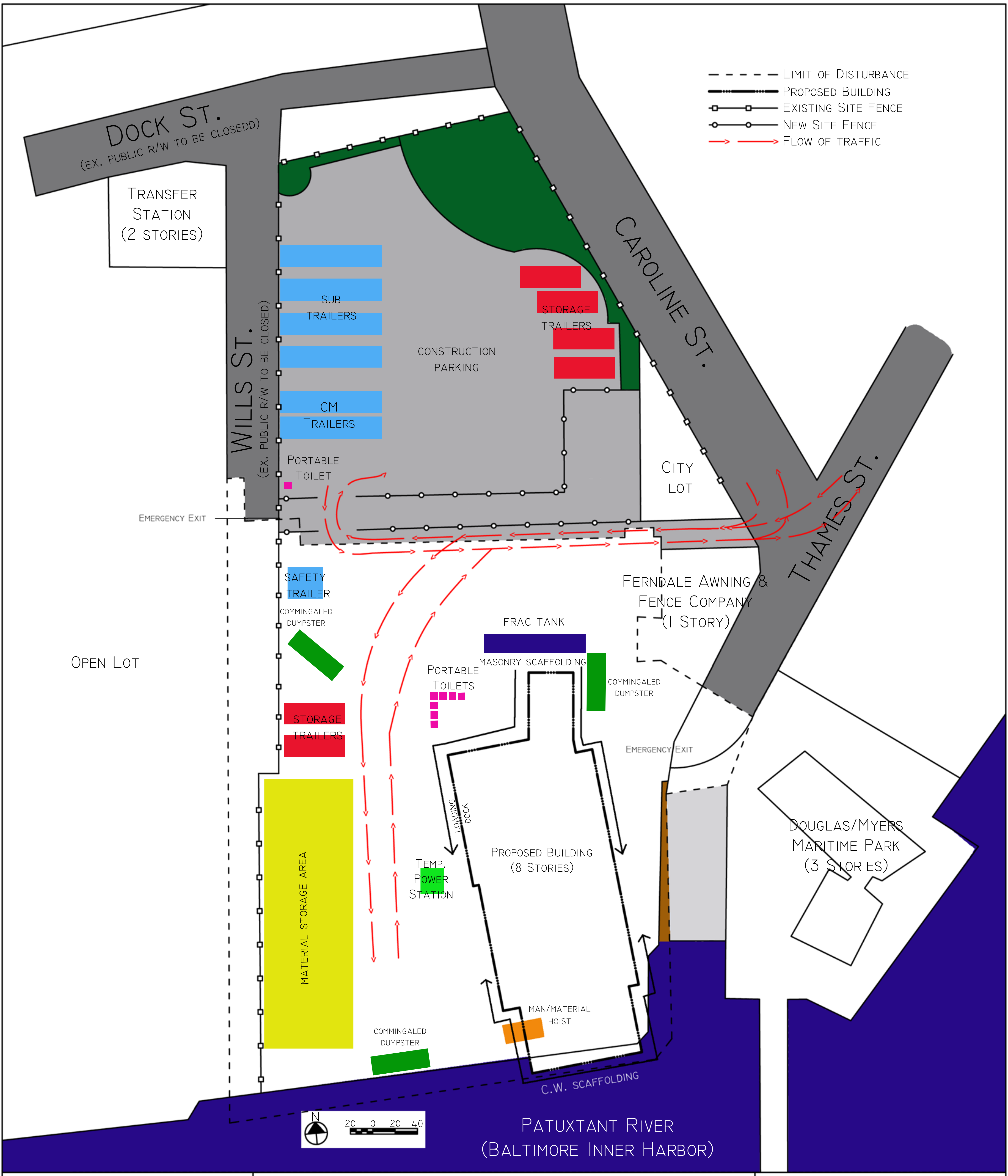
# Appendix C: Site Plans



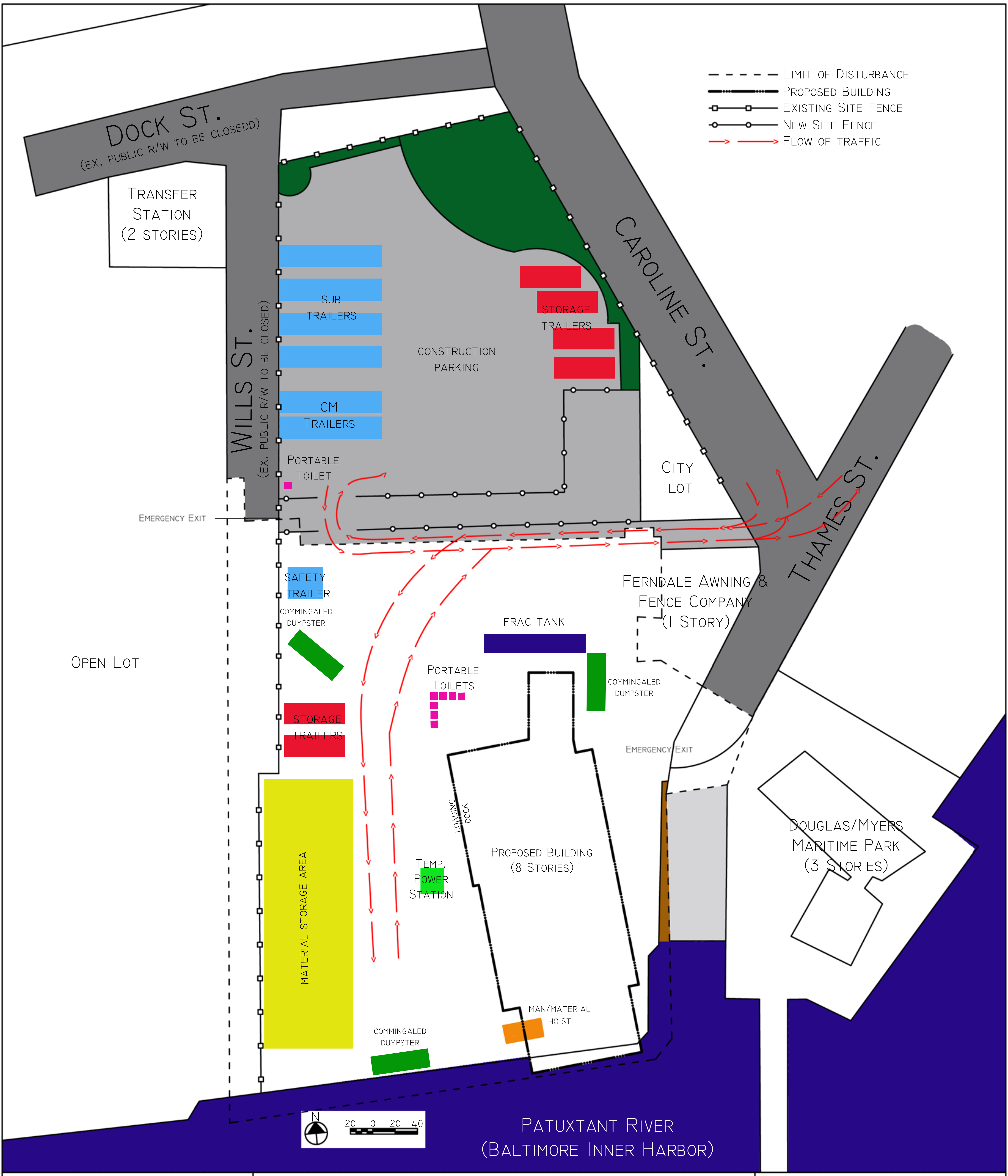
| | | |
|---|---|---|
| Chris Bell | Thames St. Wharf Office Building<br>Baltimore, MD | Excavation Phase |



| Chris Bell | Thames St. Wharf Office Building<br>Baltimore, MD | Superstructure Phase |
|---|---|---|



| Chris Bell | Thames St. Wharf Office Building<br>Baltimore, MD | Enclosure Phase |
|---|---|---|



Chris Bell

# Thames St. Wharf Office Building

Baltimore, MD

Interior Finishes Phase

# Appendix D: Square Foot Estimate

www.meanscostworks.com

**Square Foot Cost Estimate Report**

| | |
|---|---|
| Estimate Name: | **Thames St Wharf** |
| Building Type: | **Office, 5-10 Story with Face Brick with Concrete Block Back-up / R/Conc. Frame** |
| Location: | **BALTIMORE, MD** |
| Story Count: | **8** |
| Story Height (L.F.): | **13** |
| Floor Area (S.F.): | **277000** |
| Labor Type: | **Open Shop** |
| Basement Included: | **No** |
| Data Release: | **Year 2007 Quarter 4** |
| Cost Per Square Foot: | **$85.11** |
| Building Cost: | **$23,575,500** |

Costs are derived from a building model with basic components.

Scope differences and market conditions can cause costs to vary significantly.

| | | % of Total | Cost Per S.F. | Cost |
|---|---|---|---|---|
| **A Substructure** | | **2.70%** | **$2.26** | **$625,500** |
| **A1010** | **Standard Foundations**<br>Strip footing, concrete, reinforced, load 11.1 KLF, soil bearing capacity 6 KSF, 12" deep x 24" wide<br>Spread footings, 3000 PSI concrete, load 800K, soil bearing capacity 6 KSF, 12' - 0" square x 37" deep | | **$1.54** | **$427,000** |
| **A1030** | **Slab on Grade**<br>Slab on grade, 4" thick, non industrial, reinforced | | **$0.48** | **$134,000** |
| **A2010** | **Basement Excavation**<br>Excavate and fill, 10,000 SF, 4' deep, sand gravel, or common earth, on site storage | | **$0.02** | **$6,000** |
| **A2020** | **Basement Walls**<br>Foundation wall, CIP, 4' wall height, direct chute, .148 CY/LF, 7.2 PLF, 12" thick | | **$0.21** | **$58,500** |
| **B Shell** | | **27.60%** | **$23.50** | **$6,510,500** |
| **B1010** | **Floor Construction**<br>Cast-in-place concrete column, 20" square, tied, 800K load, 12' story height, 394 lbs/LF, 6000PSI<br>Cast-in-place concrete column, 20" square, tied, 900K load, 12' story height, 394 lbs/LF, 6000PSI<br>Cast-in-place concrete column, 20", square, tied, minimum reinforcing, 500K load, 10'-14' story height, 375 lbs/LF, 4000PSI<br>Flat plate, concrete, 9" slab, 20" column, 20'x25' bay, 75 PSF superimposed load, 188 PSF total load | | **$13.84** | **$3,835,000** |

