Science and Technology Center

Coppin State University
Baltimore, MD

Thesis Final Report

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Construction Option
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Science and Technology Center

Coppin State University
Baltimore, MD

Project Information

Owner: University of Maryland
Occupant: Coppin State University
Construction Manager: Barton Malow Company
Architect: Cannon Design
Total Stories: 4 Stories plus Penthouse
Size: 135,000 SF
Contracted GMP: $76.2 Million
Delivery Method: CM at Risk
Construction Dates: 11/2012 - 11/2014

Architecture

In comparison to the rest of the CSU campus, the architectural design of the Science and Technology Center includes sleek lines and a modern façade. The surrounding area buildings have typical brick facades with rectilinear building footprints. With this new design, the glass curtain walls add a modern and lively touch to the campus while still tying into the existing brick architecture. This building is designed to be LEED Gold Certified.

Structural

Foundations are made up of spread footings with support on the south end from a rammed aggregate pier system. The major structural component includes cast-in-place conrete. This starts from the lower level and extends to the fourth floor, where the greenhouses are located. The penthouse level is constructed of laterally braced structural steel framing.

Mechanical

The building is supported by 6 different VAV Trane air handling units (AHUs), 4 cooling towers and multiple boilers, lab exhaust fans, and computer room air condition units. There are three large AHUs with total CFM ranges from 23,500-44,500 that serve the building's main floors. The remaining 3 AHUs with total CFM ranges from 3,200-4,500 serve the lower levels and the lecture hall area.

Electrical

The main building switchboard is rated for 4000A, 480/277V at 3 Phase. A total of 6 transformers supply power to the building. The lower level main transformer is a general duty dry type transformer with an integral USS rated at 2500kVA. The main building load was designed for 3,066,675 VA and 3690 amps. In addition, the emergency power system is supplied by two generators (750kW and 500kW).

Nicholas Zitterbart | Construction Management
http://www.engr.psu.edu/ae/thesis/portfolios/2013/naz5020/index.html

EXECUTIVE SUMMARY

The following Senior Thesis Final Report is the culmination of multiple technical analyses developed through knowledge gained in the Architectural Engineering curriculum as well as through industry member experience. This report focuses on the construction of the Science and Technology Center at Coppin State University located northwest of Baltimore, MD. Four analyses were executed in an effort to provide schedule acceleration scenarios through production principles, modularization, and new design methods.

Analysis 1: Schedule Resequence

The first analysis addressed the feasibility of resequencing the original schedule and replacing a portion of the exterior cladding assembly. In addition, different production methods including the lean principles of Short Interval Production Scheduling and Last Planner were investigated for implementation. The cladding system replacement from terracotta wall tiles to brick veneer proved to be cost prohibitive, while the lean principle of Last Planner exemplified significant benefits.

Analysis 2: Modularization of Curtain Wall System

The second analysis focused on implementing a unitized curtain wall system. With faster prefabricated production offsite and less expensive labor necessary onsite, this method provided areas of cost savings and schedule reduction. In addition, lean production methods, such a pull production, were implemented for more efficient construction methods. Through these methods, the project schedule was reduced by 28 days and costs were reduced by $612,000.

Analysis 3: Finned Tube Radiator System Design

The third analysis investigated a value engineering option of replacing the finned tube radiators along the perimeter of the building with linear diffusers in the ceiling. Eliminating the labor-intensive brazing connections and expensive hydronic piping for the radiator units provided an opportunity to reduce the schedule and save costs. Ultimately, the total boiler load was reduced by 358,000 BTU/HR, the schedule was accelerated by 62 days and $132,000 in cost savings was determined.

Analysis 4: Alternative Foundation System

The fourth analysis focused on an alternative foundation support system in lieu of the current rammed aggregate pier design. A driven steel H-pile system was chosen to support the foundations on the south end of the building. This system provides higher quality assurance standards and, in this particular case, an accelerated installation time. In total, the schedule for this activity was reduced by 40% and a total of $25,000 was saved in the project budget.

Through these four analyses, the schedule was accelerated by 94 days and a total of $769,000 was saved. These findings lend to the overall goals of the owner for schedule acceleration and cost savings while also providing a basis for effective implementation.

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SECTION 1 – PROJECT OVERVIEW

| PROJECT SUMMARY AND CLIENT INFORMATION |

Project Summary

The University of Maryland, Baltimore has contracted Barton Malow Company to construct a new Science and Technology Center (STC) on Coppin State University's campus. This four-story,135,000 SF building located in Northwest Baltimore is designed by Cannon Design and will be the new home to the Department of Mathematics and Computer and Natural Sciences. The $76.2 million GMP contract for Barton Malow Company was granted notice to proceed on August 13, 2012 and should reach completion by November 2014.

The project site is located on the southeast corner of the Coppin State campus where an existing 210 row homes stood. The owner was responsible in securing these properties and turning over to Barton Malow in order for construction activities to begin.

The building is supported by a rammed aggregate geopier system on the south half of the building due to unsuitable soils in this area. Typical spread footings and foundation walls support the cast-in-place (CIP) concrete floor slabs for all four floors. The penthouse on top of the fourth floor is constructed of braced structural steel frames with metal decking. The top of the building features multiple green roofs and a greenhouse. The exterior skin is wrapped with a brick veneer inset with curtain wall ribbon windows. In addition to this glazing, a large cubic-shape curtain wall is featured on the northwest corner of the building. As seen in Figure 1.1 and 1.2, this design includes modern architecture while still holding true to the natural masonry architecture of the existing buildings on campus.

Courtesy of www.coppin.edu/CapitalPlanning/STC.aspx

Figure 1.1 – Rendering NW Corner

Courtesy of www.coppin.edu/CapitalPlanning/STC.aspx

Figure 1.2 – Rendering SW Corner

The original project schedule slated the substantial completion in August 2014, however due to delays in the row home property acquisition the project schedule was pushed back almost 3 months. This created an opportunity for schedule acceleration scenarios to be analyzed and implemented on the project. Potentially, further analyses can be performed to realize the full benefits of an alternate schedule scenario. This includes a resequence of the original schedule accounting for the property acquisition delay. In addition, modularization of the curtain wall system will be applied and critiqued in comparison to the currently designed stick-built method. Moving to the interior, an alternative to multiple fin tube radiators will be compared to the current system. Finally, an alternate foundation system will be considered to find potential benefits over a geopier system.

Client Information

The University of Maryland, Baltimore is the owner of this project whereas Coppin State University will be the inhabitant of the new Science and Technology Center. This procurement is just a small part of Coppin State's strategic plan and their master plan for the future. As part of the facility development, Coppin State has accomplished many property acquisitions and funding requests—one of which includes the plan for the Science and Technology Center. The main reason for building this facility is to update the deteriorating infrastructure of technology. This building will house computer science, math and management science. It is the third building to be constructed since the new capital plan has been addressed. This will make CSU much more competitive within the Maryland school system with the ability to provide better services to its students.

The Health and Human Services building just west of the Science and Technology Center site was recently completed. Coppin State has also built a new Physical Education Center in the middle of campus. This is all part of the future master plan for Coppin State.

***The above information references CSU's Strategic Plan for 2010 which has been published for public review.**[1.1]

Keys to Satisfaction

Keeping the building to a tight schedule is of concern to the owner and the client. This is a publicly funded project and its use relies heavily on the beginning of class sessions. The original schedule forecasted the building to be complete for Fall Semester of 2014. With the project delays thus far, it is now forecasted to complete late Fall of 2014. The schedule is crucial due to the occupancy and use of the end product. The full services of this building will dramatically increase the value of campus services and the ability of Coppin State to stay on the leading edge of universities in Maryland. Student enrollment is very important to any university and this building could have a great effect on the enrollment rates for future semesters.

| EXISTING CONDITIONS AND PHASING PLANS |

Existing Conditions

As seen below in Figure 1.3 and 1.4, the building is located on the southeast side of campus. The site is limited to these boundaries due to neighborhoods and major roads on the perimeter.

***See Appendix 1-A for a further detail of the existing conditions plan**

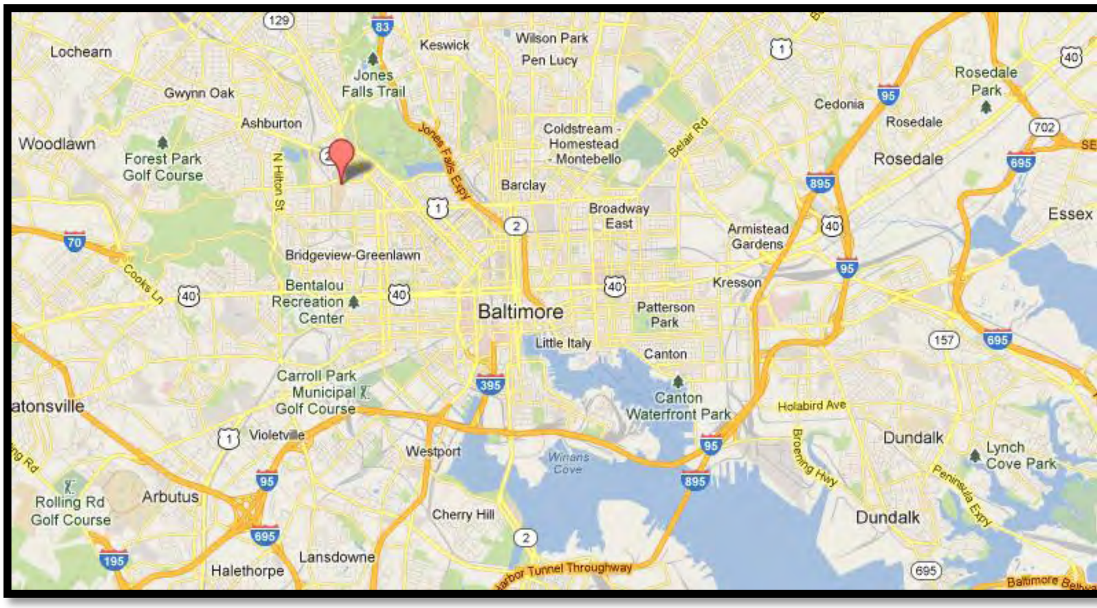
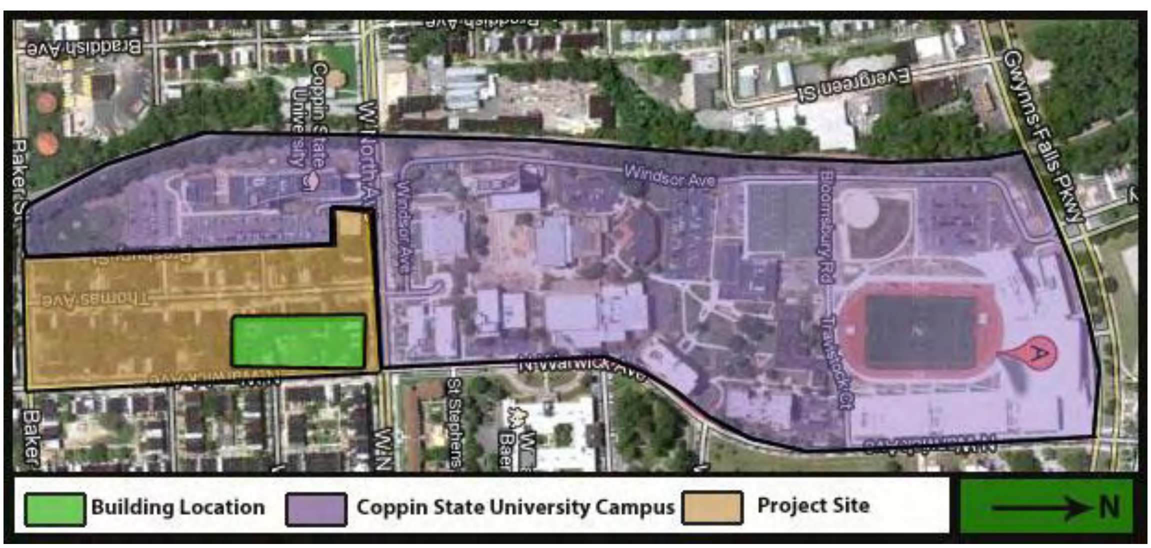


Figure 1.3 – General Project Location Courtesy of Google Maps



Courtesy of Google Maps

Figure 1.4 – Project Site Location

Demolition Phase

The demolition phase is the current major activity on site and requires much attention to the sheer scale of work. The approximate 210 row houses located in the purple shaded region of Figure 1.3 above were necessary to demolish before any earthwork or site utilities improvements could occur. A phased demolition plan can be seen in Appendix 1-A and shows the progression of demolition in regards to site logistics.

The major issue is the site access and being able to dispose of the construction waste while being mindful of recycling methods. Dumpsters can be located on the site foot print with pick up and drop off regulated through two site access gates. This will keep traffic flowing in one direction and help manage to keep traffic to one route through the local area.

In looking at the demolition plan, there are three phases that occur. A possible three crews can be progressing simultaneously to complete demolition more efficiently. By beginning at the split in the middle, this will create the traffic route for trucks in and out of the site. Demolition at Phase 3 is divided by Thomas Road and is the temporary area of construction traffic. This road will eventually be demolished making a clear site from N. Warwick Ave. to the parking lot of the HHS Building on campus.

Barton Malow can manage the demo to create as much recycled material possible to earn more LEED credit for the building. A goal of 75% recycled waste was created and this demolition phase is a major part of that goal. Once this phase has been successfully completed, the site can be rough graded in preparation for site utilities, foundations and the Geopier system.

***See Appendix 1-A for a further detail of the demolition plan**

Foundations Phase

With demolition completed, site mobilization can occur and Barton Malow can set up the site trailers. Referencing Appendix 1-A, the site logistics during this phase include the location of a soil stock pile at the south end, temporary site parking, and the beginning of site excavation.

The major activity here includes the rammed aggregate pier system on the south side of the building perimeter. Also, the smaller footprint requires less excavation so excavated soils can be stored on site. This space is available due to a future parking garage being built in the south corner. Once the spread footings have been poured and the foundations start to reach grade, more focus can be put on the structural concrete and the logistics plan required to place the significant amount of concrete.

***See Appendix 1-A for a further detail of the foundations plan**

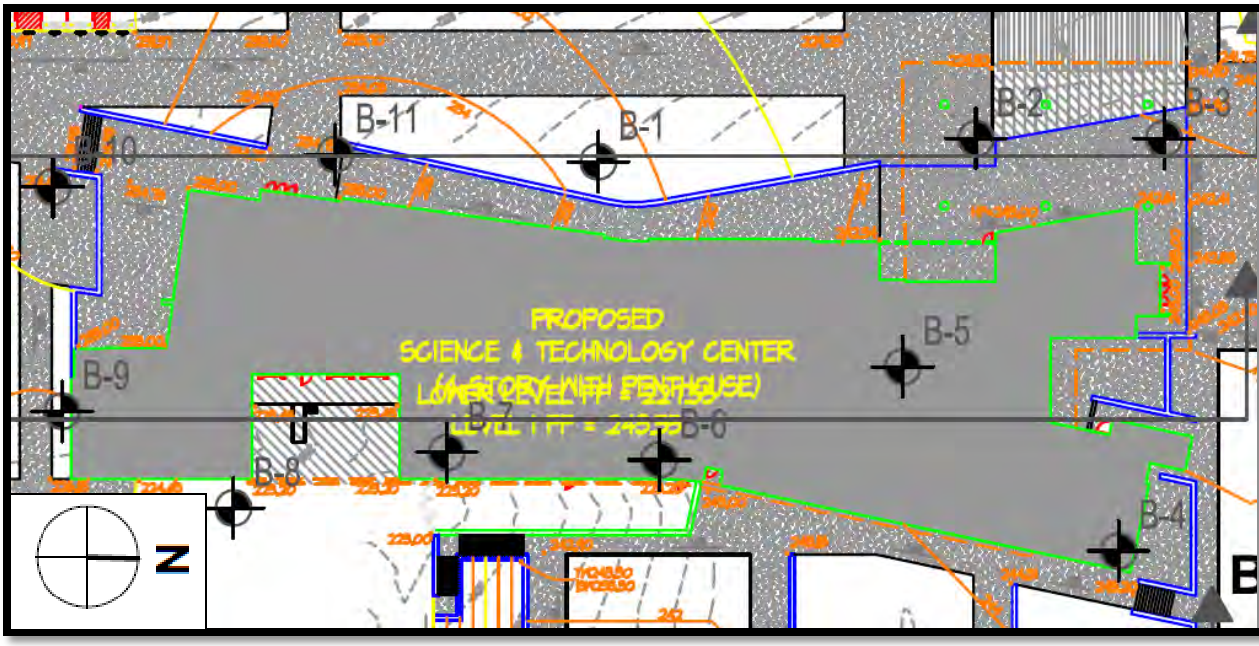
Superstructure Phase

The final site layout phase detailed includes the superstructure. Logistically, this will add more equipment on site to manage the formwork, re-steel, concrete, and structural steel necessary to erect the superstructure. Starting at the bottom, the floors can be poured segment by segment working on both the south and north ends, as detailed in the summary schedule. With two areas of construction at the same time, this doubles the amount of traffic thus management is very important. As the floors climb, more assistance is needed to move materials to the upper floors to form and place the structural concrete. A rough terrain mobile crane can be utilized to assist in material and equipment placement. Also, concrete pump trucks will be utilized to increase the productivity of placement. After the two sequences of structural walls and floors are built, the penthouse structural steel can be erected. This completes the superstructure and the building enclosure can begin.

| LOCAL CONDITIONS |

Geotechnical Report

As stated earlier, the soil profiles impacted the type of foundation system used. A rammed aggregate pier system was necessary to install due to non-bearing soils near the south end of the site. Three borings (B-08 to B-10) revealed a max bearing of 2ksf which is deemed not enough to support building loads. Borings B02 to B-05 revealed deep rock excavations where spread footings supporting 35ksf would be suitable. Finally, Borings B-01, B-06, B-07, and B-11, showed disintegrated rock where spread footings should be designed to 14ksf. These locations can be seen in Figure 1.5 below.



Courtesy Geotechnical Report, T.L.B. Associates (not intended for graphical scale)

Figure 1.5 – Soil Boring Locations

Groundwater was observed in three of the borings at different elevations. Boring B-09 showed groundwater roughly 18 ft (Elev. 212.5’) below the surface, Boring B-07at roughly 17 ft (Elev. 219.5’), and Boring B-01 at roughly 11 ft (Elev. 223.5’). Per the Geotechnical Report recommendations, there are no foreseen issues with groundwater in the lower level. However, Boring B-09 reveals conditions that may need dewatering during sub grade construction.

Due to the roughly 210 existing row homes along W. North Ave. and N. Warwick Ave., there are many subsurface conditions of concerns with regards to site utilities. The site utilities contract is rather substantial coming in around $2M. Before beginning foundations, major relocation work for the existing sanitary lines on the project footprint must occur. The corner of these two streets is the divider between the southeast side of campus and local neighborhoods. All of this can make for a congested site when this amount of work needs to be completed before building construction can begin.

Building Methods and Construction Parking

Coppin State University is made up of many masonry buildings and cast-in-place concrete structures are relatively common in the surrounding area. This type of construction will most resemble buildings on campus to fit with the architecture and building methods. Being located between a college campus and neighborhoods, the temporary parking situation for workers has to be located on the project site to eliminate congestion. The area to the west of the building footprint will serve as temporary parking for workers.

Recycling and Tipping Fees

Considering the building is in early stages of demolition, the recycling efforts for the new building are still being organized. It is the goal of Coppin State University to recycle up to 75% of construction waste which can help in LEED certification. Currently, separate or combined dumpsters for recycling are still being considered. Separated recycling dumpsters can lead to higher costs, but can also recycle more materials due to better organization. According to the Baltimore County Department of Public Works, there is a tipping charge of $80 per ton[1.2].

| PROJECT DELIVERY SYSTEM |

The Science and Technology Center Project utilizes a CM at Risk delivery method with Barton Malow Company (in association with Commercial Interiors) acting as the Construction Manager. The reason for this delivery approach was due to a set budget by the University of Maryland, thus allowing risk to be passed to the CM if the project goes over budget. Barton Malow won this project by being shortlisted based on technical abilities. After a fee percentage was submitted, Barton Malow combined for a total score higher than the competition thus winning the project.

In regards to Barton Malow's subcontractors, there is a process involved to select each contractor. Barton Malow strives to select reliable contractors with an Experience Modification Rate (EMR) of less than 1.00. This ratio provides information of past costs of injuries and future risk involved with that specific company. With these requirements, Barton Malow can then enroll each of these contractors into its own bonding program. By doing so, Barton Malow can absorb the cost of bonding on the project and claim the profits that would've otherwise been claimed by a bonding agency. Each of these subcontractors bids their scope as a lump sum contract on this project.

The organization chart on the following page details the first bid package team members. The designers, engineers, contractor, and subs are all shown for Bid Package #1 and include demolition, site work, and utilities.

***See the Organizational Chart (Figure 1.6) on the following page for more detail**

Project Organization Chart

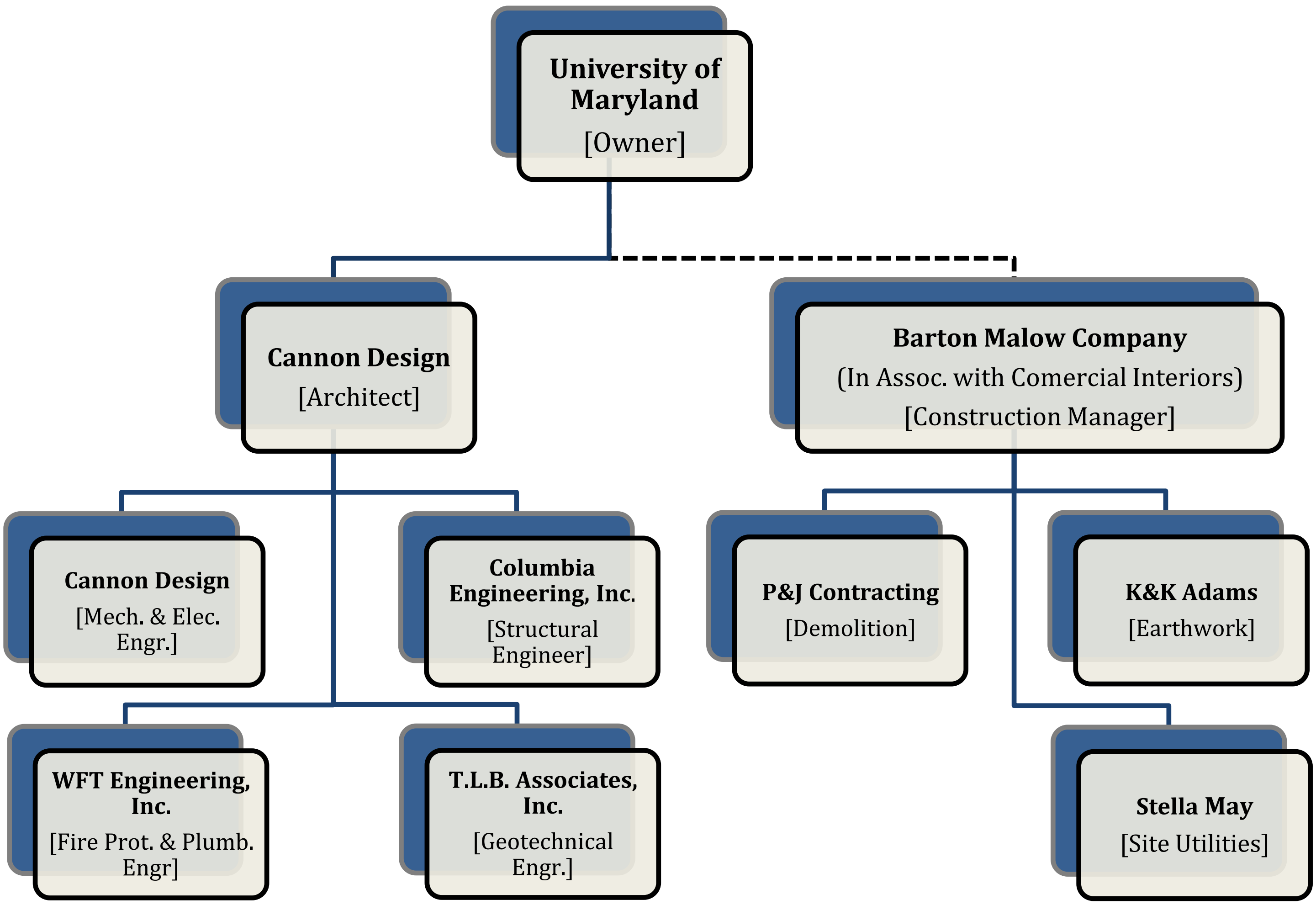
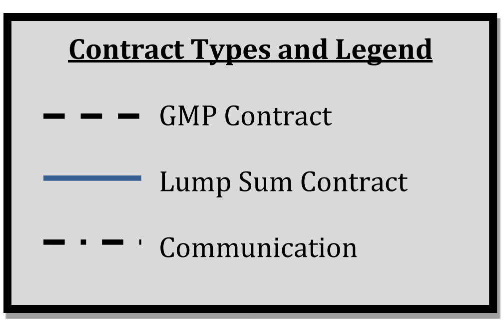


Figure 1.6 – Project Organizational Chart



| STAFFING PLAN |

Staffing Organization Chart

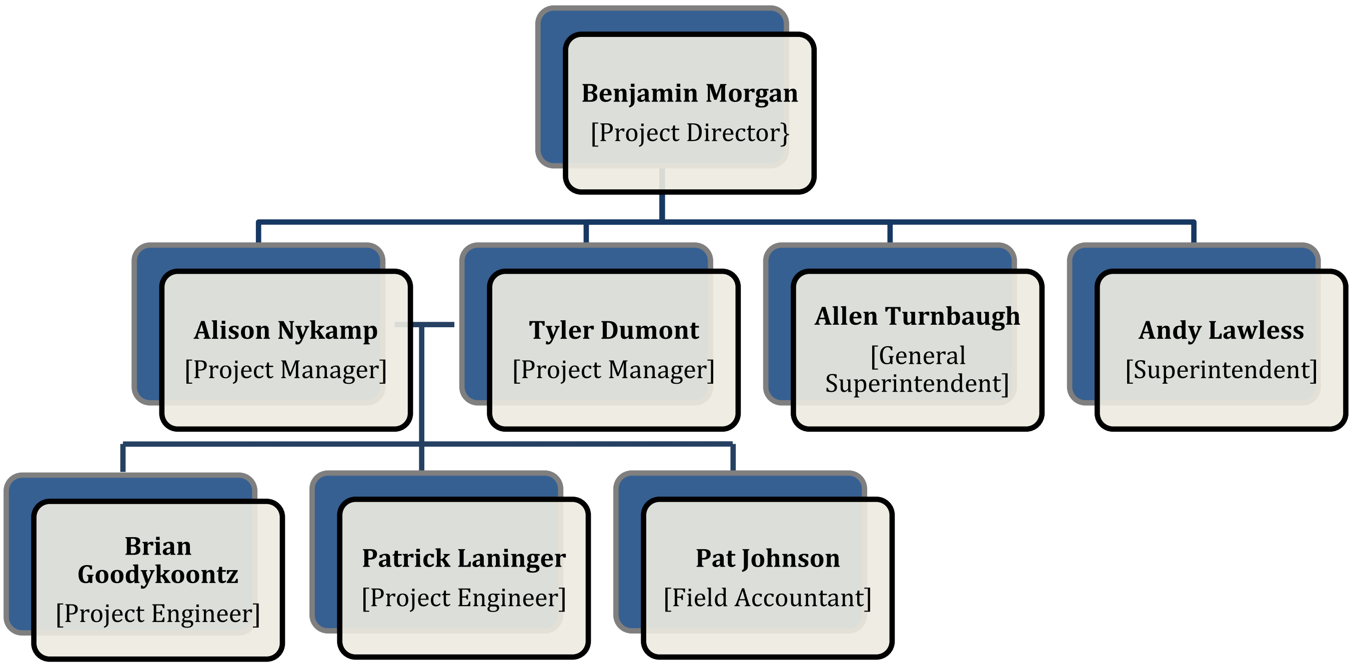


Figure 1.7 – Staffing Organizational Chart

The staffing chart, as shown above in Figure 1.7, details the structure of the Barton Malow project team responsible for the Science and Technology Center. The project team works under the management of the Baltimore, MD Regional Office, with the main headquarters of the company in Southfield, MI.

In looking at the organizational chart further, Ben Morgan serves as the Project Director in the Baltimore Office and manages this specific project team. Heading the Project Manager side, there is Alison Nykamp and Tyler Dumont. Reporting to them are the Project Engineers, Brian Goodykoontz and Pat Laninger, and Field Accountant Pat Johnson. On the field side of operations, Allen Turnbaugh directs activities as General Superintendent in a team effort with Superintendent Andy Lawless.

As with the project organizational chart, this chart reflects the staffing for Bid Package #1. When the building construction begins, Commercial Interiors (MBE association contract with Barton Malow) will provide an additional project engineer for the management team. The hierarchy will remain in the same fashion as shown above.

This staffing structure is very typical of any project bid out by Barton Malow, and by the construction industry in general. The staffing may scale to a larger size with a larger and more design-intense project, however this size project team is very typical of the Baltimore Office.

| BUILDING SYSTEMS SUMMARY |

Table 1.1 – Required Building Systems

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

Demolition

The site demolition scope of work includes the demolition of approximately 210 row homes on the project site before construction can begin. This part of the bid package will be performed by P&J Contracting and will take just over 3 months to finish, including all abatement and clearing. Arc Environmental, Inc. was responsible for pre-demolition inspections and found that 80 of the 148 properties in the first mobilization phase contained asbestos-containing building material (ACBMs). The lead-based paint (LBP) survey revealed lead-based paint in various components throughout the entire site area. The toxicity characteristic leaching procedure (TCLP) sampling was negative; therefore all non-regulated waste generated from the demolition can be disposed of as regular debris.

Structural Steel Frame

The structural steel package is valued at approximately $750,000 and represents a relatively small portion of the total GMP contract value. With that, the amount of structural steel necessary for this building is limited to the penthouse framing. This bid package is still being currently bid out, so precise figures and equipment size could not be obtained.

The type of bracing includes angle braces into a slotted end connection on a gusset plate. There will be a composite metal roof deck on top of this steel framing. As far as erection, the size and type of crane can be speculated using the building information. The crane is believed to be based roughly on a 100’ max height with a reach of 100’.

Cast-in-Place Concrete

Cast-in-place concrete is the main component of the structural system for the Science and Technology Center. This is included from the foundations and spread footings to structural walls and floor slabs. It is believed that wooden formwork will be used for all spread footings and foundation walls. A re-shore system will be used to support the floor formwork when the structure is being constructed until proper curing can occur. The same formwork should be used throughout the building structure as much of the walls are of similar.

With this amount of structural concrete being placed, a concrete pump truck would be the best method for all cast-in-place quantities. Although very expensive to maintain and operate, this method can place a higher quantity of concrete and it much more maneuverable than other means and methods.

Mechanical System

This building is supported by 6 different VAV Trane air handling units (AHUs), 4 cooling towers and multiple boilers, lab exhaust fans, and computer room air condition units. This is due to the mixed-used of this facility and has many requirements to fulfill. There are three large AHUs with total CFM ranges from 23,500-44,500 that serve the building’s main floors. The remaining 3 AHUs with total CFM ranges from 3,200-4,500 serve the lower levels and the lecture hall area. Being that a large portion of this building is represented by laboratories, there are a major number of exhaust fans to serve each of these areas.

Electrical System

The main building switchboard is rated for 4000A, 480/277V at 3 Phase. It is with this that 6 transformers supply power to the building. The lower level main transformer is a general duty dry type transformer with an integral USS rated at 2500kVA. From this branch, four other transformers supply each of the floors 1-4. The remaining transformer is located at the lower level. The main building load was designed for 3,066,675 VA and 3690 amps. In addition, the emergency power system is supplied by two generators (750kW and 500kW).

Masonry

The exterior building enclosure is comprised of a brick veneer inset with glass curtain walls. The main brick are made up of Extruded Tuscan Red Cliff brick with a Manganese Ironspot accent brick. The majority of buildings are of brick facades, so the architecture of this building will tie to current elements. The typical air cavity, rigid insulation, and vapor barrier comprise the wall section types. The installation of this system includes using free standing scaffolding.

Curtain Wall

The major architectural feature of the Science and Technology Center is the offset, cubicle-shaped curtain wall on the north end. The connection includes a 2" HSS Tube at each mullion covered by an aluminum curtain wall frame. This 1" thick, Low-E Glazing is either made up of heat strengthened, laminated, tempered, or pattern fritted glass depending on the location in the building. The pattern-fritted glazing provides for lighting control within the interior space and can eliminate excess building heat loads. The Low-E glass will also reduce building heat loads and earns LEED credits. Furthermore, there are integrated sun shades and insulated backings in the curtain wall as a sustainable means to also control buildings loads ad minimize thermal bridging.

| PROJECT COST EVALUATION |

Actual Building Costs

Construction Cost: **$76,200,000**

Total Area: **135,000 SF**

Construction Cost per SF: **$564.44**

Total Project Costs

Cost information was not able to be obtained from the Owner or Architect.

Major Building Systems Costs

Table 1.2 – Building Systems Costs

Building System	Actual Cost	Cost/SF
Building Demolition	$3,100,000	$22.96
Earthwork	$3,300,000	$24.44
Structural Concrete	$7,500,000	$55.55
Structural Steel	$750,000	$5.55
Masonry	$2,500,000	$18.52
Mechanical	$15,750,000	$167.67
Electrical	$10,000,000	$74.07
Fire Protection	$750,000	$5.55
Windows/Curtain Wall	$6,500,000	$48.15
Interior Partitions	$4,000,000	$29.63

Square Foot Estimate

A square foot estimate of the new construction was conducted using RSMeans CostWorks software. This software utilizes various pieces of building information in conjunction with construction data to provide an as accurate estimate as possible given the criteria. The location was set to Baltimore, MD while the building type was set to a 5-10 story office building (STC is zoned as Business B and 5-stories was chosen to properly represent the penthouse). In addition, 2012 Quarter 3 Cost book data was referenced for pricing and units. Table 1.3 below shows a brief overview of the results.

***See Appendix 1-B for the full RSMeans CostWorks Square Cost Foot Estimate**

Table 1.3 – RSMeans CostWorks Square Foot Cost Estimate Summary

Square Foot Cost Estimate Report		
Estimate Name:	**Science and Technology Center**	
Building Type:	**Office, 5-10 Story with Face Brick with Concrete Block Back-up / R/Conc. Frame**	
Location:	**BALTIMORE, MD**	
Story Count:	**5 (4+ penthouse)**	
Story Height (L.F.):	**17 (average)**	
Floor Area (S.F.):	**135,000**	
Labor Type:	**Union**	
Basement Included:	**Yes**	
Data Release:	**Year 2012 Quarter 3**	Costs are derived from a building model with basic components. Scope differences and market conditions can cause costs to vary significantly.
Cost Per Square Foot:	**$150.43**	
Building Cost:	**$20,308,500**	

Assemblies Estimate

The same RSMeans CostWorks software was also utilized to obtain an assemblies estimate for this building. Location settings and cost book information also remained the same for this process. This estimate is to gain further cost detail with the Mechanical, Electrical, and Plumbing systems. In analyzing both the square foot and assemblies estimates, a more accurate cost estimate can be achieved. Table 1.4 on the next page shows a brief overview of the results.

***See Appendix 1-B for the full RSMeans CostWorks Assemblies Cost Estimate**

Table 1.4 – RSMeans CostWorks Assemblies Cost Estimate Summary

Assemblies Cost Estimate Report	
Subtotal	
D20 Plumbing	**$313,999**
D30 Mechanical	**$13,867,632**
D50 Electrical	**$3,222,370**
Total	**$17,404,000**

Cost Estimate Comparative Narrative

Square Foot Estimate

In analyzing both the square foot and assemblies estimate in comparison with the actual costs, there are some differences in the figures. Overall, the actual building cost is $76.2M and the SF Estimate comes in at $20.3M. The structural concrete is represented at about half the allowance with the foundations, slab on grade, basement walls, and floor construction. These categories subtotal to be about $4.13M as shown in Table 5 on the next page. Typically a square foot estimate is accurate to within 20%; however, when looking directly at the square foot estimate break downs, some numbers stand out as seemingly too low. As referenced in Table 1.5, the only line item within reason to the square foot estimate limitations is masonry.

The reason for these discrepancies can be due too many factors. This building is mixed-use and will contain classrooms, laboratories, and computer rooms. The square foot estimate was chosen to be based on a 5-10 story office building due to its similar size and zoning classifications. However, the square foot estimate is short of many intricate systems of the building including extra piping for laboratory fixtures, and multiple types of exterior enclosures. The square foot estimate is limited to a generic building with a typical single façade. This Science and Technology Center includes large brick veneer facades with inset curtain wall windows and a large curtain wall on the north end. Also, some quantities such as demolition and structural steel are not included in the SF estimate. To remedy this without creating a detailed estimate with every contract quantity cost, a combined estimate was created using the differences in building systems. As shown in Table 1.6 on the next page, the differences from the actual costs were recorded and then added to the base SF estimate. With these additions, the new estimate totals at $62.3M with an accuracy of 18.3%. This satisfies the limits of a 20% accurate square foot estimate and is a more reasonable estimate.

Table 1.5 – Cost Comparison

Building System	Actual Cost	Cost/SF	SF Estimate Cost	Cost/SF	Difference
Building Demolition	$3,100,000	$22.96	--	--	--
Earthwork	$3,300,000	$24.44	$78,500	$0.58	(97.62%)
Structural Concrete	$7,500,000	$55.55	$4,126,500	$30.57	(44.97%)
Structural Steel	$750,000	$5.55	--	--	--
Masonry	$2,500,000	$18.52	$1,942,000	$14.39	(22.30%)
Mechanical	$15,750,000	$167.67	$2,088,500	$15.47	(90.77%)
Electrical	$10,000,000	$74.07	$2,433,500	$18.03	(75.65%)
Fire Protection	$750,000	$5.55	$482,000	$3.57	(35.67%)
Windows/Curtain Wall	$6,500,000	$48.15	$644,500	$4.77	(90.09%)
Interior Partitions	$4,000,000	$29.63	$406,000	$3.01	(89.84%)

Table 1.6 – Combined Estimate

Building System	Actual Cost	SF Estimate Cost	Actual – SF Estimate	Difference
Building Demolition	$3,100,000	--	$3,100,000	--
Earthwork	$3,300,000	$78,500	$3,221,500	(97.62%)
Structural Concrete	$7,500,000	$4,126,500	$3,373,500	(44.97%)
Structural Steel	$750,000	--	$750,000	--
Masonry	$2,500,000	$1,942,000	$558,000	(22.30%)
Mechanical	$15,750,000	$2,088,500	$13,661,500	(90.77%)
Electrical	$10,000,000	$2,433,500	$7,566,500	(75.65%)
Fire Protection	$750,000	$482,000	$268,000	(35.67%)
Windows/Curtain Wall	$6,500,000	$644,500	$5,855,500	(90.09%)
Interior Partitions	$4,000,000	$406,000	$3,594,000	(89.84%)
Base SF Estimate	--	--	$20,308,500	--
Combined Estimate	**($76,200,000 actual)**		**$62,257,000**	**(18.30%)**

Assemblies Estimate

Now analyzing the assemblies estimate, it totals at $17.4M and includes the MEP systems. When breaking it down into each category, the mechanical package was closest in estimate. Much of the equipment included in contract documents and estimates were available in the RSMeans CostWorks data books thus yielding in a closer estimate in comparison to other systems. The difference in estimates ($15.75M actual & $13.88M) is calculated to be 11.95%. With an assemblies estimate being within 10% accuracy, this difference is within understanding. A plumbing contract value was not able to be obtained, but the system and fixtures were accounted for in this estimate. The electrical estimate totals at $3.2M in comparison to the actual of $10M. These inaccuracies can be accounted for through system limitations and specialty fixtures. The cost data book includes generic information and is difficult to apply to multiple systems. Within these limitations, these estimates are believed to be within reason of the actual cost values.

| DETAILED PROJECT SCHEDULE |

A detailed project schedule was developed to go further into each element of the schedule. This schedule is broken down into four main headings, including design, construction, closeout and closeout for final completion. Furthermore, the construction phase is detailed with site work, structure, site utilities & retaining walls, penthouse enclosure & roofing, perimeter enclosure, site finishes, mechanical/electrical rooms, vertical construction, rough-in, and finishes. These categories yield better details and durations in which case further cost analyses can be taken.

As a brief overview, Table 1.7 below shows the major dates and durations of the phases in the detailed project schedule. This gives a better understanding of the project schedule in its entirety.

***See Appendix 1-C for the Detailed Project Schedule**

Table 1.7 – Project Milestone and Duration Overview

Activity	Duration (d)	Start	Finish
Design	524	5/31/2011	5/31/2013
Construction	503	8/13/2012	7/16/2014
NTP – BP1	0	8/13/2012	8/13/2012
Site Work	130	8/13/2012	2/8/2013
Structure	192	12/13/2012	9/6/2013
Site Utilities & Retaining Walls	187	11/8/2012	7/26/2013
Penthouse Enclosure & Roofing	107	8/15/2013	1/10/2014
Perimeter Enclosure	123	7/30/2013	1/16/2014
Site Finishes	338	4/1/2013	7/16/2014
Mech/Elec Rooms & Shafts	193	8/8/2013	5/5/2014
Vertical Construction	251	7/18/2013	6/19/2014
Rough-In	257	6/26/2013	6/19/2014
Finishes	211	8/27/2013	6/17/2014
Conditioned Air Available	0	2/26/2014	2/26/2014
Closeout	143	2/27/2014	9/15/2014
Subcontractor Substantial Completion	0	9/8/2014	9/8/2014
Closeout for Final Completion	76	8/14/2014	11/17/2014
Barton Malow Substantial Completion	0	11/17/2014	11/17/2014

Durations & Start and Finish Dates are taken from detailed project schedule, See Appendix 1-C.

| GENERAL CONDITIONS ESTIMATE |

A General Conditions estimate was performed with data from the RSMeans CostWorks database. The summary cost of all the categories is $3,244,208, as seen in Appendix 1-D. This includes costs incurred from Project Management, Field Office, Insurance, Safety, Field Operations, Testing & Inspections and Waste Management.