| | | | | |
|---|---|---|---|---|
| **B1020** | **Roof Construction** | | **$1.47** | **$407,000** |
| | Floor, concrete, beam and slab, 20'x25' bay, 40 PSF superimposed load, 18" deep beam, 8.5" slab, 146 PSF total load | | | |
| **B2010** | **Exterior Walls** | | **$5.43** | **$1,505,000** |
| | Brick wall, composite double wythe, standard face/CMU back-up, 8" thick, perlite core fill | | | |
| **B2020** | **Exterior Windows** | | **$2.07** | **$573,000** |
| | Windows, aluminum, sliding, insulated glass, 5' x 3' | | | |
| **B2030** | **Exterior Doors** | | **$0.20** | **$54,500** |
| | Door, aluminum & glass, with transom, narrow stile, double door, hardware, 6'-0" x 10'-0" opening | | | |
| | Door, steel 18 gauge, hollow metal, 1 door with frame, no label, 3'-0" x 7'-0" opening | | | |
| **B3010** | **Roof Coverings** | | **$0.49** | **$136,000** |
| | Roofing, asphalt flood coat, gravel, base sheet, 3 plies 15# asphalt felt, mopped | | | |
| | Insulation, rigid, roof deck, composite with 2" EPS, 1" perlite | | | |
| | Roof edges, aluminum, duranodic, .050" thick, 6" face | | | |
| | Flashing, aluminum, no backing sides, .019" | | | |
| **C Interiors** | | **20.40%** | **$17.39** | **$4,817,000** |
| **C1010** | **Partitions** | | **$1.68** | **$466,000** |
| | Metal partition, 5/8" water resistant gypsum board face, no base layer, 3-5/8" @ 24" OC framing ,same opposite face, no insulation | | | |
| | 1/2" fire ratedgypsum board, taped & finished, painted on metal furring | | | |
| **C1020** | **Interior Doors** | | **$1.87** | **$517,000** |
| | Door, single leaf, kd steel frame, hollow metal, commercial quality, flush, 3'-0" x 7'-0" x 1-3/8" | | | |
| **C1030** | **Fittings** | | **$0.63** | **$175,000** |
| | Toilet partitions, cubicles, ceiling hung, plastic laminate | | | |
| **C2010** | **Stair Construction** | | **$2.29** | **$633,000** |
| | Stairs, steel, cement filled metal pan & picket rail, 16 risers, with landing | | | |
| **C3010** | **Wall Finishes** | | **$0.68** | **$188,500** |
| | Painting, interior on plaster and drywall, walls & ceilings, roller work, primer & 2 coats | | | |
| | Vinyl wall covering, fabric back, medium weight | | | |
| **C3020** | **Floor Finishes** | | **$6.32** | **$1,751,000** |
| | Carpet, tufted, nylon, roll goods, 12' wide, 36 oz | | | |
| | Carpet, padding, add to above, minimum | | | |
| | Vinyl, composition tile, maximum | | | |
| | Tile, ceramic natural clay | | | |
| **C3030** | **Ceiling Finishes** | | **$3.92** | **$1,086,500** |
| | Acoustic ceilings, 3/4"mineral fiber, 12" x 12" tile, concealed 2" bar & channel grid, suspended support | | | |
| **D Services** | | **49.00%** | **$41.73** | **$11,560,000** |

| | | | |
|---|---|---|---|
| **D1010** | **Elevators and Lifts** | **$11.52** | **$3,190,500** |
| | 4 - Traction geared elevators, passenger, 3500 lb, 5 floors, 200 FPM | | |
| | Traction, geared passenger, 3500 lb, 8 floors, 12' story height, 2 car group, 200 FPM | | |
| **D2010** | **Plumbing Fixtures** | **$1.55** | **$428,500** |
| | Water closet, vitreous china, bowl only with flush valve, wall hung | | |
| | Urinal, vitreous china, wall hung | | |
| | Lavatory w/trim, vanity top, PE on CI, 20" x 18" | | |
| | Service sink w/trim, PE on CI, corner floor, wall hung w/rim guard, 24" x 20" | | |
| | Water cooler, electric, wall hung, 8.2 GPH | | |
| | Water cooler, electric, wall hung, wheelchair type, 7.5 GPH | | |
| **D2020** | **Domestic Water Distribution** | **$0.07** | **$18,500** |
| | Gas fired water heater, commercial, 100< F rise, 200 MBH input, 192 GPH | | |
| **D2040** | **Rain Water Drainage** | **$0.03** | **$9,500** |
| | Roof drain, CI, soil,single hub, 5" diam, 10' high | | |
| | Roof drain, CI, soil,single hub, 5" diam, for each additional foot add | | |
| **D3050** | **Terminal & Package Units** | **$14.28** | **$3,956,500** |
| | Rooftop, multizone, air conditioner, offices, 25,000 SF, 79.16 ton | | |
| **D4020** | **Standpipes** | **$0.06** | **$16,500** |
| | Wet standpipe risers, class I, steel, black, sch 40, 4" diam pipe, 1 floor | | |
| | Wet standpipe risers, class I, steel, black, sch 40, 4" diam pipe, additional floors | | |
| **D5010** | **Electrical Service/Distribution** | **$0.46** | **$128,000** |
| | Service installation, includes breakers, metering, 20' conduit & wire, 3 phase, 4 wire, 120/208 V, 1600 A | | |
| | Feeder installation 600 V, including RGS conduit and XHHW wire, 1600 A | | |
| | Switchgear installation, incl switchboard, panels & circuit breaker, 1600 A | | |
| **D5020** | **Lighting and Branch Wiring** | **$8.92** | **$2,472,000** |
| | Receptacles incl plate, box, conduit, wire, 16.5 per 1000 SF, 2.0 W per SF, with transformer | | |
| | Miscellaneous power, 1.2 watts | | |
| | Central air conditioning power, 4 watts | | |
| | Motor installation, three phase, 460 V, to and incl 15 HP motor size | | |
| | Motor feeder systems, three phase, feed to 200 V 5 HP, 230 V 7.5 HP, 460 V 15 HP, 575 V 20 HP | | |
| | Fluorescent fixtures recess mounted in ceiling, 2 watt per SF, 40 FC, 10 fixtures per 1000 SF | | |
| **D5030** | **Communications and Security** | **$3.93** | **$1,088,500** |
| | Telephone wiring for offices & laboratories, 8 jacks/MSF | | |

| | | | | |
|---|---|---|---|---|
| | Communication and alarm systems, includes outlets, boxes, conduit and wire, fire detection systems, 100 detectors | | | |
| | Internet wiring, 8 data/voice outlets per 1000 S.F. | | | |
| **D5090** | **Other Electrical Systems** | | **$0.91** | **$251,500** |
| | Generator sets, w/battery, charger, muffler and transfer switch, diesel engine with fuel tank, 100 kW | | | |
| | Uninterruptible power supply with standard battery pack, 15 kVA/12.75 kW | | | |
| **E Equipment & Furnishings** | | **0.30%** | **$0.23** | **$62,500** |
| **E1090** | **Other Equipment** | | **$0.23** | **$62,500** |
| | 32 - Detection Systems, smoke detector, duct type, excl. wires & conduit | | | |
| | 32 - Detection Systems, heat detector, smoke detector, ceiling type, excl. wires & conduit | | | |
| | 2 - Directory boards, plastic, glass covered, 36" x 48" | | | |
| | 31 - T.V. SYSTEMS, closed circuit, surveillance, for additional camera stations, add | | | |
| | 7 - T.V. SYSTEMS, closed circuit, surveillance, one station (camera & monitor) | | | |
| **F Special Construction** | | **0.00%** | **$0.00** | **$0** |
| **G Building Sitework** | | **0.00%** | **$0.00** | **$0** |
| | | | | |
| **SubTotal** | | **100%** | **$85.11** | **$23,575,500** |
| **Contractor Fees (General Conditions,Overhead,Profit)** | | **0.00%** | **$0.00** | **$0** |
| **Architectural Fees** | | **0.00%** | **$0.00** | **$0** |
| **User Fees** | | **0.00%** | **$0.00** | **$0** |
| **Total Building Cost** | | | **$85.11** | **$23,575,500** |

# Appendix E: General Conditions Estimate

| General Conditions | | | | | |
|---|---|---|---|---|---|
| Project Management Personel | | | | | |
| Item | Quantity | Amount | Units | Unit Price | Total |
| PM | 1 | 104 | wk | $ 1,925.00 | $ 200,200.00 |
| APM | 1 | 104 | wk | $ 1,650.00 | $ 171,600.00 |
| PE | 1 | 104 | wk | $ 1,350.00 | $ 140,400.00 |
| Superintendent | 1 | 104 | wk | $ 2,025.00 | $ 210,600.00 |
| Assistant Super | 1 | 104 | wk | $ 1,600.00 | $ 166,400.00 |
| PMA | 1 | 104 | wk | $ 1,200.00 | $ 124,800.00 |
| Safety Manager | 1 | 104 | wk | $ 1,350.00 | $ 140,400.00 |
| | | | | Subtotal | $ 1,154,400.00 |
| Administrative Facilities & Supplies | | | | | |
| Item | Quantity | Amount | Units | Unit Price | Total |
| 50x10 Trailer rent/month | 2 | 26 | Mo | $ 275.94 | $ 14,348.88 |
| Office Eqpt Rental | 1 | 26 | Mo | $ 152.21 | $ 3,957.46 |
| Office Supplies Avg | 1 | 26 | Mo | $ 83.47 | $ 2,170.22 |
| Telephone | 1 | 26 | Mo | $ 78.56 | $ 2,042.56 |
| lights & HVAC | 1 | 26 | Mo | $ 147.30 | $ 3,829.80 |
| IT Expenses | 1 | 26 | Mo | $ 75.00 | $ 1,950.00 |
| Drawings & Specifications | 1 | 1 | LS | $ 5,000.00 | $ 5,000.00 |
| | | | | Subtotal | $ 33,298.92 |
| Jobsite Requirements | | | | | |
| Item | Quantity | Amount | Units | Unit Price | Total |
| Fencing 6' High Chain Link | 1 | 600 | LF | $ 8.73 | $ 5,238.00 |
| Dumpsters | 4 | 26 | Mo | $ 200.00 | $ 20,800.00 |
| Temp Power | 1 | 34625 | CSF/Flr | $ 2.65 | $ 91,756.25 |
| Temp Water | 1 | 26 | Mo | $ 60.88 | $ 1,582.88 |
| Portable Toilets | 6 | 26 | Ea/month | $ 179.21 | $ 27,956.76 |
| | | | | Subtotal | $ 147,333.89 |
| Safety | | | | | |
| Item | Quantity | Amount | Units | Unit Price | Total |
| Personal Protection Eqpt. | 1 | 1 | LS | $ 1,000.00 | $ 1,000.00 |
| | | | | Subtotal | $ 1,000.00 |
| Job Extras | | | | | |
| Item | Quantity | Amount | Units | Unit Price | Total |
| Commissioning | 1 | $50,000,000 | Project | 0.75% | $ 375,000.00 |
| Concrete Testing | 1 | 1 | Project | $ 35,378.00 | $ 35,378.00 |
| | | | | Subtotal | $ 410,378.00 |
| | | | | Total | $ 1,746,410.81 |

| General Conditions Cost Per Week | | | | | |
|---|---|---|---|---|---|
| Project Management Personel | | | | | |
| Item | Quantity | Amount | Units | Unit Price | Total |
| PM | 1 | 1 | wk | $ 1,925.00 | $ 1,925.00 |
| APM | 1 | 1 | wk | $ 1,650.00 | $ 1,650.00 |
| PE | 1 | 1 | wk | $ 1,350.00 | $ 1,350.00 |
| Superintendent | 1 | 1 | wk | $ 2,025.00 | $ 2,025.00 |
| Assistant Super | 1 | 1 | wk | $ 1,600.00 | $ 1,600.00 |
| PMA | 1 | 1 | wk | $ 1,200.00 | $ 1,200.00 |
| Safety Manager | 1 | 1 | wk | $ 1,350.00 | $ 1,350.00 |
| | | | | Subtotal | $ 11,100.00 |
| Administrative Facilities & Supplies | | | | | |
| Item | Quantity | Amount | Units | Unit Price | Total |
| 50x10 Trailer rent/month | 2 | 0.25 | Mo | $ 275.94 | $ 137.97 |
| Office Eqpt Rental | 1 | 0.25 | Mo | $ 152.21 | $ 38.05 |
| Office Supplies Avg | 1 | 0.25 | Mo | $ 83.47 | $ 20.87 |
| Telephone | 1 | 0.25 | Mo | $ 78.56 | $ 19.64 |
| lights & HVAC | 1 | 0.25 | Mo | $ 147.30 | $ 36.83 |
| IT Expenses | 1 | 0.25 | Mo | $ 75.00 | $ 18.75 |
| | | | | Subtotal | $ 272.11 |
| Jobsite Requirements | | | | | |
| Item | Quantity | Amount | Units | Unit Price | Total |
| Dumpsters | 4 | 0.25 | Mo | $ 200.00 | $ 200.00 |
| Temp Water | 1 | 0.25 | Mo | $ 60.88 | $ 15.22 |
| Portable Toilets | 6 | 0.25 | Ea/month | $ 179.21 | $ 268.82 |
| | | | | Subtotal | $ 484.04 |
| | | | | Total/ Week | $ 11,856.14 |