The Project Management costs include all Barton Malow employees associated with the project. These roles were taken directly from the staffing plan. Each role was assumed to fulfill the entire duration of the project, or 24 months. Some of the cost information was slightly inflated to adjust for different roles within the project team. This part of the estimate also assumes that each member will work 5 days a week for the whole duration. The project managers, superintendents, and engineers will be working on site in the temporary office trailer whereas the field accountant will be working out of the regional office.

Field Office includes all costs incurred from the office trailers on site and anything associated with them. This takes into account all trailer expenses, telephone/electrical services, and office supplies and equipment. These will also be assumed to last the duration of the job, or 24 months.

Insurance is also a part of the General Conditions estimate. This involves builder's risk, liability and performance bond. These items are based off of the job as a total percentage of the contract ($76.2M). See Appendix 1-D for the details of these costs.

Another portion of this estimate consists of field operations, which includes items like temporary toilets, signage, and equipment rental. Depending on the phase of the project there could be more equipment or small tools necessary. The assumptions made here are for an average of the project costs.

The last item on the estimate is waste management and the dumpsters that will be on site. Due to the large demolition necessary, these dumpsters will be thoroughly used and it is mandatory for weekly pulls. During the demolition phase there may be more dumpsters on site, but it was chosen to have 3 on the general conditions as an average for total project duration.

Table 1.8 on the next page shows the cost summaries of each category and the percentage they represent of the entire estimate. Also on the next page, Figure 1.8 shows a graphical representation of those same percentages.

***See Appendix 1-D for the General Conditions Estimate**

Table 1.8 – General Conditions Estimate Summary

Category	Project Cost	Percentage of GC
Project Management Team	$ 2,262,520.00	70%
Field Office	$ 52,983.00	2%
Insurance	$ 629,412.00	19%
Safety	$ 2,600.00	0%
Field Operations	$ 40,445.00	1%
Testing & Inspections	$ 19,440.00	1%
Waste Management	$ 236,808.00	7%
Total	$ 3,244,208	100%

Cost Information Taken from GC Estimate, See Appendix 1-D

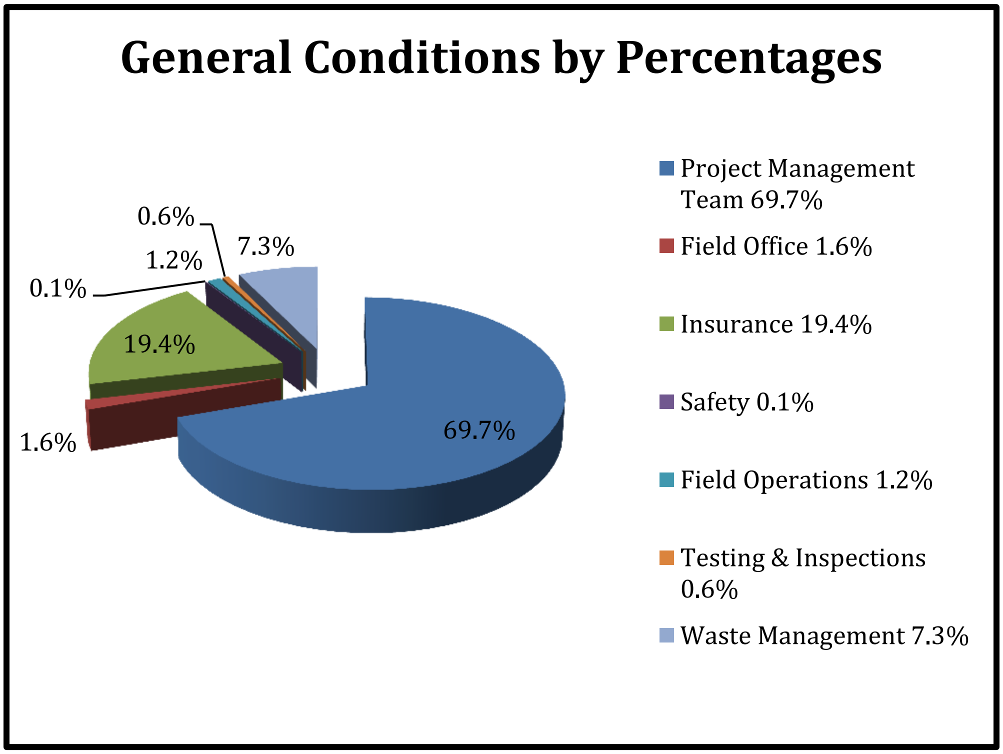


Figure 1.8 – General Conditions by Percentage

SECTION 2 – SCHEDULE RESQUENCE (ANALYSIS 1)

| OPPORTUNITY IDENTIFICATION |

Property acquisition issues caused a major delay to the initial project start date. This creates multiple opportunities to improve schedule areas and make up a large proportion of the lost time. The outlined project schedule will be evaluated to pinpoint critical tasks that have a major impact to final completion. The 3 month delay of the original schedule must be made up to deliver the project before Fall Semester of 2014.

| BACKGROUND RESEARCH |

With the project currently under construction, there is a lack of hard data to compare an alternate method of scheduling to the actual outcome. As a result, this analysis will focus on the critical activities of the schedule and possible scenarios to improve efficiency. Lean principles can be applied in the form of Last Planner, SIPS (Short Interval Production Schedule), and pull/flow production. By looking more into these production principles, the schedule can be evaluated to find areas of improvement. Case studies that utilize production methods like Last Planner and SIPS can be studied and the methods applied to this project. This will enable improvements of lessons learned from past situations and institute the best possible methods for schedule sequencing.

| POTENTIAL SOLUTIONS |

In analyzing the schedule, a potential solution can include a resequence of how the scopes of work are put in place. The trades on site are contracted to provide double crew production in order to achieve the production necessary in the delayed schedule. The original schedule was not outlined with this construction approach in mind, so there could be potential areas of improvement with resequencing. This includes productivity rates of installing the masonry and exterior skin. These two items contain the longest durations through the schedule and reducing these can impact the project greatly. In addition, possible scheduling methods could be implemented to achieve a shorter duration. This includes methods such as Last Planner and SIPS. With Last Planner, Barton Malow can establish an absolute end date for each activity and hold the subcontractors to this commitment. The same idea then applies to a SIP schedule; commitments are made to an end date and the work is scheduled within that time period. In regards to SIPS, a production schedule of repetitive activities will benefit the most.

|SOLUTION METHOD|

- Gather all original information in regards to the outlined schedule and pertinent durations.
- Evaluate schedule for areas of improvement – masonry and curtain wall installation have longest durations.
    - Evaluate productivity rates of exterior skin materials for improvement; intricate details exist between the connections of different skin materials.
    - Determine possibility of changing out exterior skin material to provide better productivity rates and reduce schedule duration.
- Utilize background research to apply different production principles.
    - Determine the process of installing the labor intensive material and benefits of changing to a new process.
- Analyze each method to quantify the best potential outcomes.
- Determine construction manager and owner capabilities.
    - Evaluate the possibility of new production processes.
- Establish any cost concerns with the owner and areas of flexibility.
- Develop a process for implementation and review with entire project team.
- Critique potential outcome and feasibility of implementation.

Resources

~ Industry Professionals and AE Faculty Members
~ Information from AE 570 course – Production Management in Construction
~ Information from AE 572 course – Project Development and Delivery Planning
~ Relative Project Documents
~ Barton Malow Project Team Members

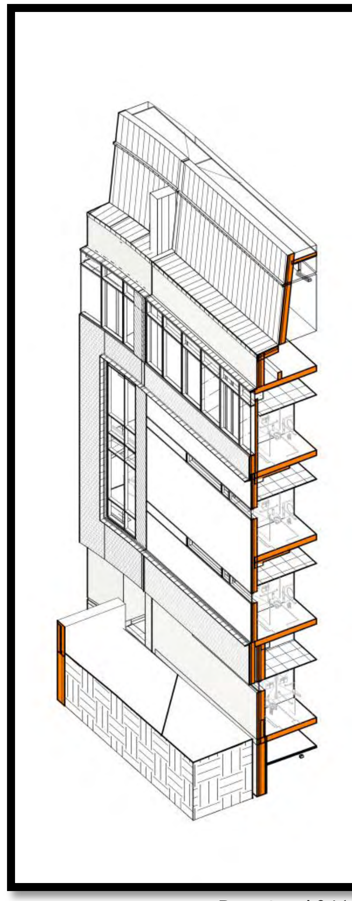
|EXPECTED OUTCOME|

The initial schedule delay allows for instituting a different production method across the entirety of the project schedule. This delay occurred before any new construction began thus creating numerous opportunities for improvement. Through a sequence analysis and a potential new production method (using more of the same material), the schedule is expected to be reduced by a significant amount. Upon successful completion, a goal is set for 50%-75% reduction of the 3 month delay.

| BUILDING SYSTEM INFORMATION AND ORIGINAL SCHEDULE |

Building System Information – Cladding Assemblies

After discussion with the project team about schedule resequencing scenarios, it was determined that the masonry and curtain wall durations had the biggest impact on the overall schedule. For this analysis, the focus will be on the masonry part of the schedule as the curtain wall will be considered in Analysis 2 as a modular system. When looking further into the masonry items on the Science and Technology Center project, it can be seen that the design is very intricate and involves multiple building assemblies in a single vertical elevation.



Drawing A0418

Figure 2.1 – Building Section Isometric at East Elevation

As a result, there a multiple thresholds of changing materials and these cause increases in project schedule durations as productivity lags at these complex areas. In looking at a building section cut at the east elevation near the north end, there are five different cladding assemblies and over 10 different major materials. Figure 2.1 shows the building cut in isometric view and Appendix 2-A shows a call out of this cut with each cladding system and details of the materials. For this reason, the standard productivity rates are hindered to change over materials at each threshold. One of the more time consuming materials is the terracotta wall tiles that are installed around the curtain wall windows on the east elevation. The hanging system necessary for the tiles has a lower daily output (130 SF) compared to that of the brick veneer (220SF).

Starting just above Level 1, the first cladding system includes a brick veneer on concrete wall. Moving vertical between Level 2and 4, the wall bumps out and is cladded with the terracotta wall tiles and curtain wall panels. Centered on the interior of the curtain wall panels are zinc panels on steel studs. Just above Level 4 there is another row of curtain wall panels before bumping back in at the penthouse level. Here, there is another band of brick veneer topped off with zinc panels at the roof line.

As stated, the elevation is quite complex with the cladding systems and does not lend easily to the productivity rates for the installation crews. A possible solution is to replace the terracotta wall tiles with the current brick that is being used above and below. There will still be a bump out as designed, however the materials will not change over this threshold.

Original Schedule

The original schedule for the perimeter enclosure (See Appendix 2-B) was analyzed to provide a baseline of comparison. Because this analysis will focus on the east elevation where the terracotta tiles are located, the durations for this section will only be used. The following durations were recorded for the project schedule:

East Elevation – Perimeter Studs, Sheathing, and Air Barrier =	**40 days**
East Elevation – Exterior Brick Veneer =	**38 days**

| SCHEDULE AND COST EVALUATION |

Schedule Evaluation

A new production schedule can now be analyzed using the solution of replacing the terracotta wall tiles with brick veneer. Through quantity takeoffs and the daily outputs (See Appendix 2-C) the following durations were calculated:

East Elevation – Terracotta Wall Tiles =	**20 days**
East Elevation – Exterior Brick Veneer =	**12 days**

With only changing the materials, an 8 days savings was calculated in the schedule. This would bring the total duration for the east elevation to 70 days, decreased from the original 78 days. A further evaluation in later sections will be discussed with production efficiency and planning methods to accelerate the schedule even more.

Estimate Evaluation

In combination with the schedule, a cost estimate was developed to determine the cost differential between the two systems – brick veneer in lieu of terracotta tiles. The initial bid packages were estimated as a total value including masonry at $2.5 million and metal panels at $2 million. Due to the fact that these initial estimates were based on the entire building enclosure, this cost evaluation will only focus on the cost differential between the brick veneer and terracotta tiles on the east elevation. By conducting the estimate in this manner, the cost savings can be determined without having to complete an entire building quantity take off.

Therefore, by analyzing the east façade, the terracotta wall tiles were estimated as one total with the second total including the replacement brick veneer for the same area. Appendix 2-D illustrates the total area considered with respective square footages for each material and area. The following cost estimate was achieved for the east elevation areas:

Table 2.1 – Cost Comparison of Terracotta Wall Tiles vs. Brick Veneer

Item	Quantity	Unit	Total Incl. O&P	Extended Total Incl. O&P
Baseline Cost				
Terracotta Wall Tile	7567.8	S.F.	$ 14.97	$ 113,290
Brick Veneer	7567.8	S.F.	$ 26.54	$ 200,849
Variance				**(add) $ 87,559**

See Appendix 2-C for full cost estimate details

The above estimate is based on three crews installing the specified cladding system. This was chosen to mimic the crews of the original schedule so a baseline could be achieved. The cost estimate reveals an additional cost for the brick veneer to replace the terracotta wall tiles. The major reason for this is that the material and labor costs for brick are higher than that of the tiles. This is reasonable as the bricks require a very high energy input to manufacture and the units are more labor intensive to install. However, the daily output values for brick veneer are 40% higher than the terracotta tiles which contributes to the overall goal of schedule accelerations. When considering the results of this report in its entirety, it is hopeful that this cost addition will be negated through the other analyses and their respective cost savings.

| LEAN PRODUCTION MANAGEMENT PRINCIPLES |

Short Interval Production Schedule

Upon further review of production methods, there are multiple principles that could be instituted on this project. A short interval production schedule (SIPS) is based upon repeatable construction activities that can be blocked as a single unit and scheduled sequentially. A matrix (see example in Figure 2.2) can be formed with blocks of equal duration representing a construction activity, such as erecting a

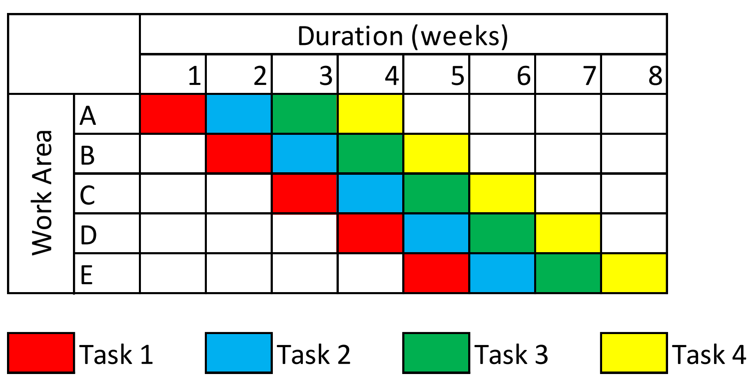


Figure 2.2 – SIPS Template

panel or a wall section. Due to the equivalent durations of each activity (and thus each crew), the matrix can reflect a direct flow of work from one activity to the next. This is significantly advantageous to a project with repeatable tasks due to the simple work flow sequencing. Each subcontractor is aware of the schedule constraints and is committed to the single duration of each task (single block). The work is planned to flow from one area to the next and can be a very lean construction practice. Management of these types of schedules can be tracked more efficiently and schedule projections and look-aheads can be forecasted more accurately.

When evaluating the Science and Technology Center for this production method, there are obstacles to implementation. The design is very complex and does not contain very many areas of repeatable construction activities. The exterior envelope has many different cladding assemblies that change back and forth when moving vertical up the building. Also, there are many horizontal changes in design as the elevation bump in and out of the building in section view. In considering a SIPS, this would not be recommended for the STC project as the results would be difficult to manage and forecast. The complex design lacks repeatable tasks in large “chunks”, especially with the perimeter enclosure. Therefore, other production methods will be looked at and evaluated for implementation.

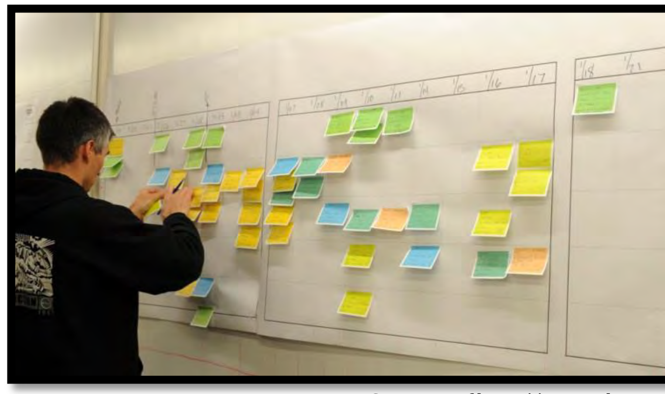
Last Planner System[2.1]

The Last Planner System (LPS) developed in association with the Lean Construction Institute is a “production planning system designed to produce predictable work flow and rapid learning in programming, design, construction and commissioning of projects”.[2.2] Throughout the Architectural Engineering curriculum, courses have presented information through case studies and industry experience to exemplify this lean process. The goal is to operate with the end in mind and base work flows on activities that succeed it. Essentially, this is utilizing a pull theory of management and not the typical push theory. By pull, it means that the current activity was *defined by* an activity further downstream in the process, where push means that the current activity *defines* the later activity downstream. The mind shift in managing a process from the end to the start is one that must be realized by managers to effectively implement Last Planner.

Speaking of this mind shift, Lean Thinking by Womack and Jones contributes to this idea of changing the way of thinking and applying building principles.[2.3] This book contributes the ideas of the Toyota Production System and how successful implementation results in a mind shift of business practices. The lean principles of value, flow, and pull can be related to many business models and management practices, like Last Planner System. In knowing the value a process can have to an organization or project, the motivation is gained to achieve this outcome. Pull and flow production are the principles used to outline how this can be effective. Pull defines the need for a product or process to occur where flow defines how those processes are put in order.[2.3] With this information of knowing a mind shift is necessary, the principles can now be applied to the Last Planner System.

Last Planner implementation starts with having collaborative meetings with all project management members who are responsible for putting the scopes of work into place. Members at the construction manager level as well as the subcontractor level are included in these meetings. Superintendent and foremen, especially from the subcontractors, are a crucial part to these collaborative meetings. These parties will be the individuals making the commitments and outlining the overall constraints of each construction task.

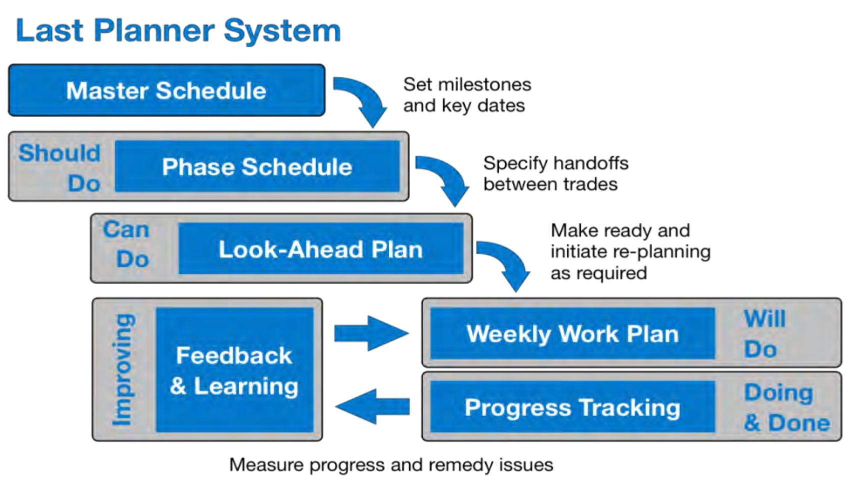
The process begins by starting at the end of construction and working backwards to determine schedule activities and durations. This process implements the lean principle of pull production as outlined earlier. Each party collaborates on tasks that rely on other activities and orders them on a board in the form of small notes (Figure 2.3). This enables activities to be moved around on the board and be sequenced in such a way to satisfy the requirements of the parties involved.



Courtesy of http;//www.gly.com

Figure 2.3 – Example of Note Board for Last Planner

Developing this sequence of notes leads to activity constraints and commitments for each party. These time commitments can then produce a physical project schedule. A master schedule, phase schedules, and look-ahead planning schedules can then be produced (See Figure 2.4 for process map). Continuing down the process, the planning schedules will produce weekly work plans for subcontractors to follow. Since these durations are the result of the collaboration process at the beginning, each subcontractor is held accountable for the weekly schedules. To track the progress of work, planned percentage complete schedules are kept up-to-date. These documents allow construction managers to follow the work completed and, if necessary, adjust production to remain on the planned schedule.



Courtesy of http://www.ennova.com.au

Figure 2.4 – Last Planner System Process

The implementation effects for Last Planner on the Science and Technology project could result in major schedule savings. Due to the significant amount thresholds for changing materials, the Last

Planner system can outline the necessary milestones for construction activities. Not only could this benefit the perimeter enclosure installation, but Last Planner could benefit the entire project schedule. According to the Lean Construction Institute, not only does schedule duration and costs decrease, but accident frequency significantly decrease. A drop of 66% in accident frequency has been reported for MT Hojgaard, the largest Danish Construction Company who has implemented Last Planner on more than 25 building projects in two years' time.[2.4] Along with the schedule savings in the previous subsection, Last Planner can launch a project and company to a new height of project management.

| CONSTRUCTION MANAGER AND OWNER CAPABILITIES |

Evaluating both the cladding replacement scenario and the Last Planner System leads to requirements for the CM and the Owner. As stated previously, every party on the project should have an open mind to different management principles. The critical factor for this analysis is willingness to adopt change in management practices. By allowing a new principle like Last Planner to guide the project, schedule duration can be more effectively managed to have a successful project. The change in façade system would be incorporated into a management style like Last Planner and the project members can be more willing to accept the changes.

| CONCLUSION AND RECOMMENDATION |

Conclusion

This analysis has evaluated the possibilities of replacing a portion of the façade system to accelerate the schedule and different project management methods for more lean construction practices. In combining both of these areas, a major project schedules can be realized. The change in façade system saved 8 days in the schedule sequence and resulted in a higher cost of almost $88,000. The next step evaluated the possibility of implementing a lean management practice with Last Planner System. This system proves to save schedule duration and even lower accident frequency by 66%. With the combination of both of these methods, the STC project could benefit from extra schedule savings and more effective management principles.

Recommendation

Through this analysis, it was determined that changing the façade system on the east elevation resulted in a savings of 8 days, but was not cost effective as it added almost $88,000 in installation costs. Therefore, using brick veneer in lieu of the terracotta wall tiles is not recommended for this project. On the other hand, the Last Planner System was evaluated to make up for schedule delays. It is strongly recommended that the project team implement this lean building tactic due to its capabilities of reducing schedules, costs, and especially accidents on the job site.

SECTION 3 – MODULARIZATION OF CURTAIN WALL (ANALYSIS 2)

| PROBLEM IDENTIFICATION |

In analyzing the schedule for resequencing issues, a major part of construction stood out – the construction of the large curtain wall. Typically these systems are stick-built with the frames installed first and then the glazing attached. This time-intensive process hinders the schedule from being accelerated and the building from being water tight earlier. The PACE Roundtable, as discussed in Technical Report 3, presented the industry issue of modularization and how it can be effectively applied. The Coppin State Science and Technology Center presents an opportunity to change the typical stick-built curtain wall into a modular design. The curtain wall installation time must be reduced in order to reach a shorter duration schedule.

| BACKGROUND RESEARCH |

Two areas of concern come to mind when looking at a modular design; (1) the structural connections necessary to attach the modular panels to the exterior frame and (2) the production rates and schedule benefits of the installation process. The modular design has to take into account how the panels will be physically connected to the exterior frame and also to each panel. These connections are critical due to the water tight specification that must be reached. Case studies can be researched to identify multiple connection types and the relative benefits. The current design contains a very detailed waterproofing design near the roof parapet, so further research here could identify more effective methods. These connections also govern the size limit of each panel. A larger size panel may need a more complex steel connection and could have more transportation limits however this could also yield a faster installation time onsite.

The second concern involving production rates and schedule benefits can be supported through research conducted in AE 570 (Production Management in Construction) as modularization was a key focus of the curriculum. The information gathered from this project and the case studies referenced will lend itself to a more developed methodology for implementing a modular design.

| POTENTIAL SOLUTIONS |

In regards to the structural connections, the first solution can be evaluated from a feasibility perspective of both cost and installation through a constructability review. By researching the typical connection types of a modular curtain wall panel, it can be analyzed in terms of cost and installation method. The owner has a very strict budget on this project, so any savings that can be found are critical. If it can be proved that schedule time will be reduced significantly by using a more expensive connection system, then this method may be more feasible.

In terms of the production rates, the modularization could significantly reduce onsite labor and mobilization of materials. For one, materials will need to be stored onsite during a stick-built installation and take up space where other trade's material could be staged. Also, the onsite skilled labor necessary to stick build a curtain wall greatly increases in comparison to a modular system. The skilled labor will be working in a controlled shop environment where production costs are reduced. By mapping the production process of each module, a cost and production analysis can be performed. This is beneficial in supporting the changeover to a modular system and providing information that it's a feasible alternative. These numbers could then translate to the project site where schedule and cost reductions are realized. From a production standpoint, this will greatly enhance the opportunity of gaining back the schedule delay.

| SOLUTION METHOD |

- Develop preliminary panel design alternatives.
- Gather information on potential steel connections with a modular curtain wall system.
- Evaluate the steel connections with regards to a specific modular panel.
- Analyze the module process for production efficiency and cost savings.
- Determine any transportation or installation coordination needs.
- Assess modular system with waterproofing specifications.
- Develop a potential installation procedure and any site logistic concerns with equipment or manpower.
- Determine qualifications of installation subcontractor and appropriate procurement strategy.
- Implement modular system to improve schedule duration of install.
- Document the analysis results through a comparison to the original schedule durations.

Resources

~ Industry Professionals (recommendations on steel connection system)
~ AE Faculty Members (Modularization process improvements)
~ AE 570 course – Production Management in Construction
    - Modularization Research Project
~ PACE Roundtable Breakout Session
~ Process Mapping

- Project Documents
- Barton Malow Project Team Members

| EXPECTED OUTCOME |

With respect to any single activity onsite, the curtain wall system stands to be both a major cost and schedule reduction area. By moving the fabrication offsite and installing the modules on a just-in-time basis onsite, the schedule should be improved greatly. The production rates for installation should improve greatly and have significant cost reduction. In addition, this will address the current waterproofing detail at the parapet and curtain wall and provide a better solution. It is believed that a schedule resequencing and a modular curtain wall system will recover a significant part of the 3 month delay.

| CRITICAL INDUSTRY ISSUES |

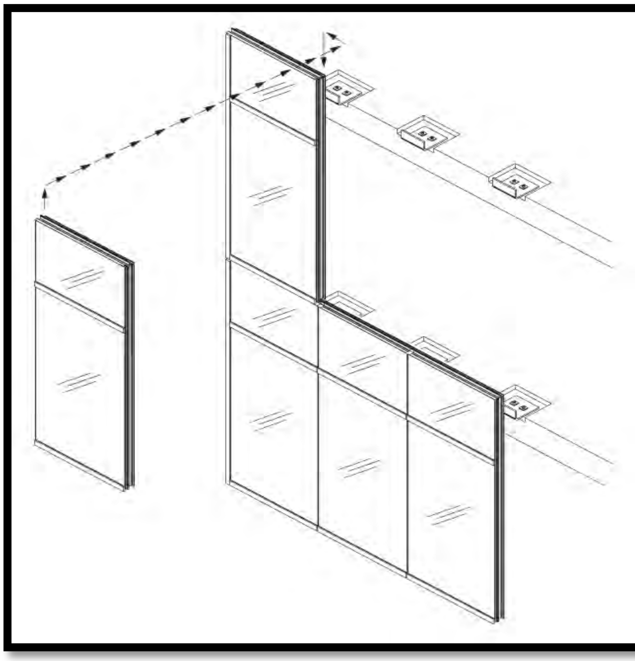
The 21st Annual PACE Roundtable was held this year and provided great insight to current industry issues and potential solutions for these areas. Modularization was a key topic of discussion with the industry members which feature recommendations and challenges. MEP systems proved to be a great area of modularization as rack piping can include many trades into one unit and be placed at one time on a construction site. This saves coordination time onsite for installation and can cut costs greatly. Modular curtain walls were also discussed with the benefits of a safer, faster, and higher quality system. These systems must be designed early on in the process with modular in mind. It is difficult to implement as an "after-thought" of design. Relating to the Science and Technology Center, this information is critical. In order for this analysis to be successful, it must be recognized and implemented early in the design. However, in this case, the modular design will be a product of a schedule delay rather than the original intent of the design. This factor can be accounted for during the thesis investigation and presented accordingly. The goal of this research is to define the feasibility of this modular curtain wall system in terms of production and installation duration.

CURTAIN WALL PANEL DESIGN ALTERNATIVES

Different manufacturers were specified for the design of the curtain wall system. The current specified manufacturer for the curtain wall and glazing is Shuco. However, two other manufacturers, Kawneer North America and Wausau Window and Wall Systems, were specified as available manufacturers when meeting the requirements of the basis-of-design. With this information, these two manufacturers were researched further to provide more information on the panel systems offered for a curtain wall design.

Kawneer North America[3.1]

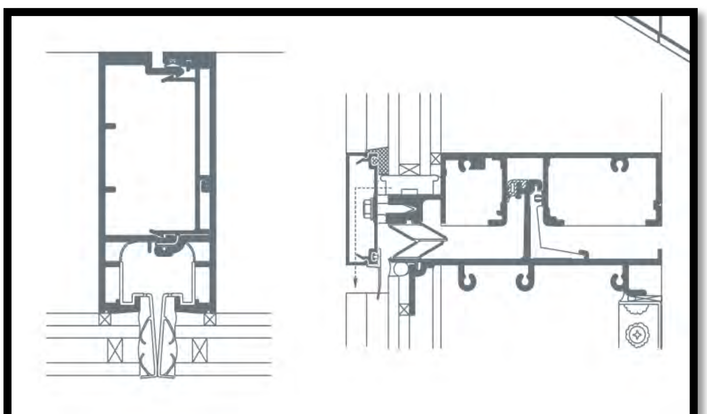
The 2500 PG Unitwall system offered by Kawneer North America is pre-glazed and prefabricated while being shipped to site in knocked-down panels. It includes adjustable slab edge drop-on anchors for ease of installation. A benefit is that no exterior joint seal needs to be applied thus eliminating significant on-site installation time. This system of panels can be customized to meet the specification of the Science and Technology and meet the glazing types of the design. Figure 3.1 and 3.2 show typical details of the 2500 PG Unitwall System.



Courtesy of http://www.kawneer.com

Figure 3.1 – 2500 PG Unitwall Overview

The overall design of the 2500 PG Unitwall system allows for quick installation of the interlocking panels. With the addition of off-site fabrication, unitizing the panels will potentially lead to a major schedule reduction and on-site field labor costs.



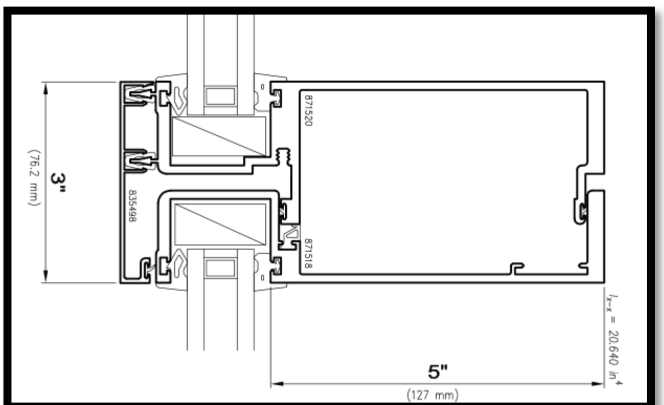
Courtesy of http://www.kawneer.com

Figure 3.2 – 2500 PG Unitwall Connection Detail

***See Appendix 3-A for 2500-PG Unitwall Technical Data**

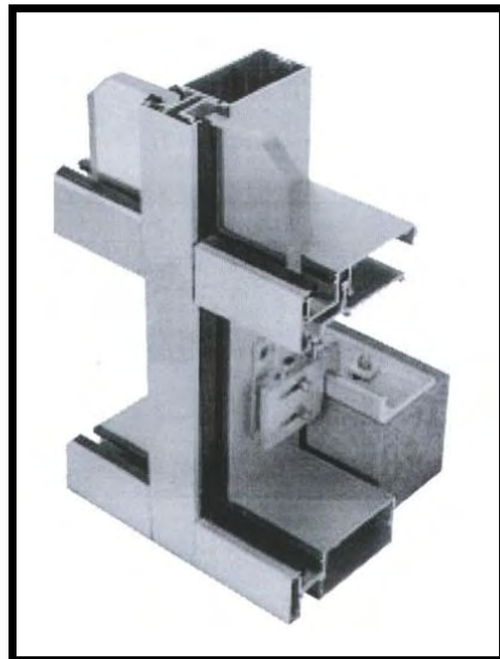
Wausau Window and Wall Systems[3.2]

The second curtain wall system researched included the 7250-UW series, manufactured by Wausau Window and Wall Systems. This system utilizes an interlocking frame design that accommodates seismic, live load and thermal building movements by accepting up to ¾" vertical movement. The system also offers captured, vertical, or four sided structural glazed – fitting the specifications of four-sided captured with the Science and Technology Center design. The unique "jack-bolt" anchoring option also allows for fast installation and seamless interlocking of panels. Figure 3.3 and 3.4 show details of the 7250-UW system.



Courtesy of http://www.wausauwindow.com

Figure 3.3 – 7250-UW Connection Detail



Courtesy of http://www.wausauwindow.com

Figure 3.3 – 7250-UW Anchor Isometric

The overall design of the "jack-bolt" anchor (seen in Figure 3.3. above) allows crews to erect and install each panel in a significantly short time period. Based on a case study by Service Glass Industries, the Metro Park 6 building in Alexandria, VA installed 52 panel sections in just 6.5 hours. This information will be utilized in further evaluation for a unitized system.[3.2]

***See Appendix 3-B for 7500-UW series Technical Data**

Manufacturer Evaluation

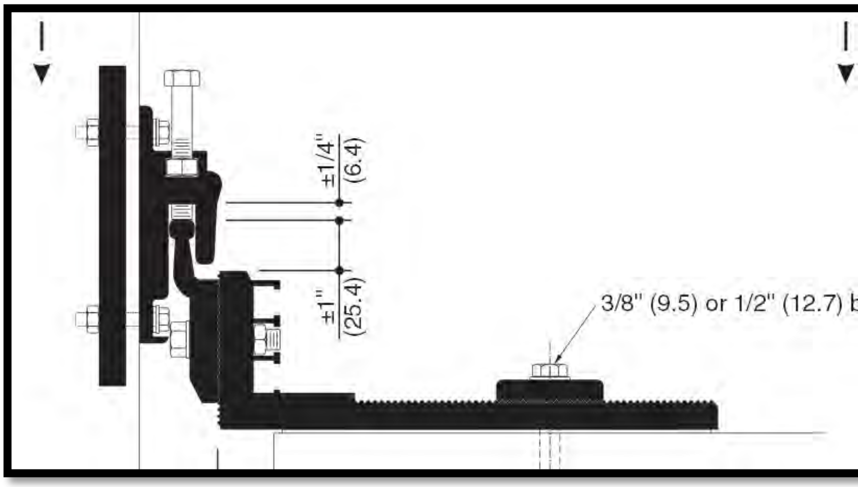
In researching the two manufactures, both systems provide the specified panel design for the Science and Technology Center. Each manufacturer has a unique system that could equally work with the current design. However, schedule reduction is a major focus of this design alternative, so a further look into the anchoring systems will enable a better comparison of the two systems.

| CURTAIN WALL PANEL ANCHORING DESIGN |

A further evaluation of each anchoring system was conducted to provide more information to choose a panel design. By comparing the two anchoring systems, potential for higher schedule reduction can be determined.

Kawneer North America[3.1]

Figure 3.5, right, depicts the anchoring detail typical to the 2500 PG Unitwall system. An angle bracket is attached to the floor slab (near right on Figure 3.5), and then the curtain wall panel is hung on this bracket with the proper hardware. See Appendix 3-A for further section details.

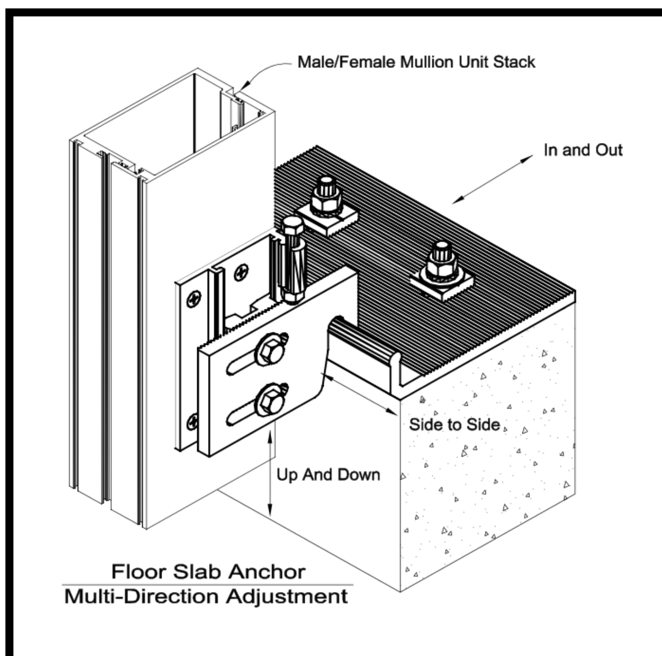


Courtesy of http://www.kawneer.com

Figure 3.5 – 2500 PG Unitwall Anchoring Detail

Wausau Window and Wall Systems[3.2]

Figure 3.6, right, show the anchoring detail typical to the 7250-UW system. This "jack-bolt" design allows for multiple points of adjustability as well as a quick installation of hanging the panel on the anchor plate. See Appendix 3-B for further section details.



Courtesy of http://www.kawneer.com

Figure 3.5 – 7250-UW Anchoring Detail

|CURTAIN WALL PANEL SELECTION|

In researching the two manufactures, it was chosen that Wausau Window and Wall Systems would provide the best opportunity for schedule reduction based on the unique anchoring system of the 7250-UW series curtain wall panels. This anchoring detail provides adjustability, and as supported by the Metro Park 6 Building, the installation process is fast-tracked.

|PRODUCTION EFFICIENCY AND COST EVALUATION|

Production Efficiency

A quantity takeoff was performed to calculate the total number of curtain wall panels and square footage, accordingly. In finding the total number of panels, a production duration can be calculated to determine the total schedule duration of the activity with unitized panels. This method is expected to have a significant schedule reduction in comparison to the stick-built curtain wall system. The summary of the quantity take off is as follows:

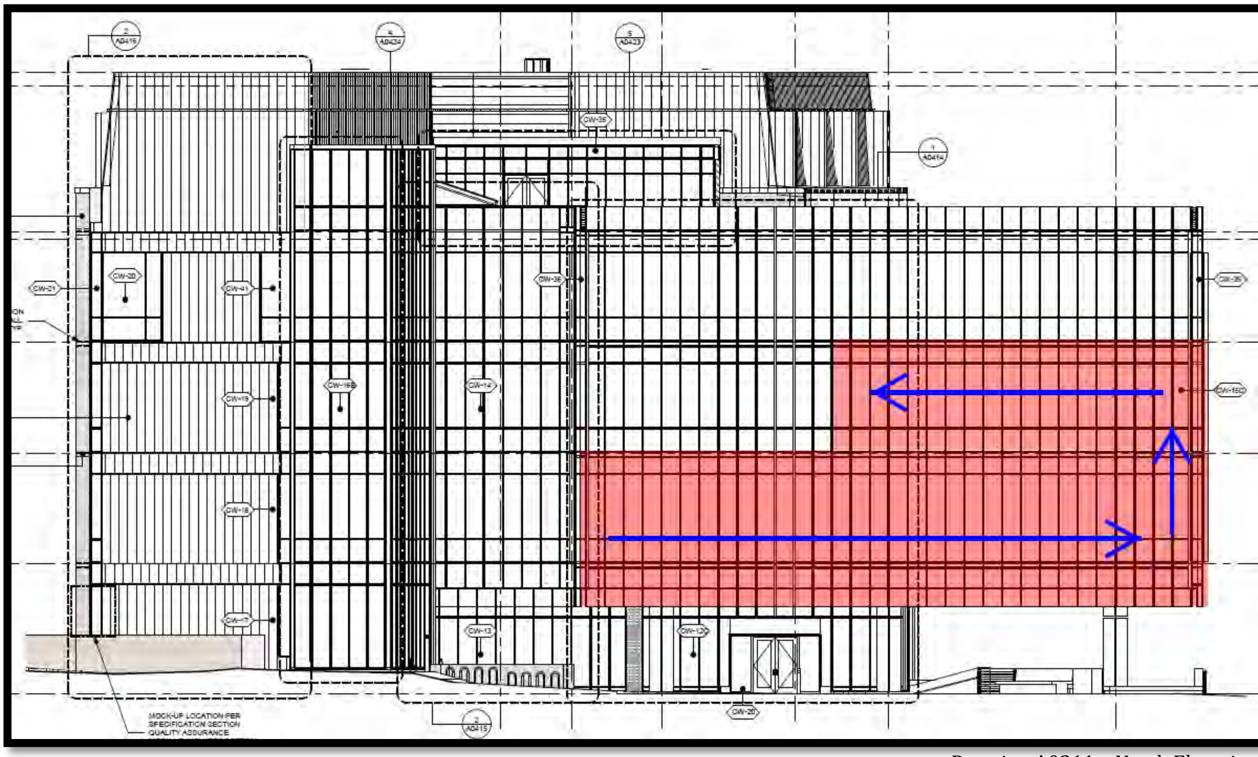
Total Number of Curtain Wall Panels – 783

Total Sq. Ft. of Curtain Wall Panels – 34,675 SF

Most Typical Panel Size – 2' - 7-1/2" x 15'-4"

Appendix 3-C shows the detailed panel sizes and square footages for each curtain wall types. It also included the number of each type of panel. As noted above, the typical panel size is 2' - 7-1/2" x 15'-4" and is located on the northwest tower. There are 101 panels of this size located in the middle strip around the northwest tower. In addition, the top and bottom portion of these walls at the northwest tower have small overhangs which extend either below or above past the floor level. With this extension the panel size length extends to 20’-4” to 21’-4” and incorporates a total of 202 panels. This northwest area includes 303 panels of roughly the same unit size, thus having a great opportunity to unitize the panels.