# Appendix F: Detailed Structural Estimate

| Detailed Concrete Estimate | | | | | | |
|---|---|---|---|---|---|---|
| Piles | | | | | | |
| Item | Quantity | Unit | Material Cost | Labor Cost | Eqpt Cost | Total Cost |
| 14" Piles - Concrete Pile | 15839.21 | V.L.F | 509705.78 | 87274.05 | 82522.28 | $ 679,502 |
| 16" Piles - Concrete Pile | 3929.58 | V.L.F | 145905.12 | 22948.72 | 21612.66 | $ 190,467 |
| | | | | | Subtotal | $ 869,969 |
| Concrete | | | | | | |
| Item | Quantity | Unit | Material Cost | Labor Cost | Eqpt Cost | Total Cost |
| 4000 psi concrete - pumped | 1455.54 | CY | 154287.58 | 24307.57 | 8878.81 | $ 187,474 |
| 5000 psi concrete - pumped | 9096.82 | CY | 1009746.74 | 288823.95 | 65724.51 | $ 1,364,295 |
| 5000psi concrete - crane and bucket | 597.33 | CY | 66304.00 | 20906.67 | 4241.07 | $ 91,452 |
| 5000 psi concrete - direct chute | 456.30 | CY | 50649.25 | 8053.69 | 264.65 | $ 58,968 |
| 8000 psi concrete - pumped | 1538.25 | CY | 316880.01 | 30380.49 | 11075.42 | $ 358,336 |
| | | | | | Subtotal | $ 2,060,524 |
| PT Tendons | | | | | | |
| Item | Quantity | Unit | Material Cost | Labor Cost | Eqpt Cost | Total Cost |
| PT Tendons | 0.00 | lb | 0.00 | 0.00 | 0.00 | $ - |
| | | | | | Subtotal | $ - |
| Mild Reinforcing | | | | | | |
| Item | Quantity | Unit | Material Cost | Labor Cost | Eqpt Cost | Total Cost |
| #3-#7 | 706.90 | Ton | 1087728.41 | 284993.85 | 0.00 | $ 1,372,722 |
| #8-#18 | 621.12 | Ton | 971405.33 | 180405.18 | 0.00 | $ 1,151,811 |
| Sorting | 1328.02 | Ton | 0.00 | 16919.01 | 10996.03 | $ 27,915 |
| Crane | 1328.02 | Ton | 0.00 | 18419.68 | 11965.49 | $ 30,385 |
| | | | | | Subtotal | $ 2,582,833 |
| Formwork | | | | | | |
| Item | Quantity | Unit | Material Cost | Labor Cost | Eqpt Cost | Total Cost |
| Slab Formwork | 214641.46 | SF | 989497.11 | 474357.62 | 0.00 | $ 1,463,855 |
| Beam Formwork | 179196.05 | SF | 510708.74 | 582387.16 | 0.00 | $ 1,093,096 |
| Column & SW | 6858.44 | SF | 24244.60 | 9601.82 | 411.51 | $ 34,258 |
| Grade beams | 3069.33 | SF | 10159.49 | 6015.89 | 0.00 | $ 16,175 |
| | | | | | Subtotal | $ 2,607,384 |
| | | | | | Total | $ 8,120,710 |

| Piles | | | | |
|---|---|---|---|---|
| Type | Length[ft] | Diam[in] | Quantity | Total Length[ft] |
| Standard Piles | 60.46 | 14.00 | 262.00 | 15839.21 |
| Marine Piles | 60.46 | 16.00 | 65.00 | 3929.58 |

| Concrete | | |
|---|---|---|
| Superstructure | | |
| Area | CY Per Floor | CY Total |
| Elevated | 575 | 4600 |
| Beams | 537 | 4294 |
| Columns | 75 | 597 |
| Shear Walls | 98 | 780 |
| Curbs | 25 | 203 |
| | | |
| Total/Floor | 1309 | |
| Superstructure Total | | 10474 |
| | | |
| Area | | CY |
| SOG | | 1342 |
| Pile Caps | | 456 |
| Shear wall | | |
| Foundations | | 758 |
| Grade/Edge Beams | | 113 |
| 4000 psi piles | | 627 |
| 5000 psi piles | | 203 |
| | | |
| Foundation Total | | 3500 |
| Building Total | | 13974 |

## Detailed Steel Estimate

### Beams

| Type | Size | Length [ft] | Quantity | Material Cost | Labor Cost | Eqpt. Cost | Total Cost |
|---|---|---|---|---|---|---|---|
| W | 18X35 | 36 | 9 | $ 17,641.80 | $ 923.40 | $ 1,075.68 | $ 19,640.88 |
| W | 10x49 | 36 | 3 | $ 8,739.36 | $ 307.80 | $ 358.56 | $ 9,405.72 |
| W | 18x40 | 30 | 3 | $ 6,092.10 | $ 256.50 | $ 298.80 | $ 6,647.40 |
| W | 18x40 | 24 | 4 | $ 6,498.24 | $ 273.60 | $ 318.72 | $ 7,090.56 |
| W | 18x40 | 38 | 1 | $ 2,572.22 | $ 108.30 | $ 126.16 | $ 2,806.68 |
| W | 10x12 | 40 | 2 | $ 1,582.40 | $ 208.80 | $ 243.20 | $ 2,034.40 |
| W | 21x44 | 40 | 5 | $ 14,486.00 | $ 440.00 | $ 368.00 | $ 15,294.00 |
| W | 12X48 | 40 | 3 | $ 9,890.40 | $ 250.80 | $ 291.60 | $ 10,432.80 |
| W | 24X55 | 30 | 2 | $ 5,454.60 | $ 127.20 | $ 106.20 | $ 5,688.00 |
| W | 21X44 | 30 | 3 | $ 6,518.70 | $ 198.00 | $ 165.60 | $ 6,882.30 |
| W | 12X14 | 7.25 | 4 | $ 767.63 | $ 51.62 | $ 60.32 | $ 879.57 |
| W | 16X26 | 12 | 2 | $ 1,031.04 | $ 37.68 | $ 43.68 | $ 1,112.40 |
| W | 16X26 | 24 | 2 | $ 2,062.08 | $ 75.36 | $ 87.36 | $ 2,224.80 |
| W | 12X38 | 12 | 1 | $ 695.28 | $ 23.16 | $ 27.00 | $ 745.44 |
| HSS | 16X12X5/8 | 45 | 3 | $ 235,665.45 | $ 4,660.20 | $ 5,425.65 | $ 245,751.30 |
| HSS | 16X12X5/8 | 38 | 2 | $ 132,670.92 | $ 2,623.52 | $ 3,054.44 | $ 138,348.88 |
| C | 6X10.5 | 45 | 6 | $ 54,621.00 | $ 3,916.35 | $ 4,527.90 | $ 63,065.25 |
| | | | | | | Subtotal | $ 538,050.38 |

### Columns

| Type | Size | Length [ft] | Quantity | Material Cost | Labor Cost | Eqpt. Cost | Total Cost |
|---|---|---|---|---|---|---|---|
| W | 10X39 | 16.5 | 9 | $ 11,052.86 | $ 225.72 | $ 262.85 | $ 11,278.58 |
| HSS | 6X6X1/2 | 16.5 | 14 | $ 93,462.60 | $ 6,701.31 | $ 7,747.74 | $ 100,163.91 |
| HSS | 12X12X1/4 | 16.5 | 3 | $ 80,357.31 | $ 1,627.56 | $ 1,893.38 | $ 81,984.87 |
| | | | | | | Subtotal | $ 193,427.36 |

### Cross Bracing

| Type | Size | Length [ft] | Quantity | Material Cost | Labor Cost | Eqpt. Cost | Total Cost |
|---|---|---|---|---|---|---|---|
| L | 4x4x1/4 | 39.5 | 2 | $ 9,786.13 | $ 1,069.66 | $ 1,241.88 | $ 10,855.79 |
| L | 4x4x1/4 | 43 | 2 | $ 10,653.25 | $ 1,164.44 | $ 1,351.92 | $ 11,817.69 |
| | | | | | | Subtotal | $ 22,673.48 |