Based upon the Metro Park 6 Building mentioned above, the production for repetitive panels like these can be based on 52 panels in 6.5 hours. This equivocates to 7.5 minutes per panel to be installed. This time is has its limitation however – it does not include staging time and preparation of the panels. To stage these panels on each floor and have them ready for erection, it can be assumed that each panel would take 10 minutes of handling time to prepare in place. This is based on the assumption that the 52 panels placed at Metro Park 6 were being prepped while the erection crew was hanging the panels. By having two crews, there can be a continuous flow of work. This preparation and staging of panels will be performed by a second crew as to not inhibit the erection crew. The additional crew will amount to additional costs, but the 52 panels per day production can be maintained. Therefore, a production rate of 52 panels per day will be used to plan the installations sequence at the Science and Technology Center project.



Drawing A0311 – North Elevation

Figure 3.6 – Installation Sequence of Typical Curtain Wall Panels

Figure 3.6 above illustrates the installation sequence for a typical day of an erection crew. The crew would hang 52 panels per day in a sequence that follows the pattern as set by the blue arrows in Figure 3.6. This wrap-around process would occur for the entire northwest tower section of the building. In doing so, this will reach the highest production levels of all curtain wall panels as this is the most repetitive. The remaining panels, due to complexity and size, will be based on a production rate double that of the northwest corner. Therefore, these panels will be based on a 26 per day rate. Again, there will be one crew staging the panels and another crew hanging the panels. The trimout and caulking of the panels will be based upon the original schedule duration of Barton Malow at approximately 30 panels per day.

The schedule estimation for hanging the curtain wall panels is as follows:

Northwest Tower – 303 Panels @ 52 panels/day =	**6 days**
Balance of Panels – 480 Panels @ 26 panels/day =	**19 days**
Trimout/Caulk Panels – 783 Panels @ 30 panels/day =	**27 days**
Total =	**52 days**

Based upon the original schedule (See Appendix 3-D) produced by Barton Malow, the projected duration of the curtain wall installation was 80 days (Sept 2013 to Jan 2014). With this information the new schedule projection is as follows:

Original Schedule Duration – Stick Built Curtain Wall = 80 days

Projected Schedule Duration – Unitized Curtain Wall = 52 days

Savings = 28 days

Cost Evaluation

Now that a schedule reduction has been determined, a cost evaluation will now be assembled to show the feasibility of this method of construction. The cost estimation of the stick-built system was determined from the square footage of the quantities taken off. In the same manner, the unitized panels were estimated. The material and equipment costs were assumed to be equivalent as it is the same material in the design. The cost information anchoring for the panels from Wausau was not available; therefore both the original anchors and the unitized anchors will be equivocated in terms of cost. The major difference occurs with assembly time and labor rates. The production costs in a controlled shop environment can be assumed to be 15% less than that of field labor for the same activity. The savings from the production costs for the panels will contribute to the double crew size installing the panels. The estimate for the two systems is seen in Table 3.1 below.

Table 3.1 – Cost Estimation of Curtain Wall Systems

Item	Quantity	Unit	Total Incl. O&P	Extended Total Incl. O&P
Stick Built System	34,675	SF	$ 180.00	$ 6,241,500.00
			Subtotal	**$ 6,241,500.00**
Unitized System	34,675	SF	$ 153.00	$ 5,305,275.00
Staging Crew for Panels	34,675	SF	$ 9.35	$ 324,211.00
			Subtotal	**$ 5,629,486.00**
			Total Savings	**$612,014**

See Appendix 3-C for complete estimate details

In concluding the schedule and cost estimation, the unitized curtain all system can make up significant time of the delayed schedule. Overall, 28 days can be gained back and a total of $612,000 can be saved. This will contribute to the overall schedule acceleration in achieving the schedule reduction goal.

| TRANSPORTATION AND INSTALLATION PROCEDURE REQUIREMENTS |

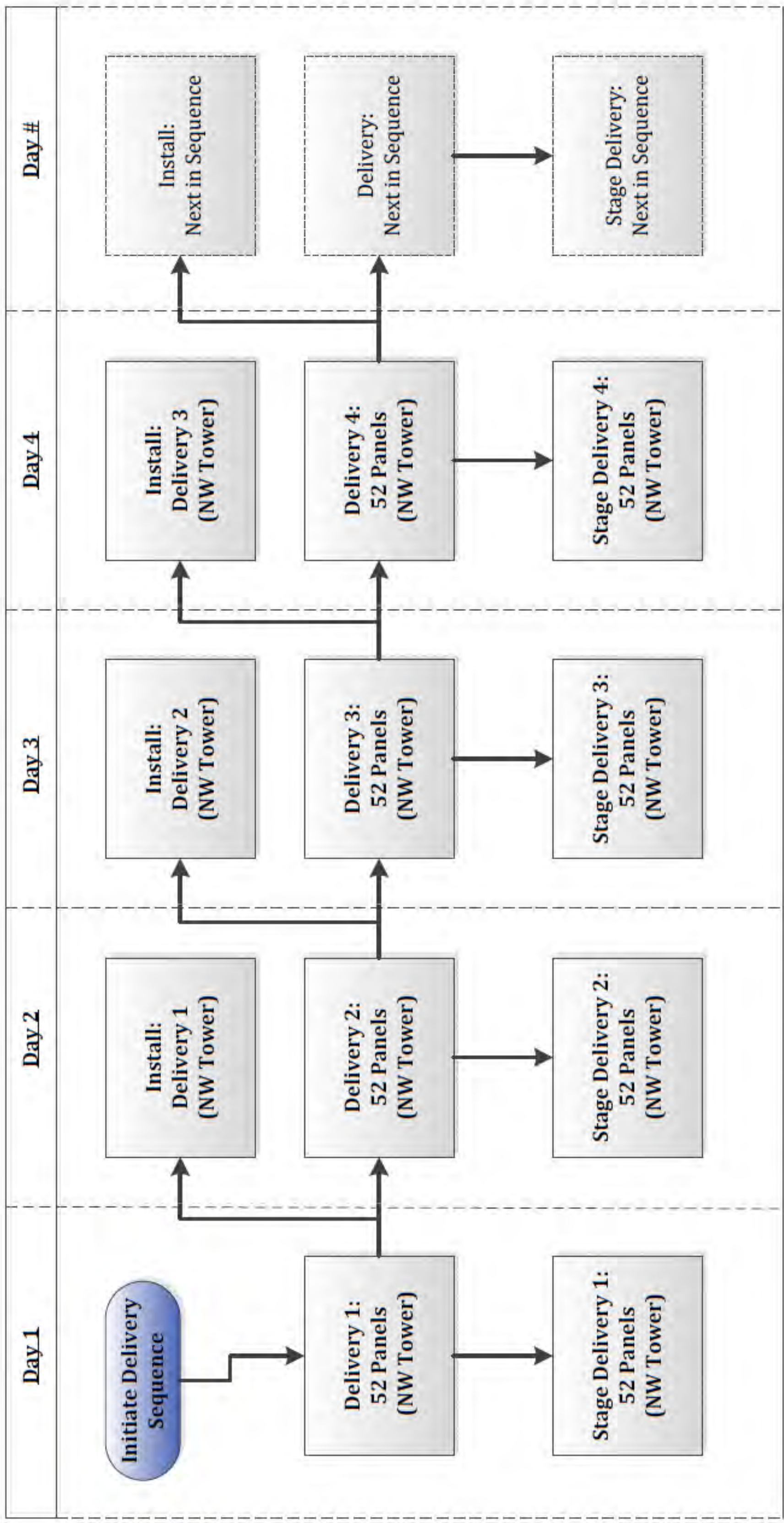
The schedule outlined in the previous section cannot be obtained if certain transportation and installation requirements are not met. One of the biggest and most crucial aspects of the curtain wall installation is to have the prefabricated panels delivered on-site at the specified and planned time period. This area must not be overlooked by the management team and the installers because the production efficiency can only be reached if the material is on the project site at the time necessary. In order for this to occur fluidly, the project team should outline a production plan similar to the following:

I. Determine the installation sequence of the curtain wall panels and the flow of work.
II. Coordinate between the prefabrication shop and the field which components will be loaded and delivered according to the installation sequence.
    a. This step is crucial; delivering out of sequence can result in major schedule delays.
III. Evaluate the transportation route and determine any necessary vehicle permits for the roads being traveled.
IV. Define offload and staging area on-site for each delivery truck.
V. Evaluate the site logistics for necessary equipment to move panels into building space for erection.

By strategically defining and organizing a plan similar to the one above, the project team will be better capable of delivering and installing the curtain wall panels in alignment with the projected schedule. The panels are within a typical 53' trailer's tolerances, so there are no foreseen issues with permitting. The planning sequence should be based on the idea of pull production for leaner construction practices. The panels are already being inventoried at the prefabrication shop, so there should never be a need to stage them again on-site. By instituting the pull production principle, the customer (Barton Malow and CSU) plans for panels they need on-site on a particular day. Simply, the panel manufacturer does not deliver a component to the project site unless it is asked for by the contractor (hence, "pulled" principle). By limiting the upstream vendor from delivering until the contractor pulls for it from downstream will enable a flowing production process.[2.2]

The logistical concerns on-site would remain minimal with the proper delivery sequence. The panels for the northwest tower would be lifted internally from a floor hoist, where the panels for the windows and other areas along the perimeter would use an external lift. With the deliveries being delivered on a just-in-time basis, the small external lift (hoist/crane) would have more space to maneuver on site. These logistical concerns can be managed effectively if pull production and the just-in-time delivery sequence are followed as planned.

Optimally, the delivery sequence would follow the pattern as seen on the next page in Figure 3.7.



Developed by Nick Zitterbart

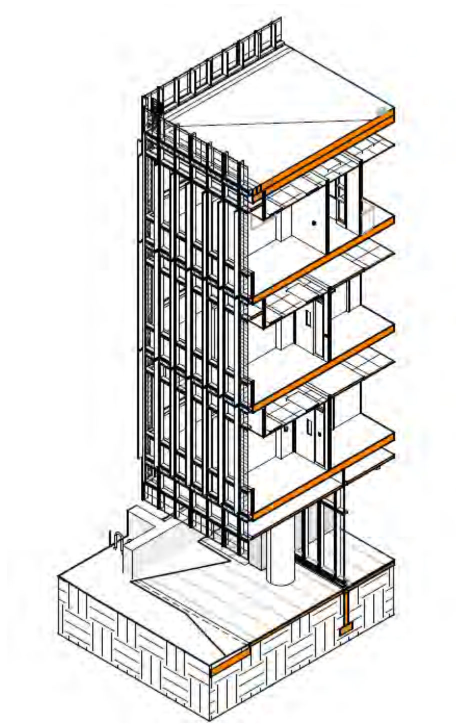
Figure 3.7 – Typical Delivery and Installation Sequence of Curtain Wall Panels

It is important to note that Figure 3.7 shows the delivery and installation stage of the construction process. This process would be preceded by a detailed planning stage to account for all panels and the sequence in which they would be loaded for delivery.

The delivery sequence as depicted in Figure 3.7 outlines the order in which curtain wall components will be offloaded and staged on site. The first staging of panels on the appropriate floor will occur the day the first delivery occurs. Once this happens, the erection crew can begin hanging the panels a day behind the staging crew. In following this sequence, the deliveries follow the pull production principle, the panels are staged on the floors eliminating storage space on-site, and the panels are hung directly after being staged on the floors. This lean construction process can have both significant schedule savings from minimal delivery delays and cost savings from lowered inventory and storage needs.

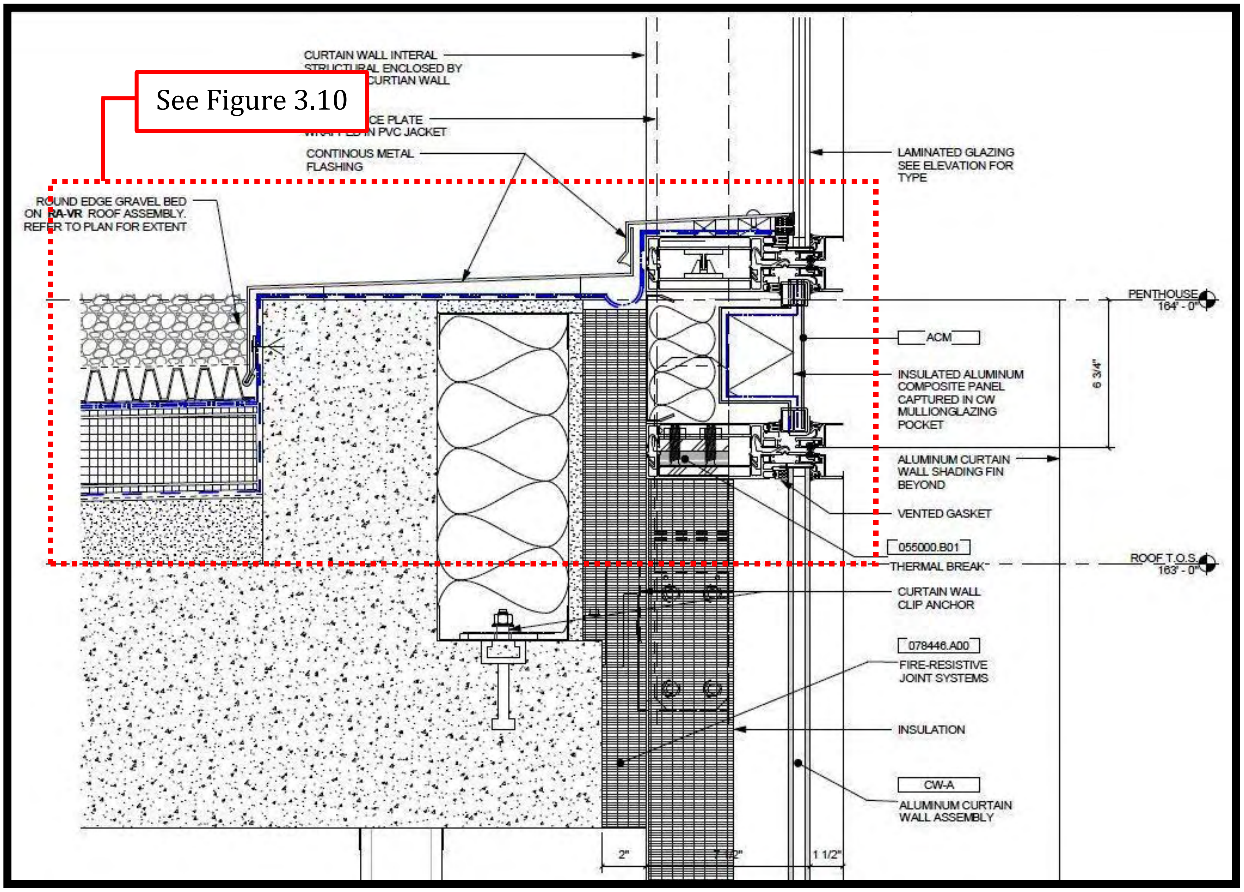
|WATERPROOFING REQUIREMENTS |

Due to the specified design, the waterproofing detail is very complex at the roof line of the north tower section. The curtain wall panels actually extend vertically above the roofline creating a parapet-type wall (See Figure 3.8 and 3.9). The critical issue that occurs is the intense waterproofing detail to maintain a water-tight structure. To change the design architecturally and end the curtain wall panels at the roof line elevation would solve the waterproofing issue – the waterproofing extending beyond the outside of the roof edge (in blue on Figure 3.10 on the next page) would be eliminated. If the panel was to end at the roof line, the air barrier and waterproofing would be typical of a flat roof and not be incorporated down the side of the curtain wall. However, this would significantly alter the design architecturally and it would not be recommended to do so. A positive note, this 3'-6" parapet extension gives the proper fall protection requirement by OSHA standards at 42" above the walking surface. This would be convenient and more efficient for any maintenance requirements that occur while the building is operated. For these reasons, the waterproofing detail will remain the same, thus proper attention for quality assurance must occur. Quality issues here could account for large cost impacts in the future.



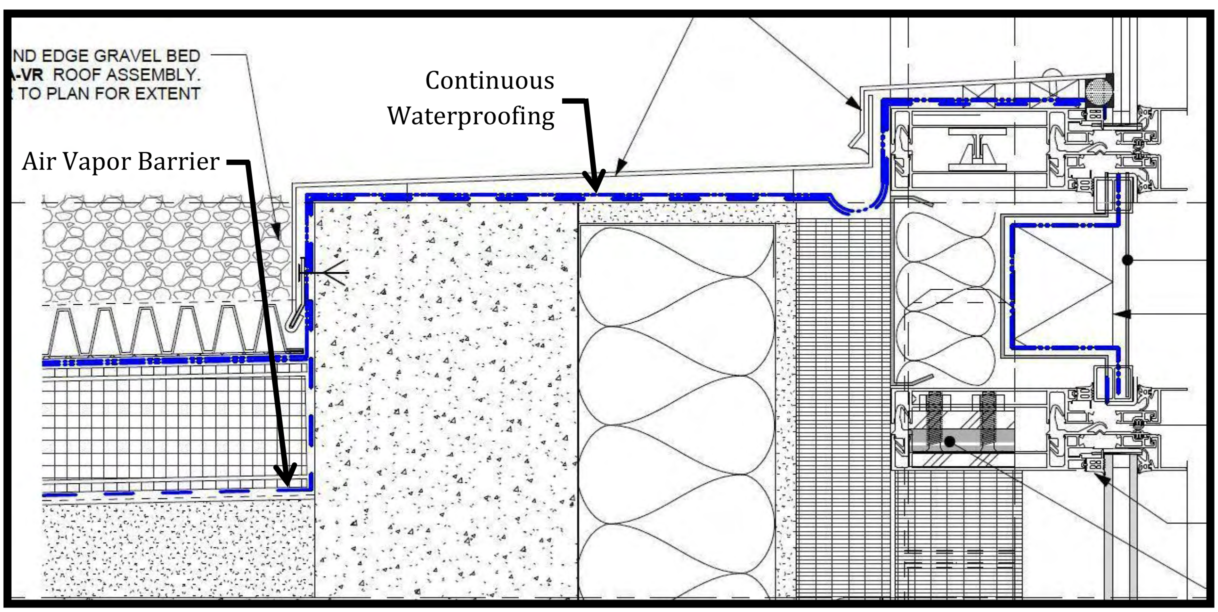
Drawing A0414 –Detail 5

Figure 3.8 – Northwest Tower Building Section Cut



Drawing A0457 –Detail 3

Figure 3.9 – Waterproofing Detail at North Tower Exterior Section



Callout of Figure 3.8

Figure 3.10 – Waterproofing Detail at North Tower Exterior Section

| INSTALLER QUALIFICATIONS |

The installer responsible for installing the unitized curtain wall panel will need to meet multiple requirements. First, a mock-up will be necessary to set quality standards for materials and execution. By completing this mock-up area, the installer can gain acceptance to complete the remaining work. Also with quality assurance, the installer must follow the manufacturer's authorized representative who can approve the installation of the units themselves. A special warranty of 10 years will be granted for failures and a warranty for 20 years will be granted for deterioration, both implemented by the installer. The installer also agrees to use all required materials including three-way adjustable anchors with a minimum adjustment of 1 inch. These anchors will be hot-dip galvanized to be protected when installed as concrete inserts. By meeting these requirements, the installer is capable of completing the work for the unitized curtain wall panels.

| CRITICAL INDUSTRY ISSUE DISCUSSION |

Throughout this analysis, there were many factors considered when implementing this unitized curtain wall system. One of the main factors was that of early planning for the delivery sequence and installation. As discussed in this year's PACE Roundtable, modularization of any kind heavily involves months of planning and forethought to be a practical use in construction. If this process is thought of as just an "add-on" to the design, then this would never be an efficient and practical use of modularization. As many industry members addressed, prefabricating units into modules is production efficient and can reduce construction schedules by large amounts. However, each individual focused on the essential need to plan during the design for the prefabrication process ad have the modularization be integrated into the design as one. In doing so, this will yield the best potential results for implementation during the construction phase. Specifically on the Science and Technology Project, unitizing the curtain wall would be effective when integrated into the initial design. As discussed through this analysis, there are great opportunities for schedule reduction scenarios if properly planned. Both the PACE Roundtable discussions and industry members alike agree on one thing – planning surpasses every other need on a project design in order to have the best outcomes.

| CONCLUSION AND RECOMMENDATION |

Conclusion

This analysis presents an alternative modular system to an on-site stick-built system where installation is an inhibiting factor. A stick-built curtain wall system requires on-site staging areas for all materials and long durations of time for erecting the framing and glazing for the curtain wall. This includes scaffolding systems, cranes and lifts, and multiple skilled craftsmen performing in various weather conditions. On the other hand, a prefabricated unitized curtain wall system includes panels constructed in a controlled shop environment and little equipment for on-site installation. In addition, the skilled craftsmen are not required to work as many hours due to the panels being constructed into units. The quality standards alone are much higher when the panels are built in a controlled facility.

Overall, the schedule was calculated to reduce by 28 days and costs upwards of $612,000 could be achieved. This is made possible through the prefabrication of the unitized panels at an off-site location. Furthermore, the lean principles of pull production and just-in-time delivery lend to the overall schedule and cost savings. By planning out a delivery and installation sequence through the pull theory, the curtain wall panels can be installed at a fast-tracked rate.

Recommendation

It is recommended that the Science and Technology Center project incorporate a modular design into the curtain wall to reduce overall schedule and recover the initial 3 months delayed on the project. Almost an entire month can be eliminated from the schedule by implementing a modular design of the curtain wall. Inevitably, this alternative construction method will lend to the overall goal of schedule acceleration and leaner construction methods.

SECTION 4 – FINNED TUBE RADIATOR DESIGN (ANALYSIS 3)

| PROBLEM IDENTIFICATION |

A major goal of the owner is to remain under budget and value engineer as many items feasible to achieve this. To avoid any funding issues, design alternatives are reviewed in order to provide cost reduction. A feature noticed in the mechanical design was the finned tube radiators along the exterior walls of rooms and how many units were involved in the design. These units supply warm air through hydronic piping to maintain the thermal gradient of the space. This system accounts for a larger amount of labor and installation time and an alternative system can be considered to save time and costs.

| BACKGROUND RESEARCH |

The designed finned tube radiator system involves many units that account for a significant installation time. Installing these units consists of brazing pipe material at each connection and can be very time consuming. Also, the load on the boiler increases significantly with these units. An alternative to research includes linear diffusers at the ceiling and transferring load from the boiler to the air handling unit. The feasibility of this system will be considered in terms of installation time, efficiency, and cost savings.

| POTENTIAL SOLUTIONS |

The alternative for this finned tube radiator system will incorporate linear diffusers at the ceiling along the window line of particular spaces. The University of Maryland standard is to deliver air along the windows at the same temperature of the surrounding space. The load provided from the boilers will then be converted equivalently to the air handlers. In doing so, material costs (pipe length and connections) and installation labor costs could be reduced. This alternative will be compared to the original finned tube radiators for advantages.

| SOLUTION METHOD |

- Evaluate current design and amount of fin tube radiators
- Determine the benefits (schedule/cost) of instituting the linear diffusers.
- Determine best areas for replacement based on the current design.
- Calculate the loads necessary for the new diffusers and the savings on the boilers.
- Determine the effects of diffusers on the air handlers and provide upgraded equipment information, if necessary.
- Evaluate the feasibility of implementation in terms of alternative system.
- Propose new system with cost/time savings and impact on project.

Resources

~ Barton Malow Project Team
~ AE Faculty Members
~ AE Classmates
~ Applicable Books, Papers & Websites

| EXPECTED OUTCOME |

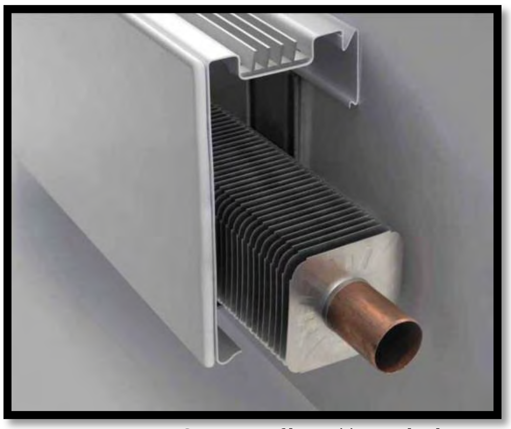
The major effect of this analysis is expected to have the most savings on installation time and labor costs. Also, there is expected to be savings within the mechanical system. By reducing the load on the boilers through less hydronic piping, this can provide cost savings and may be more efficient.

| AREA OF IMPLEMENTATION SELECTION |

Discussions with the project team and background research were conducted in order to choose the best area of implementation for an alternative system design. While considering the building system, it was determined to replace all of the finned tube radiators and install diffusers along the perimeter to supply the same air temperature. This choice was made based on the inefficiencies of the installation time of the radiator units and the fact that there was a large opportunity for major time savings. In keeping with the trend of schedule acceleration, the replacement of all finned tube radiators is projected to have the biggest effect on schedule savings.

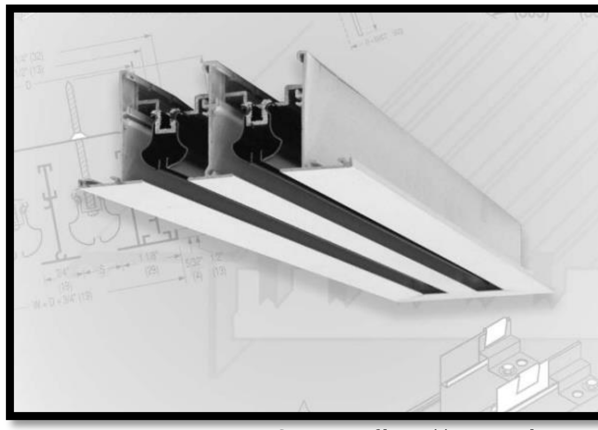
| LINEAR DIFUSSER BACKGROUND INFORMATION |

As mentioned, the design of the finned tube radiators involves expensive copper hydronic piping and time-consuming brazing connections. In addition, the University of Maryland standard is to provide the same air temperature along the window as the room temperature air, which is more stringent the ASHRAE standard. This will enable the building to have better thermal controllability and meet the goals of the owner. By installing the linear diffusers, this will potentially amount to a large labor savings, less installation time, and thermal controllability. Figures 4.1 and 4.2 below depict the specified finned tube radiator in comparison to a typical linear diffuser.



Courtesy of http://www.hydro-air.net

Figure 4.1 – Rittling Finned Tubed Radiator



Courtesy of http://www.nailor.com

Figure 4.2 – Nailor Linear Diffuser

| FINNED TUBE RADIATOR ESTIMATE AND INSTALLATION – MECHANICAL BREADTH |

Cost Evaluation

After determining that the finned tube radiators would be replaced by linear diffusers, a cost analysis was performed to determine major cost savings. A quantity takeoff of all materials was performed to put together a final cost estimate. This takeoff included the perimeter heating water pumps, the hydronic copper pipe, and the finned tube radiator unit themselves. In addition, the load from the finned tube radiators was calculated to find the decrease in load on the costly boilers. Table 4.1, see next page, shows the quantities and costs of the finned tube radiator system.

Table 4.1 – Cost Estimation of Finned Tube Radiator System

Item	Quantity	Unit	Total Incl. O&P	Extended Total Incl. O&P
Pipe Insulation	4536	S.F.	$ 10.12	$ 2,297.24
Fittings (add 15%)	680	L.F.	$ 26.65	$ 18,122.00
3/4" Copper Pipe	2584	L.F.	$ 16.05	$ 41,473.20
1" Copper Pipe	1313	L.F.	$ 20.45	$ 26,850.85
1-1/4" Copper Pipe	551	L.F.	$ 26.65	$ 14,684.15
2" Copper Pipe	36	L.F.	$ 46.50	$ 1,674.00
2-1/2" Copper Pipe	55	L.F.	$ 66.50	$ 3,657.50
Insulation Waste (5%)	227	L.F.	$ 10.12	$ 2,297.24
Hydronic Pump	2	Ea.	$ 4,234.00	$ 8,468.00
FTR Units	1550	L.F.	$ 79.00	$ 122,450.00
Total				**$ 241,974.18**

See Appendix 4-A for full cost estimate details

The above values reflect the total cost of the finned tube radiator system and portion of the mechanical bid package that will be further evaluated. With these values, this will establish a baseline to analyze the alternative solution of linear diffusers and the potential cost savings that could be gained.

With an established cost estimate for the finned tube radiator system, the installation time was then determined. The daily output values for each task were used to determine total duration of this sequence of activities. Table 4.2, see next page, reflects the results of these durations:

Schedule Evaluation

Table 4.2 – Installation Time of Finned Tube Radiator System

Item	Quantity	Unit	Daily Output	Total Duration
Pipe Insulation	4536	S.F.	160.00	28.35
Fittings (add 15%)	680	L.F.	65.00	10.46
3/4" Copper Pipe	2584	L.F.	76.00	34.00
1" Copper Pipe	1313	L.F.	68.00	19.31
1-1/4" Copper Pipe	551	L.F.	58.00	9.50
2" Copper Pipe	36	L.F.	42.00	0.86
2-1/2" Copper Pipe	55	L.F.	62.00	0.89
Insulation Waste (5%)	227	L.F.	160.00	1.42
Hydronic Pump, 3HP	2	Ea.	5.00	0.40
FTR Units	1550	L.F.	38.00	40.79
Total				**146***

*See Appendix 4-A for daily output details, *Reflects install time and not necessarily total schedule days*

The totals above reflect the daily outputs of the quantities taken from the design. This will provide a base line for comparison to the linear diffuser system. Also note that the total shows total man-hours for the activities in Table 4.2. These activities will be sequenced accordingly, and total schedule duration will be discussed in the 'Feasibility for Implementation' section (Table 4.5).

| LINEAR DIFFUSER ESTIMATE AND INSTALLATION TIME – MECHANICAL BREADTH |

Cost Evaluation

With a baseline comparison now calculated, the linear diffuser estimate can now be effectively determined. Each finned tube radiator's load of MBH (1000BTU/HR) was converted to CFM based on a 20 degree temperature difference. These values for each finned tube unit can be seen in Appendix 4-B. At the same time, each finned tube unit was designated to its corresponding air handling unit for load purposes. There are three main AHU's that serve all of the areas in which the finned tube radiators are located. By, assigning these equivalent loads (MBH to CFM) to the proper AHU will enable an accurate load evaluation for a new AHU. Essentially, the load from the radiators (MBH) will now be transferred to the AHUs (CFM). Quantity takeoffs and calculations in regards to the linear diffusers are shown in Table 4.3, seen on the next page.

Table 4.3 – Cost Estimation of Linear Diffuser System

Item	Quantity	Unit	Total Incl. O&P	Extended Total Incl. O&P
Aluminum Ductwork	6046	Lb.	$ 14.93	$ 90,266.78
Linear Diffusers	155	Ea.	$ 130.00	$ 20,150.00
Total				**$ 110,416.78**

See Appendix 4-A for full cost estimate details

The values in Table 4.3 represent the summary of the quantity takeoffs from design drawings. Each diffuser was sized based on the CFM output equivalent to the MBH output of the radiator unit. This value was then used to size the proper round duct size for the CFM amount.[4.1] Next, the total weight of duct work was calculated and evaluating as seen in Table 4.3.[4.2] This calculation information can be seen in Appendix 4-B.

Schedule Evaluation

Now, another evaluation was performed to determine the total installation time of the alternative linear diffuser system. Table 4.4 below reflects the values of the daily outputs.

Table 4.4 – Installation Time Summary

Item	Quantity	Unit	Daily Output	Total Duration
Aluminum Ductwork	6046	Lb.	145.00	41.70
Linear Diffusers	155	Ea.	14.00	11.07
Total				**53***

*See Appendix 4-A for daily output details, *Reflects install time and not necessarily total schedule days*

The totals above reflect the daily outputs of the quantities taken from the design. This can now be compared to the baseline of the finned tube radiators.. Also note that the total shows total man-hours for the activities in Table 4.4. These activities will be sequenced accordingly, and total schedule duration will be discussed in the 'Feasibility for Implementation' section (Table 4.5).

The mechanical analysis of these two systems resulted in a load differential from the hydronic piping to the air handling units. In total, AHU-1 increased by 8,162 CFM, AHU-2 increased by 2,425 CFM, and AHU-3 increased by 5,977 CFM. With this information, new AHU's can be designed and chosen to fulfill the new capacity requirements. On the other side, there was a reduction in the load on the boiler as hydronic piping was eliminated that supplied the radiator units. In total, the decreased load on the Boiler 3 amounted to 358 MBH (358,000 BTU/HR). Both of these areas of the mechanical analysis provide positive impacts to the project design.

| FEASIBILITY OF IMPLEMENTATION |

The feasibility of implementing the linear diffuser system depends on the installation duration of both systems. In order to realistically compare the two systems, a schedule duration was developed for each system, seen below in Table 4.5. The crew number reflects the number of crews that will be simultaneously working on the same activity. Realistically, the items would not be installed sequentially one after the other, but rather each crew would split the work. Due to the size of the building, it was decided to use two crews on the major activities and limit the other activities to one crew. This will be cost effective and still save time on the schedule. The total duration for scheduling can be seen in Table 4.5 below.

Table 4.5 – Schedule Duration Comparison

Item	Daily Output	Duration Per Crew	Crew No.	Total Duration (w/ Crews)
Finned Tube Radiator System				
Pipe Insulation	160	28.35	1	29.77
Insulation Waste (5%)	160	1.42		
Fittings (add 15%)	65	10.46	2	37.51
3/4" Copper Pipe	76	34		
1" Copper Pipe	68	19.31		
1-1/4" Copper Pipe	58	9.5		
2" Copper Pipe	42	0.86		
2-1/2" Copper Pipe	62	0.89		
Hydronic Pump, 3HP	5	0.4	1	0.4
FTR Units	38	40.79	2	20.395
Total Duration for Finned Tube Radiator System				**89**
Finned Tube Radiator System				
Aluminum Ductwork	145	41.7	2	26.385
Linear Diffusers	14	11.07		
Total Duration for Linear Diffuser System				**27**

With the final schedule values, a comparison for the linear diffuser system can be evaluated in regards to the baseline finned tubed radiator system. This summary can be seen in Table 4.6 below.

Table 4.6 – Summary of Cost and Schedule Comparison

Item	Finned Tube Radiator	Linear Diffuser	Difference
Cost ($)	$ 241,974.18	$ 110,416.78	**~ $ 132,000**
Schedule (Days)	89	27	**62**

| CONCLUSION AND RECOMMENDATION |

Conclusion

After a final evaluation of both cost and schedule impacts, the alternative solution of utilizing linear diffusers can result in major benefits. When looking at the individual schedule activity, this alternative system of linear diffusers will result in a schedule reduction of 62 days. At the same time, the linear diffuser system costs $132,000 less in time and materials. Due to the major delay at the beginning of the project, the project team has the ability to make up a larger portion of that duration by changing the design of the perimeter heating system.

By completing this specific activity of perimeter heating earlier, it enables other trades to move into the building and perform their work earlier. In saving 62 total days for this mechanical activity, the project team has the opportunity to schedule future activities earlier, and in turn reducing the overall project schedule.

Recommendation

The final recommendation would be to install the linear diffuser system in lieu of the finned tubed radiators. Not only is this a faster installation by 62 days, but it provides a significant cost savings of $132,000. This will also reduce the load on the boilers by 358MBH, thus enabling a smaller capacity boiler to be installed. This alternative will also lend to the overall schedule acceleration goal to gain back the initial 3 months lost in schedule duration.

SECTION 5 – ALTERNATIVE FOUNDATION SYSTEM (ANALYSIS 4)

| PROBLEM IDENTIFICATION |

A rammed aggregate geopier system is the current design for shallow foundation support. This system involves drilling holes at locations in the soil not suitable for bearing capacity. These holes are then filled with aggregate (crushed stone) in 4' lifts. Each lift is compacted successively to specifications (generally reaching a lift height of 3') and creates a bellow shaped pier. This shape yields the proper bearing capacity necessary for the foundations. Alternative systems will be explored to identify any benefits related to lifecycle, total cost, and installation duration.

| BACKGROUND RESEARCH |

In order to find a feasible alternative to the geopier system research must be conducted for other foundation support types. Drilled micro-piles are a potential alternative to support the foundations in this building. Research can be conducted to find the popular foundation systems near the location of this project. With this known, basic costs can be compared to see if an alternate system is more feasible than the original rammed aggregate geopier.

| POTENTIAL SOLUTIONS |

An alternative to the geopier system includes drilled micro-piles. The installation methods can be compared relative to labor, material, and equipment costs. The two systems will also be compared in regards to bearing capacity and lifecycle. A major effort will be put forth on a cost analysis, as cost savings are a major goal of the project. Finally, the two foundation systems will be compared with respect to total installation time to cut down on site construction time. This comparison will then be repeated and performed with other alternative systems to show other additional advantages or disadvantages.

| SOLUTION METHOD |

- Gather design and construction information for alternative foundation systems.
- Determine the costs and installation time of each alternative.

- Compare all aspects to the rammed aggregate pier system – consider site logistics and procurement issues.
- Evaluate the benefits and possible implementation on the project.
- Propose the most appropriate alternative system with supporting data.

Resources

- ~ Industry Professionals (those experienced with both foundation systems)
- ~ AE Faculty Members
- ~ AE Classmates (Structural)
- ~ Barton Malow Project Team
- ~ Applicable books, manuals & websites

| EXPECTED OUTCOME |

The expected results are to find an alternate system that may be less cost than the original geopier system. Also, this alternate system should reduce installation time in order to help make up for the original schedule delay.

| ALTERNATIVE SYSTEM SELECTION |

Background research for an alternative foundation system included many possible methods of construction. The geotechnical report revealed three borings (B08-B10) with inadequate bearing capacity (max 2ksf) for spread footings. Due to this low bearing capacity, T.L.B. Associates deemed that a deep foundation system be utilized to be more feasible with construction methods. In order to reach the proper bearing capacity for spread footings, deep excavation and shoring would be necessary and cost prohibitive to the project. Considering cost reduction is majorly emphasized, the method of deep excavation is not feasible.

When considering other means to support the structure and reach proper bearing, other options are to be analyzed. Drilled micro-piles and driven piles were the two items considered for support of foundation. Ultimately, driven steel H-piles were selected as the alternative foundation system to be analyzed further. This was heavily based on the recommendation of T.L.B Associates and their experience in the area. Now, an analysis can be completed in order to compare a new system to the current rammed aggregate piers.

| DRIVEN STEEL H-PILES ESTIMATE AND SCHEDULE – STRUCTURAL BREADTH |

Cost Evaluation

The structural calculations for this alternative system were based on the AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications and a design example by the Federal Highway Administration.[5.1] In referencing the geotechnical report, the boring locations of B-08, B-09, and B-10 resulted in inadequate soil bearing capacity. Therefore, spread footings within these areas need to be designed for alternate support. It was chosen that the footings to the south of column line 4/4A would need deep foundation support due to the results of the geotechnical report. A footing location layout can be seen in Appendix 5-A with a blue outline of each location. Each footing type corresponds to the schedule found on drawing S100 – this information is available in Appendix 5-A at the top of each footing calculation.

Based upon the calculations (supported by tables given in geotechnical report) for each footing below column line 4/4A , the following results (Table 5.1) were found:

Table 5.1 – Summary of Steel H-Pile Calculations

Footing Location (Column Lines)	Footing Type (Per S100)	Footing Size (Per S100)	Pile Type	Qty. of Pile (27' length)
4A-EE	F2B	6'-0" x 6'-0" x 1'-10"	HP12x 53	4
3A-EE	F2A	6'-0" x 6'-0" x 1'-2"	HP12x 53	4
2D-FF, 2D-DD.9, 2C-FF, 2C-DD.9	F11A	4'-0" x 4'-0" x 1'-0"	HP12x 53	16 (4 ea.)
2A-DD.9	F11A	4'-0" x 4'-0" x 1'-0"	HP12x 53	1
2B-DD.2	F1A	5'-0" x 5'-0" x 1'-0"	HP12x 53	1
4A-DD	F9A (Part 1)	15'-0" x 16'-0" x 3'-0"	HP12x 53	12
4A-DD	F9A (Part 2)	30'-0" x 4'-0" x 3'-0"	HP12x 53	5
4A-DD	F9A (Part 3)	32'-0" x 9'-0" x 3'-0"	HP12x 53	12
4-B	F5B	9'-0" x 9'-0" x 2'-8"	HP12x 53	9
4-A.1	F3B	7'-0" x 7'-0" x 2'-4"	HP12x 84	4
3-B to A	F10A	42'-0" x 17'-0" x 4'-0"	HP12x 84	15
2-B	F8A	14'-0" x 14'-0" x 3'-0"	HP12x 53	9
2-A.1	F7A	11'-0" x 11'-0" x 2'-4"	HP12x 53	6
1-A.1	F5A	9'-0" x 9'-0" x 1'-10"	HP12x 53	4
1-B	F7A	11'-0" x 11'-0" x 2'-4"	HP12x 53	6
Totals				
			HP12x 53	**77**
			HP12x 84	**19**

See Appendix 5-A for footing calculation details

After the total number of H-piles were calculated and sized, an estimate was put together for cost comparison. The production unit for the driven piles is vertical linear feet (V.L.F), and each pile on this site will be approximately 27 feet in length. The final depth was determined by bedrock locations a result of the geotechnical report (See Appendix 5-B for sections of Borings 08-10). By using this 27' length and the total number of piles a cost estimate was developed, as seen below in Table 5.2. This value will then be compared to the cost of the geopier system.

Table 5.2 – Cost Estimation of Driven Steel H-Piles vs. Geopier System

Item	Quantity	Unit	Total Incl. O&P	Extended Total Incl. O&P
Driven Steel H-Piles				
HP12x 53	2079	V.L.F.	$ 41.58	$ 86,444.82
HP12x 84	513	V.L.F.	$ 54.31	$ 27,861.03
Mob./Demob.	5184	V.L.F.	$ 1.98	$ 10,264.32
Total				**$ 124,570.17**
Geopier System (Based upon Bid Package #1)				**$ 150,000.00**
Variance			*(Savings)*	**$ (25,429.83)**

See Appendix 5-A for full cost estimate details

Schedule Evaluation

Following the cost estimation, a schedule was developed to determine relative durations to compare to the original geopier system. A summary of the durations can be seen below in Table 5.3.

Table 5.3 – Schedule Summary of Driven Steel H-Piles and Geopier System

Item	Quantity	Unit	Daily Output (V.L.F)	Total Duration (days)
Driven Steel H-Piles				
HP12x 53	2079	V.L.F.	590	3.52
HP12x 84	513	V.L.F.	590	0.87
Mob./Demob.	5184	V.L.F.	3300	1.57
Total				**6**
Geopier System (Based upon Bid Package #1)				**10**
Variance			*(Savings)*	**(4)**

See Appendix 5-A for daily output values

| IMPLEMENTATION EFFECTS |

After calculating the cost estimate the schedule duration of the alternative driven steel H-piles, the implementation effects can be looked upon for comparison. When considering both the geopier and driven pile foundation systems, many disadvantages and advantages exist besides cost and schedule. The following will address both of these areas in regards to the two foundation systems under consideration.

Driven H-Piles

Advantages

Quality stands as a large benefit of driven piles due to the quantifiable properties to satisfy various subsurface conditions. By this, it means that driven piles are reliable with their known properties and resistance to deformation in shape. As a pile is driven, with the correct equipment, the shape of the pile resists deformation and can reach quality standards much easier than other methods. The designed pile checks easily against quality control standards and inspections.[5.2]

In the specific case of the Science and Technology Center, the piles would only need to reach a length of 27 vertical linear feet. This favorably impacts the construction process as it is cost effective and schedule friendly. It is cost effective in this particular scenario due to the depth of bedrock and the piles can be managed effectively on site in terms of logistics.

Another advantage of the driven piles is that no spoils are produced from drilling large holes in footing locations. This can result in less transportation and handling costs of extra material, as well as avoiding any possible contaminated spoils from excavation.[5.2]

Disadvantages

In looking at a case study presented by the American Society of Civil Engineers (ASCE), a six-story parking garage in Washington County, Oregon showed results of driven piles being cost prohibitive when using at large depths and multiple locations. The vast amounts of steel necessary to meet design standards for locations where soil conditions are suitable are very large depths. In the case of deep bedrock, it would be recommended to use alternative solutions to provide better costs to the project.[5.3]

Geopiers (Rammed Aggregate Piers)

Advantages

Now, when looking at the other option of geopiers, there are also many advantages to this method of foundation support. Due to its simplicity of design and the material use of crushed stone, the geopier design is relatively cost effective. In the same ASCE case study of the parking garage, it was found that geopiers produced over a 50% savings in costs alone when compared to the driven pile system designed. For this reason, that parking garage implemented the geopier foundation support system and realized a large cost savings.[5.3] In addition, the designs for geopiers are relatively simple in comparison to other foundation support systems. This design improves the soil conditions in a radial direction due to bellowed shape of the rammed piers.[5.4] Finally, the equipment necessary for the installation can be mounted on two excavators and cut costs for total equipment in comparison to a large diesel hammer necessary for driven piles.

Disadvantages

Geopiers within a complex design can be difficult to design for high uplift pressure.[5.4] Also, quality control standards must be monitored more closely as each lift (4’ at STC) must be compacted to a certain specification (3’ at STC). With multiple geopier location groupings on site, this process must be managed effectively to get the strength results necessary to support the foundations and building.

| CONCLUSION AND RECOMMENDATION |

Conclusion

After conducting this analysis, the results were evaluated and the implementation effects were considered. For the Science and Technology Center, it was found that the driven steel H-piles costs $124,570 and took a total of 6 days to install including mobilization and demobilization. These costs can be compared to the existing design of geopiers with a cost of $150,000 (Bid Package 1) and an installation time of 10 days. With an approximate depth of 27’ to supporting bedrock, the driven piles are concluded to have the lowest cost, while also saving 4 days on the schedule.

Recommendation

In considering the aforementioned advantages and disadvantages, it is recommended that the driven steel H-piles be implemented in place of the geopier system. This scenario involves shorter piles (27’) to reach bedrock than can be driven faster than the compacted stone with the geopiers. In addition, the quality assurance of the driven piles is much more effective than that of the geopier system. By implementing driven steel H-piles, Barton Malow and the rest of the project team can save over $25,000 and 4 days on the schedule.

SECTION 6 – MAE REQUIREMENTS

The analyses performed were aided by the knowledge gained in graduate level courses from the MAE curriculum. The courses referenced included AE 570 [Production Management in Construction] and AE 572 [Project Development and Delivery Planning].

The information from these classes gave support to Analyses 1 and 2 with a focus on production management tactics. Analysis 1 investigated Last Planner and SIPS, both of which were a strong focus in AE 570. These lean principles demonstrate management techniques to provide constructability solutions in the form of logistics, scheduling, and cost savings. Also, these methods provide best management practices for companies involved. By being lean in construction, a project can be constructed much more effectively due to better coordination and communication on a job site. Last Planner demonstrates this through the ability to connect directly with subcontractors for schedule and constructability input. As a result, subcontractors are much more integrated into the management process and the projects tend to have fewer conflicts. At the same time, this improves safety management on the jobs as fewer accidents are reported when implementing lean building principles.

The second analysis focused on modularization, which was both a critical industry issue at this years' PACE Roundtable and a major topic of AE 570. Within this class, a modularization project was performed and a case study experiment demonstrated pull production as a reality. Both modularization and pull production were major portions of the methodology for the second analysis. Unitizing or modularizing the curtain wall system into prefabricated panels is a current industry trend and provided major schedule benefits. The MAE curriculum supported information that modularization is much faster for installation and provides less on-site labor costs. The class also followed the book, *Lean Thinking* by Womack and Jones, which demonstrated the elements of pull production.[2.3] The idea that goods will not be produced until pulled from downstream in the process was most certainly a mind shift of thinking. Throughout the course, the benefits of pull production and just-in-time delivery were realized by changing the method of planning. By planning for delivery in advance and having manufacturers coordinate with site constraints result in benefits for each party. The barrier to implementation is having that mind shift in thinking where the consumer of the good pulls it from the manufacturer and not vice versa. This applied directly to the STC project with pull production and just-in-time delivery for the curtain wall panels. Sequencing deliveries properly allowed for preparation of the panel the same day, as opposed to staging the panel for an extended period of time somewhere on site.

The MAE curriculum lent a great deal of information to this final report, especially with lean building practices. As the industry adopts more green building methods, this information will be extremely beneficial to know when entering the industry.

SECTION 7 – REPORT CONCLUSIONS

Four different analyses focused on improving the schedule and cost areas of the Science and Technology Center at Coppin State University. Through these investigations, multiple benefits were determined and implementation strategies were developed.

The implementation of the modularized curtain wall panels, the linear diffusers at ceiling level around the perimeter, and the driven H-piles showed a significant schedule and cost savings. These three analyses combined for a total of 94 days in schedule acceleration and a cost savings of almost $769,000. With these results, these three systems are highly feasible and implementation will only benefit the project. The first analysis provides for even further schedule savings due to implementing a Last Planner System of management. While there are no hard statistics for schedule or cost savings with this strategy, case studies provide evidence of such benefits. In addition, safety management is improved utilizing Last Planner, as past projects have proved to decrease accident frequency by 66% with the lean construction method of management.

Analysis 1 provided a look into lean construction practices which motivates construction managers to provide better management methods on building projects. Last Planner involves subcontractors participating in the planning process earlier which provides more accurate information into a project schedule. At the same time, constructability issues can be found much sooner with collaboration from all parties on site. This collaborative effort also leads to a master schedule that filters down to weekly work plans and planned percentage complete documents. Ultimately, lean construction principles can lead to a more effective project delivery.

The second analysis focused on unitizing the curtain wall into prefabricated panels. This methodology implemented another lean principle of pull production with just-in-time delivery. The prefabricated panels cost less to produce in a controlled shop environment and provide significantly faster installation times. Coordinating the delivery sequence for the panels to be transported to site on a just-in-time basis eliminates the need for staging material on part of the job site. Again, lean building principles lend to schedule savings and more organized site.

A mechanical design change was the focus of the third analysis and investigated the implementation of linear diffusers in lieu of a hydronic finned tube radiator system. The radiator units involve costly brazing connection for the copper hydronic piping where the linear diffusers can be installed much more efficiently. This design change also reduced the total load on the boiler system by 358MBH.

The last analysis demonstrated an alternative foundation support system with installing driven steel H-piles in place of rammed aggregate piers. The overall schedule for the rammed aggregate piers took a total of 10 days to install, where the driven piles only could be installed in 6 days. The quality assurance standards for driven steel piles also proved to be advantageous for the system. The results saved $25,000 and 4 days on the schedule, therefore this method is just as feasible as the current design.

In conclusion, the results of this Senior Thesis Final Report demonstrated the ability to apply construction management knowledge from the Architectural Engineering curriculum and provide feasible alternatives to a current building design and construction methods. Also, a significant amount of experience was gained through the research and analyses performed throughout this report which will be beneficial when entering the design and construction industry.

SECTION 8 – RESOURCES

General Sources:

Rendering on Cover Page Courtesy of www.coppin.edu/CapitalPlanning/STC.aspx

Reed Construction Data. *RSMeansOnline*. http://rsmeansonline.com/SearchData.

Section Sources:

1.1 Coppin State University – Strategic Plan 2010

http://131.118.128.52/Assessment/2007-2010StrategicPlanCSU.pdf

1.2 "Baltimore County Md. Public Works - Department of Public Works Overview." Accessed September 21, 2012. http://www.baltimorecountymd.gov/Agencies/publicworks.

2.1 Based upon AE presentations in MAE courses (AE 570) with industry experience input.

2.2 "Last Planner - How Do I Get Started?" http://www.leanconstruction.org/lastplanner.htm.

2.3 Womack, James P., and Daniel T. Jones. *Lean Thinking*. New York, NY: Free Press, 2003.

2.4 "What Others Are Saying About LCI." http://www.leanconstruction.org/whatsay.htm#leading.

3.1 "2500 PG Unitwall." Kawneer North America. http://www.kawneer.com/kawneer/north_america/catalog/pdf/2500_PG_Wall--A.pdf

3.2 "Unitized Curtainwall." Wausau Window and Wall Systems. http://www.wausauwindow.com/products/index.cfm?page=productsDetail&seriesID=1&productID=174#tabs

4.1 "Field Duct Sizing Chart." http://hvac-talk.com/vbb/attachment.php?attachmentid=488&d

4.2 "Circular Duct Sizes." http://www.engineeringtoolbox.com/circular-ducts-d_1009.html.

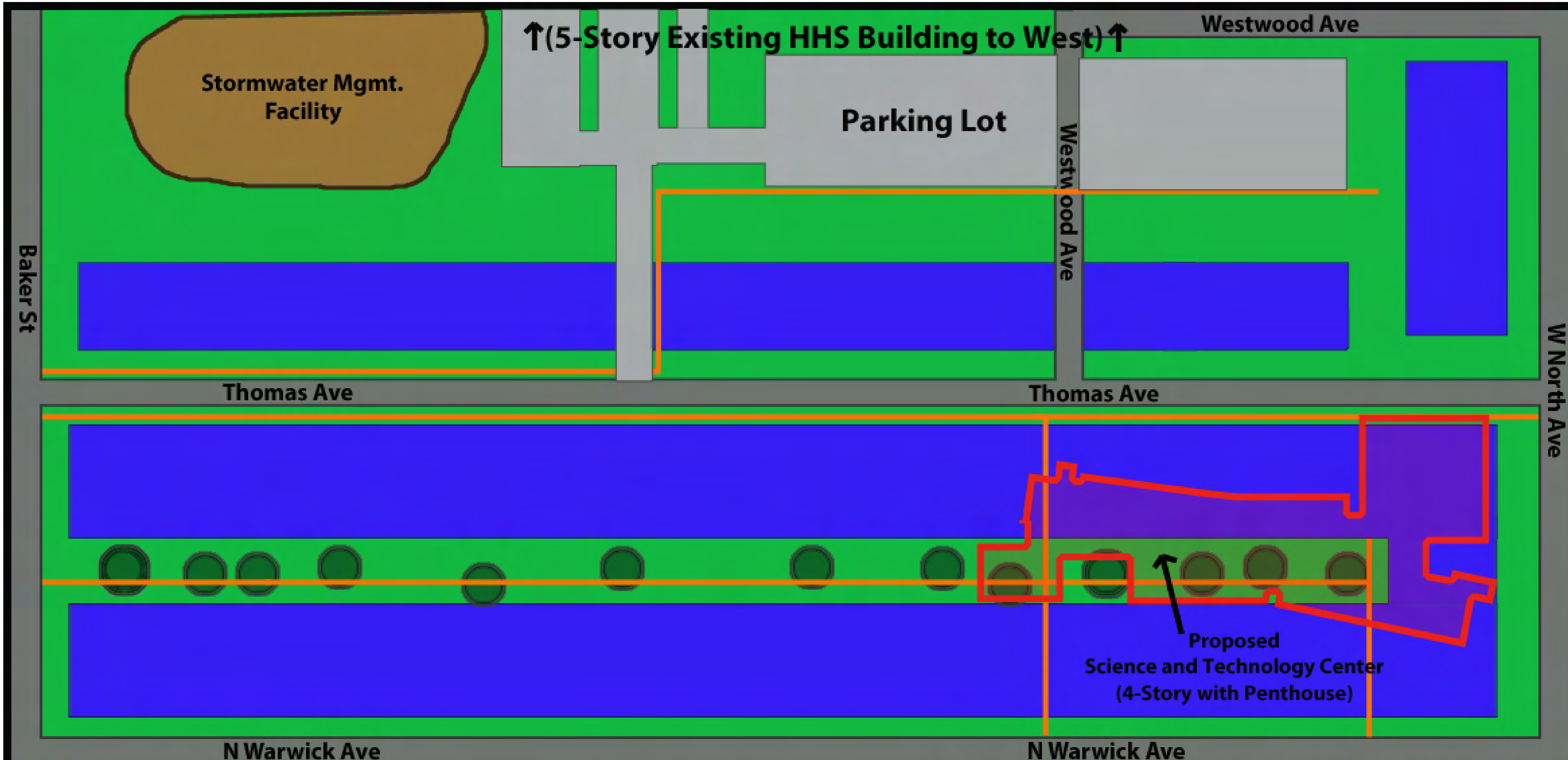
5.1 "Pile Foundation Design Example." http://www.fhwa.dot.gov/bridge/lrfd/us_dsp.htm#designstepp2_1.

5.2 "Benefits of Driven Piles." http://www.piledrivers.org/benefits-of-driven-piles/.

5.3 "Rammed Aggregate Piers Defeat 75-Foot Long Driven Piles (ASCE)." http://www.helicaldrilling.com/Documents/911TP08RammedAggregatePiersDefeat75FtDrivenPiles.pdf.

5.4 Kumar, Neeraj Jha. *Construction Project Management*. Pearson Education, 2011.

APPENDIX 1-A – EXISTING CONDITIONS PLAN & PHASING PLANS

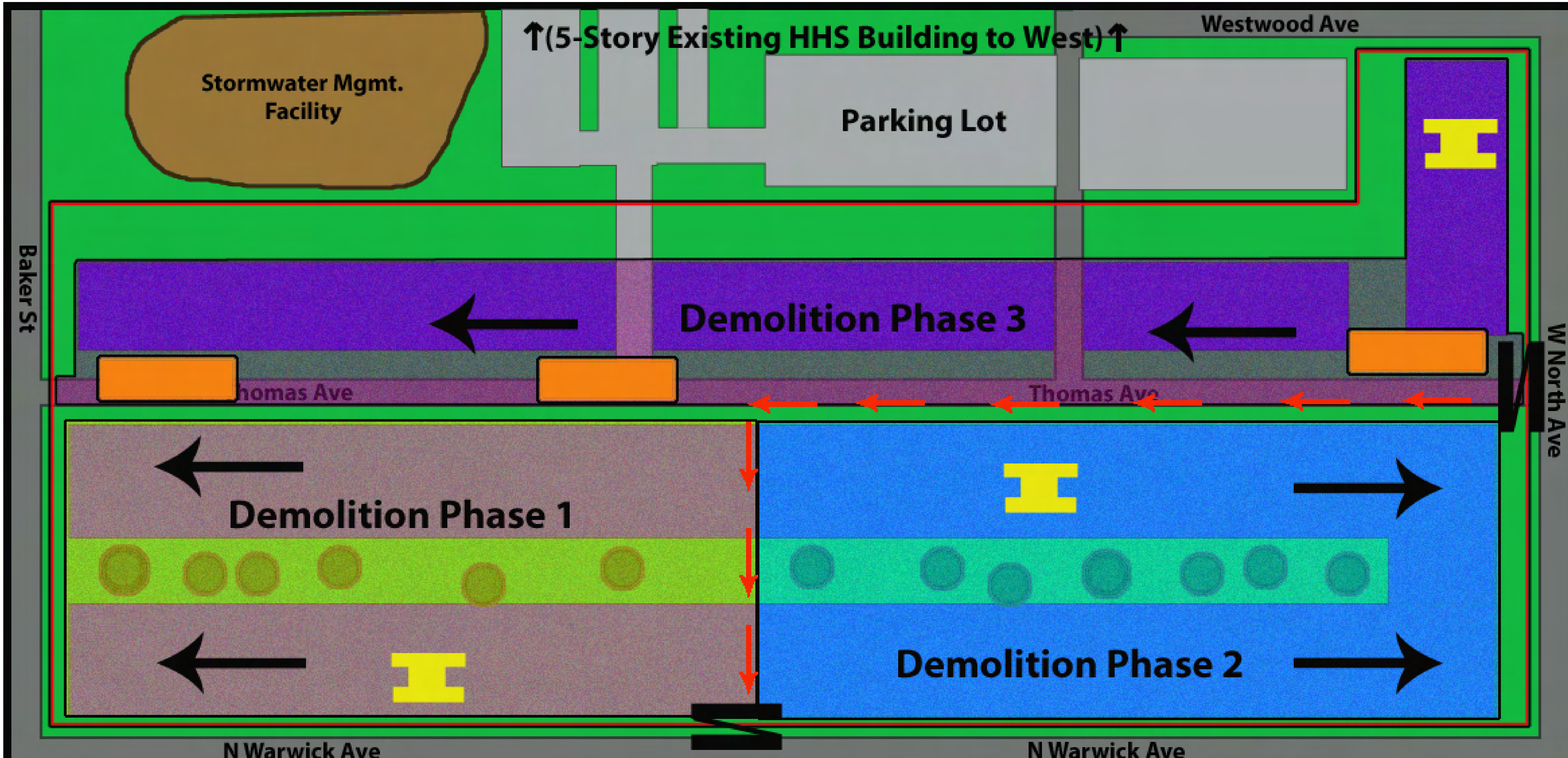


N

Legend

- Roads
- Parking Lots
- Ex. Row Homes
- Trees/Shrubs
- Ex. Sanitary Lines
- Proposed Building Perimeter

Coppin State University	Nicholas Zitterbart
Science and Technology Center	September 21, 2012
Baltimore, Maryland	**Existing Conditions**

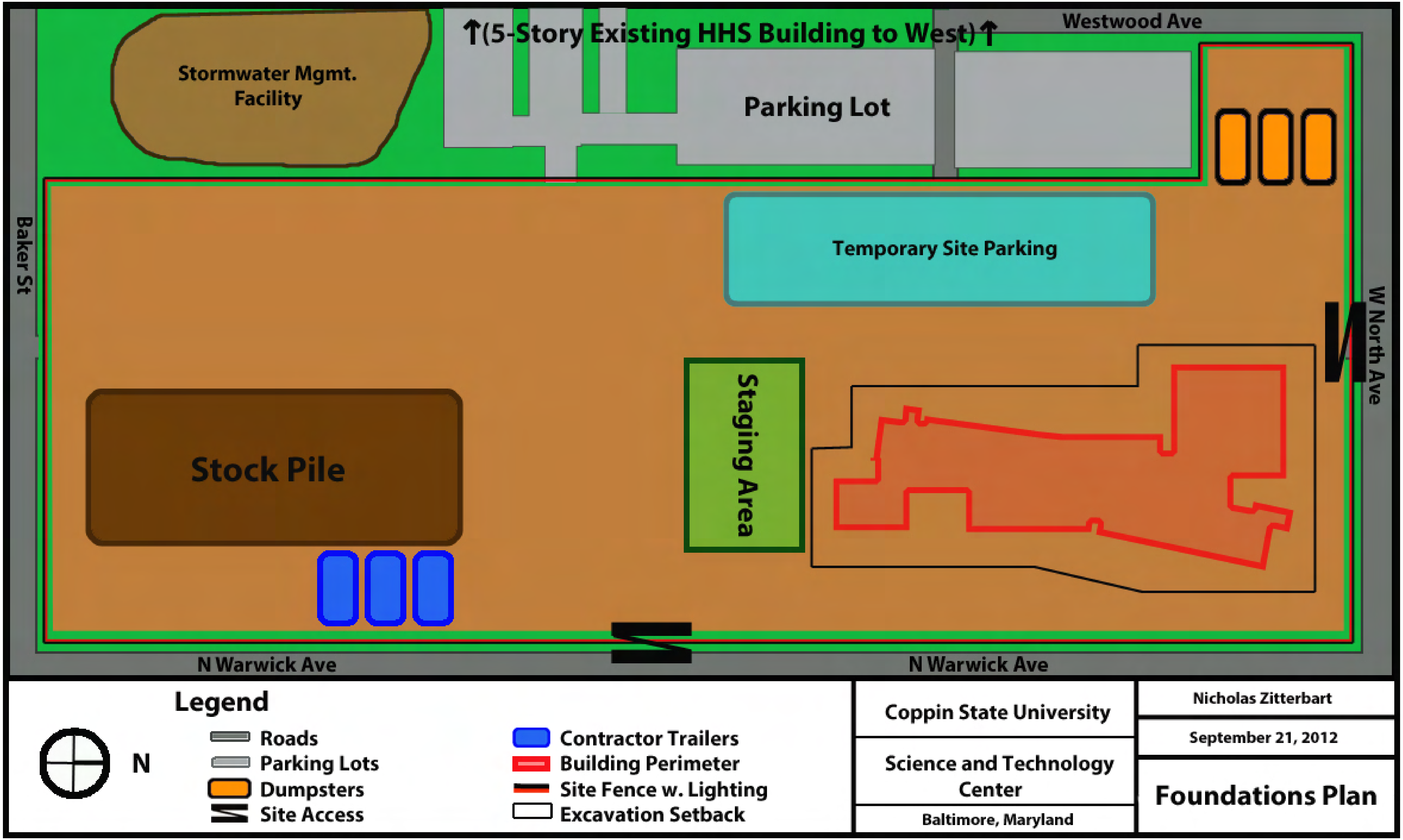


Legend

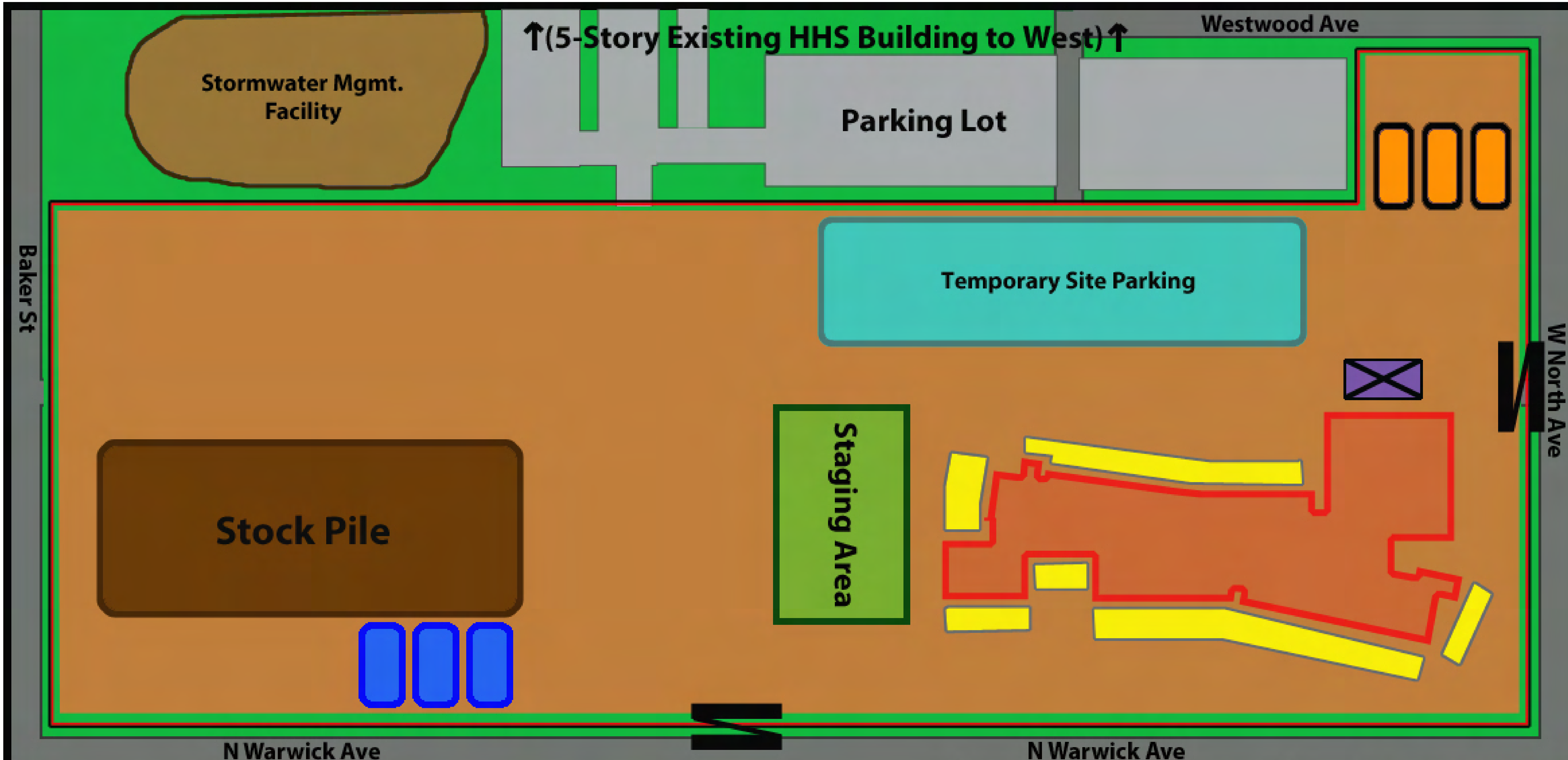
N

- Roads
- Parking Lots
- Dumpsters
- Site Access
- Demo Equipment/Excavator
- Site Traffic Flow
- Site Fence w. Lighting

Coppin State University	Nicholas Zitterbart
Science and Technology Center	September 21, 2012
Baltimore, Maryland	**Demolition Plan**



Westwood Ave
↑(5-Story Existing HHS Building to West)↑
Stormwater Mgmt. Facility
Parking Lot
Baker St
Temporary Site Parking
W North Ave
Stock Pile
Staging Area
N Warwick Ave
N Warwick Ave
Legend
N
Roads
Parking Lots
Dumpsters
Site Access
Contractor Trailers
Building Perimeter
Site Fence w. Lighting
Excavation Setback
Coppin State University
Science and Technology Center
Baltimore, Maryland
Nicholas Zitterbart
September 21, 2012
Foundations Plan



Legend

N

- Roads
- Parking Lots
- Dumpsters
- Site Access
- Scaffolding
- Contractor Trailers
- Building Perimeter
- Site Fence w. Lighting
- Mobile Crane

Coppin State University	Nicholas Zitterbart
Science and Technology Center	September 21, 2012
Baltimore, Maryland	**Superstructure Plan**

APPENDIX 1-B – PROJECT COST EVALUATION

Square Foot Cost Estimate Report	
Estimate Name:	Science and Technology Center
Building Type:	Office, 5-10 Story with Face Brick with Concrete Block Back-up / R/Conc. Frame
Location:	BALTIMORE, MD
Story Count:	5 (4+ penthouse)
Story Height (L.F.):	17 (average)
Floor Area (S.F.):	135,000
Labor Type:	Union
Basement Included:	Yes
Data Release:	Year 2012 Quarter 3
Cost Per Square Foot:	$150.43
Building Cost:	$20,308,500

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		7.00%	$9.35	$1,262,500
A1010	**Standard Foundations**		$5.97	$805,500
	KSF, 12" deep x 32" wide			
	9' - 6" square x 30" deep			
A1030	**Slab on Grade**		$0.96	$130,000
	Slab on grade, 4" thick, non industrial, reinforced			
A2010	**Basement Excavation**		$0.58	$78,500
	site storage			
A2020	**Basement Walls**		$1.84	$248,500
	thick			
B Shell		33.60%	$44.99	$6,073,000
B1010	**Floor Construction**		$21.80	$2,942,500
	height, 394 lbs/LF, 4000PSI			
	height, 394 lbs/LF, 6000PSI			
	height, 394 lbs/LF, 6000PSI			
	500K load, 10'-14' story height, 375 lbs/LF, 4000PSI			
	15'x15' bay, 75 PSF superimposed load, 153 PSF total load			
	superimposed load, 188 PSF total load			
B1020	**Roof Construction**		$2.77	$373,500
	18" deep beam, 8.5" slab, 146 PSF total load			
B2010	**Exterior Walls**		$14.39	$1,942,000
	perlite core fill			
B2020	**Exterior Windows**		$4.77	$644,500
	Windows, aluminum, sliding, insulated glass, 5' x 3'			
B2030	**Exterior Doors**		$0.24	$33,000
	hardware, 6'-0" x 10'-0" opening			
	0" opening			
B3010	**Roof Coverings**		$1.02	$137,500
	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		17.90%	$23.99	$3,238,500
C1010	**Partitions**		**$3.01**	**$406,000**
	5/8" @ 24" OC framing ,same opposite face, no insulation			
	1/2" fire ratedgypsum board, taped & finished, painted on metal furring			
C1020	**Interior Doors**		**$2.84**	**$384,000**
	3'-0" x 7'-0" x 1-3/8"			
C1030	**Fittings**		**$0.64**	**$86,500**
	Toilet partitions, cubicles, ceiling hung, plastic laminate			
C2010	**Stair Construction**		**$2.79**	**$376,500**
	Stairs, steel, cement filled metal pan & picket rail, 16 risers, with landing			
C3010	**Wall Finishes**		**$0.86**	**$116,500**
	primer & 2 coats			
	Vinyl wall covering, fabric back, medium weight			
C3020	**Floor Finishes**		**$7.95**	**$1,073,000**
	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**		**$5.90**	**$796,000**
	channel grid, suspended support			
D Services		41.50%	$55.56	$7,500,500
D1010	**Elevators and Lifts**		**$15.25**	**$2,059,000**
	200 FPM			
D2010	**Plumbing Fixtures**		**$2.46**	**$332,500**
	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,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**		**$0.52**	**$70,500**
	Gas fired water heater, commercial, 100< F rise, 200 MBH input, 192 GPH			
D2040	**Rain Water Drainage**		**$0.26**	**$34,500**
	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**		**$15.47**	**$2,088,500**
	Rooftop, multizone, air conditioner, offices, 25,000 SF, 79.16 ton			
D4010	**Sprinklers**		**$2.74**	**$370,000**
	Wet pipe sprinkler systems, steel, light hazard, 1 floor, 10,000 SF			
	10,000 SF			
	Standard High Rise Accessory Package 8 story			
D4020	**Standpipes**		**$0.83**	**$112,000**
	Wet standpipe risers, class III, steel, black, sch 40, 4" diam pipe, 1 floor			
	floors			
	Fire pump, electric, with controller, 5" pump, 100 HP, 1000 GPM			
	Fire pump, electric, for jockey pump system, add			
D5010	**Electrical Service/Distribution**		**$1.17**	**$157,500**

	phase, 4 wire, 120/208 V, 1600 A			
	Feeder installation 600 V, including RGS conduit and XHHW wire, 60 A			
	Feeder installation 600 V, including RGS conduit and XHHW wire, 200 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**		**$11.44**	**$1,544,500**
	with transformer			
	Miscellaneous power, 1.2 watts			
	Central air conditioning power, 4 watts			
	Motor installation, three phase, 460 V, 15 HP motor size			
	V 15 HP, 575 V 20 HP			
	Motor connections, three phase, 200/230/460/575 V, up to 5 HP			
	Motor connections, three phase, 200/230/460/575 V, up to 100 HP			
	fixtures @32watt per 1000 SF			
D5030	**Communications and Security**		**$4.30**	**$581,000**
	Telephone wiring for offices & laboratories, 8 jacks/MSF			
	detectors, includes outlets, boxes, conduit and wire			
	Fire alarm command center, addressable with voice, excl. wire & conduit			
	Internet wiring, 8 data/voice outlets per 1000 S.F.			
D5090	**Other Electrical Systems**		**$1.11**	**$150,500**
	engine with fuel tank, 100 kW			
	kW			
E Equipment & Furnishings		**0.00%**	**$0.00**	**$0**
E1090	**Other Equipment**		**$0.00**	**$0**
F Special Construction		**0.00%**	**$0.00**	**$0**
G Building Sitework		**0.00%**	**$0.00**	**$0**
SubTotal		**100%**	**$133.89**	**$18,074,500**
Contractor Fees (General Conditions,Overhead,Profit)		**6.00%**	**$8.03**	**$1,084,500**
Architectural Fees		**6.00%**	**$8.51**	**$1,149,500**
User Fees		**0.00%**	**$0.00**	**$0**
Total Building Cost			**$150.43**	**$20,308,500**

Science and Technology Center Assembly Estimate					
Data Release :Year 2012 Quarter 3					
Quantity	**Assembly Number**	**Description**	**Unit**	**Total O&P**	**Ext. Total O&P**
4	D20101201760	Water closets, battery mount, wall hung, side by side, first closet	Ea.	$ 2,564.86	$ 10,259.44
14	D20101201800	Water closetss, battery mount, wall hung, side by side, each additional water closet, add	Ea.	$ 2,452.03	$ 34,328.42
4	D20101203000	Water closets, battery mount, wall hung, back to back, first pair of closets	Ea.	$ 3,980.01	$ 15,920.04
2	D20101203100	Water closets, battery mount, wall hung, each additional pair of closets, back to back	Ea.	$ 3,929.96	$ 7,859.92
4	D20102201760	Urinals, battery mount, side by side, first urinal	Ea.	$ 1,415.62	$ 5,662.48
6	D20102201800	Urinals, battery mount, side by side, each additional urinal, add	Ea.	$ 1,394.65	$ 8,367.90
2	D20103201760	Lavatories, battery mount, side by side, first lavatory	Ea.	$ 1,977.14	$ 3,954.28
10	D20103201800	Lavatories, battery mount, side by side, each additional lavatory, add	Ea.	$ 1,596.26	$ 15,962.60
3	D20103202000	Lavatories, battery mount, back to back, first pair of lavatories	Ea.	$ 3,172.56	$ 9,517.68
6	D20103202100	Lavatories, battery mount, back to back, each additional pair of lavatories	Ea.	$ 2,862.71	$ 17,176.26
1	D20107101600	Shower, stall, baked enamel, molded stone receptor, 32" square	Ea.	$ 2,010.12	$ 2,010.12
20	D20104301640	Lab sink w/trim, polyethylene, single bowl, single drainboard, 47" x 24"OD	Ea.	$ 2,553.15	$ 51,063.00
4	D20202502140	Gas fired water heater, commercial, 100< F rise, 300 MBH input, 278 GPH	Ea.	$ 15,597.70	$ 62,390.80
1	D20202401980	Electric water heater, commercial, 100< F rise, 150 gal, 120 KW 490 GPH	Ea.	$ 30,017.73	$ 30,017.73
1	D20202401940	Electric water heater, commercial, 100< F rise, 120 gal, 36 KW 147 GPH	Ea.	$ 11,219.18	$ 11,219.18
20	D20402102040	Roof drain, DWV PVC, 4" diam, diam, 10' high	Ea.	$ 1,146.97	$ 22,939.40
180	D20402102080	Roof drain, DWV PVC, 4" diam, for each additional foot add	Ea.	$ 29.72	$ 5,349.60
1	D30401161040	AHU, rooftop, cool/heat coils, VAV, filters, 20,000 CFM	Ea.	$ 152,528.80	$ 152,528.80

1	D30401161050	AHU, rooftop, cool/heat coils, VAV, filters, 30,000 CFM	Ea.	$ 206,012.90	$ 206,012.90
1	D30401161050	AHU, rooftop, cool/heat coils, VAV, filters, 30,000 CFM	Ea.	$ 206,012.90	$ 206,012.90
3	D30401121020	AHU, central station, cool/heat coils, VAV, filters, 10,000 CFM	Ea.	$ 58,019.80	$ 174,059.40
20000	D30301103480	Packaged chiller, air cooled, with fan coil unit, offices, 20,000 SF, 63.33 ton	S.F.	$ 11.95	$ 239,000.00
35000	D30301103520	Packaged chiller, air cooled, with fan coil unit, offices, 40,000 SF, 126.66 ton	S.F.	$ 10.37	$ 362,950.00
35000	D30301103520	Packaged chiller, air cooled, with fan coil unit, offices, 40,000 SF, 126.66 ton	S.F.	$ 10.37	$ 362,950.00
35000	D30301103520	Packaged chiller, air cooled, with fan coil unit, offices, 40,000 SF, 126.66 ton	S.F.	$ 10.37	$ 362,950.00
35000	D30301103520	Packaged chiller, air cooled, with fan coil unit, offices, 40,000 SF, 126.66 ton	S.F.	$ 10.37	$ 362,950.00
35000	D30301154000	Packaged chiller, water cooled, with fan coil unit, offices, 40,000 SF, 126.66 ton	S.F.	$ 13.33	$ 466,550.00
35000	D30301154000	Packaged chiller, water cooled, with fan coil unit, offices, 40,000 SF, 126.66 ton	S.F.	$ 13.33	$ 466,550.00
35000	D30301154000	Packaged chiller, water cooled, with fan coil unit, offices, 40,000 SF, 126.66 ton	S.F.	$ 13.33	$ 466,550.00
35000	D30301154000	Packaged chiller, water cooled, with fan coil unit, offices, 40,000 SF, 126.66 ton	S.F.	$ 13.33	$ 466,550.00
8	D30201301110	Boiler, cast iron, gas, hot water, 3808 MBH	Ea.	$ 77,895.80	$ 623,166.40
1	D30201301040	Boiler, cast iron, gas, hot water, 440 MBH	Ea.	$ 20,535.35	$ 20,535.35
40000	D30201103360	Heating systems, CI boiler, gas, fin tube radiation, 1,088 MBH, 14,500 SF bldg	S.F.	$ 13.52	$ 540,800.00
40000	D30201103360	Heating systems, CI boiler, gas, fin tube radiation, 1,088 MBH, 14,500 SF bldg	S.F.	$ 13.52	$ 540,800.00
20000	D30201103280	Heating systems, CI boiler, gas, fin tube radiation, 169 MBH, 2,140 SF bldg	S.F.	$ 16.75	$ 335,000.00
2	D30402401080	Roof vent. system, power, centrifugal, aluminum, galvanized curb, back draft damper, 13,800 CFM	Ea.	$ 59,773.10	$ 119,546.20
1	D30402401060	Roof vent. system, power, centrifugal, aluminum, galvanized curb, back draft damper, 5000 CFM	Ea.	$ 32,048.85	$ 32,048.85
6	D30402401020	Roof vent. system, power, centrifugal, aluminum, galvanized curb, back draft damper, 800 CFM	Ea.	$ 5,222.18	$ 31,333.08

1	D30402401060	Roof vent. system, power, centrifugal, aluminum, galvanized curb, back draft damper, 5000 CFM	Ea.	$ 32,048.85	$ 32,048.85
3	D30402401040	Roof vent. system, power, centrifugal, aluminum, galvanized curb, back draft damper, 2750 CFM	Ea.	$ 15,652.80	$ 46,958.40
1	D30402401050	Roof vent. system, power, centrifugal, aluminum, galvanized curb, back draft damper, 3500 CFM	Ea.	$ 19,977.40	$ 19,977.40
1	D30402401030	Roof vent. system, power, centrifugal, aluminum, galvanized curb, back draft damper, 1500 CFM	Ea.	$ 7,755.80	$ 7,755.80
5	D30401201050	Fan coil A/C system, cabinet mounted, electric heat, controls, 2 pipe, 3 ton	Ea.	$ 7,966.65	$ 39,833.25
6	D30401201020	Fan coil A/C system, cabinet mounted, electric heat, controls, 2 pipe, 1 ton	Ea.	$ 3,401.83	$ 20,410.98
11	D30501850860	Computer room unit, chilled water, for connection to existing chiller system, 10 ton	Ea.	$ 17,391.83	$ 191,310.13
20000	D30501703680	Split system, air cooled condensing unit, offices, 20,000 SF, 63.32 ton	S.F.	$ 10.41	$ 208,200.00
20000	D30501703680	Split system, air cooled condensing unit, offices, 20,000 SF, 63.32 ton	S.F.	$ 10.41	$ 208,200.00
20000	D30501703680	Split system, air cooled condensing unit, offices, 20,000 SF, 63.32 ton	S.F.	$ 10.41	$ 208,200.00
20000	D30501703680	Split system, air cooled condensing unit, offices, 20,000 SF, 63.32 ton	S.F.	$ 10.41	$ 208,200.00
20000	D30501703680	Split system, air cooled condensing unit, offices, 20,000 SF, 63.32 ton	S.F.	$ 10.41	$ 208,200.00
20000	D30501703680	Split system, air cooled condensing unit, offices, 20,000 SF, 63.32 ton	S.F.	$ 10.41	$ 208,200.00
20000	D30501703680	Split system, air cooled condensing unit, offices, 20,000 SF, 63.32 ton	S.F.	$ 10.41	$ 208,200.00
2	D30501401020	Unit heater, cabinet type, horizontal blower, hot water, 60 MBH	Ea.	$ 4,724.83	$ 9,449.66
3	D30501201070	Space heater, suspended, gas fired, propeller fan, 320 MBH	Ea.	$ 6,350.30	$ 19,050.90
10	D30502301040	Heat pump, central station, water source, constant volume, 30 ton	Ea.	$ 38,146.90	$ 381,469.00
7	D30401381040	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 800 CFM	Ea.	$ 7,747.10	$ 54,229.70
4	D30401381020	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 400 CFM	Ea.	$ 5,745.23	$ 22,980.92
17	D30401381010	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 200 CFM	Ea.	$ 4,727.73	$ 80,371.41