### Decking

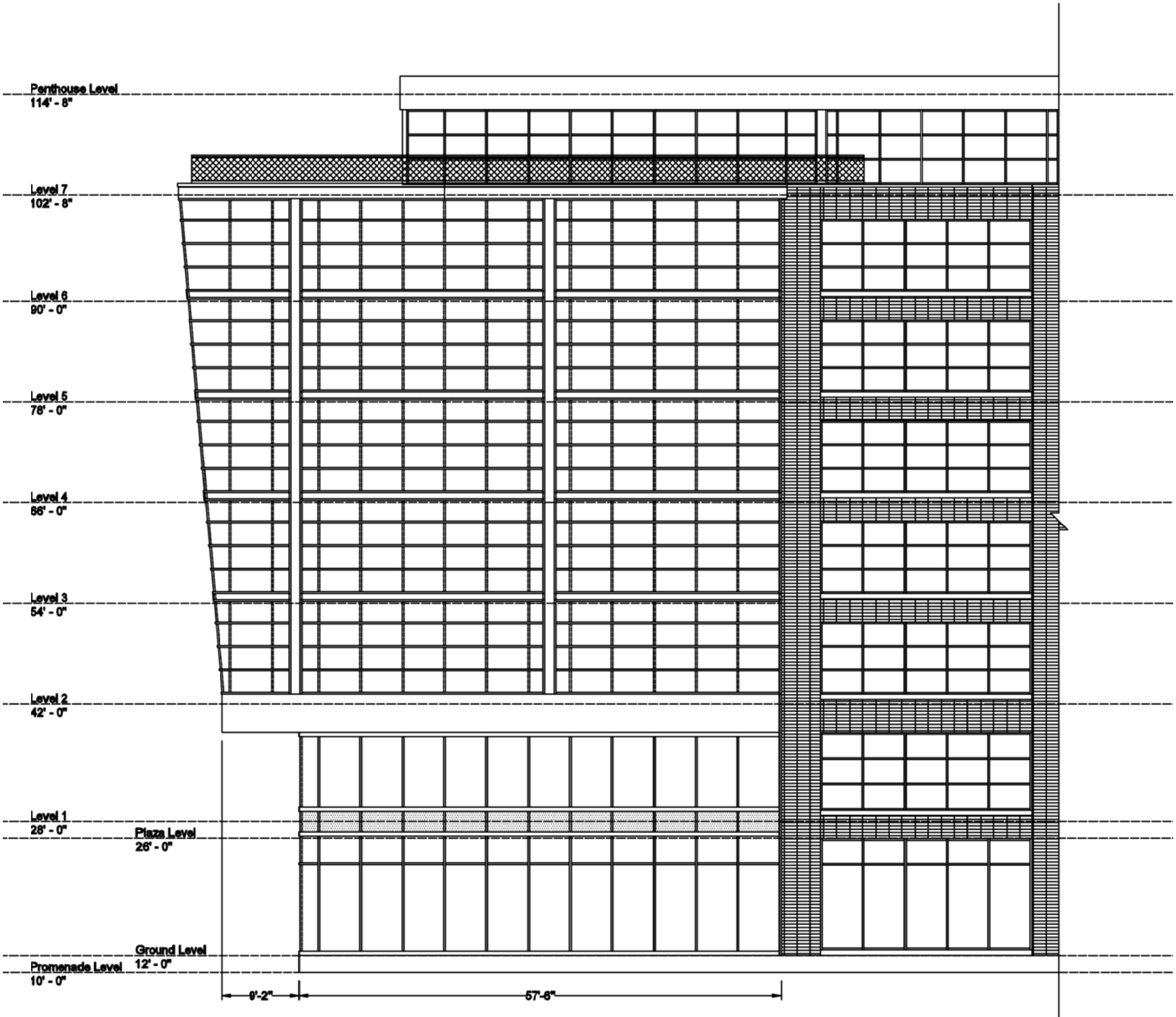
| Type | Size | Length [ft] | Quantity | Material Cost | Labor Cost | Eqpt. Cost | Total Cost |
|---|---|---|---|---|---|---|---|
| 20G Galvanized | 3" | 106 | 76 | $ 25,456.96 | $ 2,416.80 | $ 322.24 | $ 28,196.00 |
| | | | | | | Subtotal | $ 28,196.00 |
| | | | | | | Total | $ 782,347.21 |

| Reinforcing | | |
|---|---|---|
| Mild | | |
| Superstructure | | |
| Area | Tons Per Floor | Total Tons |
| Elevated | 6.81 | 54.44 |
| Beams | 102.89 | 823.09 |
| Columns | 7.75 | 62.03 |
| Shear Walls | 6.62 | 53.00 |
| Curbs | 1.79 | 14.31 |
| Total/Floor | 125.86 | |
| Superstructure Total | | 1007.36 |
| Foundation | | |
| Area | | Tons |
| SOG | | 148.15 |
| Pile Caps & S.W. Foundations | | 99.21 |
| Grade/Edge Beams | | 5.26 |
| Piles | | 68.04 |
| Foundation Total | | 320.66 |
| Total Mild Reinforcing | | 1328.02 |

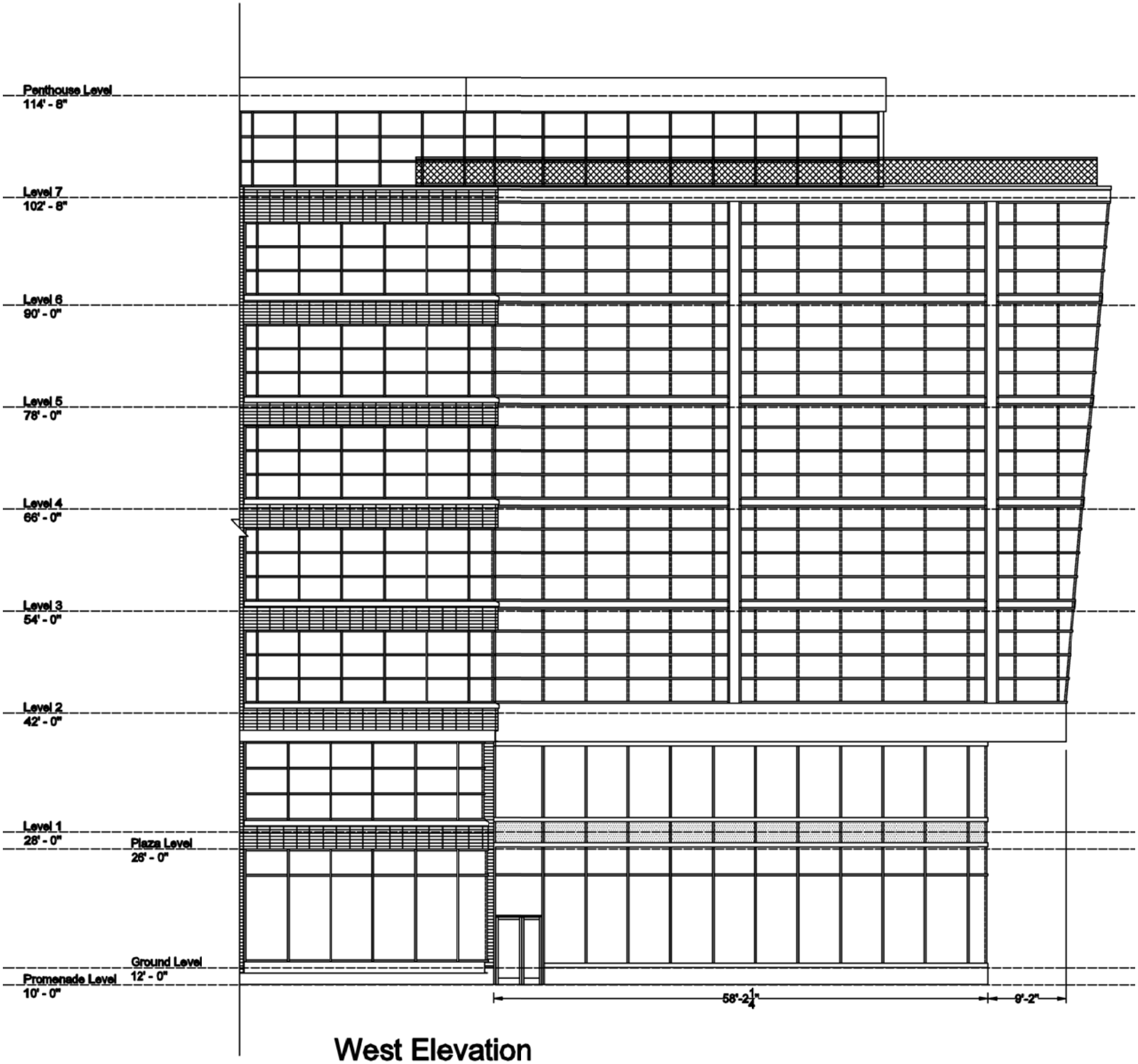
| Post Tension | | | | |
|---|---|---|---|---|
| Area | Ft/ Floor | Ft Total | lbs/Ft | lbs |
| Elevated | 1450.00 | 11600.00 | 0.67 | 7772.00 |
| Beams | 5663.74 | 45309.90 | 0.67 | 30357.63 |
| Total PT Cable | | | | 38129.63 |

# Appendix G: Curtain Wall Elevations

**South Elevation**
**Scale: ⅟16" = 1'-0"**



East Elevation
Scale: $\frac{1}{16}$" = 1'-0"



West Elevation

Scale: 1/16" = 1'-0"

# Appendix H: Curtain Wall Mechanical Calculations

## Original Totals

Q=(U*SC*SHGF*CLF)+(U*A*CLTD)