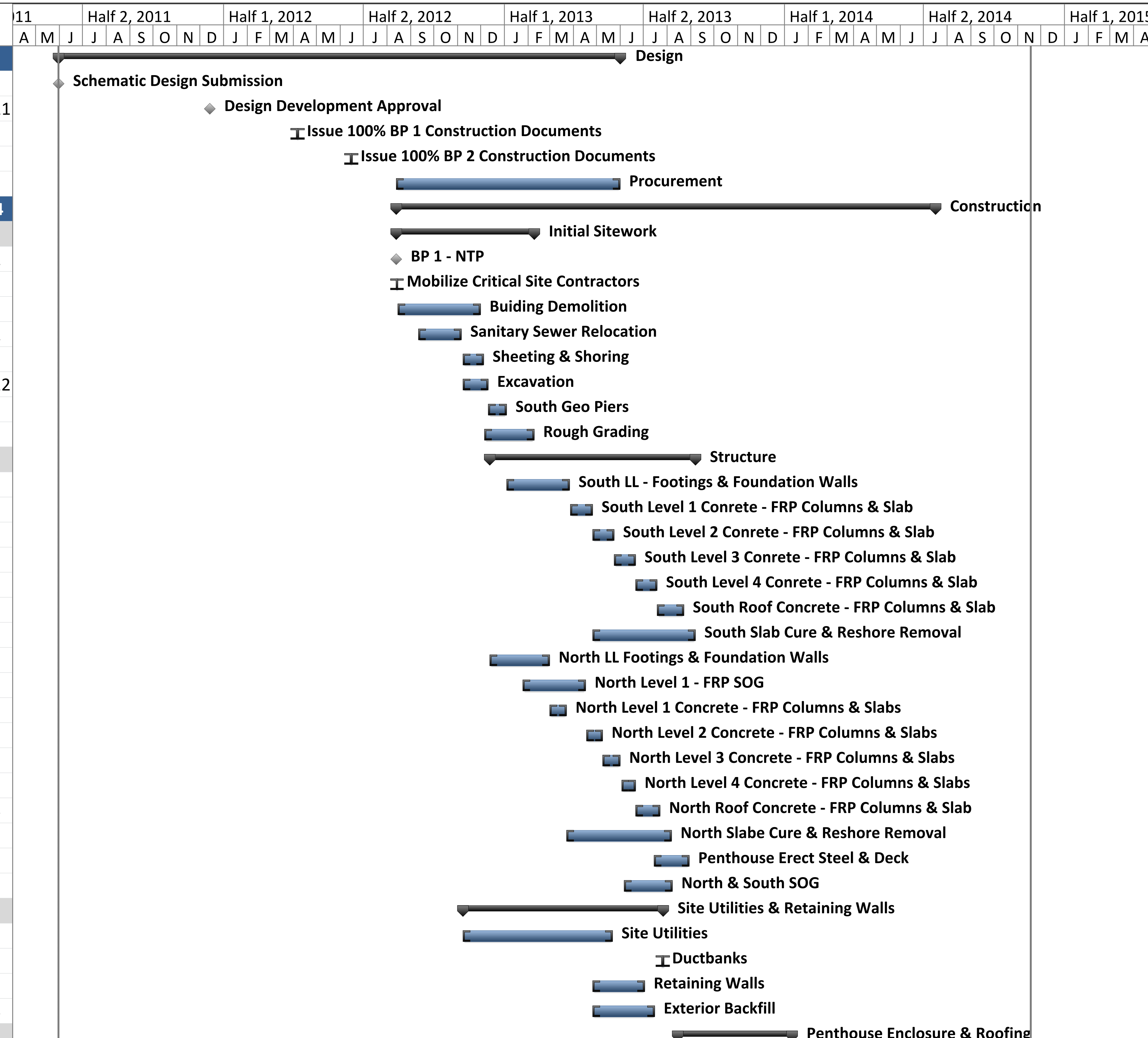
5	D30401381030	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 600 CFM	Ea.	$ 7,068.53	$ 35,342.65
1	D30401381050	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 1000 CFM	Ea.	$ 8,529.83	$ 8,529.83
7	D30401381060	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 1250 CFM	Ea.	$ 10,217.08	$ 71,519.56
2	D30401381080	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 2000 CFM	Ea.	$ 15,226.18	$ 30,452.36
9	D30401381010	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 200 CFM	Ea.	$ 4,727.73	$ 42,549.57
11	D30401381020	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 400 CFM	Ea.	$ 5,745.23	$ 63,197.53
9	D30401381030	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 600 CFM	Ea.	$ 7,068.53	$ 63,616.77
5	D30401381040	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 800 CFM	Ea.	$ 7,747.10	$ 38,735.50
1	D30401381060	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 1250 CFM	Ea.	$ 10,217.08	$ 10,217.08
3	D30401381010	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 200 CFM	Ea.	$ 4,727.73	$ 14,183.19
11	D30401381020	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 400 CFM	Ea.	$ 5,745.23	$ 63,197.53
4	D30401381030	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 600 CFM	Ea.	$ 7,068.53	$ 28,274.12
1	D30401381040	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 800 CFM	Ea.	$ 7,747.10	$ 7,747.10
1	D30401381050	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 1000 CFM	Ea.	$ 8,529.83	$ 8,529.83
2	D30401381010	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 200 CFM	Ea.	$ 4,727.73	$ 9,455.46
2	D30401381020	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 400 CFM	Ea.	$ 5,745.23	$ 11,490.46
2	D30401381040	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 800 CFM	Ea.	$ 7,747.10	$ 15,494.20
3	D30401381060	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 1250 CFM	Ea.	$ 10,217.08	$ 30,651.24
2	D30401381080	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 2000 CFM	Ea.	$ 15,226.18	$ 30,452.36
7	D30401381010	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 200 CFM	Ea.	$ 4,727.73	$ 33,094.11

8	D30401381020	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 400 CFM	Ea.	$ 5,745.23	$ 45,961.84
8	D30401381030	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 600 CFM	Ea.	$ 7,068.53	$ 56,548.24
3	D30401381040	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 800 CFM	Ea.	$ 7,747.10	$ 23,241.30
2	D30401381050	VAV terminal, cool, hot water reheat, fan powered, with actuator/controls, 1000 CFM	Ea.	$ 8,529.83	$ 17,059.66
35000	D30105201960	Commercial building heating systems, fin tube radiation, forced hot water, 1,000 SF bldg, 1 floor	S.F.	$ 29.90	$ 1,046,500.00
35000	D30105201960	Commercial building heating systems, fin tube radiation, forced hot water, 1,000 SF bldg, 1 floor	S.F.	$ 29.90	$ 1,046,500.00
35000	D30105201960	Commercial building heating systems, fin tube radiation, forced hot water, 1,000 SF bldg, 1 floor	S.F.	$ 29.90	$ 1,046,500.00
35000	D30105201960	Commercial building heating systems, fin tube radiation, forced hot water, 1,000 SF bldg, 1 floor	S.F.	$ 29.90	$ 1,046,500.00
26000	D50202080600	Fluorescent fixtures, type A, 17 fixtures per 1000 SF	S.F.	$ 7.87	$ 204,620.00
15000	D50202080600	Fluorescent fixtures, type A, 17 fixtures per 1000 SF	S.F.	$ 7.87	$ 118,050.00
10000	D50202140400	Incandescent fixtures recess mounted, 100 FC, type A, 34 fixtures per 400 SF	S.F.	$ 33.16	$ 331,600.00
26000	D50202080600	Fluorescent fixtures, type A, 17 fixtures per 1000 SF	S.F.	$ 7.87	$ 204,620.00
26000	D50202080600	Fluorescent fixtures, type A, 17 fixtures per 1000 SF	S.F.	$ 7.87	$ 204,620.00
26000	D50202080600	Fluorescent fixtures, type A, 17 fixtures per 1000 SF	S.F.	$ 7.87	$ 204,620.00
26000	D50201150200	Receptacle systems, underfloor duct, 5' on center, low density	S.F.	$ 9.79	$ 254,540.00
26000	D50201150200	Receptacle systems, underfloor duct, 5' on center, low density	S.F.	$ 9.79	$ 254,540.00
26000	D50201150200	Receptacle systems, underfloor duct, 5' on center, low density	S.F.	$ 9.79	$ 254,540.00
26000	D50201150200	Receptacle systems, underfloor duct, 5' on center, low density	S.F.	$ 9.79	$ 254,540.00
26000	D50201150200	Receptacle systems, underfloor duct, 5' on center, low density	S.F.	$ 9.79	$ 254,540.00
13000	D50201150200	Receptacle systems, underfloor duct, 5' on center, low density	S.F.	$ 9.79	$ 127,270.00

4	D50309100454	Communication and alarm systems, fire detection, addressable, 50 detectors, includes outlets, boxes, conduit and wire	Ea.	$ 37,926.70	$ 151,706.80
1	D50309100452	Communication and alarm systems, fire detection, addressable, 25 detectors, includes outlets, boxes, conduit and wire	Ea.	$ 19,427.10	$ 19,427.10
3	D50101200320	Service installation, includes breakers, metering, 20' conduit & wire, 3 phase, 4 wire, 120/208 V, 400 A	Ea.	$ 7,512.98	$ 22,538.94
3	D50101200280	Service installation, includes breakers, metering, 20' conduit & wire, 3 phase, 4 wire, 120/208 V, 200 A	Ea.	$ 3,589.93	$ 10,769.79
50000	D50201300360	Wall switches, 5.0 per 1000 SF	S.F.	$ 1.20	$ 60,000.00
60	D50102300400	Feeder installation 600 V, including RGS conduit and XHHW wire, 800 A	L.F.	$ 264.34	$ 15,860.40
2	D50102400400	Switchgear installation, incl switchboard, panels & circuit breaker, 2000 A	Ea.	$ 54,961.00	$ 109,922.00
1	D50102300440	Feeder installation 600 V, including RGS conduit and XHHW wire, 1000 A	L.F.	$ 308.87	$ 308.87
1	D50102300520	Feeder installation 600 V, including RGS conduit and XHHW wire, 1600 A	L.F.	$ 530.66	$ 530.66
1	D50102300440	Feeder installation 600 V, including RGS conduit and XHHW wire, 1000 A	L.F.	$ 308.87	$ 308.87
135	D50309200104	Internet wiring, 4 data/voice outlets per 1000 S.F.	M.S.F.	$ 1,206.64	$ 162,896.40
				Subtotal	
				D20 Plumbing	$ 313,999
				D30 Mechanical	$ 13,867,632
				D50 Electrical	$ 3,222,370
				Total	**$ 17,404,000**

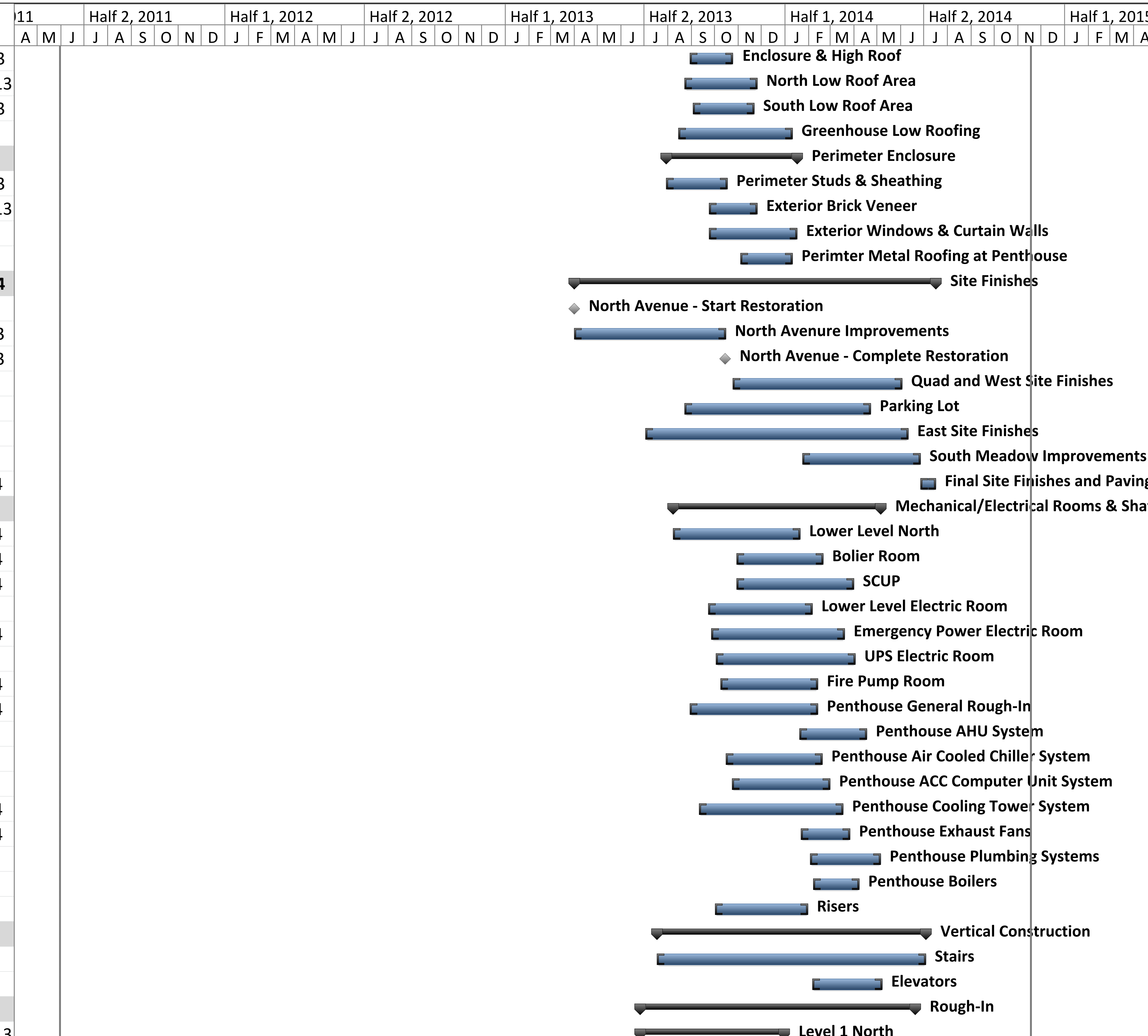
APPENDIX 1-C – DETAILED PROJECT SCHEDULE

ID	Task Name	Duration	Start	Finish
1	**Design**	**524 days**	**Tue 5/31/11**	**Fri 5/31/13**
2	Schematic Design Submission	0 days	Tue 5/31/11	Tue 5/31/11
3	Design Development Approval	0 days	Wed 12/14/11	Wed 12/14/11
4	Issue 100% BP 1 Construction Documents	1 day	Fri 4/6/12	Fri 4/6/12
5	Issue 100% BP 2 Construction Documents	1 day	Fri 6/15/12	Fri 6/15/12
6	Procurement	210 days	Mon 8/13/12	Fri 5/31/13
7	**Construction**	**503 days**	**Mon 8/13/12**	**Wed 7/16/14**
8	**Initial Sitework**	**130 days**	**Mon 8/13/12**	**Fri 2/8/13**
9	BP 1 - NTP	0 days	Mon 8/13/12	Mon 8/13/12
10	Mobilize Critical Site Contractors	2 days	Mon 8/13/12	Tue 8/14/12
11	Buiding Demolition	78 days	Wed 8/15/12	Fri 11/30/12
12	Sanitary Sewer Relocation	40 days	Tue 9/11/12	Mon 11/5/12
13	Sheeting & Shoring	19 days	Thu 11/8/12	Tue 12/4/12
14	Excavation	23 days	Thu 11/8/12	Mon 12/10/12
15	South Geo Piers	18 days	Tue 12/11/12	Thu 1/3/13
16	Rough Grading	47 days	Thu 12/6/12	Fri 2/8/13
17	**Structure**	**192 days**	**Thu 12/13/12**	**Fri 9/6/13**
18	South LL - Footings & Foundation Walls	58 days	Fri 1/4/13	Tue 3/26/13
19	South Level 1 Conrete - FRP Columns & Slab	21 days	Thu 3/28/13	Thu 4/25/13
20	South Level 2 Conrete - FRP Columns & Slab	20 days	Fri 4/26/13	Thu 5/23/13
21	South Level 3 Conrete - FRP Columns & Slab	20 days	Fri 5/24/13	Thu 6/20/13
22	South Level 4 Conrete - FRP Columns & Slab	20 days	Fri 6/21/13	Thu 7/18/13
23	South Roof Concrete - FRP Columns & Slab	25 days	Fri 7/19/13	Thu 8/22/13
24	South Slab Cure & Reshore Removal	96 days	Fri 4/26/13	Fri 9/6/13
25	North LL Footings & Foundation Walls	56 days	Thu 12/13/12	Thu 2/28/13
26	North Level 1 - FRP SOG	58 days	Fri 1/25/13	Tue 4/16/13
27	North Level 1 Concrete - FRP Columns & Slabs	16 days	Fri 3/1/13	Fri 3/22/13
28	North Level 2 Concrete - FRP Columns & Slabs	15 days	Thu 4/18/13	Wed 5/8/13
29	North Level 3 Concrete - FRP Columns & Slabs	17 days	Thu 5/9/13	Fri 5/31/13
30	North Level 4 Concrete - FRP Columns & Slabs	14 days	Mon 6/3/13	Thu 6/20/13
31	North Roof Concrete - FRP Columns & Slab	22 days	Fri 6/21/13	Mon 7/22/13
32	North Slabe Cure & Reshore Removal	98 days	Sat 3/23/13	Tue 8/6/13
33	Penthouse Erect Steel & Deck	34 days	Mon 7/15/13	Thu 8/29/13
34	North & South SOG	45 days	Thu 6/6/13	Wed 8/7/13
35	**Site Utilities & Retaining Walls**	**187 days**	**Thu 11/8/12**	**Fri 7/26/13**
36	Site Utilities	139 days	Thu 11/8/12	Tue 5/21/13
37	Ductbanks	1 day	Fri 7/26/13	Fri 7/26/13
38	Retaining Walls	48 days	Fri 4/26/13	Tue 7/2/13
39	Exterior Backfill	57 days	Fri 4/26/13	Mon 7/15/13
40	**Penthouse Enclosure & Roofing**	**107 days**	**Thu 8/15/13**	**Fri 1/10/14**



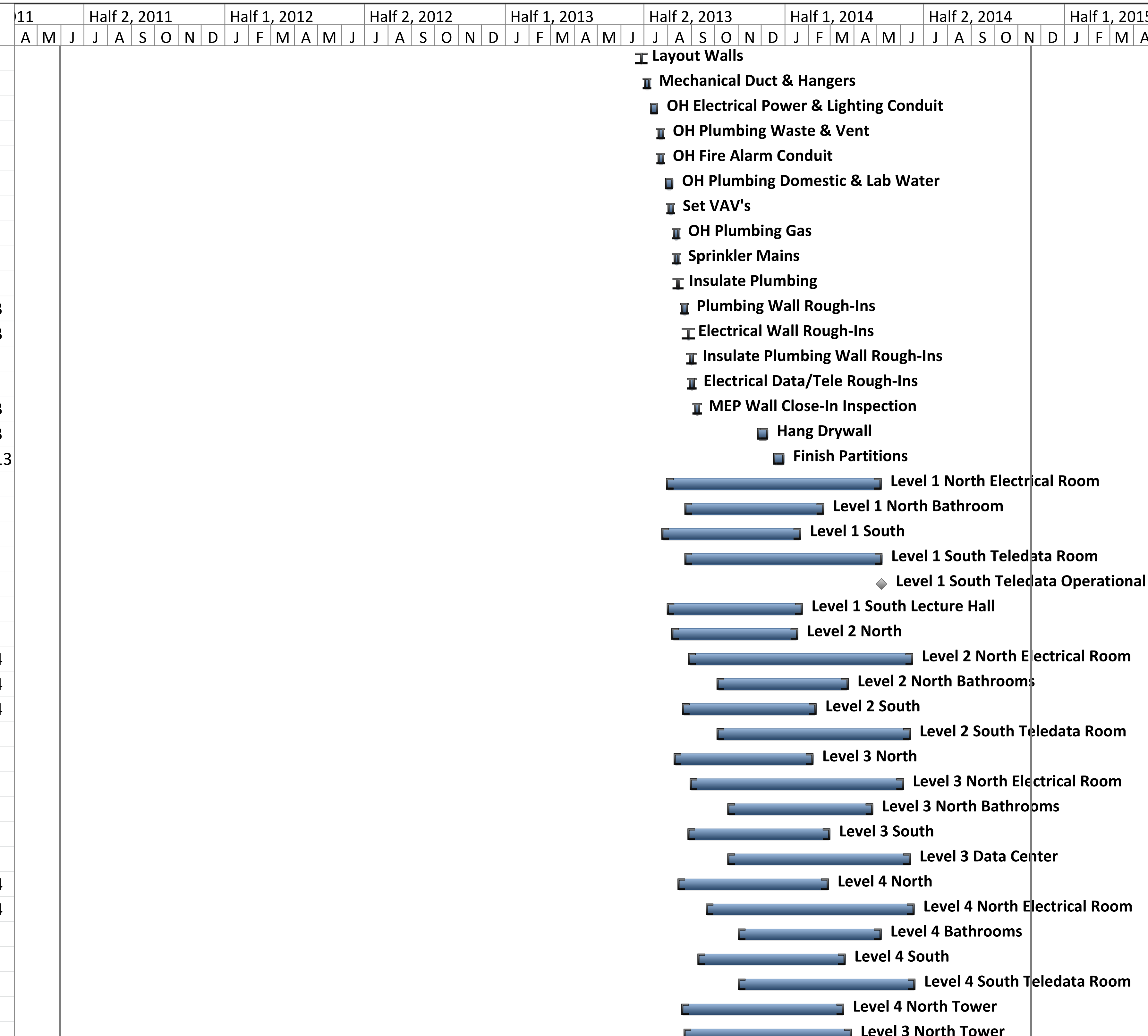
Project: Detailed Proj. Schedule | Summary | Task | Milestone

ID	Task Name	Duration	Start	Finish
41	Enclosure & High Roof	40 days	Fri 8/30/13	Thu 10/24/13
42	North Low Roof Area	67 days	Fri 8/23/13	Mon 11/25/13
43	South Low Roof Area	58 days	Tue 9/3/13	Thu 11/21/13
44	Greenhouse Low Roofing	107 days	Thu 8/15/13	Fri 1/10/14
45	**Perimeter Enclosure**	**123 days**	**Tue 7/30/13**	**Thu 1/16/14**
46	Perimeter Studs & Sheathing	58 days	Tue 7/30/13	Thu 10/17/13
47	Exterior Brick Veneer	45 days	Tue 9/24/13	Mon 11/25/13
48	Exterior Windows & Curtain Walls	83 days	Tue 9/24/13	Thu 1/16/14
49	Perimter Metal Roofing at Penthouse	50 days	Mon 11/4/13	Fri 1/10/14
50	**Site Finishes**	**338 days**	**Mon 4/1/13**	**Wed 7/16/14**
51	North Avenue - Start Restoration	0 days	Mon 4/1/13	Mon 4/1/13
52	North Avenure Improvements	142 days	Mon 4/1/13	Tue 10/15/13
53	North Avenue - Complete Restoration	0 days	Tue 10/15/13	Tue 10/15/13
54	Quad and West Site Finishes	157 days	Fri 10/25/13	Mon 6/2/14
55	Parking Lot	173 days	Fri 8/23/13	Tue 4/22/14
56	East Site Finishes	245 days	Wed 7/3/13	Tue 6/10/14
57	South Meadow Improvements	110 days	Fri 1/24/14	Thu 6/26/14
58	Final Site Finishes and Paving	14 days	Fri 6/27/14	Wed 7/16/14
59	**Mechanical/Electrical Rooms & Shafts**	**193 days**	**Thu 8/8/13**	**Mon 5/5/14**
60	Lower Level North	118 days	Thu 8/8/13	Mon 1/20/14
61	Bolier Room	81 days	Wed 10/30/13	Wed 2/19/14
62	SCUP	109 days	Wed 10/30/13	Mon 3/31/14
63	Lower Level Electric Room	98 days	Mon 9/23/13	Wed 2/5/14
64	Emergency Power Electric Room	124 days	Fri 9/27/13	Wed 3/19/14
65	UPS Electric Room	130 days	Thu 10/3/13	Wed 4/2/14
66	Fire Pump Room	91 days	Wed 10/9/13	Wed 2/12/14
67	Penthouse General Rough-In	119 days	Fri 8/30/13	Wed 2/12/14
68	Penthouse AHU System	64 days	Mon 1/20/14	Thu 4/17/14
69	Penthouse Air Cooled Chiller System	90 days	Wed 10/16/13	Tue 2/18/14
70	Penthouse ACC Computer Unit System	92 days	Thu 10/24/13	Fri 2/28/14
71	Penthouse Cooling Tower System	134 days	Wed 9/11/13	Mon 3/17/14
72	Penthouse Exhaust Fans	46 days	Wed 1/22/14	Wed 3/26/14
73	Penthouse Plumbing Systems	66 days	Mon 2/3/14	Mon 5/5/14
74	Penthouse Boilers	42 days	Fri 2/7/14	Mon 4/7/14
75	Risers	87 days	Wed 10/2/13	Thu 1/30/14
76	**Vertical Construction**	**251 days**	**Thu 7/18/13**	**Thu 7/3/14**
77	Stairs	251 days	Thu 7/18/13	Thu 7/3/14
78	Elevators	65 days	Thu 2/6/14	Wed 5/7/14
79	**Rough-In**	**257 days**	**Wed 6/26/13**	**Thu 6/19/14**
80	Level 1 North	134 days	Wed 6/26/13	Mon 12/30/13



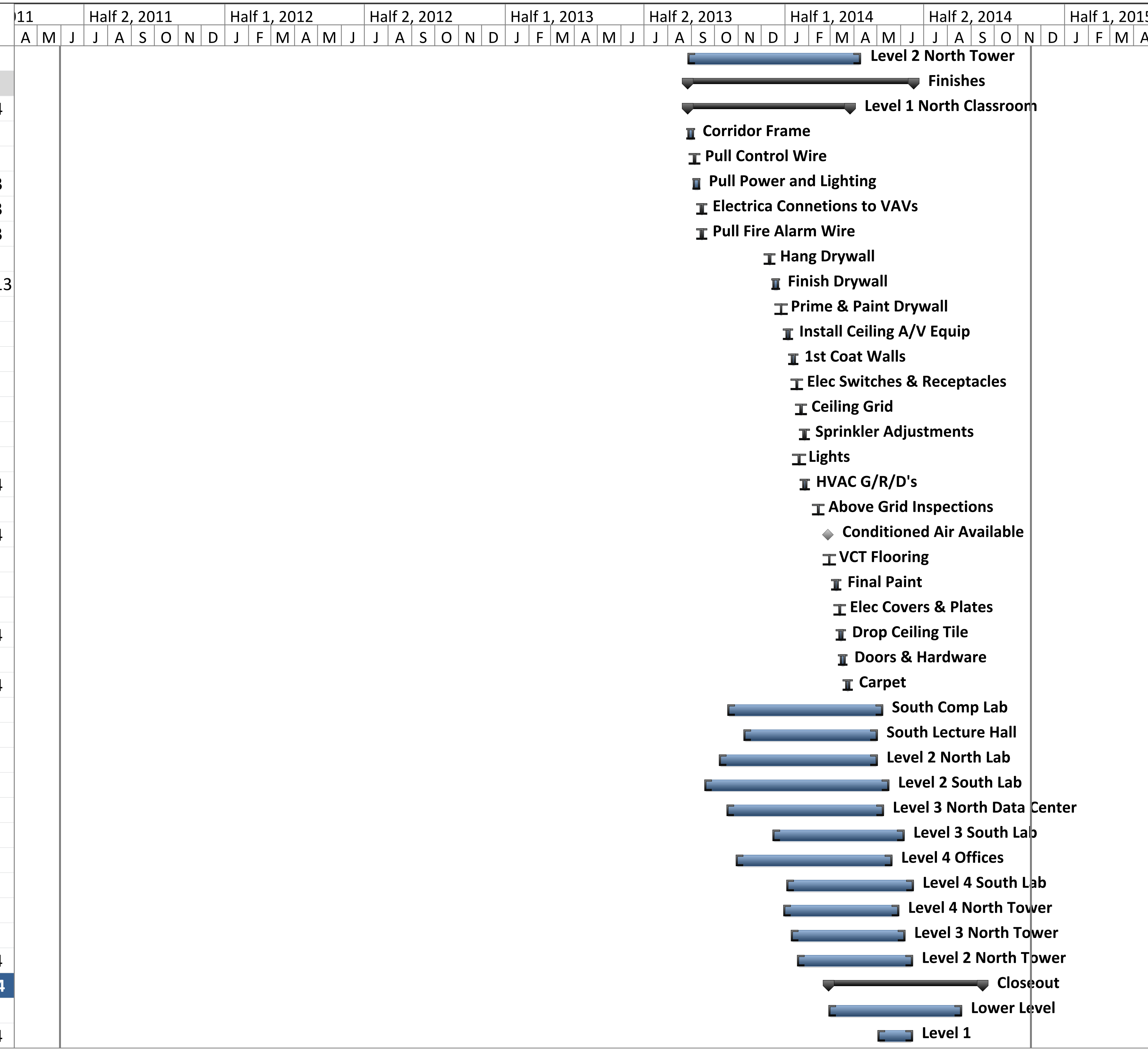
Project: Detailed Proj. Schedule | Summary | Task | Milestone

ID	Task Name	Duration	Start	Finish
81	Layout Walls	3 days	Wed 6/26/13	Fri 6/28/13
82	Mechanical Duct & Hangers	6 days	Mon 7/1/13	Mon 7/8/13
83	OH Electrical Power & Lighting Conduit	8 days	Tue 7/9/13	Thu 7/18/13
84	OH Plumbing Waste & Vent	6 days	Fri 7/19/13	Fri 7/26/13
85	OH Fire Alarm Conduit	6 days	Fri 7/19/13	Fri 7/26/13
86	OH Plumbing Domestic & Lab Water	8 days	Mon 7/29/13	Wed 8/7/13
87	Set VAV's	6 days	Thu 8/1/13	Thu 8/8/13
88	OH Plumbing Gas	6 days	Thu 8/8/13	Thu 8/15/13
89	Sprinkler Mains	5 days	Fri 8/9/13	Thu 8/15/13
90	Insulate Plumbing	5 days	Mon 8/12/13	Fri 8/16/13
91	Plumbing Wall Rough-Ins	6 days	Mon 8/19/13	Mon 8/26/13
92	Electrical Wall Rough-Ins	2 days	Tue 8/27/13	Wed 8/28/13
93	Insulate Plumbing Wall Rough-Ins	4 days	Thu 8/29/13	Tue 9/3/13
94	Electrical Data/Tele Rough-Ins	5 days	Thu 8/29/13	Wed 9/4/13
95	MEP Wall Close-In Inspection	5 days	Thu 9/5/13	Wed 9/11/13
96	Hang Drywall	10 days	Tue 11/26/13	Mon 12/9/13
97	Finish Partitions	10 days	Tue 12/17/13	Mon 12/30/13
98	Level 1 North Electrical Room	201 days	Tue 7/30/13	Tue 5/6/14
99	Level 1 North Bathroom	130 days	Fri 8/23/13	Thu 2/20/14
100	Level 1 South	130 days	Wed 7/24/13	Tue 1/21/14
101	Level 1 South Teledata Room	184 days	Fri 8/23/13	Wed 5/7/14
102	Level 1 South Teledata Operational	0 days	Wed 5/7/14	Wed 5/7/14
103	Level 1 South Lecture Hall	127 days	Wed 7/31/13	Thu 1/23/14
104	Level 2 North	119 days	Tue 8/6/13	Fri 1/17/14
105	Level 2 North Electrical Room	209 days	Wed 8/28/13	Mon 6/16/14
106	Level 2 North Bathrooms	122 days	Fri 10/4/13	Mon 3/24/14
107	Level 2 South	125 days	Tue 8/20/13	Mon 2/10/14
108	Level 2 South Teledata Room	181 days	Fri 10/4/13	Fri 6/13/14
109	Level 3 North	130 days	Fri 8/9/13	Thu 2/6/14
110	Level 3 North Electrical Room	199 days	Fri 8/30/13	Wed 6/4/14
111	Level 3 North Bathrooms	136 days	Fri 10/18/13	Fri 4/25/14
112	Level 3 South	134 days	Tue 8/27/13	Fri 2/28/14
113	Level 3 Data Center	171 days	Fri 10/18/13	Fri 6/13/14
114	Level 4 North	141 days	Wed 8/14/13	Wed 2/26/14
115	Level 4 North Electrical Room	194 days	Fri 9/20/13	Wed 6/18/14
116	Level 4 Bathrooms	133 days	Fri 11/1/13	Tue 5/6/14
117	Level 4 South	139 days	Mon 9/9/13	Thu 3/20/14
118	Level 4 South Teledata Room	165 days	Fri 11/1/13	Thu 6/19/14
119	Level 4 North Tower	152 days	Mon 8/19/13	Tue 3/18/14
120	Level 3 North Tower	157 days	Thu 8/22/13	Fri 3/28/14



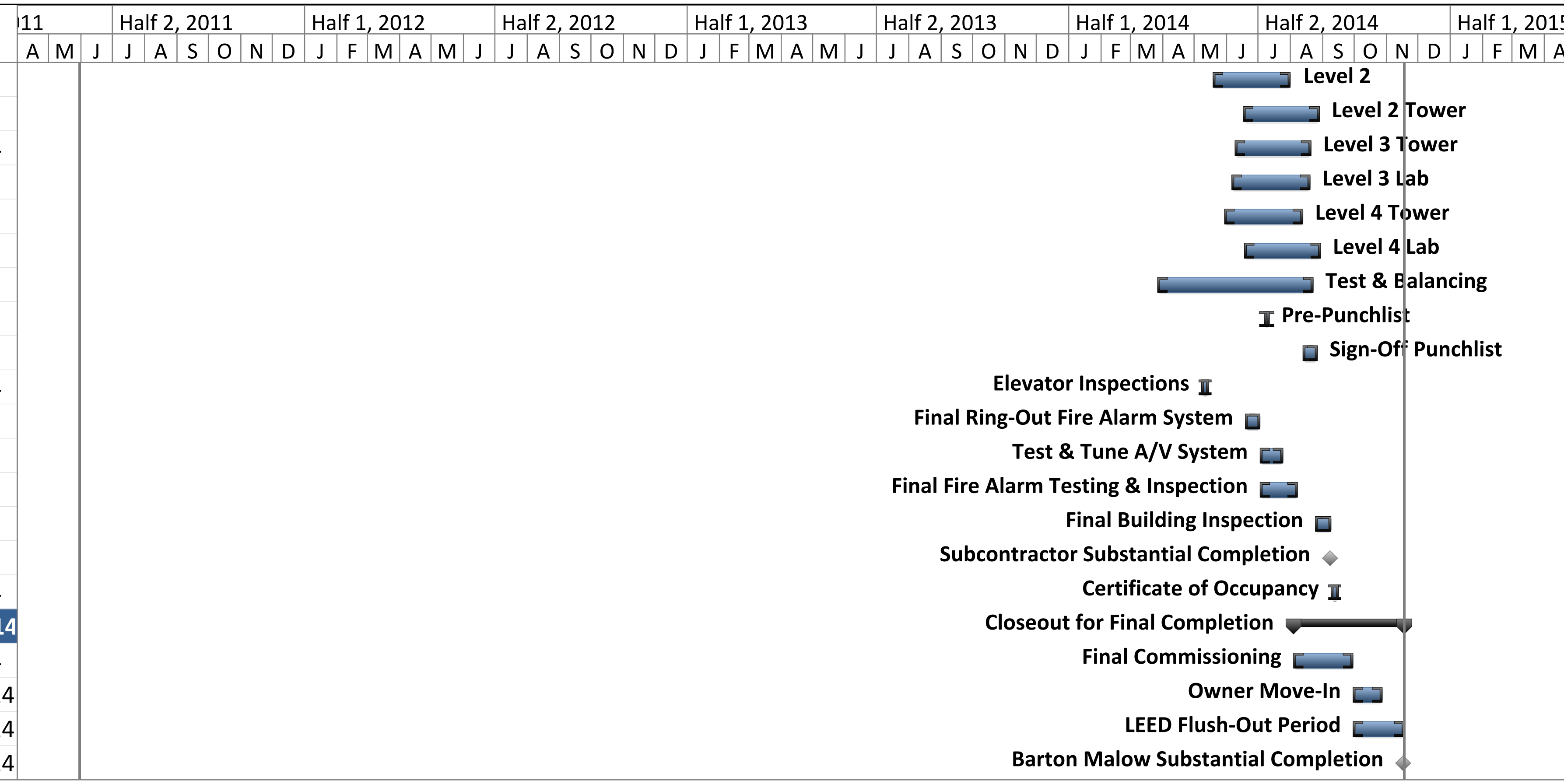
Project: Detailed Proj. Schedule | Summary | Task | Milestone

ID	Task Name	Duration	Start	Finish
121	Level 2 North Tower	162 days	Tue 8/27/13	Wed 4/9/14
122	**Finishes**	**211 days**	**Tue 8/27/13**	**Tue 6/17/14**
123	Level 1 North Classroom	152 days	Tue 8/27/13	Wed 3/26/14
124	Corridor Frame	6 days	Tue 8/27/13	Tue 9/3/13
125	Pull Control Wire	4 days	Tue 9/3/13	Fri 9/6/13
126	Pull Power and Lighting	7 days	Tue 9/3/13	Wed 9/11/13
127	Electrica Connetions to VAVs	3 days	Thu 9/12/13	Mon 9/16/13
128	Pull Fire Alarm Wire	3 days	Thu 9/12/13	Mon 9/16/13
129	Hang Drywall	4 days	Tue 12/10/13	Fri 12/13/13
130	Finish Drywall	6 days	Mon 12/16/13	Mon 12/23/13
131	Prime & Paint Drywall	2 days	Thu 12/26/13	Fri 12/27/13
132	Install Ceiling A/V Equip	4 days	Thu 1/2/14	Tue 1/7/14
133	1st Coat Walls	4 days	Thu 1/9/14	Tue 1/14/14
134	Elec Switches & Receptacles	3 days	Wed 1/15/14	Fri 1/17/14
135	Ceiling Grid	4 days	Mon 1/20/14	Thu 1/23/14
136	Sprinkler Adjustments	3 days	Fri 1/24/14	Tue 1/28/14
137	Lights	1 day	Sun 1/19/14	Sun 1/19/14
138	HVAC G/R/D's	4 days	Fri 1/24/14	Wed 1/29/14
139	Above Grid Inspections	3 days	Wed 2/12/14	Fri 2/14/14
140	Conditioned Air Available	0 days	Wed 2/26/14	Wed 2/26/14
141	VCT Flooring	2 days	Thu 2/27/14	Fri 2/28/14
142	Final Paint	4 days	Thu 3/6/14	Tue 3/11/14
143	Elec Covers & Plates	3 days	Wed 3/12/14	Fri 3/14/14
144	Drop Ceiling Tile	4 days	Wed 3/12/14	Mon 3/17/14
145	Doors & Hardware	5 days	Fri 3/14/14	Thu 3/20/14
146	Carpet	4 days	Fri 3/21/14	Wed 3/26/14
147	South Comp Lab	145 days	Fri 10/18/13	Thu 5/8/14
148	South Lecture Hall	125 days	Fri 11/8/13	Thu 5/1/14
149	Level 2 North Lab	149 days	Mon 10/7/13	Thu 5/1/14
150	Level 2 South Lab	173 days	Wed 9/18/13	Fri 5/16/14
151	Level 3 North Data Center	147 days	Thu 10/17/13	Fri 5/9/14
152	Level 3 South Lab	124 days	Mon 12/16/13	Thu 6/5/14
153	Level 4 Offices	146 days	Tue 10/29/13	Tue 5/20/14
154	Level 4 South Lab	118 days	Fri 1/3/14	Tue 6/17/14
155	Level 4 North Tower	109 days	Mon 12/30/13	Thu 5/29/14
156	Level 3 North Tower	107 days	Thu 1/9/14	Fri 6/6/14
157	Level 2 North Tower	107 days	Fri 1/17/14	Mon 6/16/14
158	**Closeout**	**143 days**	**Thu 2/27/14**	**Mon 9/15/14**
159	Lower Level	124 days	Thu 2/27/14	Tue 8/19/14
160	Level 1	32 days	Fri 5/2/14	Mon 6/16/14