Btu/hr

| Floor Hr | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | 6.00 | 7.00 | 8.00 | 9.00 | 10.00 | 11.00 | 12.00 | 13.00 | 14.00 | 15.00 | 16.00 | 17.00 | 18.00 | 19.00 | 20.00 | 21.00 | 22.00 | 23.00 | 24.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G | 7,626 | 5,497 | 3,292 | 854 | 392 | 391 | 531 | 3,966 | 6,830 | 9,710 | 14,325 | 17,686 | 23,034 | 25,405 | 27,708 | 28,383 | 27,454 | 26,292 | 23,480 | 20,662 | 17,381 | 13,890 | 11,911 | 9,914 |
| 1 | 7,848 | 5,639 | 3,171 | 537 | 15 | 448 | 805 | 4,804 | 8,319 | 11,666 | 17,036 | 21,010 | 27,272 | 29,930 | 31,347 | 31,559 | 31,623 | 29,770 | 26,360 | 22,848 | 19,005 | 15,016 | 12,805 | 10,483 |
| 2 | 9,255 | 7,327 | 5,061 | 2,651 | 1,971 | 2,630 | 3,190 | 6,632 | 9,676 | 12,527 | 17,153 | 20,736 | 26,199 | 28,520 | 29,412 | 29,656 | 29,881 | 28,047 | 25,295 | 22,344 | 19,104 | 15,734 | 13,805 | 11,667 |
| 3 | 7,736 | 5,836 | 3,733 | 1,435 | 925 | 1,586 | 2,330 | 5,743 | 8,427 | 10,970 | 15,159 | 18,351 | 23,448 | 25,636 | 26,636 | 27,034 | 27,043 | 25,376 | 22,761 | 20,081 | 17,011 | 13,762 | 11,910 | 9,986 |
| 4 | 7,565 | 5,690 | 3,602 | 1,327 | 825 | 1,502 | 2,254 | 5,669 | 8,349 | 10,883 | 15,055 | 18,227 | 23,293 | 25,444 | 25,975 | 26,350 | 26,779 | 25,102 | 22,493 | 19,820 | 16,773 | 13,539 | 11,702 | 9,801 |
| 5 | 7,755 | 5,844 | 3,728 | 1,417 | 907 | 1,566 | 2,310 | 5,746 | 8,454 | 11,021 | 15,246 | 18,463 | 23,596 | 25,797 | 26,377 | 26,778 | 27,206 | 25,527 | 22,889 | 20,186 | 17,092 | 13,820 | 11,956 | 10,019 |
| 6 | 7,765 | 5,848 | 3,727 | 1,410 | 899 | 1,559 | 2,301 | 5,747 | 8,466 | 11,044 | 15,285 | 18,513 | 23,662 | 25,868 | 26,453 | 26,855 | 27,278 | 25,595 | 22,946 | 20,233 | 17,129 | 13,846 | 11,977 | 10,034 |
| 7 | 1,379 | 200 | (1,154) | (2,507) | (2,580) | (1,606) | (580) | 2,337 | 4,656 | 6,566 | 9,765 | 12,158 | 16,279 | 17,516 | 17,969 | 18,028 | 17,886 | 15,884 | 13,325 | 10,730 | 8,134 | 5,538 | 4,222 | 2,869 |
| MAX | 9,255 | 7,327 | 5,061 | 2,651 | 1,971 | 2,630 | 3,190 | 6,632 | 9,676 | 12,527 | 17,153 | 21,010 | 27,272 | 29,930 | 31,347 | 31,559 | 31,623 | 29,770 | 26,360 | 22,848 | 19,104 | 15,734 | 13,805 | 11,667 |
|  | Tons |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| G | 0.64 | 0.46 | 0.27 | 0.07 | 0.03 | 0.03 | 0.04 | 0.33 | 0.57 | 0.81 | 1.19 | 1.47 | 1.92 | 2.12 | 2.31 | 2.37 | 2.29 | 2.19 | 1.96 | 1.72 | 1.45 | 1.16 | 0.99 | 0.83 |
| 1 | 0.65 | 0.47 | 0.26 | 0.04 | 0.00 | 0.04 | 0.07 | 0.40 | 0.69 | 0.97 | 1.42 | 1.75 | 2.27 | 2.49 | 2.61 | 2.63 | 2.64 | 2.48 | 2.20 | 1.90 | 1.58 | 1.25 | 1.07 | 0.87 |
| 2 | 0.77 | 0.61 | 0.42 | 0.22 | 0.16 | 0.22 | 0.27 | 0.55 | 0.81 | 1.04 | 1.43 | 1.73 | 2.18 | 2.38 | 2.45 | 2.47 | 2.49 | 2.34 | 2.11 | 1.86 | 1.59 | 1.31 | 1.15 | 0.97 |
| 3 | 0.64 | 0.49 | 0.31 | 0.12 | 0.08 | 0.13 | 0.19 | 0.48 | 0.70 | 0.91 | 1.26 | 1.53 | 1.95 | 2.14 | 2.22 | 2.25 | 2.25 | 2.11 | 1.90 | 1.67 | 1.42 | 1.15 | 0.99 | 0.83 |
| 4 | 0.63 | 0.47 | 0.30 | 0.11 | 0.07 | 0.13 | 0.19 | 0.47 | 0.70 | 0.91 | 1.25 | 1.52 | 1.94 | 2.12 | 2.16 | 2.20 | 2.23 | 2.09 | 1.87 | 1.65 | 1.40 | 1.13 | 0.98 | 0.82 |
| 5 | 0.65 | 0.49 | 0.31 | 0.12 | 0.08 | 0.13 | 0.19 | 0.48 | 0.70 | 0.92 | 1.27 | 1.54 | 1.97 | 2.15 | 2.20 | 2.23 | 2.27 | 2.13 | 1.91 | 1.68 | 1.42 | 1.15 | 1.00 | 0.83 |
| 6 | 0.65 | 0.49 | 0.31 | 0.12 | 0.07 | 0.13 | 0.19 | 0.48 | 0.71 | 0.92 | 1.27 | 1.54 | 1.97 | 2.16 | 2.20 | 2.24 | 2.27 | 2.13 | 1.91 | 1.69 | 1.43 | 1.15 | 1.00 | 0.84 |
| 7 | 0.11 | 0.02 | (0.10) | (0.21) | (0.21) | (0.13) | (0.05) | 0.19 | 0.39 | 0.55 | 0.81 | 1.01 | 1.36 | 1.46 | 1.50 | 1.50 | 1.49 | 1.32 | 1.11 | 0.89 | 0.68 | 0.46 | 0.35 | 0.24 |
| MAX | 0.77 | 0.61 | 0.42 | 0.22 | 0.16 | 0.22 | 0.27 | 0.55 | 0.81 | 1.04 | 1.43 | 1.75 | 2.27 | 2.49 | 2.61 | 2.63 | 2.64 | 2.48 | 2.20 | 1.90 | 1.59 | 1.31 | 1.15 | 0.97 |

## Proposed Totals

Q=(U*SC*SHGF*CLF)+(U*A*CLTD)

Btu/hr

| Floor Hr | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | 6.00 | 7.00 | 8.00 | 9.00 | 10.00 | 11.00 | 12.00 | 13.00 | 14.00 | 15.00 | 16.00 | 17.00 | 18.00 | 19.00 | 20.00 | 21.00 | 22.00 | 23.00 | 24.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G | 7,533 | 5,608 | 3,649 | 1,458 | 995 | 832 | 763 | 3,639 | 6,073 | 8,597 | 12,615 | 15,535 | 20,113 | 22,189 | 22,531 | 22,637 | 22,734 | 23,448 | 21,128 | 18,803 | 16,014 | 13,016 | 11,283 | 9,532 |
| 1.00 | 7,579 | 5,930 | 4,110 | 2,124 | 1,602 | 1,679 | 1,667 | 4,250 | 6,577 | 8,874 | 12,557 | 15,330 | 19,600 | 21,539 | 22,455 | 22,923 | 23,268 | 22,288 | 20,173 | 17,957 | 15,410 | 12,716 | 11,153 | 9,479 |
| 2.00 | 9,021 | 7,581 | 5,879 | 4,031 | 3,351 | 3,589 | 3,700 | 5,859 | 7,852 | 9,764 | 12,889 | 15,403 | 19,142 | 20,900 | 21,715 | 22,039 | 22,493 | 21,538 | 19,913 | 18,090 | 15,976 | 13,734 | 12,368 | 10,794 |
| 3.00 | 7,510 | 6,084 | 4,530 | 2,782 | 2,272 | 2,523 | 2,814 | 4,968 | 6,629 | 8,261 | 10,991 | 13,141 | 16,548 | 18,174 | 18,974 | 19,454 | 19,814 | 19,025 | 17,510 | 15,930 | 13,960 | 11,810 | 10,508 | 9,134 |
| 4.00 | 7,341 | 5,936 | 4,394 | 2,666 | 2,163 | 2,430 | 2,729 | 4,892 | 6,555 | 8,181 | 10,902 | 13,039 | 16,425 | 18,021 | 18,792 | 19,245 | 19,593 | 18,791 | 17,275 | 15,695 | 13,741 | 11,599 | 10,309 | 8,954 |
| 5.00 | 7,528 | 6,093 | 4,530 | 2,772 | 2,261 | 2,511 | 2,800 | 4,972 | 6,651 | 8,301 | 11,059 | 13,228 | 16,662 | 18,297 | 19,108 | 19,587 | 19,939 | 19,142 | 17,610 | 16,012 | 14,024 | 11,857 | 10,546 | 9,162 |
| 6.00 | 7,537 | 6,098 | 4,531 | 2,768 | 2,256 | 2,506 | 2,795 | 4,974 | 6,662 | 8,319 | 11,089 | 13,267 | 16,713 | 18,353 | 19,168 | 19,647 | 19,996 | 19,195 | 17,655 | 16,050 | 14,054 | 11,879 | 10,564 | 9,176 |
| 7.00 | 1,215 | 392 | (533) | (1,458) | (1,531) | (971) | (395) | 1,519 | 3,110 | 4,460 | 6,681 | 8,331 | 11,097 | 12,173 | 12,341 | 12,312 | 12,217 | 10,939 | 9,237 | 7,497 | 5,758 | 4,019 | 3,130 | 2,205 |
| MAX | 9,021 | 7,581 | 5,879 | 4,031 | 3,351 | 3,589 | 3,700 | 5,859 | 7,852 | 9,764 | 12,889 | 15,535 | 20,113 | 22,189 | 22,531 | 22,923 | 23,268 | 23,448 | 21,128 | 18,803 | 16,014 | 13,734 | 12,368 | 10,794 |
|  | Tons |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| G | 0.63 | 0.47 | 0.30 | 0.12 | 0.08 | 0.07 | 0.06 | 0.30 | 0.51 | 0.72 | 1.05 | 1.29 | 1.68 | 1.85 | 1.88 | 1.89 | 1.89 | 1.95 | 1.76 | 1.57 | 1.33 | 1.08 | 0.94 | 0.79 |
| 1.00 | 0.63 | 0.49 | 0.34 | 0.18 | 0.13 | 0.14 | 0.14 | 0.35 | 0.55 | 0.74 | 1.05 | 1.28 | 1.63 | 1.79 | 1.87 | 1.91 | 1.94 | 1.86 | 1.68 | 1.50 | 1.28 | 1.06 | 0.93 | 0.79 |
| 2.00 | 0.75 | 0.63 | 0.49 | 0.34 | 0.28 | 0.30 | 0.31 | 0.49 | 0.65 | 0.81 | 1.07 | 1.28 | 1.60 | 1.74 | 1.81 | 1.84 | 1.87 | 1.79 | 1.66 | 1.51 | 1.33 | 1.14 | 1.03 | 0.90 |
| 3.00 | 0.63 | 0.51 | 0.38 | 0.23 | 0.19 | 0.21 | 0.23 | 0.41 | 0.55 | 0.69 | 0.92 | 1.10 | 1.38 | 1.51 | 1.58 | 1.62 | 1.65 | 1.59 | 1.46 | 1.33 | 1.16 | 0.98 | 0.88 | 0.76 |
| 4.00 | 0.61 | 0.49 | 0.37 | 0.22 | 0.18 | 0.20 | 0.23 | 0.41 | 0.55 | 0.68 | 0.91 | 1.09 | 1.37 | 1.50 | 1.57 | 1.60 | 1.63 | 1.57 | 1.44 | 1.31 | 1.15 | 0.97 | 0.86 | 0.75 |
| 5.00 | 0.63 | 0.51 | 0.38 | 0.23 | 0.19 | 0.21 | 0.23 | 0.41 | 0.55 | 0.69 | 0.92 | 1.10 | 1.39 | 1.52 | 1.59 | 1.63 | 1.66 | 1.60 | 1.47 | 1.33 | 1.17 | 0.99 | 0.88 | 0.76 |
| 6.00 | 0.63 | 0.51 | 0.38 | 0.23 | 0.19 | 0.21 | 0.23 | 0.41 | 0.56 | 0.69 | 0.92 | 1.11 | 1.39 | 1.53 | 1.60 | 1.64 | 1.67 | 1.60 | 1.47 | 1.34 | 1.17 | 0.99 | 0.88 | 0.76 |
| 7.00 | 0.10 | 0.03 | (0.04) | (0.12) | (0.13) | (0.08) | (0.03) | 0.13 | 0.26 | 0.37 | 0.56 | 0.69 | 0.92 | 1.01 | 1.03 | 1.03 | 1.02 | 0.91 | 0.77 | 0.62 | 0.48 | 0.33 | 0.26 | 0.18 |
| MAX | 0.75 | 0.63 | 0.49 | 0.34 | 0.28 | 0.30 | 0.31 | 0.49 | 0.65 | 0.81 | 1.07 | 1.29 | 1.68 | 1.85 | 1.88 | 1.91 | 1.94 | 1.95 | 1.76 | 1.57 | 1.33 | 1.14 | 1.03 | 0.90 |

# Appendix I: Non-Enclosure Mechanical Calculations

| | | Occupants | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | W/SF | Q=(W/SF)(3.41)(A)(CFLt) [Btu/hr] | | | | | | | | | | | | | | | | | | | | | | | |
| 34,000 | SF | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| | | 15,072 | 12,753 | 11,594 | 10,435 | 9,275 | 8,116 | 6,956 | 61,448 | 71,883 | 79,999 | 85,796 | 89,274 | 92,752 | 96,230 | 98,549 | 100,868 | 103,187 | 48,695 | 39,420 | 32,463 | 26,666 | 23,188 | 19,710 | 17,391 |
| | | Lighting | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | W/SF | Q=(W/SF)(3.41)(A)(CFLt) [Btu/hr] | | | | | | | | | | | | | | | | | | | | | | | |
| 34000 | SF | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| | | 44,057 | 39,420 | 37,101 | 34,782 | 32,463 | 32,463 | 30,144 | 27,826 | 176,229 | 180,866 | 183,185 | 185,504 | 187,823 | 192,460 | 194,779 | 197,098 | 199,417 | 199,417 | 201,736 | 204,054 | 55,651 | 51,014 | 48,695 | 46,376 |
| | | Equipment | | | | | | | | | | | | | | | | | | | | | | | |
| 34000 | SF | Q=(W/SF)(3.41)(A)(CFLt) [Btu/hr] | | | | | | | | | | | | | | | | | | | | | | | |
| 3.5 | W/SF | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| | | 44,637 | 40,579 | 32,463 | 28,405 | 28,405 | 24,347 | 20,290 | 243,474 | 275,937 | 296,227 | 312,458 | 328,690 | 336,806 | 344,922 | 353,037 | 361,153 | 365,211 | 146,084 | 117,679 | 97,390 | 81,158 | 68,984 | 60,869 | 52,753 |
| | | Total | | | | | | | | | | | | | | | | | | | | | | | |
| | Btu/hr | 103,766 | 92,752 | 81,158 | 73,622 | 70,144 | 64,926 | 57,390 | 332,748 | 524,049 | 557,092 | 581,439 | 603,468 | 617,381 | 633,612 | 646,366 | 659,119 | 667,814 | 394,196 | 358,834 | 333,907 | 163,475 | 143,186 | 129,273 | 116,520 |
| | Ton | 8.65 | 7.73 | 6.76 | 6.14 | 5.85 | 5.41 | 4.78 | 27.73 | 43.67 | 46.42 | 48.45 | 50.29 | 51.45 | 52.80 | 53.86 | 54.93 | 55.65 | 32.85 | 29.90 | 27.83 | 13.62 | 11.93 | 10.77 | 9.71 |

CLF Occupants (Curtiss, 2002)

| Total hours in space | Hours after each entry into the space | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 2 | 0.49 | 0.58 | 0.17 | 0.13 | 0.1 | 0.08 | 0.07 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 4 | 0.49 | 0.59 | 0.66 | 0.71 | 0.27 | 0.21 | 0.16 | 0.14 | 0.11 | 0.1 | 0.08 | 0.07 | 0.06 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 |
| 6 | 0.5 | 0.6 | 0.67 | 0.72 | 0.76 | 0.79 | 0.34 | 0.26 | 0.21 | 0.18 | 0.15 | 0.13 | 0.11 | 0.1 | 0.08 | 0.07 | 0.06 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |
| 8 | 0.51 | 0.61 | 0.67 | 0.72 | 0.76 | 0.8 | 0.82 | 0.84 | 0.38 | 0.3 | 0.25 | 0.21 | 0.18 | 0.15 | 0.13 | 0.12 | 0.1 | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 | 0.05 | 0.04 |
| 10 | 0.53 | 0.62 | 0.69 | 0.74 | 0.77 | 0.8 | 0.83 | 0.85 | 0.87 | 0.89 | 0.42 | 0.34 | 0.28 | 0.23 | 0.2 | 0.17 | 0.15 | 0.13 | 0.11 | 0.1 | 0.09 | 0.08 | 0.07 | 0.06 |
| 12 | 0.55 | 0.64 | 0.7 | 0.75 | 0.79 | 0.81 | 0.84 | 0.86 | 0.88 | 0.89 | 0.91 | 0.92 | 0.45 | 0.36 | 0.3 | 0.25 | 0.21 | 0.19 | 0.16 | 0.14 | 0.12 | 0.11 | 0.09 | 0.08 |
| 14 | 0.58 | 0.66 | 0.72 | 0.77 | 0.8 | 0.83 | 0.85 | 0.87 | 0.89 | 0.9 | 0.91 | 0.92 | 0.93 | 0.94 | 0.47 | 0.38 | 0.31 | 0.26 | 0.23 | 0.2 | 0.17 | 0.15 | 0.13 | 0.11 |
| 16 | 0.62 | 0.7 | 0.75 | 0.79 | 0.82 | 0.85 | 0.87 | 0.88 | 0.9 | 0.91 | 0.92 | 0.93 | 0.94 | 0.95 | 0.95 | 0.96 | 0.49 | 0.39 | 0.33 | 0.28 | 0.24 | 0.2 | 0.18 | 0.16 |
| 18 | 0.66 | 0.74 | 0.79 | 0.82 | 0.85 | 0.87 | 0.89 | 0.9 | 0.92 | 0.93 | 0.94 | 0.94 | 0.95 | 0.96 | 0.96 | 0.97 | 0.97 | 0.97 | 0.5 | 0.4 | 0.33 | 0.28 | 0.24 | 0.21 |

CLF - Lighting (Curtiss 2002)

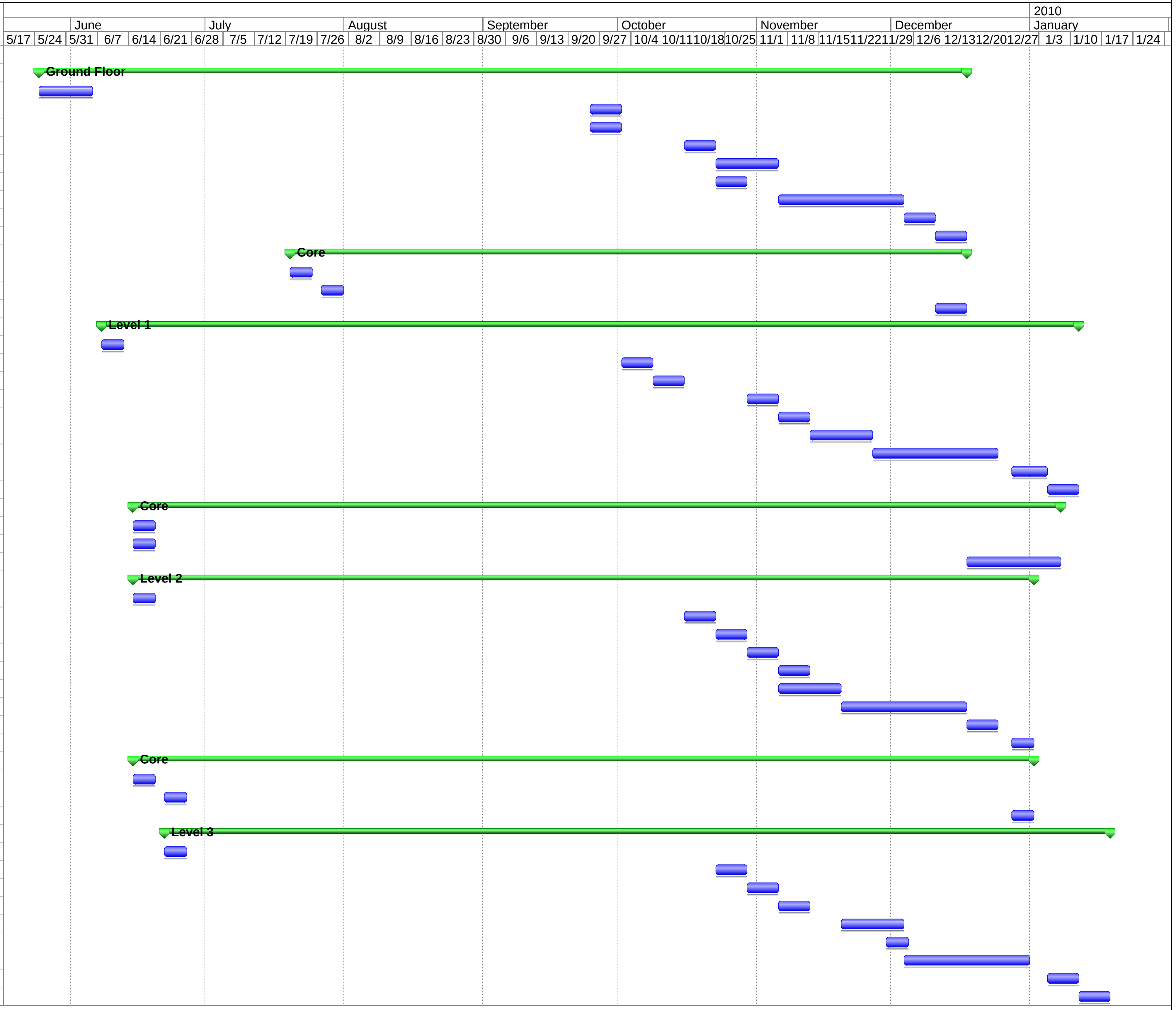
| "a" coefficient | "b" classification | Number of hours after lights are turned on | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 45 | A | 0.05 | 0.49 | 0.59 | 0.67 | 0.73 | 0.78 | 0.83 | 0.86 | 0.89 | 0.91 | 0.93 | 0.94 | 0.95 | 0.51 | 0.41 | 0.33 | 0.27 | 0.22 | 0.17 | 0.14 | 0.11 | 0.09 | 0.07 | 0.06 |
| | B | 0.13 | 0.57 | 0.61 | 0.65 | 0.69 | 0.72 | 0.75 | 0.77 | 0.79 | 0.82 | 0.83 | 0.85 | 0.87 | 0.43 | 0.39 | 0.35 | 0.31 | 0.28 | 0.25 | 0.23 | 0.21 | 0.18 | 0.17 | 0.15 |
| | C | 0.19 | 0.63 | 0.65 | 0.67 | 0.69 | 0.71 | 0.73 | 0.74 | 0.76 | 0.77 | 0.79 | 0.8 | 0.81 | 0.37 | 0.35 | 0.33 | 0.31 | 0.29 | 0.27 | 0.26 | 0.24 | 0.23 | 0.21 | 0.2 |
| | D | 0.22 | 0.66 | 0.67 | 0.68 | 0.69 | 0.7 | 0.71 | 0.72 | 0.73 | 0.74 | 0.74 | 0.75 | 0.76 | 0.32 | 0.31 | 0.3 | 0.29 | 0.28 | 0.27 | 0.26 | 0.26 | 0.25 | 0.24 | 0.23 |
| 55 | A | 0.04 | 0.58 | 0.66 | 0.73 | 0.78 | 0.82 | 0.86 | 0.89 | 0.91 | 0.93 | 0.94 | 0.95 | 0.96 | 0.42 | 0.34 | 0.27 | 0.22 | 0.18 | 0.14 | 0.11 | 0.09 | 0.07 | 0.06 | 0.05 |
| | B | 0.11 | 0.65 | 0.68 | 0.72 | 0.74 | 0.77 | 0.79 | 0.81 | 0.83 | 0.85 | 0.86 | 0.88 | 0.89 | 0.35 | 0.32 | 0.28 | 0.26 | 0.23 | 0.21 | 0.19 | 0.17 | 0.15 | 0.14 | 0.12 |
| | C | 0.15 | 0.69 | 0.71 | 0.73 | 0.75 | 0.76 | 0.78 | 0.79 | 0.8 | 0.81 | 0.83 | 0.84 | 0.85 | 0.3 | 0.29 | 0.27 | 0.25 | 0.24 | 0.22 | 0.21 | 0.2 | 0.19 | 0.17 | 0.16 |
| | D | 0.18 | 0.72 | 0.73 | 0.74 | 0.75 | 0.76 | 0.76 | 0.77 | 0.78 | 0.78 | 0.79 | 0.8 | 0.8 | 0.26 | 0.25 | 0.24 | 0.24 | 0.23 | 0.22 | 0.22 | 0.21 | 0.2 | 0.2 | 0.19 |
| 65 | A | 0.03 | 0.67 | 0.74 | 0.79 | 0.83 | 0.86 | 0.89 | 0.91 | 0.93 | 0.94 | 0.95 | 0.96 | 0.97 | 0.33 | 0.26 | 0.21 | 0.17 | 0.14 | 0.11 | 0.09 | 0.07 | 0.06 | 0.05 | 0.04 |
| | B | 0.09 | 0.73 | 0.75 | 0.78 | 0.8 | 0.82 | 0.84 | 0.85 | 0.87 | 0.88 | 0.89 | 0.9 | 0.91 | 0.27 | 0.25 | 0.22 | 0.2 | 0.18 | 0.16 | 0.15 | 0.13 | 0.12 | 0.11 | 0.1 |
| | C | 0.12 | 0.76 | 0.78 | 0.79 | 0.8 | 0.81 | 0.83 | 0.84 | 0.85 | 0.86 | 0.86 | 0.87 | 0.88 | 0.24 | 0.22 | 0.21 | 0.2 | 0.19 | 0.17 | 0.16 | 0.15 | 0.14 | 0.14 | 0.13 |
| | D | 0.14 | 0.79 | 0.79 | 0.8 | 0.8 | 0.81 | 0.82 | 0.82 | 0.83 | 0.83 | 0.84 | 0.84 | 0.85 | 0.2 | 0.2 | 0.19 | 0.18 | 0.18 | 0.17 | 0.17 | 0.16 | 0.16 | 0.15 | 0.15 |
| 75 | A | 0.02 | 0.77 | 0.81 | 0.85 | 0.88 | 0.9 | 0.92 | 0.94 | 0.95 | 0.96 | 0.97 | 0.97 | 0.98 | 0.23 | 0.19 | 0.15 | 0.12 | 0.1 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.03 |
| | B | 0.06 | 0.81 | 0.82 | 0.84 | 0.86 | 0.87 | 0.88 | 0.9 | 0.91 | 0.92 | 0.92 | 0.93 | 0.94 | 0.19 | 0.18 | 0.16 | 0.14 | 0.13 | 0.12 | 0.1 | 0.09 | 0.08 | 0.08 | 0.07 |
| | C | 0.09 | 0.83 | 0.84 | 0.85 | 0.86 | 0.87 | 0.88 | 0.88 | 0.89 | 0.9 | 0.9 | 0.91 | 0.91 | 0.17 | 0.16 | 0.15 | 0.14 | 0.13 | 0.12 | 0.12 | 0.11 | 0.1 | 0.1 | 0.09 |
| | D | 0.1 | 0.85 | 0.85 | 0.86 | 0.86 | 0.86 | 0.87 | 0.87 | 0.88 | 0.88 | 0.88 | 0.89 | 0.89 | 0.14 | 0.14 | 0.14 | 0.13 | 0.13 | 0.12 | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 |