Project: Detailed Proj. Schedule — Summary, Task, Milestone

ID	Task Name	Duration	Start	Finish
161	Level 2	54 days	Mon 5/19/14	Thu 7/31/14
162	Level 2 Tower	53 days	Tue 6/17/14	Thu 8/28/14
163	Level 3 Tower	53 days	Mon 6/9/14	Wed 8/20/14
164	Level 3 Lab	53 days	Fri 6/6/14	Tue 8/19/14
165	Level 4 Tower	53 days	Fri 5/30/14	Tue 8/12/14
166	Level 4 Lab	53 days	Wed 6/18/14	Fri 8/29/14
167	Test & Balancing	107 days	Thu 3/27/14	Fri 8/22/14
168	Pre-Punchlist	5 days	Mon 7/7/14	Fri 7/11/14
169	Sign-Off Punchlist	10 days	Wed 8/13/14	Tue 8/26/14
170	Elevator Inspections	5 days	Thu 5/8/14	Wed 5/14/14
171	Final Ring-Out Fire Alarm System	10 days	Thu 6/19/14	Wed 7/2/14
172	Test & Tune A/V System	16 days	Thu 7/3/14	Thu 7/24/14
173	Final Fire Alarm Testing & Inspection	26 days	Thu 7/3/14	Thu 8/7/14
174	Final Building Inspection	11 days	Mon 8/25/14	Mon 9/8/14
175	Subcontractor Substantial Completion	0 days	Mon 9/8/14	Mon 9/8/14
176	Certificate of Occupancy	5 days	Tue 9/9/14	Mon 9/15/14
177	Closeout for Final Completion	76 days	Mon 8/4/14	Mon 11/17/14
178	Final Commissioning	41 days	Mon 8/4/14	Mon 9/29/14
179	Owner Move-In	20 days	Tue 9/30/14	Mon 10/27/14
180	LEED Flush-Out Period	35 days	Tue 9/30/14	Mon 11/17/14
181	Barton Malow Substantial Completion	0 days	Mon 11/17/14	Mon 11/17/14



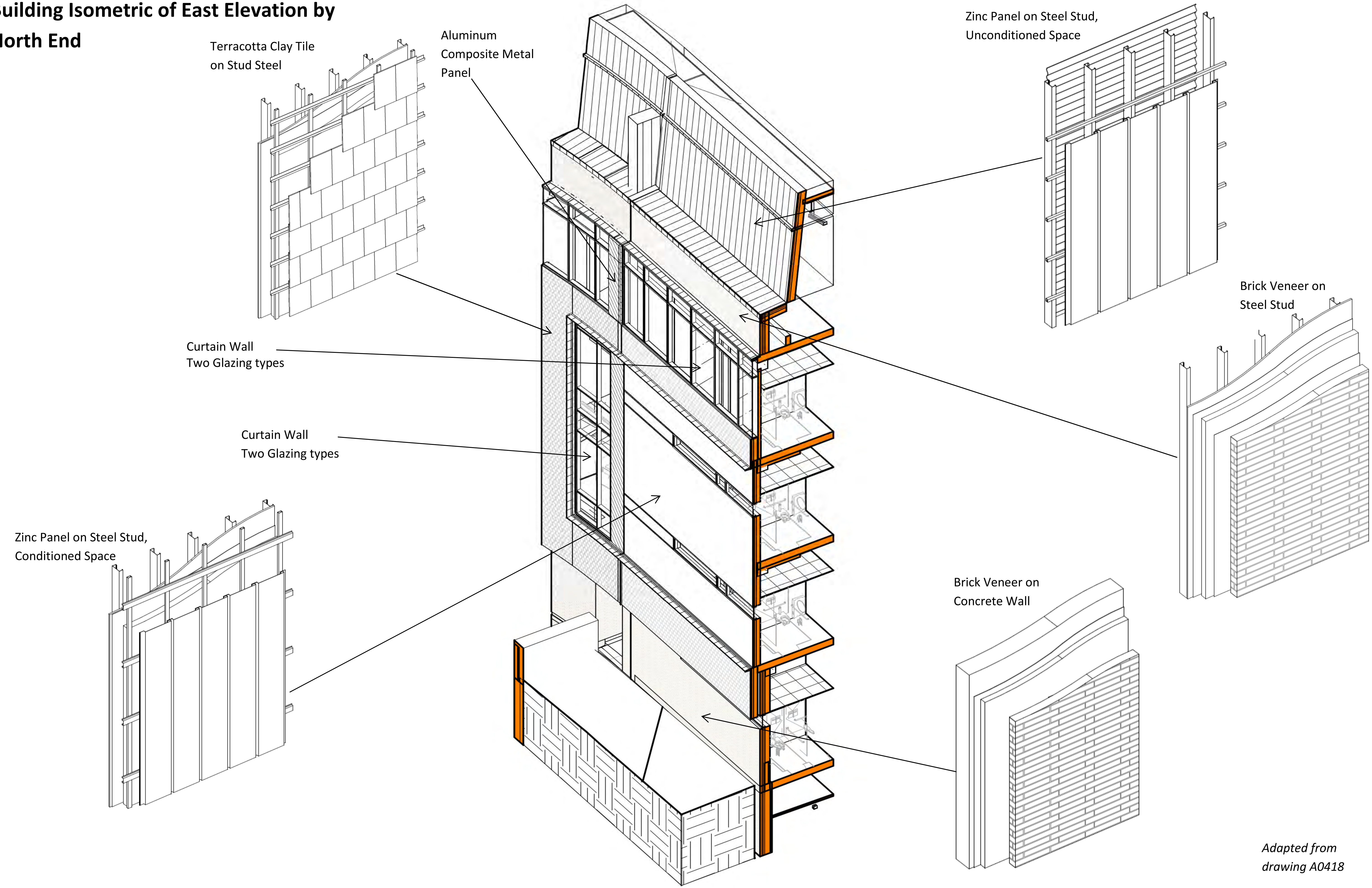
Project: Detailed Proj. Schedule
Summary
Task
Milestone

APPENDIX 1-D – GENERAL CONDITIONS ESTIMATE

General Conditions Estimate					*RSMeans CostWorks
					Project Duration - 24 months - 104 weeks
Cost Code*	Description	Quantity	Unit	Cost	Amount
	Project Management Team				**$ 2,262,520.00**
013113200220	Project Director (inflate 20% from PM)	104	Week	$ 3,930.00	$ 408,720.00
013113200220	Project Manager	104	Week	$ 3,275.00	$ 340,600.00
013113200220	Project Manager	104	Week	$ 3,275.00	$ 340,600.00
013113200280	General Superintendent (inflate 20% from Super)	104	Week	$ 3,630.00	$ 377,520.00
013113200280	Superintendent	104	Week	$ 3,025.00	$ 314,600.00
013113200140	Project Engineer	104	Week	$ 2,025.00	$ 210,600.00
013113200140	Project Engineer	104	Week	$ 2,025.00	$ 210,600.00
013113200020	Field Accountant	104	Week	$ 570.00	$ 59,280.00
	Field Office				**$ 52,983.00**
015213200550	(3) Trailer, Furnished, no hookups, rent, 50'x12'	24	Month	$ 1,230.00	$ 29,520.00
015213200700	(3) Trailer A/C	24	Month	$ 135.00	$ 3,240.00
015213200800	(3) Trailer Delivery, assume 100 mi	100	mi	$ 4.95	$ 495.00
015213400140	Telephone	24	Month	$ 231.00	$ 5,544.00
015213400160	Trailer Power	24	Month	$ 121.00	$ 2,904.00
015213400120	Office Supplies/Drawing Copies	24	Month	$ 105.00	$ 2,520.00
015213400100	Copier Machines	24	Month	$ 165.00	$ 3,960.00
-	Postage ($200/mo)	24	Month	$ 200.00	$ 4,800.00
	Insurance				**$ 629,412.00**
013113300020	Builders Risk (based on GMP)	76200000	($)	0.24%	$ 18,288.00
013113300600	Liability	76200000	($)	2.02%	$ 153,924.00
013113900020	Performance Bond	76200000	($)	0.60%	$ 457,200.00
	Safety				**$ 2,600.00**
-	First Aid (assume $25/wk)	104	Week	$ 25.00	$ 2,600.00
	Field Operations				**$ 40,445.00**
017123131100	Survey	3	Day	$ 1,016.00	$ 3,048.00
015813500020	Signage (20SF)	20	SF	$ 19.70	$ 394.00
015433406410	Temporary Toilets (3)	24	Month	$ 504.00	$ 12,096.00
015113800700	Temporary Water	24	Month	$ 68.00	$ 1,632.00
-	Small Tools & Equip (assume lump sum $20,000)	1	Ea	$ 20,000.00	$ 20,000.00
015433400010	Equipment Rental	1	Ea	$ 1,000.00	$ 1,000.00
015113500050	Temp Power, 400 Amp	1	Ea	$ 2,275.00	$ 2,275.00
	Testing & Inspections				**$ 19,440.00**
014523505570	Testing Service (2/month)	48	Ea	$ 270.00	$ 12,960.00
014523505570	Inspection Service (1/month)	24	Ea	$ 270.00	$ 6,480.00
	Waste Management				**$ 236,808.00**
024119230725	(3) Dumpsters	104	Week	$ 2,277.00	$ 236,808.00
	Total				**$ 3,244,208.00**

APPENDIX 2-A – CALLOUT OF CLADDING ASSEMBLIES

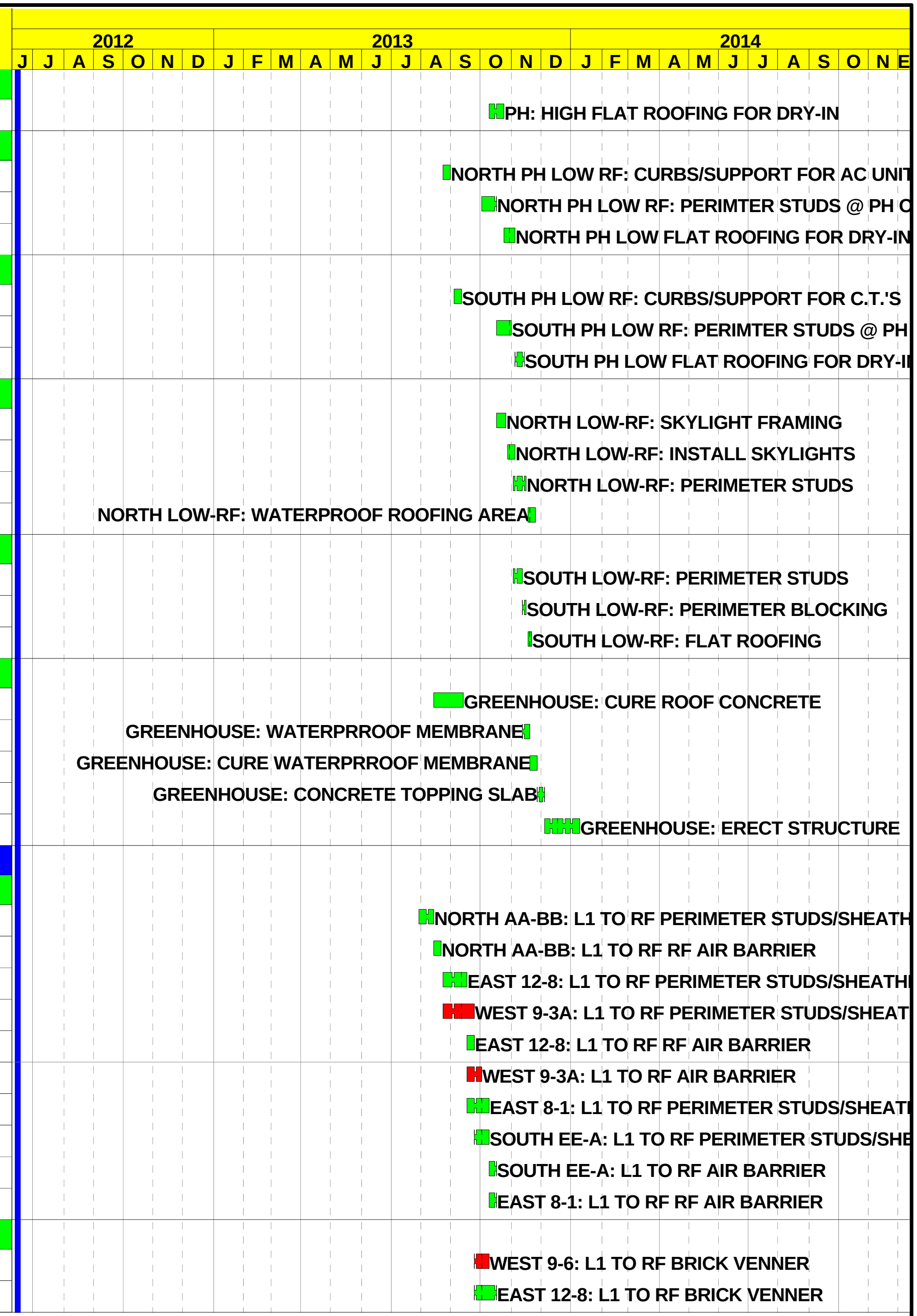
Building Isometric of East Elevation by North End



Adapted from drawing A0418

APPENDIX 2-B – ORIGINAL PERIMETER ENCLOSURE SCHEDULE

Activity ID	BDPK	Activity Description	OD	%	Early Start	Early Finish
PENTHOUSE ENCLOSURE & HIGH ROOF						
19100	B073	PH: HIGH FLAT ROOFING FOR DRY-IN	10	0	10OCT13	24OCT13
NORTH LOW ROOF AREA @ PENTHOUSE OPEN AREA						
19200	B151	NORTH PH LOW RF: CURBS/SUPPORT FOR AC UNITS	6	0	23AUG13	30AUG13
19220	B091	NORTH PH LOW RF: PERIMTER STUDS @ PH OPEN AREA	10	0	03OCT13	17OCT13
19280	B073	NORTH PH LOW FLAT ROOFING FOR DRY-IN @ OPEN	6	0	25OCT13	04NOV13
SOUTH LOW ROOF AREA @ PENTHOUSE OPEN AREA						
19300	B151	SOUTH PH LOW RF: CURBS/SUPPORT FOR C.T.'S	6	0	03SEP13	10SEP13
19320	B091	SOUTH PH LOW RF: PERIMTER STUDS @ PH OPEN AREA	10	0	18OCT13	01NOV13
19380	B073	SOUTH PH LOW FLAT ROOFING FOR DRY-IN @ OPEN AREA	6	0	05NOV13	14NOV13
NORTH LOW ROOF AREA						
19500	B052	NORTH LOW-RF: SKYLIGHT FRAMING	6	0	18OCT13	25OCT13
19600	B081	NORTH LOW-RF: INSTALL SKYLIGHTS	6	0	28OCT13	05NOV13
19550	B091	NORTH LOW-RF: PERIMETER STUDS	8	0	04NOV13	15NOV13
19560	B073	NORTH LOW-RF: WATERPROOF ROOFING AREA	5	0	18NOV13	25NOV13
SOUTH LOW ROOF AREA						
19700	B091	SOUTH LOW-RF: PERIMETER STUDS	5	0	04NOV13	11NOV13
19720	B073	SOUTH LOW-RF: PERIMETER BLOCKING	3	0	12NOV13	15NOV13
19760	B073	SOUTH LOW-RF: FLAT ROOFING	3	0	18NOV13	21NOV13
GREENHOUSE LOW ROOFING						
19800	B031	GREENHOUSE: CURE ROOF CONCRETE	30	0	15AUG13	13SEP13
19810	B073	GREENHOUSE: WATERPRROOF MEMBRANE	5	0	12NOV13	19NOV13
19820	B031	GREENHOUSE: CURE WATERPRROOF MEMBRANE	7	0	20NOV13	26NOV13
19850	B031	GREENHOUSE: CONCRETE TOPPING SLAB	4	0	27NOV13	05DEC13
19900	B131	GREENHOUSE: ERECT STRUCTURE	20	0	06DEC13	10JAN14
PERIMETER ENCLOSURE						
PERIMETER STUDS & SHEATHING						
21100	B091	NORTH AA-BB: L1 TO RF PERIMETER STUDS/SHEATHING	10	0	30JUL13	13AUG13
21110	B091	NORTH AA-BB: L1 TO RF RF AIR BARRIER	5	0	14AUG13	20AUG13
21130	B091	EAST 12-8: L1 TO RF PERIMETER STUDS/SHEATHING	15	0	23AUG13	16SEP13
21000	B091	WEST 9-3A: L1 TO RF PERIMETER STUDS/SHEATHING	20	0	23AUG13	23SEP13
21140	B091	EAST 12-8: L1 TO RF RF AIR BARRIER	5	0	17SEP13	23SEP13
21010	B091	WEST 9-3A: L1 TO RF AIR BARRIER	10	0	17SEP13	01OCT13
21190	B091	EAST 8-1: L1 TO RF PERIMETER STUDS/SHEATHING	15	0	17SEP13	09OCT13
21030	B091	SOUTH EE-A: L1 TO RF PERIMETER STUDS/SHEATHING	10	0	24SEP13	09OCT13
21040	B091	SOUTH EE-A: L1 TO RF AIR BARRIER	5	0	10OCT13	17OCT13
21200	B091	EAST 8-1: L1 TO RF RF AIR BARRIER	5	0	10OCT13	17OCT13
EXTERIOR BRICK VENEER						
20400	B041	WEST 9-6: L1 TO RF BRICK VENNER	10	0	24SEP13	09OCT13
20700	B041	EAST 12-8: L1 TO RF BRICK VENNER	15	0	24SEP13	17OCT13



Start Date	01APR11
Finish Date	17NOV14
Data Date	15JUN12
Run Date	01AUG12 15:06

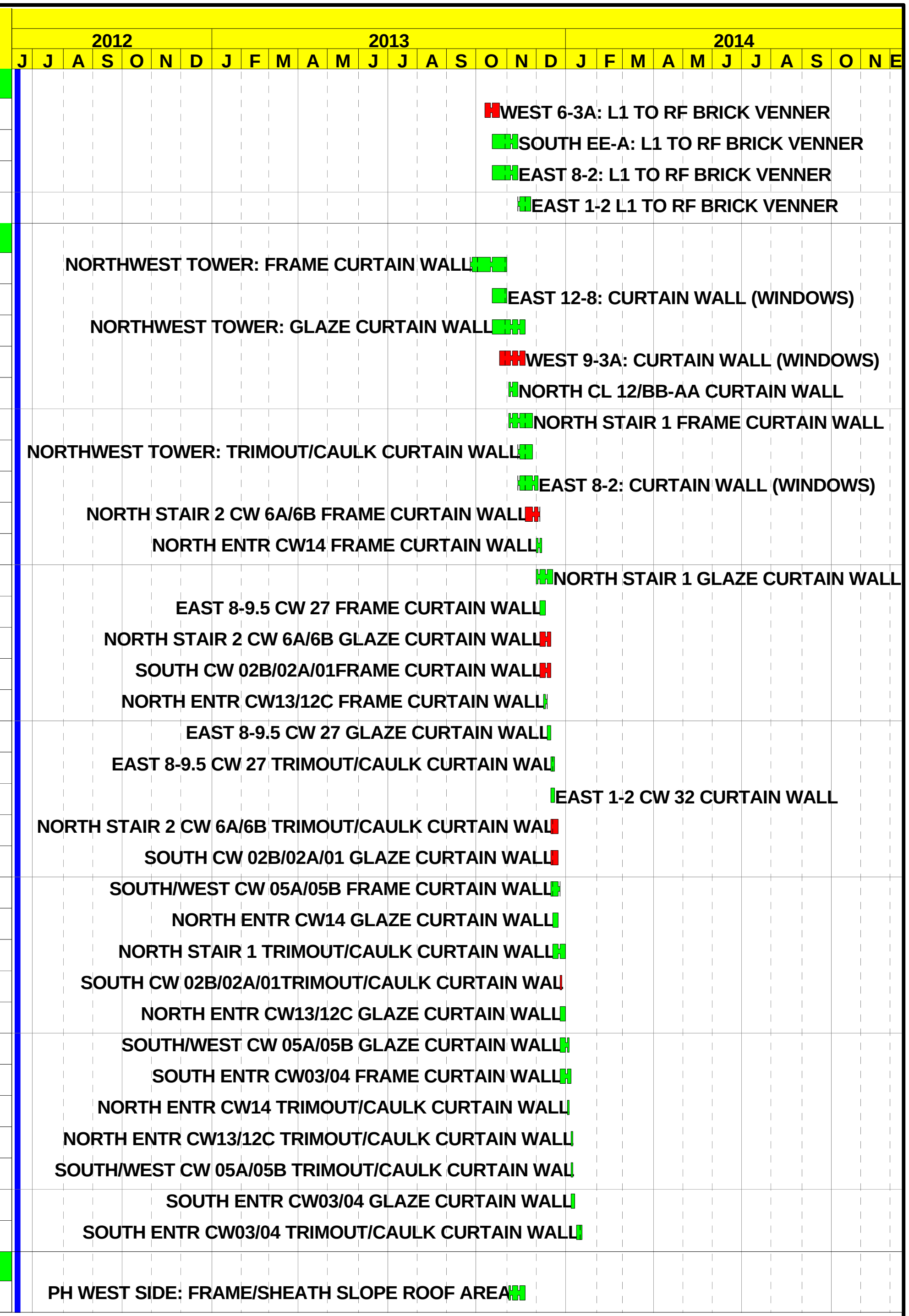
Early Bar
Progress Bar
Critical Activity

WIF4

BARTON MALOW
SCIENCE AND TECHNOLOGY CENTER
MASTER PROJECT

Date	Revision	Checked	Approved
14JUN12	MASTER PROJECT SCHEDULE for GMP #1 (BP 1)	RP	AWT
01AUG12	MASTER PROJECT SCHEDULE	AWT	BM

Activity ID	BDPK	Activity Description	OD	%	Early Start	Early Finish
EXTERIOR BRICK VENEER						
20410	B041	WEST 6-3A: L1 TO RF BRICK VENNER	10	0	10OCT13	24OCT13
20530	B041	SOUTH EE-A: L1 TO RF BRICK VENNER	15	0	18OCT13	11NOV13
20710	B041	EAST 8-2: L1 TO RF BRICK VENNER	15	0	18OCT13	11NOV13
20590	B041	EAST 1-2 L1 TO RF BRICK VENNER	8	0	12NOV13	25NOV13
EXTERIOR WINDOWS & CURTAIN WALLS						
22500	B081	NORTHWEST TOWER: FRAME CURTAIN WALL	25	0	24SEP13	01NOV13
22300	B081	EAST 12-8: CURTAIN WALL (WINDOWS)	10	0	18OCT13	01NOV13
22550	B081	NORTHWEST TOWER: GLAZE CURTAIN WALL	20	0	18OCT13	19NOV13
22000	B081	WEST 9-3A: CURTAIN WALL (WINDOWS)	15	0	25OCT13	19NOV13
22320	B081	NORTH CL 12/BB-AA CURTAIN WALL	5	0	04NOV13	11NOV13
22600	B081	NORTH STAIR 1 FRAME CURTAIN WALL	15	0	04NOV13	27NOV13
22560	B081	NORTHWEST TOWER: TRIMOUT/CAULK CURTAIN WALL	10	0	12NOV13	27NOV13
22340	B081	EAST 8-2: CURTAIN WALL (WINDOWS)	12	0	12NOV13	03DEC13
22100	B081	NORTH STAIR 2 CW 6A/6B FRAME CURTAIN WALL	8	0	21NOV13	05DEC13
22650	B081	NORTH ENTR CW14 FRAME CURTAIN WALL	4	0	02DEC13	06DEC13
22610	B081	NORTH STAIR 1 GLAZE CURTAIN WALL	10	0	02DEC13	17DEC13
22400	B081	EAST 8-9.5 CW 27 FRAME CURTAIN WALL	4	0	05DEC13	10DEC13
22110	B081	NORTH STAIR 2 CW 6A/6B GLAZE CURTAIN WALL	6	0	06DEC13	16DEC13
22150	B081	SOUTH CW 02B/02A/01FRAME CURTAIN WALL	6	0	06DEC13	16DEC13
22700	B081	NORTH ENTR CW13/12C FRAME CURTAIN WALL	3	0	09DEC13	12DEC13
22410	B081	EAST 8-9.5 CW 27 GLAZE CURTAIN WALL	3	0	12DEC13	16DEC13
22420	B081	EAST 8-9.5 CW 27 TRIMOUT/CAULK CURTAIN WAL	2	0	17DEC13	19DEC13
22450	B081	EAST 1-2 CW 32 CURTAIN WALL	3	0	17DEC13	19DEC13
22130	B081	NORTH STAIR 2 CW 6A/6B TRIMOUT/CAULK CURTAIN WAL	4	0	17DEC13	23DEC13
22160	B081	SOUTH CW 02B/02A/01 GLAZE CURTAIN WALL	4	0	17DEC13	23DEC13
22200	B081	SOUTH/WEST CW 05A/05B FRAME CURTAIN WALL	5	0	17DEC13	26DEC13
22660	B081	NORTH ENTR CW14 GLAZE CURTAIN WALL	3	0	19DEC13	23DEC13
22620	B081	NORTH STAIR 1 TRIMOUT/CAULK CURTAIN WALL	6	0	19DEC13	30DEC13
22180	B081	SOUTH CW 02B/02A/01TRIMOUT/CAULK CURTAIN WAL	2	0	26DEC13	27DEC13
22710	B081	NORTH ENTR CW13/12C GLAZE CURTAIN WALL	3	0	26DEC13	30DEC13
22210	B081	SOUTH/WEST CW 05A/05B GLAZE CURTAIN WALL	4	0	27DEC13	03JAN14
22850	B081	SOUTH ENTR CW03/04 FRAME CURTAIN WALL	5	0	27DEC13	06JAN14
22670	B081	NORTH ENTR CW14 TRIMOUT/CAULK CURTAIN WALL	2	0	02JAN14	03JAN14
22720	B081	NORTH ENTR CW13/12C TRIMOUT/CAULK CURTAIN WALL	2	0	06JAN14	07JAN14
22230	B081	SOUTH/WEST CW 05A/05B TRIMOUT/CAULK CURTAIN WAL	3	0	06JAN14	08JAN14
22860	B081	SOUTH ENTR CW03/04 GLAZE CURTAIN WALL	4	0	07JAN14	10JAN14
22870	B081	SOUTH ENTR CW03/04 TRIMOUT/CAULK CURTAIN WALL	3	0	13JAN14	16JAN14
PERIMETER METAL ROOFING AROUND PENTHOUSE						
23000	B091	PH WEST SIDE: FRAME/SHEATH SLOPE ROOF AREA	10	0	04NOV13	19NOV13



Start Date	01APR11
Finish Date	17NOV14
Data Date	15JUN12
Run Date	01AUG12 15:06

Early Bar
Progress Bar
Critical Activity

WIF4

Sheet 32 of 88

BARTON MALOW
SCIENCE AND TECHNOLOGY CENTER
MASTER PROJECT

Date	Revision	Checked	Approved
14JUN12	MASTER PROJECT SCHEDULE for GMP #1 (BP 1)	RP	AWT
01AUG12	MASTER PROJECT SCHEDULE	AWT	BM

APPENDIX 2-C – ENCLOSURE ESTIMATE REPORT

Analysis 1 - Exterior Envelope Estimate
Year 2013 Quarter 1
Unit Detail Report

Prepared By:
Nick Zitterbart
PSU

LineNumber				Description	Quantity	Unit	Daily Output*	Total Incl. O&P*	Ext. Total Incl. O&P
Division 04 Masonry									
042113132020				Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	7,567.80	S.F.	660	$26.54	*$200,849
042129200300				Terra cotta tile, dry set, square/hexagonal/lattice shapes, glazed, intense colors, 1/2" thick, on walls, includes mortar, excludes scaffolding	7,567.80	S.F.	390	$14.97	*$113,290

Difference: $87,559 (add)

*Adjusted for 3 working crews

Total Duration with upgraded crews:

Terracotta Tiles = 20 days
Brick Veneer = 12 days

APPENDIX 2-D – EAST ELEVATION CLADDING AREA

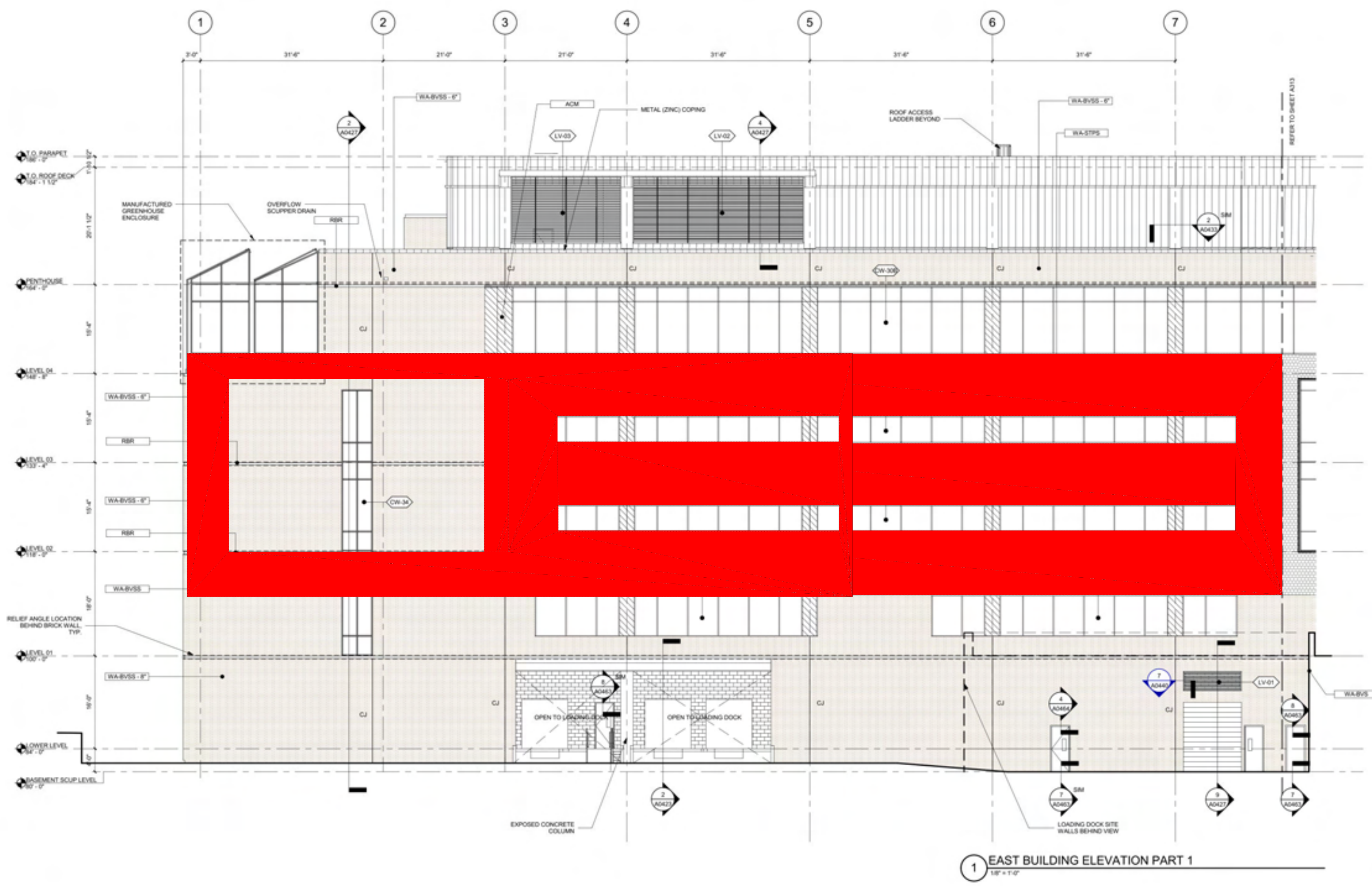
Total Area of Terracotta Wall Tiles = 4,628.3 SF

EXTERIOR MATERIAL LEGEND	
CLADDING ASSEMBLIES	
WA-BVSS	SEE WALL ASSEMBLY DETAIL 01/A400
WA-DSW	SEE WALL ASSEMBLY DETAIL 02/A400
WA-SSMPS	SEE WALL ASSEMBLY DETAIL 03/A400
WA-BVCP	SEE WALL ASSEMBLY DETAIL 04/A400
WA-STPS	SEE WALL ASSEMBLY DETAIL 05/A400
WA-SSMCP	SEE WALL ASSEMBLY DETAIL 06/A400
WA-SWP	SEE WALL ASSEMBLY DETAIL 07/A400
WA-SSM	SEE WALL ASSEMBLY DETAIL 08/A400
WA-MPPS	SEE WALL ASSEMBLY DETAIL 09/A400
WA-BV	SEE WALL ASSEBMLY DETAIL 01/A401
WA-BVS	SEE WALL ASSEBMLY DETAIL 02/A401
WA-DS	SEE WALL ASSEMBLY DETAIL 03/A401
ROOFING ASSEMBLIES	
RA-VR	SEE ROOF ASSEMBLY DETAL 04/A401
RA-EP	SEE ROOF ASSEMBLY DETAL 05/A401
RA-SPC	SEE ROOF ASSEMBLY DETAL 06/A401
RA-SP	SEE ROOF ASSEMBLY DETAL 07/A401
ACCENT	
RBR	RECESSED BRICK REVEAL
AL-1	ALUMINUM COPING (ZINC COATED)
SSR-1	STAINLESS STEEL GUARDRAIL
SSR-2	STAINLESS STEEL HANDRAIL
FNC-1	DECORATIVE FENCING
ACM	ALUMINUM COMPOSITE METAL PANE
SOFFIT	
SA-LM	LINEAR METAL SOFFIT ASSEMBLY

- REFER TO SHEET A400 AND A401 FOR EXTERIOR WALL ASSEMBLIES AND ROOF ASSEMBLIES.

- REFER TO A1100 DRAWING SERIES FOR CURTAIN WALL, WINDOW, AND LOUVER SCHEDULE.

- REFER TO A340 FOR SLANTED PENTHOUSE WALL INFORMATION, SUCH AS SHAPE, WORKING POINT DIMENIONS, ETC.



1 EAST BUILDING ELEVATION PART 1
1/8" = 1'-0"

0 4' 8' 16' 32'

Coppin State University
Office of Capital Planning

The Science and Technology Center
2500 West North Ave
Baltimore, Maryland 21216

UMB Project No. 10-910

CANNONDESIGN
250 West Pratt Street, Suite 2100
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Site Resources, Inc
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Structural Engineer
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T.L.B. Associates, Inc.
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Lansdale, Pennsylvania 19446
T: 215.661.1600 F: 215.661.1280

Barton Malow Company
Construction Manager
300 West Pratt Street, Suite 310
Baltimore, Maryland 21201
T: 443.757.1000 F: 443.757.1011

KEY PLAN

No.	Description	Date
-	Conformed Construction Documents	DEC 1, 2012

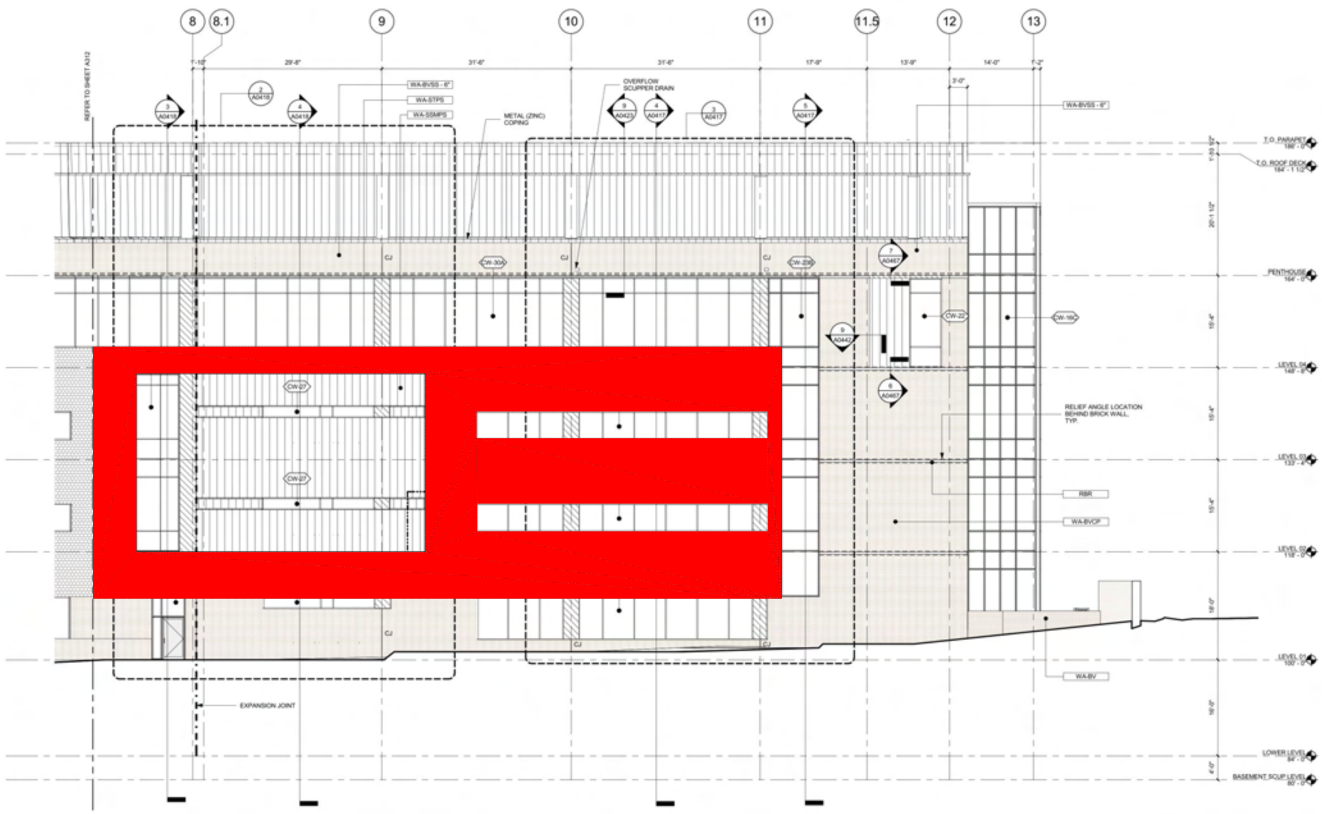
Drawing Title:
BUILDING ELEVATIONS

Project No.: 03312.00 Checked by: EMU

A0312

11/30/2012 1:03:54 PM

Total Area of Terracotta Wall Tiles = 2,939.5 SF



1 EAST BUILDING ELEVATION PART 2

1/8" = 1'-0"

EXTERIOR MATERIAL LEGEND

CLADDING ASSEMBLIES	
WA-BVSS	SEE WALL ASSEMBLY DETAIL 01/A400
WA-DSW	SEE WALL ASSEMBLY DETAIL 02/A400
WA-SSMPS	SEE WALL ASSEMBLY DETAIL 03/A400
WA-BVCP	SEE WALL ASSEMBLY DETAIL 04/A400
WA-STPS	SEE WALL ASSEMBLY DETAIL 05/A400
WA-SSMCP	SEE WALL ASSEMBLY DETAIL 06/A400
WA-SWP	SEE WALL ASSEMBLY DETAIL 07/A400
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WA-MPPS	SEE WALL ASSEMBLY DETAIL 09/A400
WA-BV	SEE WALL ASSEBMLY DETAIL 01/A401
WA-BVS	SEE WALL ASSEBMLY DETAIL 02/A401
WA-DS	SEE WALL ASSEMBLY DETAIL 03/A401
ROOFING ASSEMBLIES	
RA-VR	SEE ROOF ASSEMBLY DETAIL 04/A401
RA-EP	SEE ROOF ASSEMBLY DETAIL 05/A401
RA-SPC	SEE ROOF ASSEMBLY DETAIL 06/A401
RA-SP	SEE ROOF ASSEMBLY DETAIL 07/A401
ACCENT	
RBR	RECESSED BRICK REVEAL
AL-1	ALUMINUM COPING (ZINC COATED)
SSR-1	STAINLESS STEEL GUARDRAIL
SSR-2	STAINLESS STEEL HANDRAIL
FNC-1	DECORATIVE FENCING
ACM	ALUMINUM COMPOSITE METAL PANE
SOFFIT	
SA-LM	LINEAR METAL SOFFIT ASSEMBLY

- REFER TO SHEET A400 AND A401 FOR EXTERIOR WALL ASSEMBLIES AND ROOF ASSEMBLIES.

- REFER TO A1100 DRAWING SERIES FOR CURTAIN WALL, WINDOW, AND LOUVER SCHEDULE.

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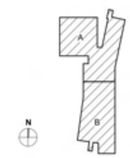


KEY PLAN

No.	Description	Date
-	Conformed Construction Documents	DEC 1, 2012

Drawing Title:

BUILDING ELEVATIONS

Project No.: 03312.00 Checked by: EMU

A0313

APPENDIX 3-A – KAWNEER NORTH AMERICA – 2500-PG UNITWALL TECHNICAL DATA

Features

- 2500 PG Unitwall™ is a pre-glazed unitized curtain wall
- 2-1/2" (63.5) sight lines and 7-1/2" (190.5) system depth
- Prefabricated and shipped knocked-down
- Screw spline shop assembly
- Shop glazed infill options:
  - 1" (25.4) insulating vision
  - 1/4" (6.3) or 1" (25.4) insulating spandrel
  - Spandrel back panning
- Four system types available:
  - 4-side captured
  - 4-side SSG
  - Vertical SSG
  - Horizontal SSG
- Adjustable slab edge, drop-on anchors
- No exterior applied joint seals
- Exterior re-glazing capability
- 90° inside and outside corners
- ±1/2" total allowable vertical movement per floor
- Fully tested including thermal and acoustical
- Permanodic® anodized finishes in 7 choices
- Painted finishes in standard and custom choices

Optional Features

- Dual finish capability
- Interior trim options
- Steel reinforcing
- Accepts GLASSvent™ with 4-side captured system type
- Available pressure equalization enhancement option

Product Applications

- Suitable for new construction or remodel
- Ideal for mid-rise and high-rise applications

For specific product applications,
Consult your Kawneer representative.

LAWS AND BUILDING AND SAFETY CODES GOVERNING THE DESIGN AND USE OF GLAZED ENTRANCE, WINDOW, AND CURTAIN WALL PRODUCTS VARY WIDELY. KAWNEER DOES NOT CONTROL THE SELECTION OF PRODUCT CONFIGURATIONS, OPERATING HARDWARE, OR GLAZING MATERIALS, AND ASSUMES NO RESPONSIBILITY THEREFOR.

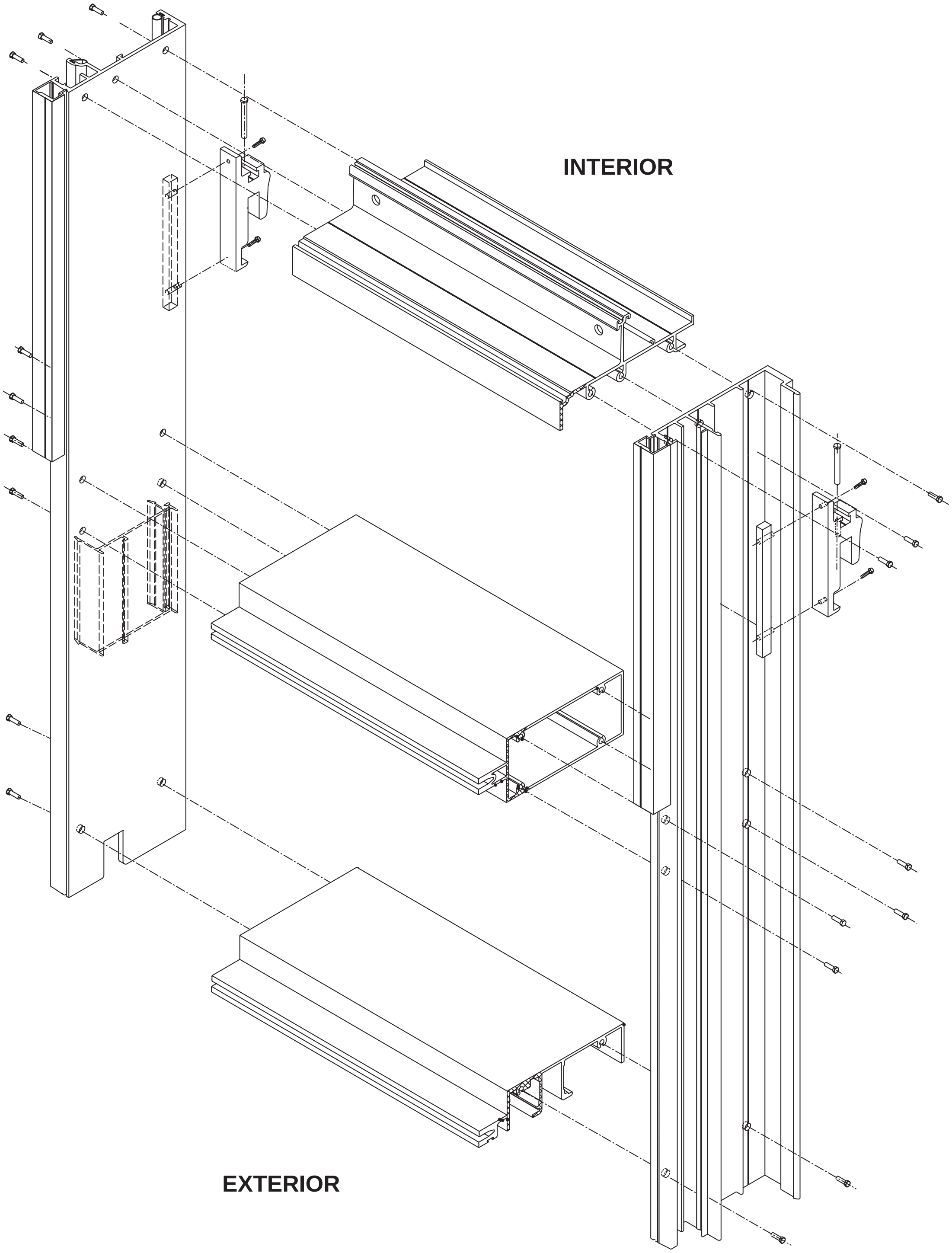
Metric (SI) conversion figures are included throughout these details for reference.
Numbers in parentheses (   ) are millimeters unless otherwise noted.

The following metric (SI) units are found in these details:

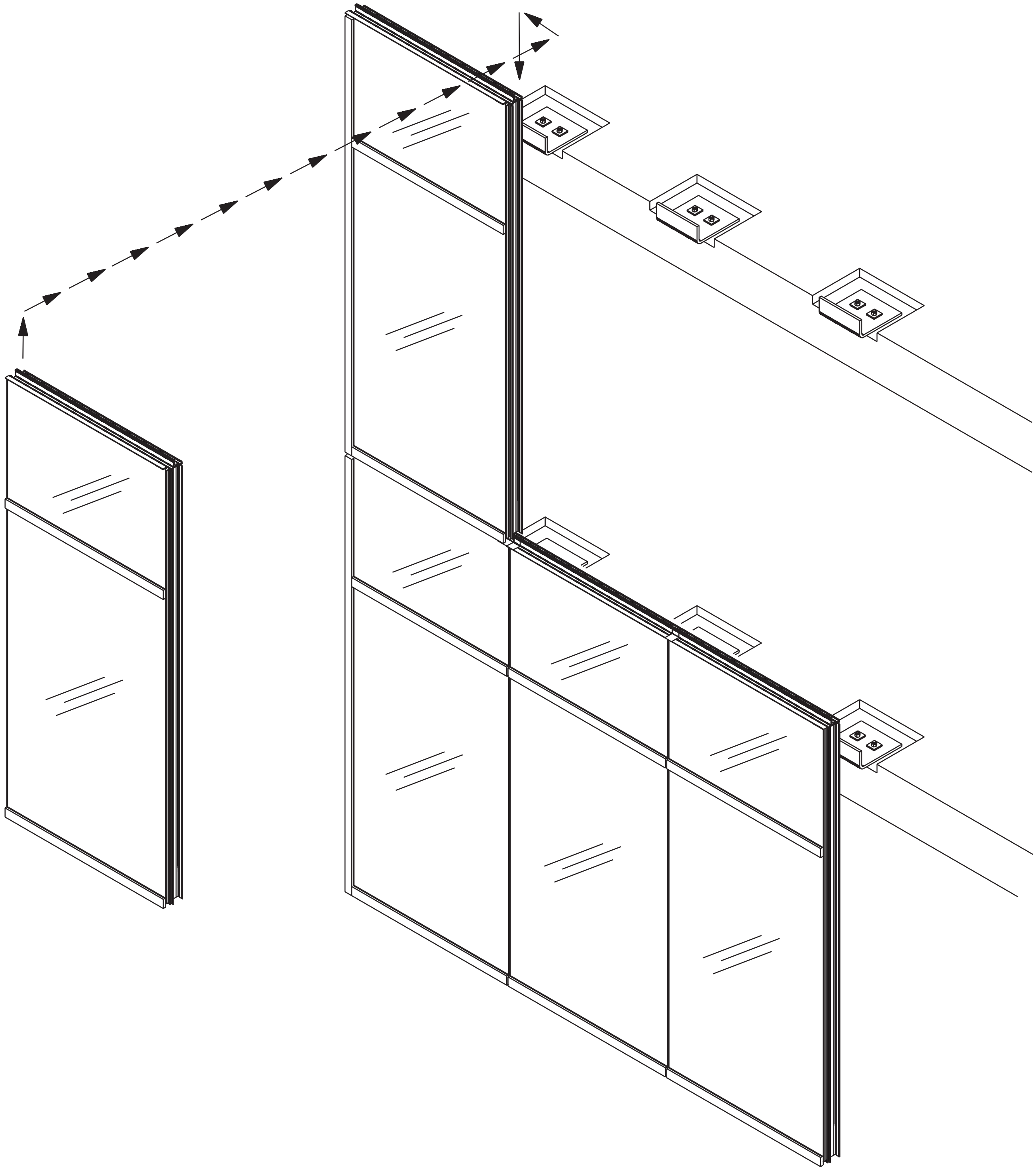
m – meter
cm – centimeter
mm – millimeter
s – second
Pa – pascal
MPa – megapascal

Kawneer reserves the right to change configurations without prior notice when deemed necessary for product improvement.

KAWNEER
AN ALCOA COMPANY

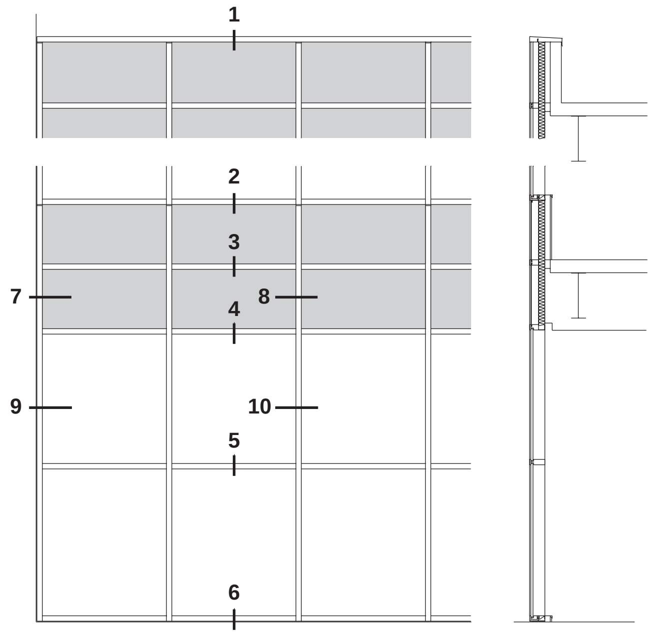


TYPICAL UNIT
(4-SIDE CAPTURED SYSTEM)

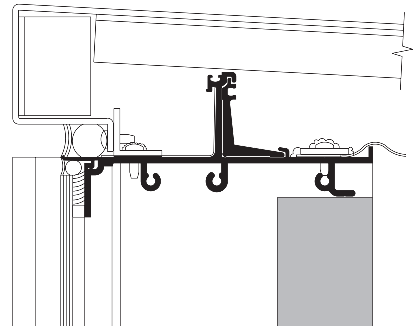


VERTICAL SSG SYSTEM SHOWN

SCALE: 3" = 1'-0"



TYPICAL ELEVATION
(4-SIDE CAPTURED SYSTEM)



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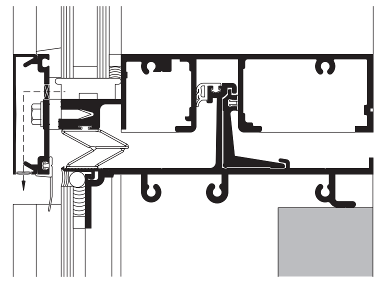
HEAD



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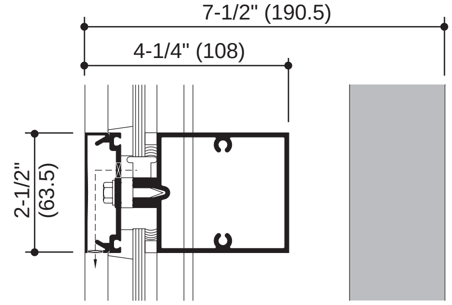
EXPANSION HORIZONTAL



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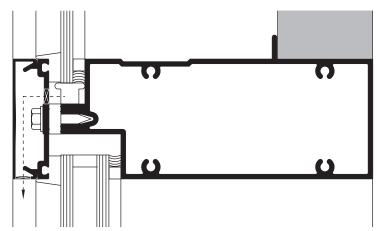
SHALLOW HORIZONTAL



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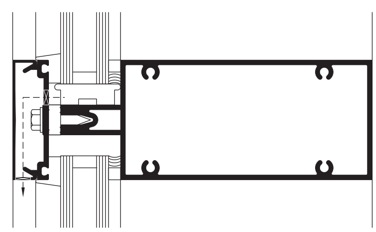

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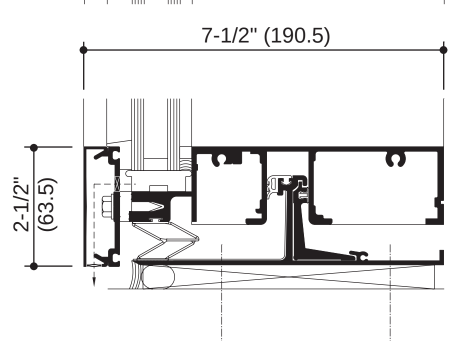

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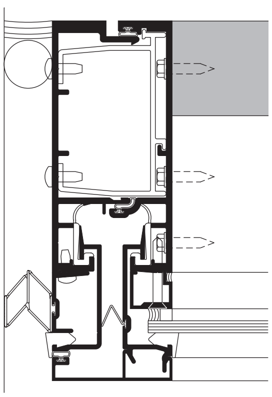
SILL



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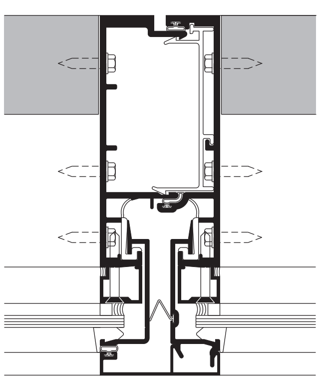
JAMB
1/4" INFILL



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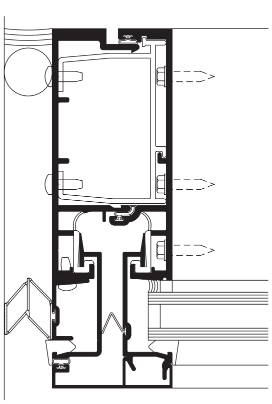
MULLION
1/4" INFILL



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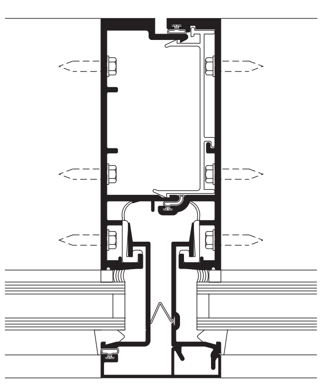

10
MULLION

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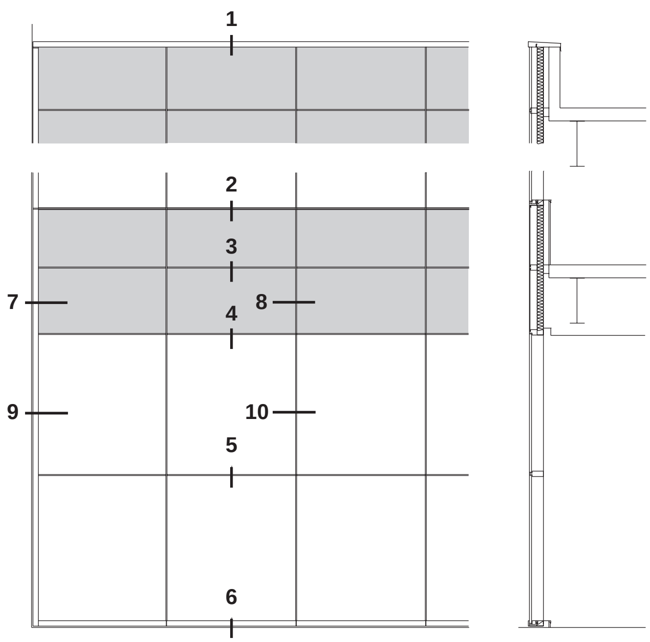
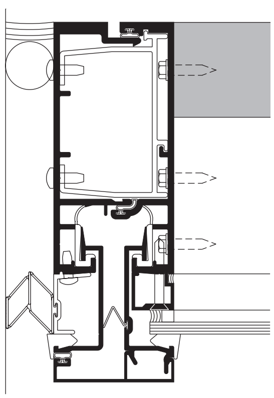


TYPICAL ELEVATION
(4-SIDE SSG SYSTEM)



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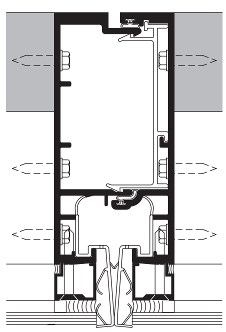

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SSG MULLION
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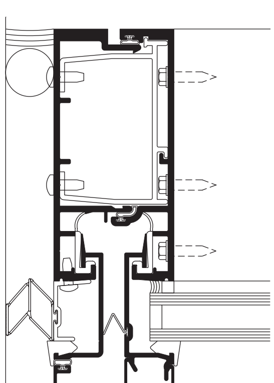

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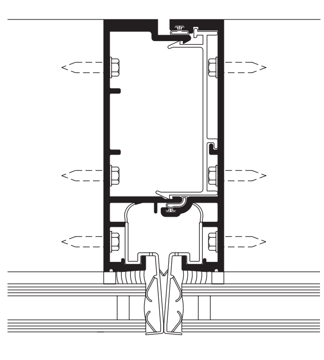

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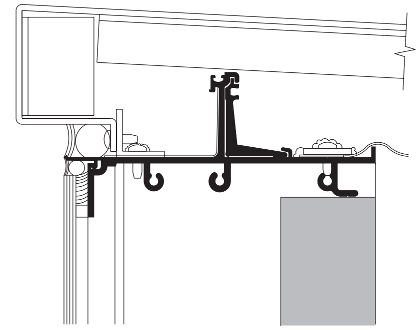

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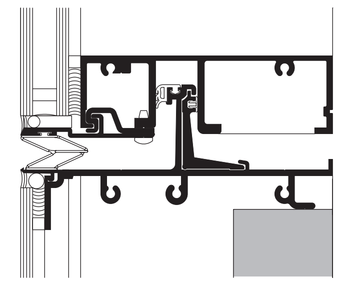

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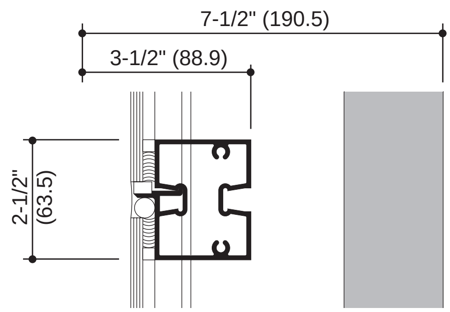
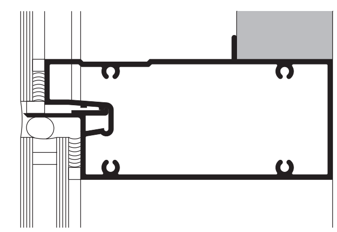
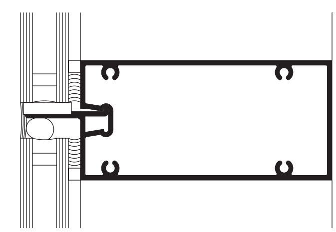
EXPANSION
SSG HORIZONTAL



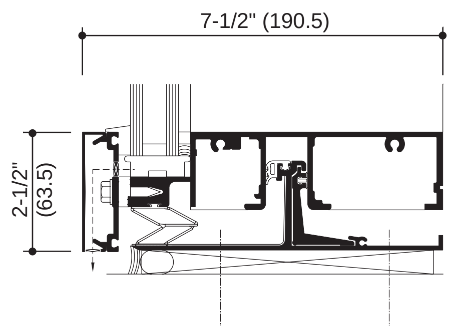
3
SHALLOW
SSG
HORIZONTAL



4
1/4" OVER 1"
SSG HORIZONTAL

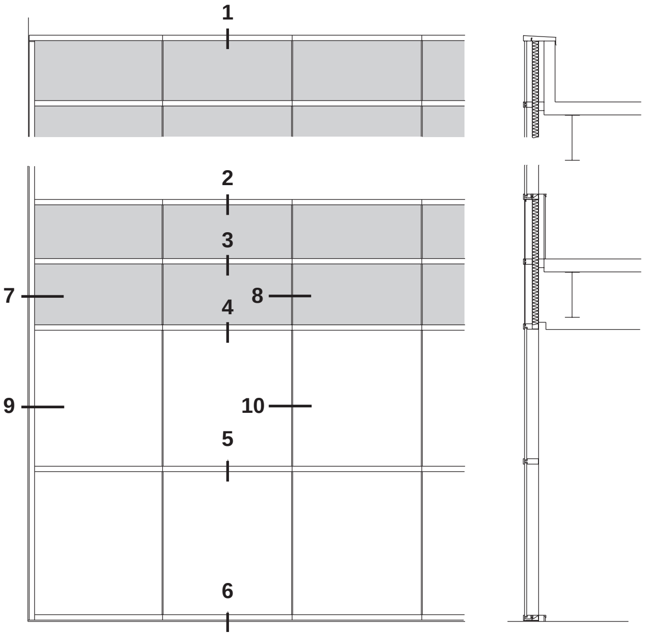


5
1" OVER 1"
SSG HORIZONTAL

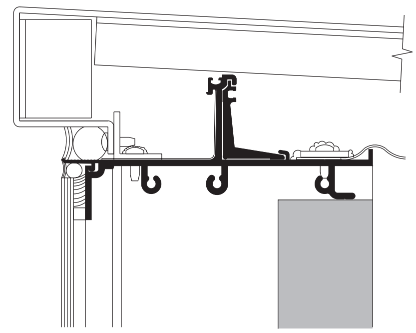


6
SILL

SCALE: 3" = 1'-0"



TYPICAL ELEVATION
(VERTICAL SSG SYSTEM)



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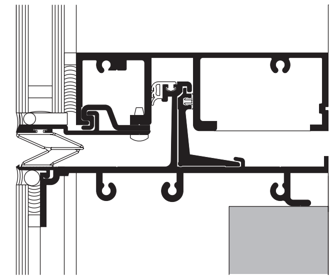

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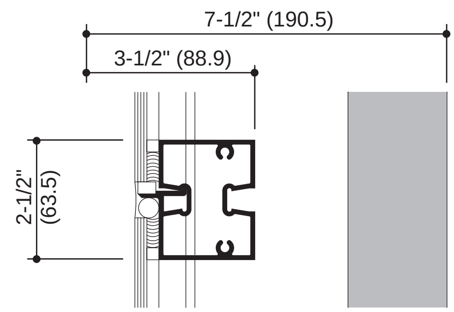

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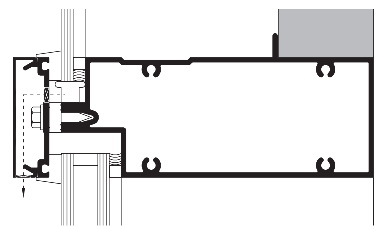

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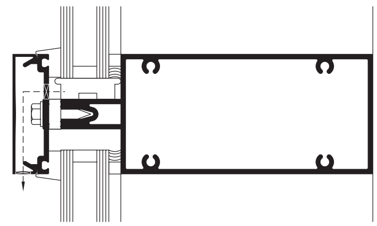

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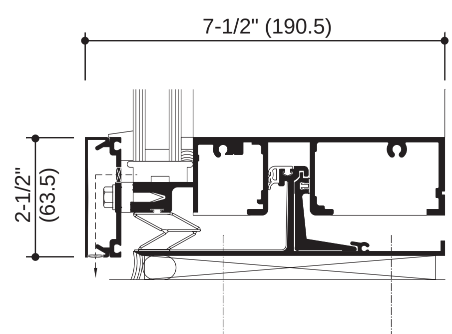
1" OVER 1" HORIZONTAL



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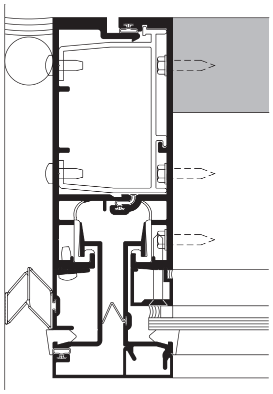
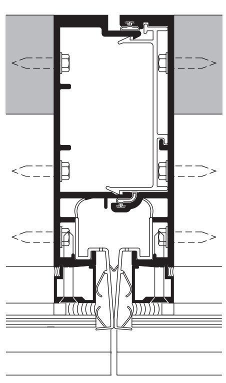


7
JAMB
1/4" INFILL



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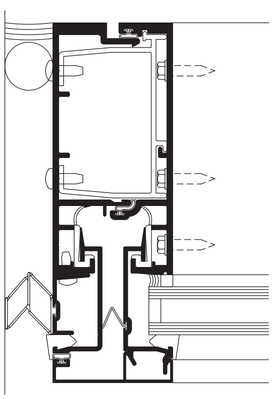
SSG MULLION
1/4" INFILL



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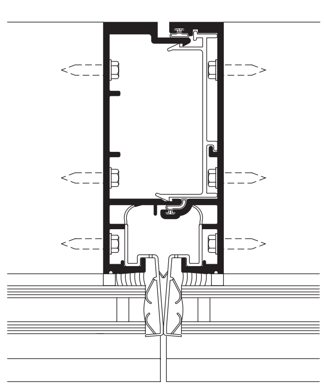
JAMB

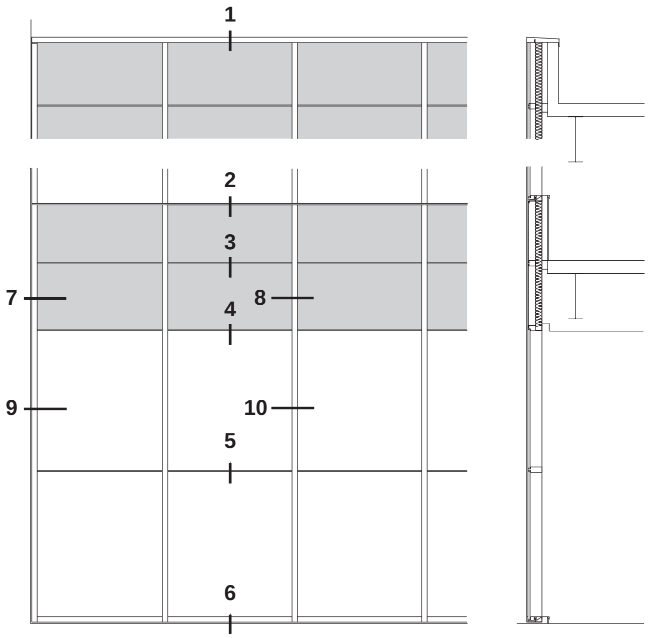


10
SSG MULLION

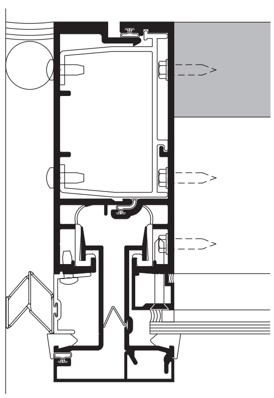
Laws and building and safety codes governing the design and use of glazed entrance, window, and curtain wall products vary widely. Kawneer does not control the selection of product configurations, operating hardware, or glazing materials, and assumes no responsibility therefor.

Kawneer reserves the right to change configuration without prior notice when deemed necessary for product improvement.

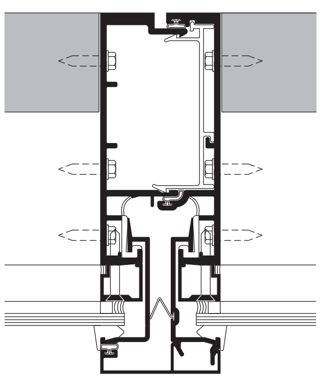
SCALE: 3" = 1'-0"



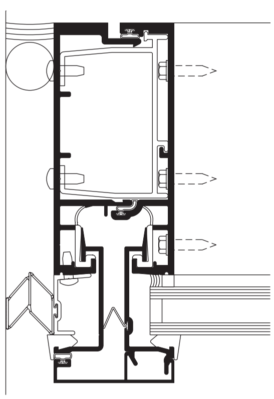
TYPICAL ELEVATION
(HORIZONTAL SSG SYSTEM)



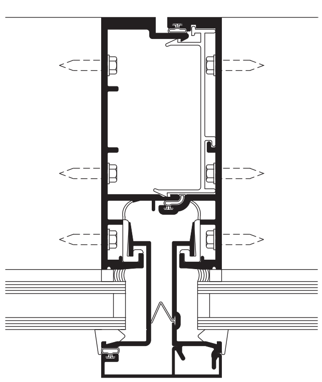
7
JAMB
1/4" INFILL



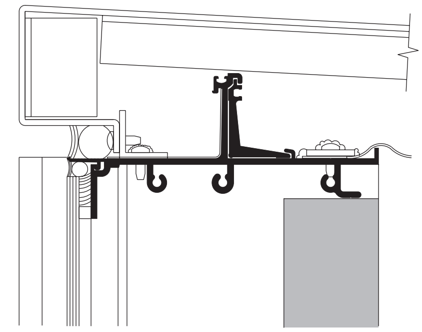
8
MULLION
1/4" INFILL



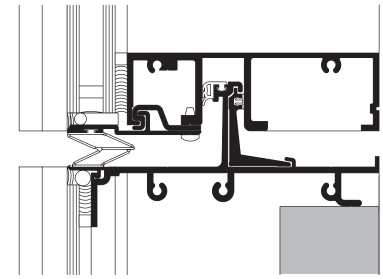
9
JAMB



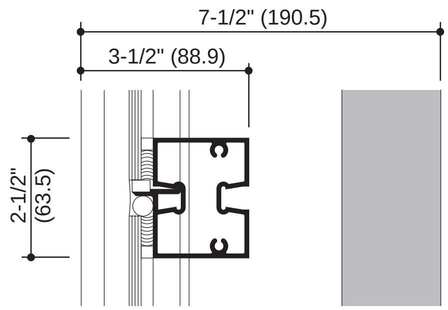
10
MULLION



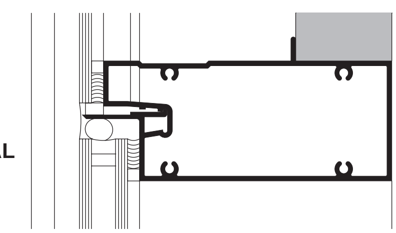
1
HEAD



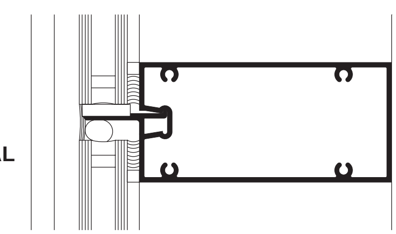
2
EXPANSION
SSG HORIZONTAL



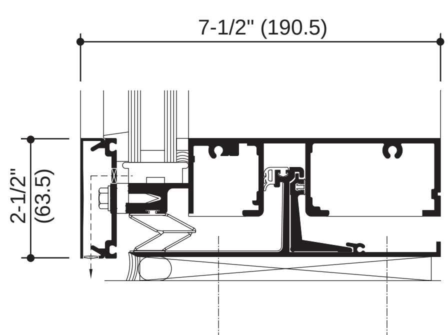
3
SHALLOW
SSG
HORIZONTAL



4
1/4" OVER 1"
SSG HORIZONTAL



5
1" OVER 1"
SSG HORIZONTAL



6
SILL

Laws and building and safety codes governing the design and use of glazed entrance, window, and curtain wall products vary widely. Kawneer does not control the selection of product configurations, operating hardware, or glazing materials, and assumes no responsibility therefor.

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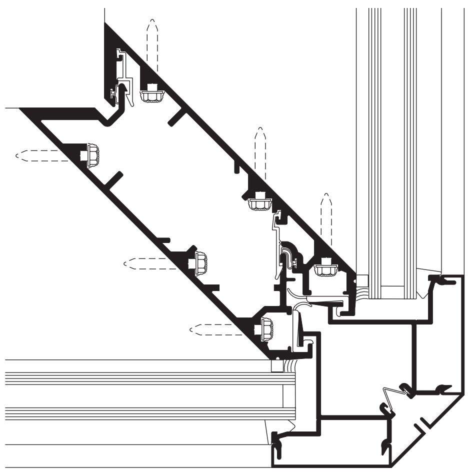
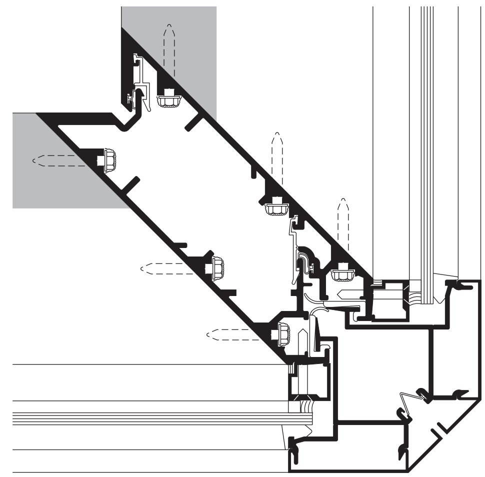
KAWNEER
AN ALCOA COMPANY

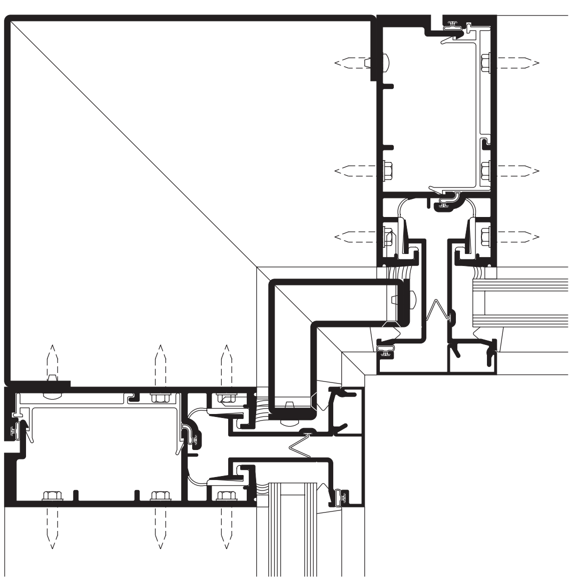
SCALE: 3" = 1'-0"



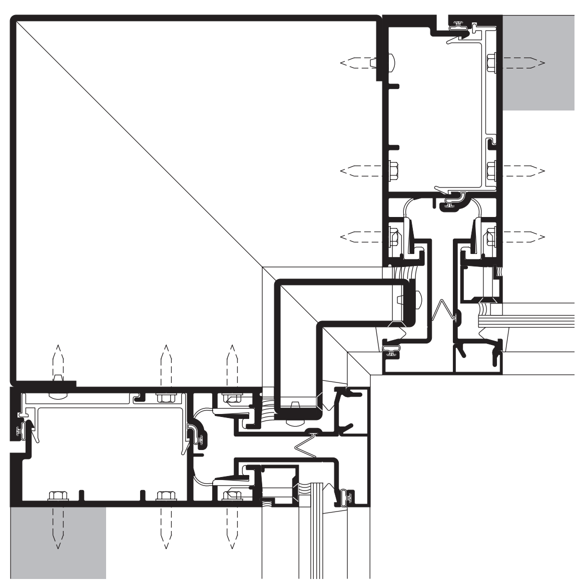
OUTSIDE CORNER
(1" Infill)



OUTSIDE CORNER
(1/4" Infill)



INSIDE CORNER
(1" Infill)

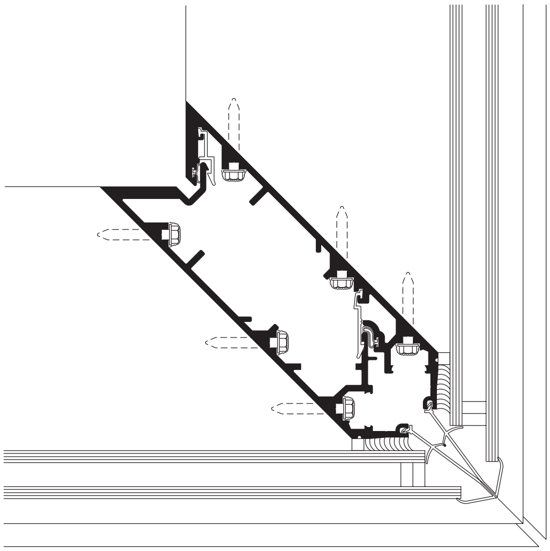


INSIDE CORNER
(1/4" Infill)

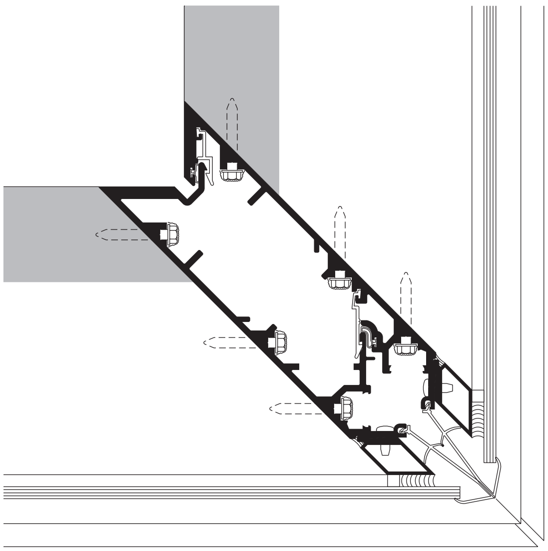
Laws and building and safety codes governing the design and use of glazed entrance, window, and curtain wall products vary widely. Kawneer does not control the selection of product configurations, operating hardware, or glazing materials, and assumes no responsibility therefor.

Kawneer reserves the right to change configuration without prior notice when deemed necessary for product improvement.