**CLF - Unhooded appliances (Curtiss, 2002)**

| Run hours | Number of hours after appliances have been turned on | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 2 | 0.56 | 0.64 | 0.15 | 0.11 | 0.08 | 0.07 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 4 | 0.57 | 0.65 | 0.71 | 0.75 | 0.23 | 0.18 | 0.14 | 0.12 | 0.1 | 0.08 | 0.07 | 0.06 | 0.05 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 |
| 6 | 0.57 | 0.65 | 0.71 | 0.76 | 0.79 | 0.82 | 0.29 | 0.22 | 0.18 | 0.15 | 0.13 | 0.11 | 0.1 | 0.08 | 0.07 | 0.06 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 |
| 8 | 0.58 | 0.66 | 0.72 | 0.76 | 0.8 | 0.82 | 0.85 | 0.87 | 0.33 | 0.26 | 0.21 | 0.18 | 0.15 | 0.13 | 0.11 | 0.1 | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 |
| 10 | 0.6 | 0.68 | 0.73 | 0.77 | 0.81 | 0.83 | 0.85 | 0.87 | 0.89 | 0.9 | 0.36 | 0.29 | 0.24 | 0.2 | 0.17 | 0.15 | 0.13 | 0.11 | 0.1 | 0.08 | 0.07 | 0.07 | 0.06 | 0.05 |
| 12 | 0.62 | 0.69 | 0.75 | 0.79 | 0.82 | 0.84 | 0.86 | 0.88 | 0.89 | 0.91 | 0.92 | 0.93 | 0.38 | 0.31 | 0.25 | 0.21 | 0.18 | 0.16 | 0.14 | 0.12 | 0.11 | 0.09 | 0.08 | 0.07 |
| 14 | 0.64 | 0.71 | 0.76 | 0.8 | 0.83 | 0.85 | 0.87 | 0.89 | 0.9 | 0.92 | 0.93 | 0.93 | 0.94 | 0.95 | 0.4 | 0.32 | 0.27 | 0.23 | 0.19 | 0.17 | 0.15 | 0.13 | 0.11 | 0.1 |
| 16 | 0.67 | 0.74 | 0.79 | 0.82 | 0.85 | 0.87 | 0.89 | 0.9 | 0.91 | 0.92 | 0.93 | 0.94 | 0.95 | 0.96 | 0.96 | 0.97 | 0.42 | 0.34 | 0.28 | 0.24 | 0.2 | 0.18 | 0.15 | 0.13 |
| 18 | 0.71 | 0.78 | 0.82 | 0.85 | 0.87 | 0.89 | 0.9 | 0.92 | 0.93 | 0.94 | 0.94 | 0.95 | 0.96 | 0.96 | 0.97 | 0.97 | 0.97 | 0.98 | 0.43 | 0.35 | 0.29 | 0.24 | 0.21 | 0.18 |

# Appendix J: Mechanical Schedule

| ID | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | **Ground Floor** | **149 days** | **Mon 5/25/09** | **Thu 12/17/09** | |
| 3 | MEP Riser | 10 days | Mon 5/25/09 | Fri 6/5/09 | |
| 4 | Layout Floor Ductwork - North | 5 days | Fri 9/25/09 | Thu 10/1/09 | |
| 5 | Layout Floor Ductwork - South | 5 days | Fri 9/25/09 | Thu 10/1/09 | |
| 6 | Install Underfloor Duct North | 5 days | Fri 10/16/09 | Thu 10/22/09 | |
| 7 | Set Mechanical Eqpt. | 10 days | Fri 10/23/09 | Thu 11/5/09 | |
| 8 | Install Underfloor Duct - South | 5 days | Fri 10/23/09 | Thu 10/29/09 | |
| 9 | MEP Connections to Eqpt. | 20 days | Fri 11/6/09 | Thu 12/3/09 | |
| 10 | Start Up Eqpt. | 5 days | Fri 12/4/09 | Thu 12/10/09 | |
| 11 | Pre Test Eqpt. | 5 days | Fri 12/11/09 | Thu 12/17/09 | |
| 12 | **Core** | **109 days** | **Mon 7/20/09** | **Thu 12/17/09** | |
| 13 | Rough In Bathroom Duct | 5 days | Mon 7/20/09 | Fri 7/24/09 | |
| 14 | Set SCU's | 5 days | Mon 7/27/09 | Fri 7/31/09 | |
| 15 | HVAC Trim | 5 days | Fri 12/11/09 | Thu 12/17/09 | |
| 16 | **Level 1** | **156 days** | **Mon 6/8/09** | **Mon 1/11/10** | |
| 17 | MEP Risers | 5 days | Mon 6/8/09 | Fri 6/12/09 | |
| 18 | Layout Floor Duct North | 5 days | Fri 10/2/09 | Thu 10/8/09 | |
| 19 | Layout Floor Duct South | 5 days | Fri 10/9/09 | Thu 10/15/09 | |
| 20 | Install Underfloor Duct North | 5 days | Fri 10/30/09 | Thu 11/5/09 | |
| 21 | Install Underfloor Duct South | 5 days | Fri 11/6/09 | Thu 11/12/09 | |
| 22 | Set Mechanical Eqpt. | 10 days | Fri 11/13/09 | Thu 11/26/09 | |
| 23 | MEP Connections To Eqpt. | 20 days | Fri 11/27/09 | Thu 12/24/09 | |
| 24 | Start-up Eqpt. | 6 days | Mon 12/28/09 | Mon 1/4/10 | |
| 25 | Pre-test Eqpt. | 5 days | Tue 1/5/10 | Mon 1/11/10 | |
| 26 | **Core** | **149 days** | **Mon 6/15/09** | **Thu 1/7/10** | |
| 27 | Rough-in Bathroom Duct | 5 days | Mon 6/15/09 | Fri 6/19/09 | |
| 28 | Set SCU's | 5 days | Mon 6/15/09 | Fri 6/19/09 | |
| 29 | HVAC Trim | 15 days | Fri 12/18/09 | Thu 1/7/10 | |
| 30 | **Level 2** | **145 days** | **Mon 6/15/09** | **Fri 1/1/10** | |
| 31 | MEP Risers | 5 days | Mon 6/15/09 | Fri 6/19/09 | |
| 32 | Layout Floor Duct North | 5 days | Fri 10/16/09 | Thu 10/22/09 | |
| 33 | Layout Floor Duct South | 5 days | Fri 10/23/09 | Thu 10/29/09 | |
| 34 | Install Underfloor Duct North | 5 days | Fri 10/30/09 | Thu 11/5/09 | |
| 35 | Install Underfloor Duct South | 5 days | Fri 11/6/09 | Thu 11/12/09 | |
| 36 | Set Mechanical Eqpt | 10 days | Fri 11/6/09 | Thu 11/19/09 | |
| 37 | MEP Connections to Eqpt | 20 days | Fri 11/20/09 | Thu 12/17/09 | |
| 38 | Start-up Eqpt | 5 days | Fri 12/18/09 | Thu 12/24/09 | |
| 39 | Pre-test Eqpt | 5 days | Mon 12/28/09 | Fri 1/1/10 | |
| 40 | **Core** | **145 days** | **Mon 6/15/09** | **Fri 1/1/10** | |
| 41 | Rough In Bathroom Duct | 5 days | Mon 6/15/09 | Fri 6/19/09 | |
| 42 | Set SCU's | 5 days | Mon 6/22/09 | Fri 6/26/09 | |
| 43 | HVAC Trim | 5 days | Mon 12/28/09 | Fri 1/1/10 | |
| 44 | **Level 3** | **151 days** | **Mon 6/22/09** | **Mon 1/18/10** | |
| 45 | MEP Risers | 5 days | Mon 6/22/09 | Fri 6/26/09 | |
| 46 | Layout Floor Duct North | 5 days | Fri 10/23/09 | Thu 10/29/09 | |
| 47 | Layout Floor Duct South | 5 days | Fri 10/30/09 | Thu 11/5/09 | |
| 48 | Install Underfloor Duct North | 5 days | Fri 11/6/09 | Thu 11/12/09 | |
| 49 | Set Mechanical Eqpt | 10 days | Fri 11/20/09 | Thu 12/3/09 | |
| 50 | Install Underfloor Duct South | 5 days | Mon 11/30/09 | Fri 12/4/09 | |
| 51 | MEP Connections to Eqpt | 20 days | Fri 12/4/09 | Thu 12/31/09 | |
| 52 | Start-up Eqpt | 5 days | Tue 1/5/10 | Mon 1/11/10 | |
| 53 | Pre-test Eqpt | 5 days | Tue 1/12/10 | Mon 1/18/10 | |



Project: Mechanical Base Schedule
Date: Tue 4/6/10

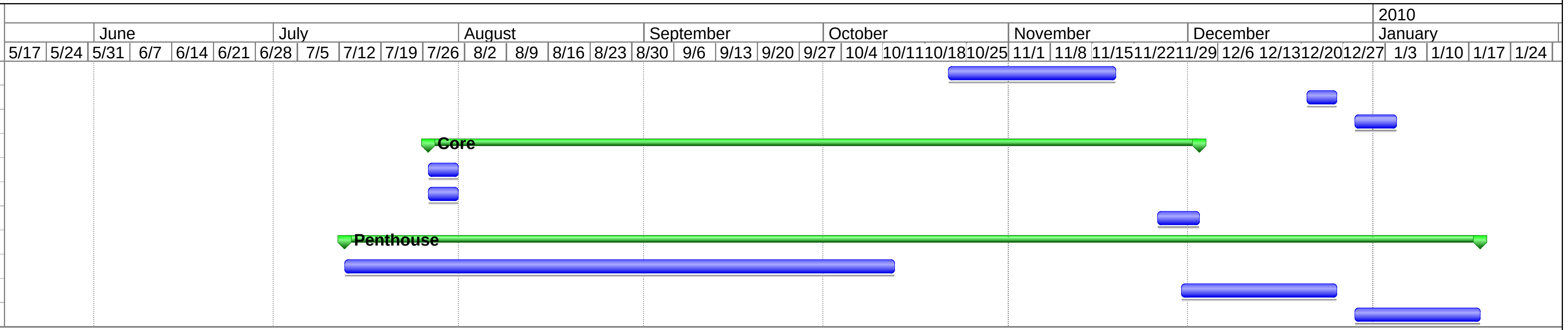
| | | | | | |
|---|---|---|---|---|---|
| Task | Milestone ◆ | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary |
| Progress | Summary | Rolled Up Milestone ◇ | Split | Project Summary | Deadline ⇩ |

| ID | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|
| 54 | **Core** | **141 days** | **Mon 6/29/09** | **Mon 1/11/10** | |
| 55 | Rough In Bathroom Duct | 5 days | Mon 6/29/09 | Fri 7/3/09 | |
| 56 | Set SCU's | 5 days | Mon 6/29/09 | Fri 7/3/09 | |
| 57 | HVAC Trim | 5 days | Tue 1/5/10 | Mon 1/11/10 | |
| 58 | **Level 4** | **120 days** | **Mon 6/29/09** | **Fri 12/11/09** | |
| 59 | MEP Risers | 5 days | Mon 6/29/09 | Fri 7/3/09 | |
| 60 | Layout Floor Duct South | 5 days | Mon 7/20/09 | Fri 7/24/09 | |
| 61 | Install Underfloor Duct North | 5 days | Mon 8/24/09 | Fri 8/28/09 | |
| 62 | Install Underfloor Duct South | 5 days | Mon 8/24/09 | Fri 8/28/09 | |
| 63 | Layout Floor Duct North | 5 days | Fri 9/25/09 | Thu 10/1/09 | |
| 64 | Set Mechanical Eqpt | 10 days | Fri 10/2/09 | Thu 10/15/09 | |
| 65 | MEP Connections to Eqpt | 20 days | Fri 10/16/09 | Thu 11/12/09 | |
| 66 | Start-up Eqpt | 5 days | Mon 11/30/09 | Fri 12/4/09 | |
| 67 | Pre-test Eqpt | 5 days | Mon 12/7/09 | Fri 12/11/09 | |
| 68 | **Core** | **112 days** | **Mon 6/29/09** | **Tue 12/1/09** | |
| 69 | Rough In Bathroom Duct | 5 days | Mon 6/29/09 | Fri 7/3/09 | |
| 70 | Set SCU's | 5 days | Mon 7/6/09 | Fri 7/10/09 | |
| 71 | HVAC Trim | 5 days | Wed 11/25/09 | Tue 12/1/09 | |
| 72 | **Level 5** | **120 days** | **Mon 7/6/09** | **Fri 12/18/09** | |
| 73 | MEP Risers | 5 days | Mon 7/6/09 | Fri 7/10/09 | |
| 74 | Layout Floor Duct North | 5 days | Mon 7/20/09 | Fri 7/24/09 | |
| 75 | Layout Floor Duct South | 5 days | Mon 7/27/09 | Fri 7/31/09 | |
| 76 | Install Underfloor Duct North | 5 days | Mon 9/21/09 | Fri 9/25/09 | |
| 77 | Install Underfloor Duct South | 5 days | Wed 9/23/09 | Tue 9/29/09 | |
| 78 | Set Mechanical Eqpt | 10 days | Wed 9/30/09 | Tue 10/13/09 | |
| 79 | MEP Connections to Eqpt | 20 days | Wed 10/14/09 | Tue 11/10/09 | |
| 80 | Start-up Eqpt | 5 days | Mon 12/7/09 | Fri 12/11/09 | |
| 81 | Pre-test Eqpt | 5 days | Mon 12/14/09 | Fri 12/18/09 | |
| 82 | **Core** | **97 days** | **Mon 7/13/09** | **Tue 11/24/09** | |
| 83 | Rough In Bathroom Duct | 5 days | Mon 7/13/09 | Fri 7/17/09 | |
| 84 | Set SCU's | 5 days | Mon 7/13/09 | Fri 7/17/09 | |
| 85 | HVAC Trim | 5 days | Wed 11/18/09 | Tue 11/24/09 | |
| 86 | **Level 6** | **121 days** | **Mon 7/13/09** | **Mon 12/28/09** | |
| 87 | MEP Risers | 5 days | Mon 7/13/09 | Fri 7/17/09 | |
| 88 | Layout Floor Duct North | 5 days | Mon 7/27/09 | Fri 7/31/09 | |
| 89 | Layout Floor Duct South | 5 days | Fri 9/11/09 | Thu 9/17/09 | |
| 90 | Install Underfloor Duct North | 5 days | Mon 9/28/09 | Fri 10/2/09 | |
| 91 | Set Mechanical Eqpt | 10 days | Wed 9/30/09 | Tue 10/13/09 | |
| 92 | Install Underfloor Duct South | 5 days | Mon 10/5/09 | Fri 10/9/09 | |
| 93 | MEP Connections to Eqpt | 20 days | Wed 10/14/09 | Tue 11/10/09 | |
| 94 | Start-up Eqpt | 5 days | Mon 12/14/09 | Fri 12/18/09 | |
| 95 | Pre-test Eqpt | 5 days | Tue 12/22/09 | Mon 12/28/09 | |
| 96 | **Core** | **92 days** | **Mon 7/20/09** | **Tue 11/24/09** | |
| 97 | Rough In Bathroom Duct | 5 days | Mon 7/20/09 | Fri 7/24/09 | |
| 98 | Set SCU's | 5 days | Mon 7/20/09 | Fri 7/24/09 | |
| 99 | HVAC Trim | 5 days | Wed 11/18/09 | Tue 11/24/09 | |
| 100 | **Level 7** | **121 days** | **Mon 7/20/09** | **Mon 1/4/10** | |
| 101 | MEP Risers | 5 days | Mon 7/20/09 | Fri 7/24/09 | |
| 102 | Layout Floor Duct North | 5 days | Fri 9/11/09 | Thu 9/17/09 | |
| 103 | Layout Floor Duct South | 5 days | Fri 9/18/09 | Thu 9/24/09 | |
| 104 | Install Underfloor Duct North | 5 days | Thu 9/24/09 | Wed 9/30/09 | |
| 105 | Install Underfloor Duct South | 5 days | Thu 10/1/09 | Wed 10/7/09 | |
| 106 | Set Mechanical Eqpt | 10 days | Thu 10/8/09 | Wed 10/21/09 | |

Project: Mechanical Base Schedule
Date: Tue 4/6/10

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Task | ▬ | Milestone | ◆ | Rolled Up Task | ▬ | Rolled Up Progress | ▬ | External Tasks | ▬ | Group By Summary | ▬ |
| Progress | ▭ | Summary | ▬ | Rolled Up Milestone | ◇ | Split | ┆ | Project Summary | ▬ | Deadline | ⇩ |

| ID | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|
| 107 | MEP Connections to Eqpt | 20 days | Thu 10/22/09 | Wed 11/18/09 | |
| 108 | Start-up Eqpt | 5 days | Mon 12/21/09 | Fri 12/25/09 | |
| 109 | Pre-test Eqpt | 5 days | Tue 12/29/09 | Mon 1/4/10 | |
| 110 | **Core** | **93 days** | **Mon 7/27/09** | **Wed 12/2/09** | |
| 111 | Rough In Bathroom Duct | 5 days | Mon 7/27/09 | Fri 7/31/09 | |
| 112 | Set SCU's | 5 days | Mon 7/27/09 | Fri 7/31/09 | |
| 113 | HVAC Trim | 5 days | Thu 11/26/09 | Wed 12/2/09 | |
| 114 | **Penthouse** | **136 days** | **Mon 7/13/09** | **Mon 1/18/10** | |
| 115 | MEP Equipment & Tie-ins | 66 days | Mon 7/13/09 | Mon 10/12/09 | |
| 116 | Start-up | 20 days | Mon 11/30/09 | Fri 12/25/09 | |
| 117 | Test & Balance | 15 days | Tue 12/29/09 | Mon 1/18/10 | |



| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Project: Mechanical Base Schedule<br>Date: Tue 4/6/10 | Task | ▬ | Milestone | ◆ | Rolled Up Task | ▬ | Rolled Up Progress | ▬ | External Tasks | ▬ | Group By Summary | ▬ |
| | Progress | ▭ | Summary | ▬ | Rolled Up Milestone | ◇ | Split | ┆ | Project Summary | ▬ | Deadline | ⇩ |