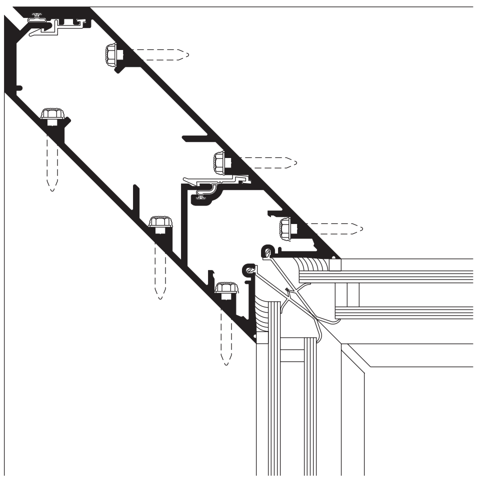
SCALE: 3" = 1'-0"



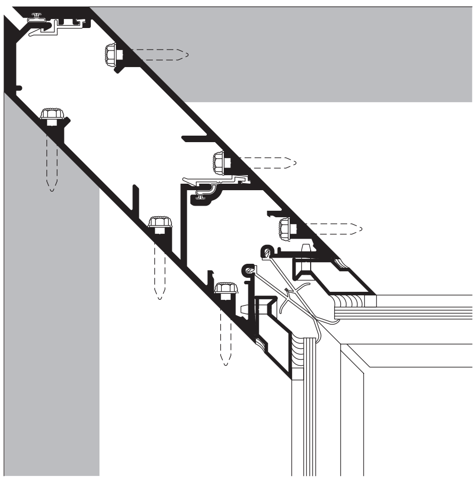
OUTSIDE CORNER
(1" Infill)



OUTSIDE CORNER
(1/4" Infill)



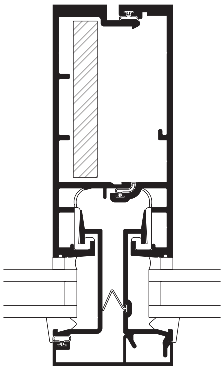
INSIDE CORNER
(1" Infill)



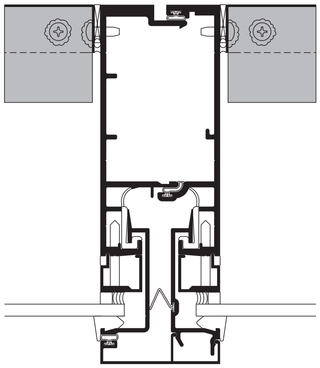
INSIDE CORNER
(1/4" Infill)

SCALE: 3" = 1'-0"

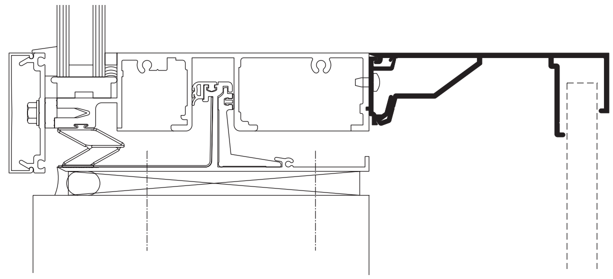
STEEL REINFORCING



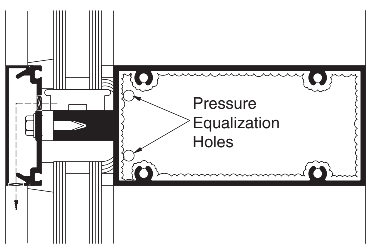
BACK PAN OPTION



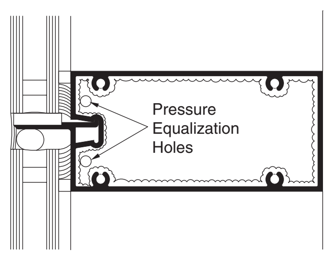
INTERIOR TRIM AT SILL (Head and Jamb similar)



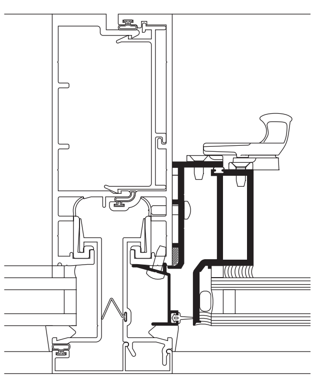
PRESSURE EQUALIZATION ENHANCEMENT OPTION (Captured System)

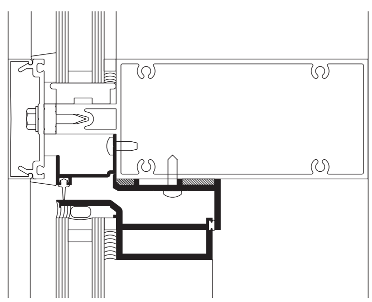


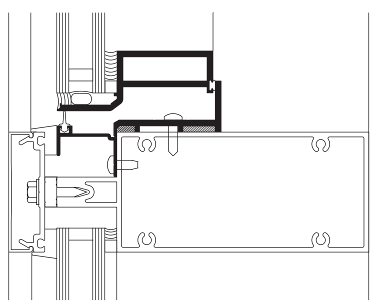
PRESSURE EQUALIZATION ENHANCEMENT OPTION (SSG System)

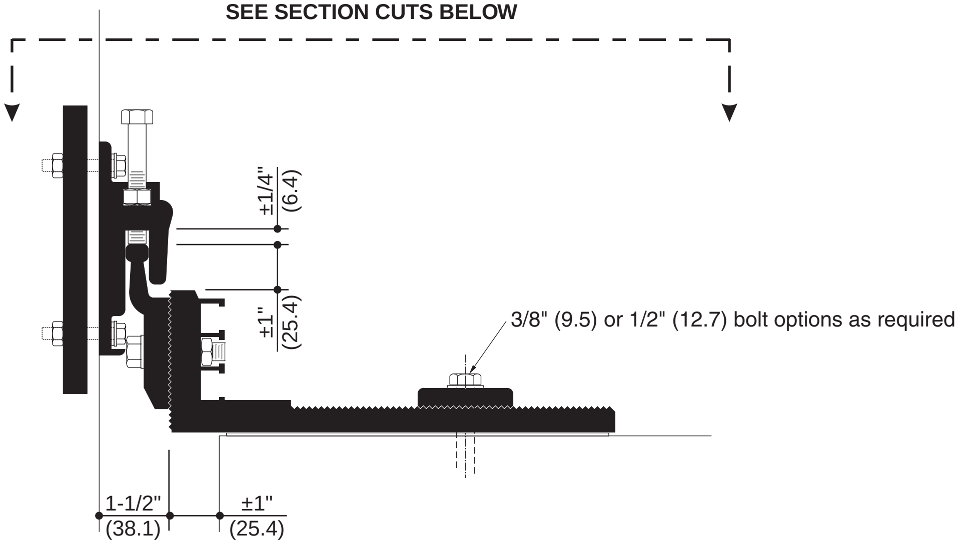


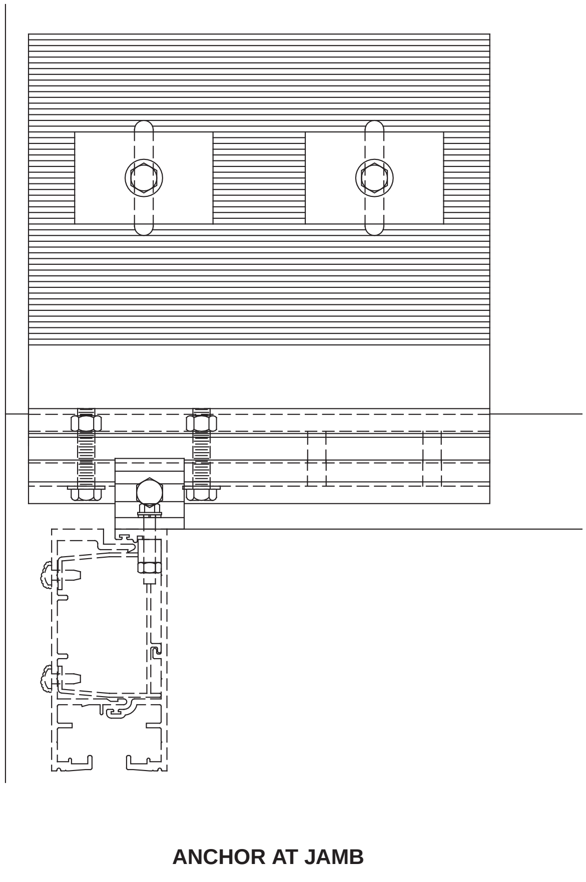
Curtain Wall GLASSvent™



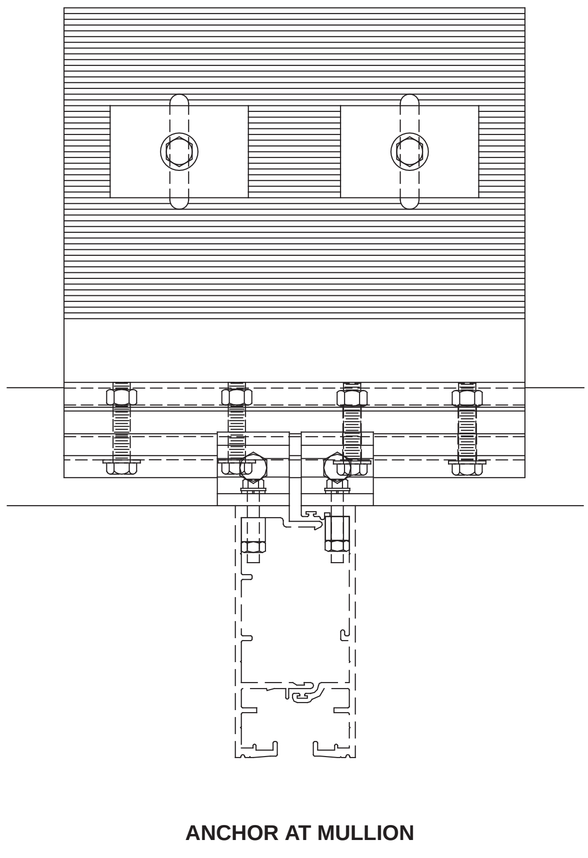








ANCHOR AT JAMB



ANCHOR AT MULLION

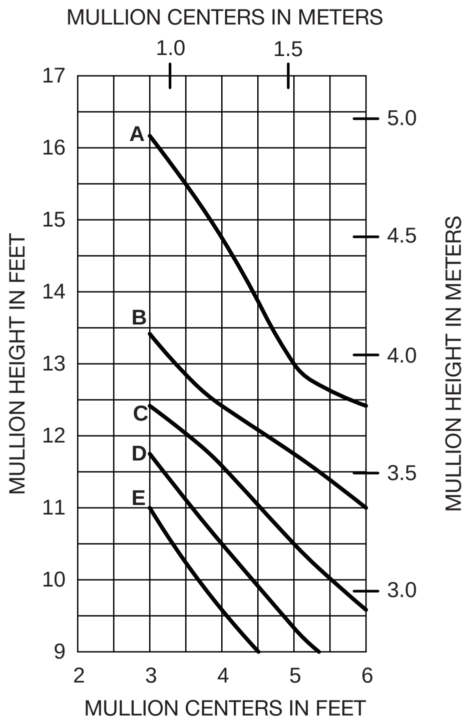
WIND LOAD CHARTS

Mullions are designed for deflection limitations in accordance with AAMA TIR-A11 of L/175 up to 13'-6" and L/240 +1/4" above 13'-6". These curves are for mullions WITH HORIZONTALS and are based on engineering calculations for stress and deflection. Allowable wind load stress for ALUMINUM Mullion 425001 = 12,000 psi (83 MPa),
ALUMINUM Mullion 425002 = 10100 psi (70 MPa), STEEL 21,600 psi (149 MPa). Charted curves, in all cases are for the limiting value. A 4/3 increase in allowable stress has not been used to develop these curves. Charts based on lateral support no more than 30" apart. Lateral support can be horizontal mullions, anchors or lateral buckling clips.
For special situations not covered by these curves, contact your Kawneer representative for additional information.

When mullion is used in a SSG application, curves become straight due to structural silicone limits, represented by dashed lines on chart. *Charts are for typical spans, not beginning or ending spans. C/L of stack horizontal to be at noted stool height above C/L of anchor.

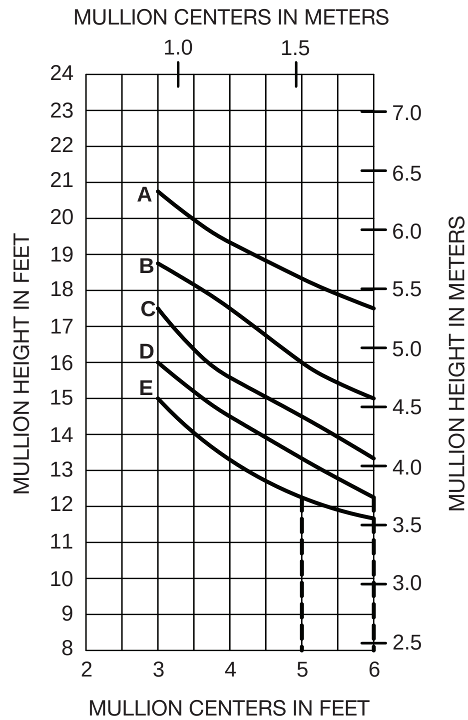
- - - - - - - SSG Structural Silicone Limit - Silicone joint contact is .625".

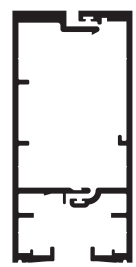
SINGLE SPAN



A = 20 PSF (960)
B = 30 PSF (1440)
C = 40 PSF (1920)
D = 50 PSF (2400)
E = 60 PSF (2880)

***MULTI-SPAN**
24" STOOL HEIGHT

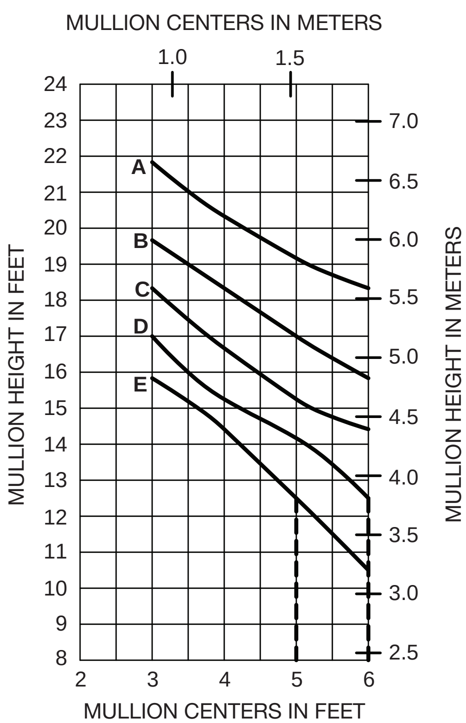




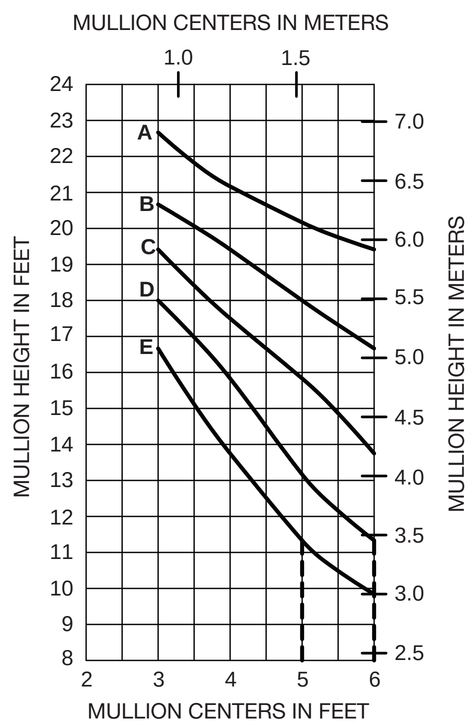
425-001 **425-002**

I = 8.797 (366.16 x 10^4)
S = 3.120 (51.13 x 10^3)

***MULTI-SPAN**
30" STOOL HEIGHT



***MULTI-SPAN**
36" STOOL HEIGHT



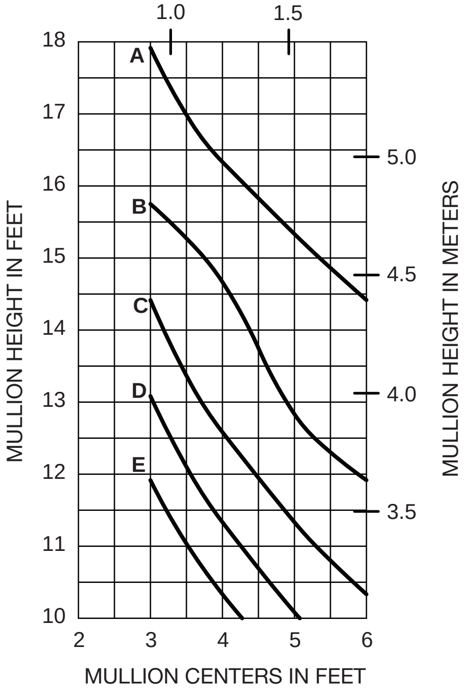
When mullion is used in a SSG application, curves become straight due to structural silicone limits, represented by dashed lines on chart. *Charts are for typical spans, not beginning or ending spans. C/L of stack horizontal to be at noted stool height above C/L of anchor.

———— Steel bar running from 6" above sill stack to 6" below anchor.

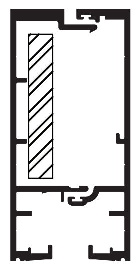
- - - - - - 1/2" steel bar as shown running from 6" above stack to 6" below stack above (Unit height - 12").

— — — — SSG Structural Silicone Limit - Silicone joint contact is .625".

SINGLE SPAN
with 1/2" x 3" Steel Bar



A = 20 PSF (960)
B = 30 PSF (1440)
C = 40 PSF (1920)
D = 50 PSF (2400)
E = 60 PSF (2880)



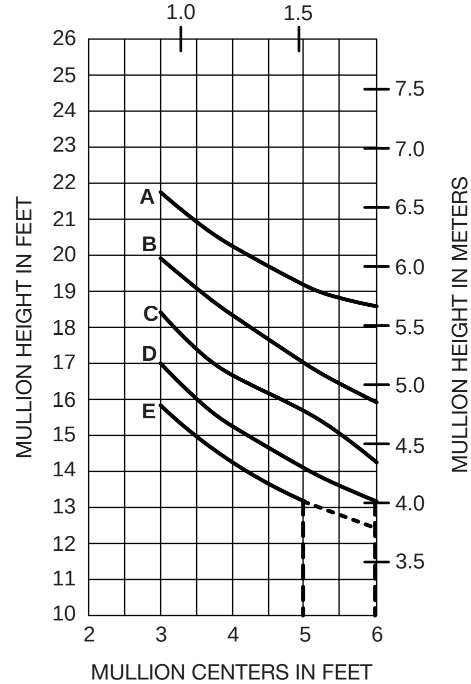
425-001 **425-002**

WITH 1/2" X 3" STEEL BAR

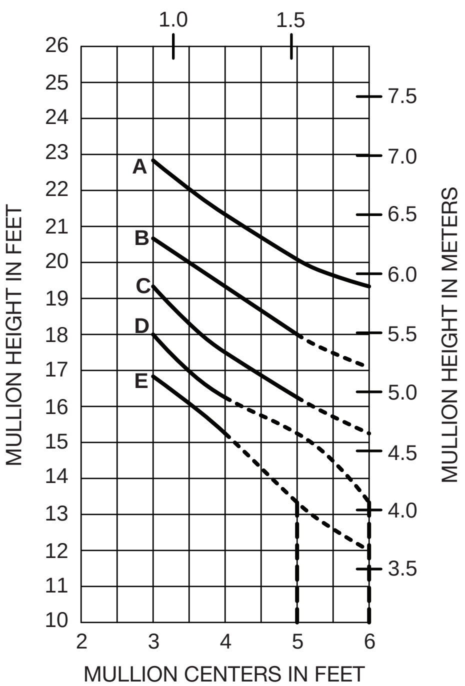
(Aluminum)
I = 8.797 (366.16 x 10^4)
S = 3.120 (51.13 x 10^3)

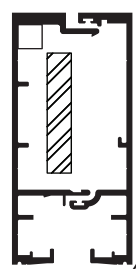
(Steel)
I = 3.263 (135.82 x 10^4)
S = 0.750 (12.29 x 10^3)

***MULTI-SPAN 24" STOOL HEIGHT**
with 1/2" x 2-1/2" Steel Bar



***MULTI-SPAN 30" STOOL HEIGHT**
with 1/2" x 2-1/2" Steel Bar





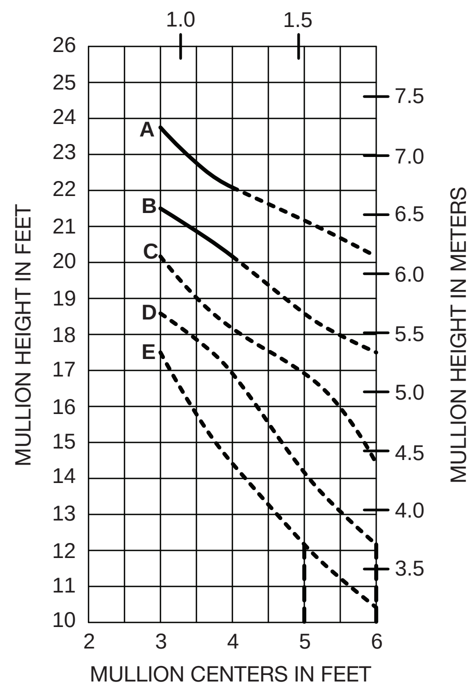
425-001 **425-002**

WITH 1/2" X 2-1/2" STEEL BAR

(Aluminum)
I = 8.797 (366.16 x 10^4)
S = 3.120 (51.13 x 10^3)

(Steel)
I = 1.888 (78.58 x 10^4)
S = 0.521 (8.54 x 10^3)

***MULTI-SPAN 36" STOOL HEIGHT**
with 1/2" x 2-1/2" Steel Bar

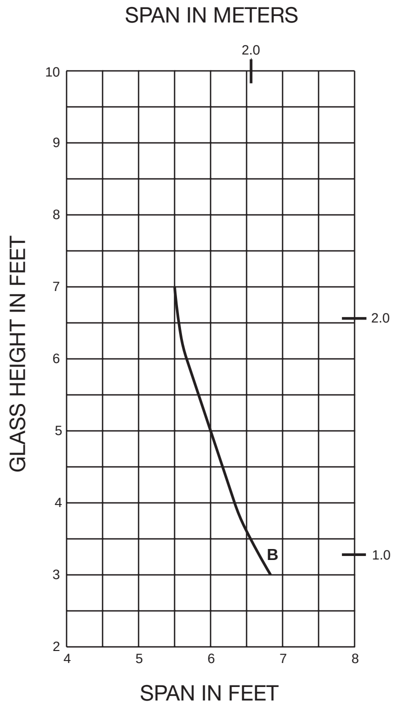


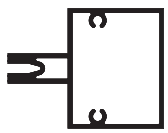
DEADLOAD CHARTS

Horizontal or deadload limitations are based upon 1/8" (3.2), maximum allowable deflection at the center of an intermediate horizontal member. The accompanying charts are calculated for 1" (25.4) thick insulating glass or 1/4" (6.35) thick glass supported on two setting blocks placed at the loading points shown. Maximum allowable stress for aluminum is 15,152 PSI (104MPa).

A = 1/4" GLASS (1/4 POINT LOADING)
B = 1" GLASS (1/4 POINT LOADING)

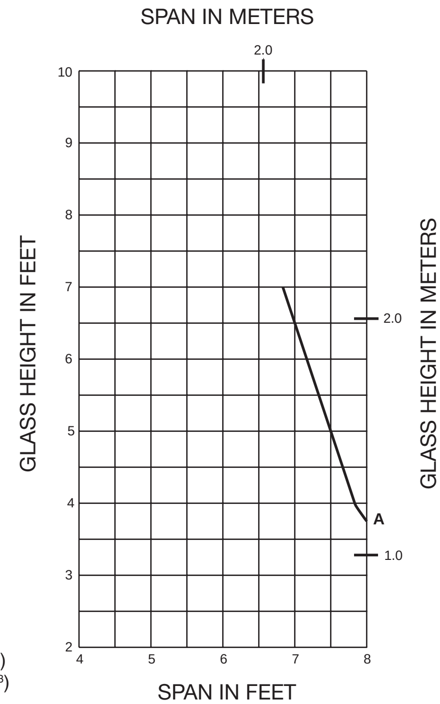
425-005

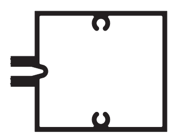




425-005
I = 0.885 (36.84 x 10^4)
S = 0.708 (11.60 x 10^3)

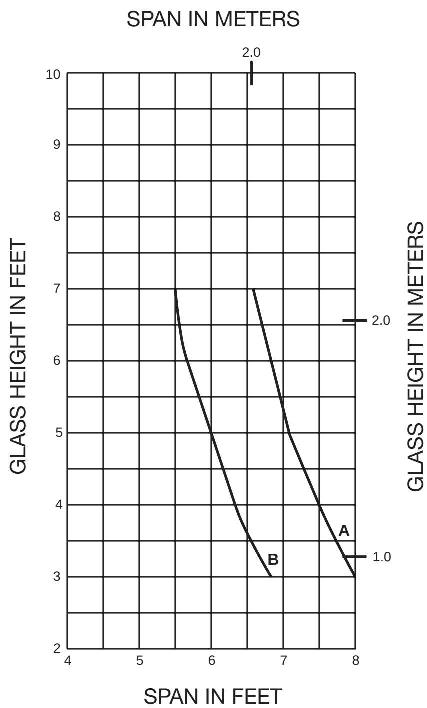
425-006

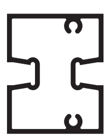




425-006
I = 1.059 (44.08 x 10^4)
S = 0.847 (13.88 x 10^3)

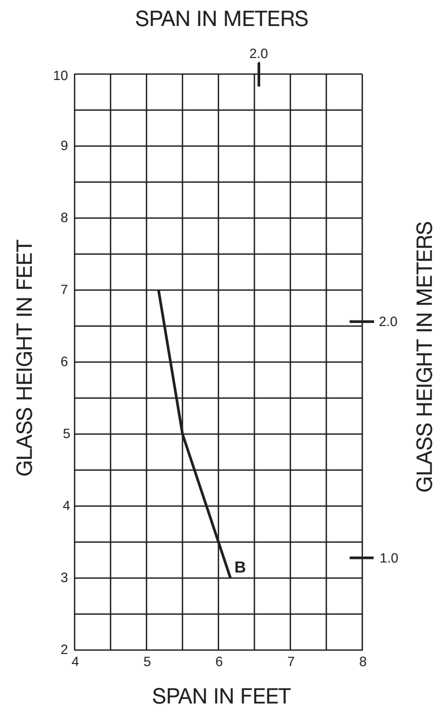
425-007

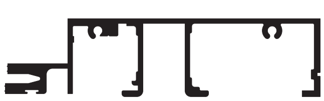




425-007
I = 0.868 (36.13 x 10^4)
S = 0.695 (11.39 x 10^3)

425-008





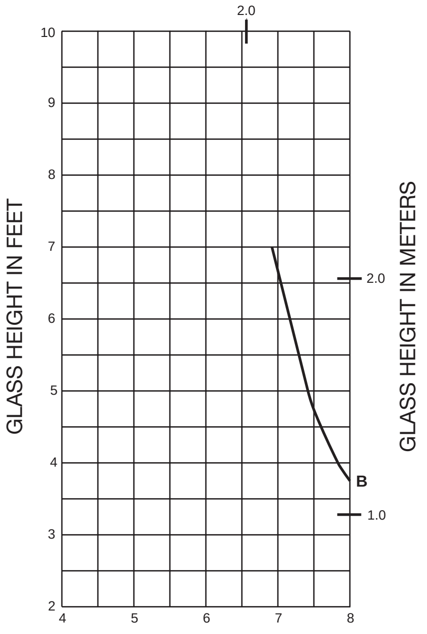
425-008

I = 0.656 (27.30 x 10^4)
S = 0.702 (11.50 x 10^3)

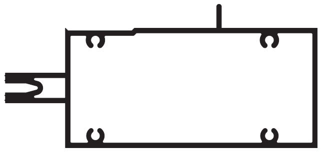
A = 1/4" GLASS (1/4 POINT LOADING)
B = 1" GLASS (1/4 POINT LOADING)

425-011

SPAN IN METERS



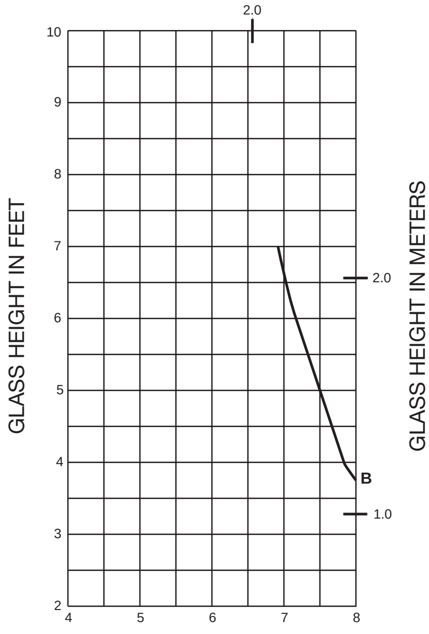
SPAN IN FEET



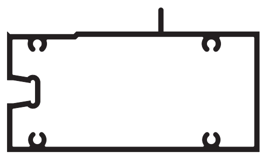
425-011
I = 2.090 (87.00 x 10^4)
S = 1.213 (19.88 x 10^3)

425-012

SPAN IN METERS



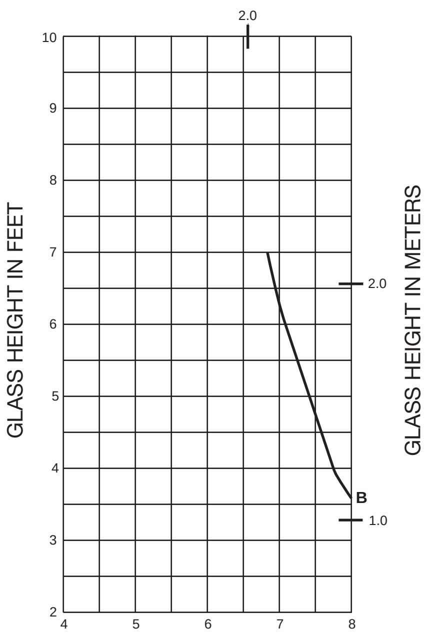
SPAN IN FEET



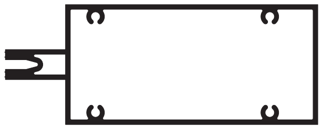
425-012
I = 2.078 (86.50 x 10^4)
S = 1.208 (19.8 x 10^3)

425-013

SPAN IN METERS



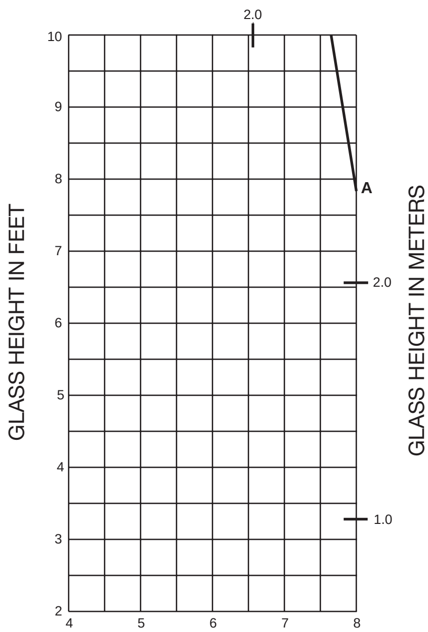
SPAN IN FEET



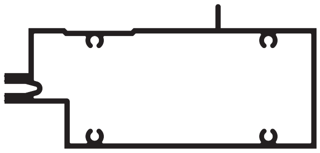
425-013
I = 2.008 (83.58 x 10^4)
S = 1.607 (26.34 x 10^3)

425-014

SPAN IN METERS



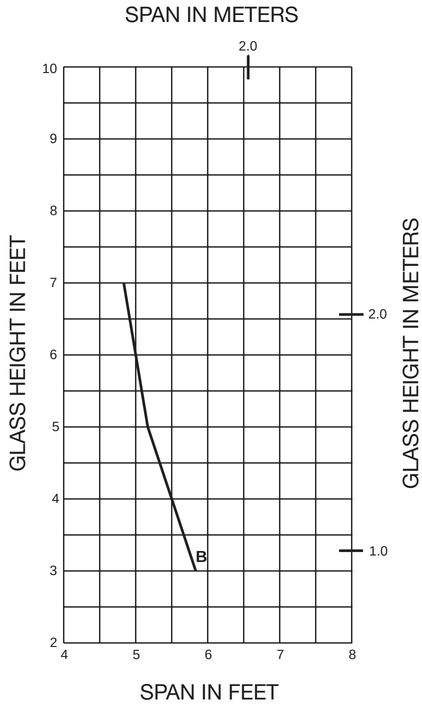
SPAN IN FEET

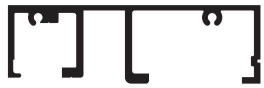


425-014
I = 2.182 (90.83 x 10^4)
S = 1.288 (21.11 x 10^3)

A = 1/4" GLASS (1/4 POINT LOADING)
B = 1" GLASS (1/4 POINT LOADING)

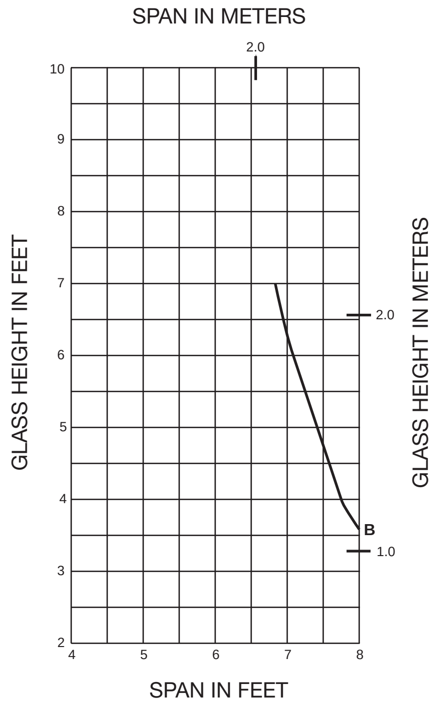
425-024





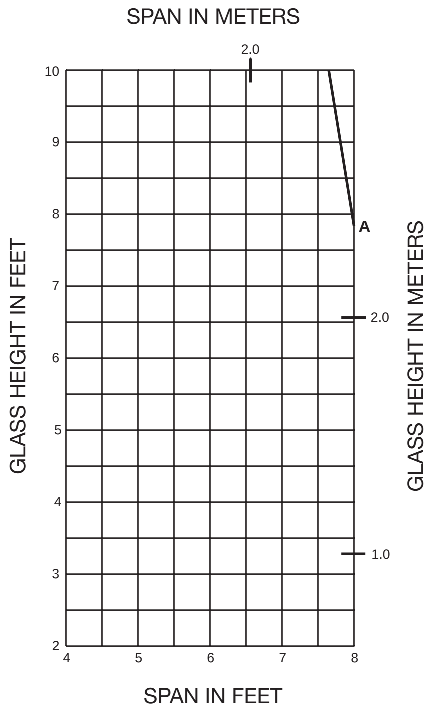
425-024
I = 0.508 (21.15 x 10^4)
S = 0.480 (7.87 x 10^3)

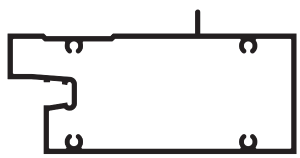
425-027



425-027
I = 1.977 (83.08 x 10^4)
S = 1.597 (26.17 x 10^3)

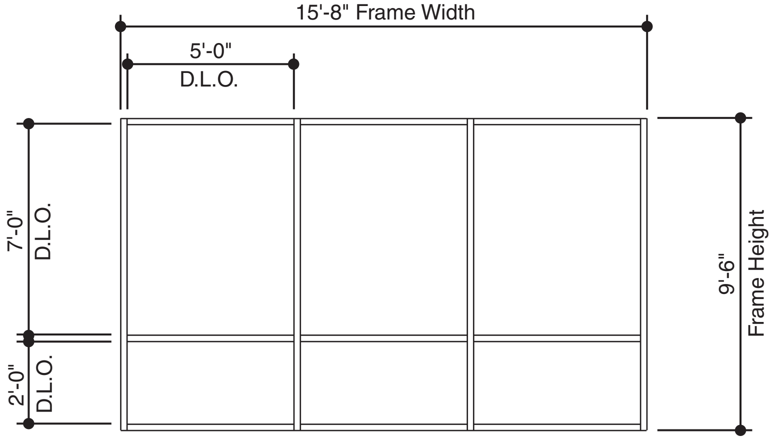
425-030





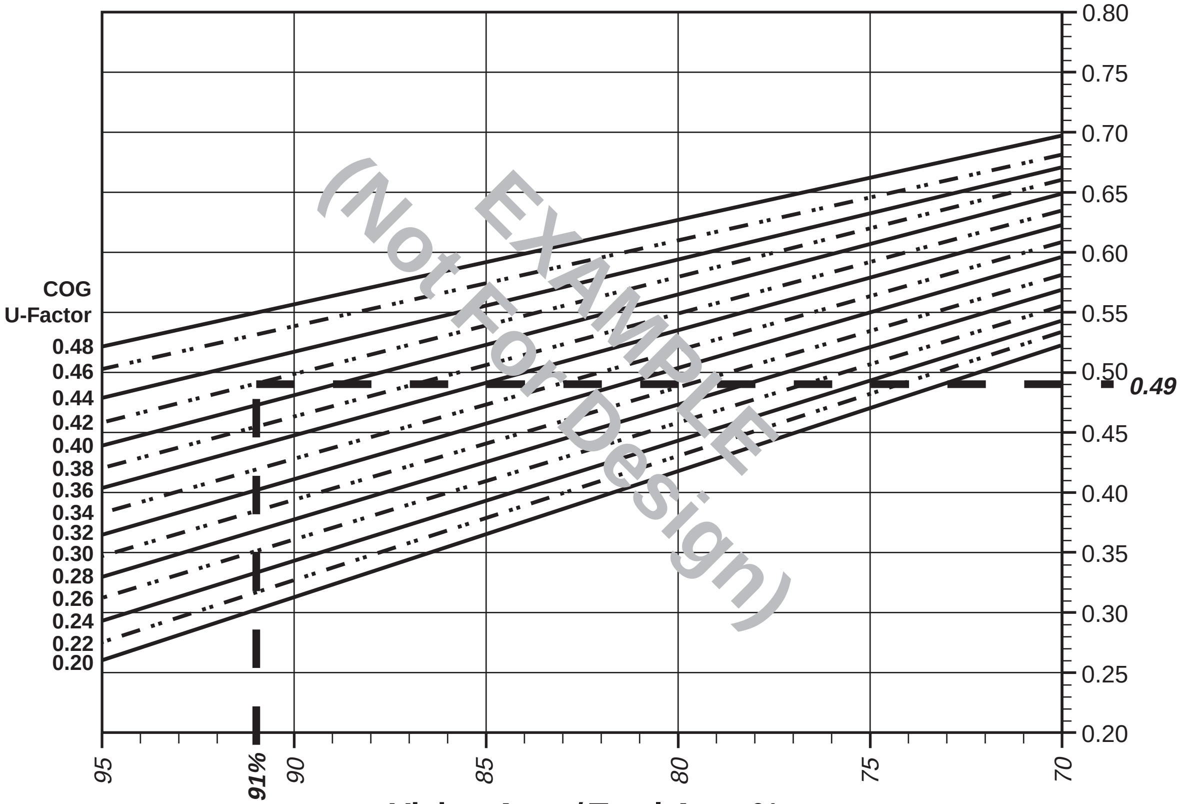
425-030
I = 2.179 (90.70 x 10^4)
S = 1.307 (21.42 x 10^3)

Project Specific U-Factor
Example Calculation



Example Glass U-Factor	= 0.42 Btu/hr • ft² • °F
Total Daylight Opening	= 3(5' x 7') + 3(5' x 2') = 135 ft²
Total Projected Area	= 15'-8" x 9'-6" = 148.83 ft²
Percent of Glass	= (Total Daylight Opening ÷ Total Projected Area) = (135 ÷ 148.83)100 = 91%

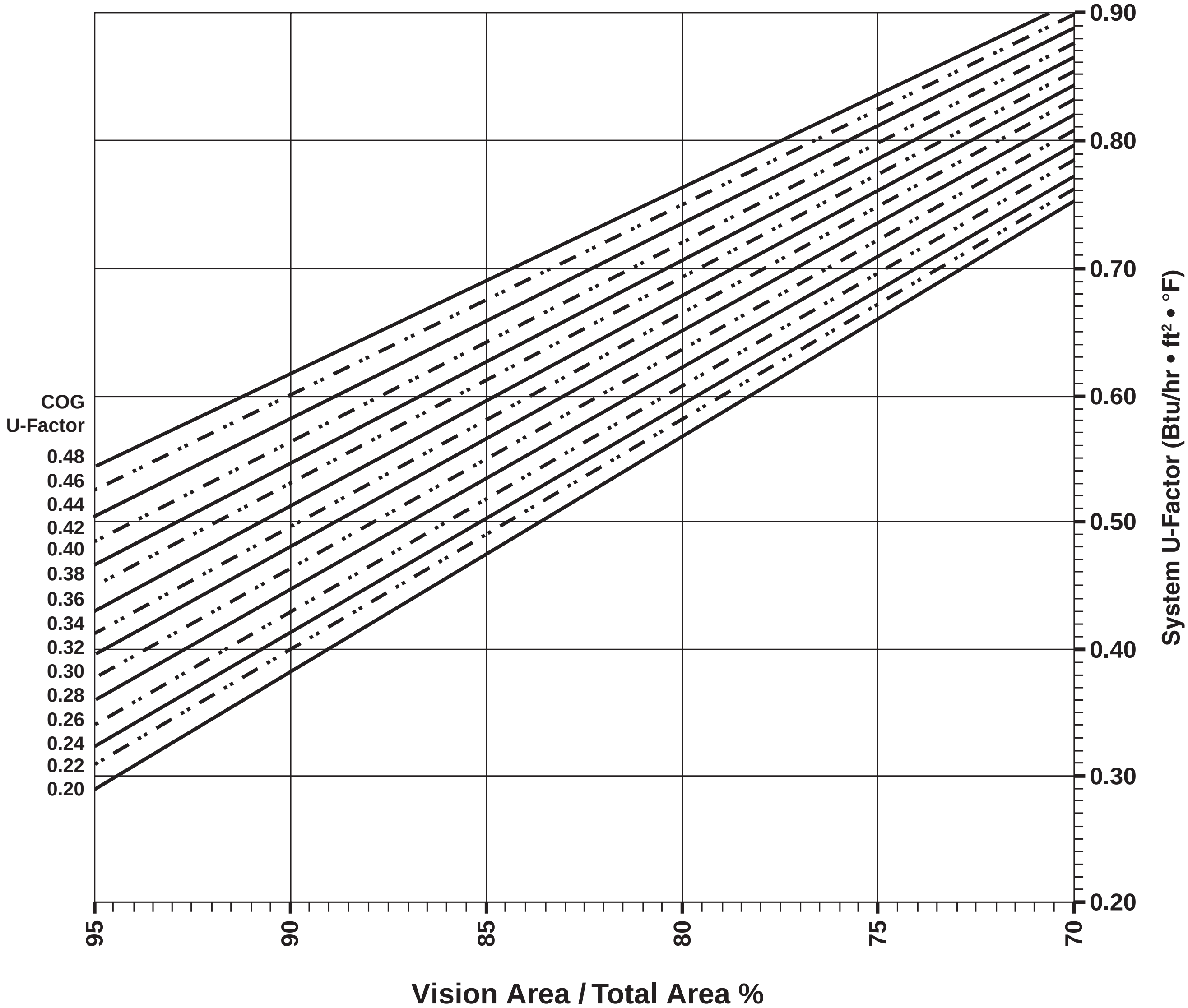
System U-Factor vs Percent of Glass Area



Based on 91% glass and center of glass U-Factor of 0.42
System U-Factor is equal to 0.49 Btu/hr • ft² • °F

4 Side Captured

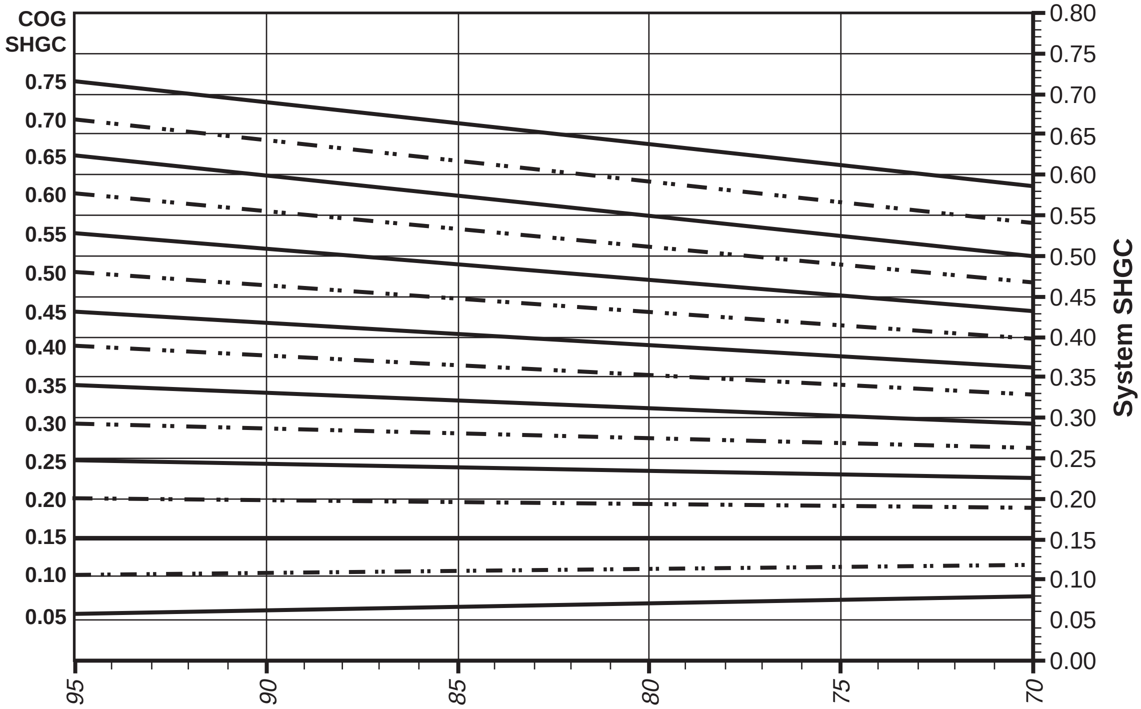
System U-Factor vs Percent of Glass Area



Notes for System U-Factor, SHGC and VT charts:
For glass values that are not listed, linear interpolation is permitted.
Glass properties are based on center of glass values and are obtained from your glass supplier.

4 Side Captured

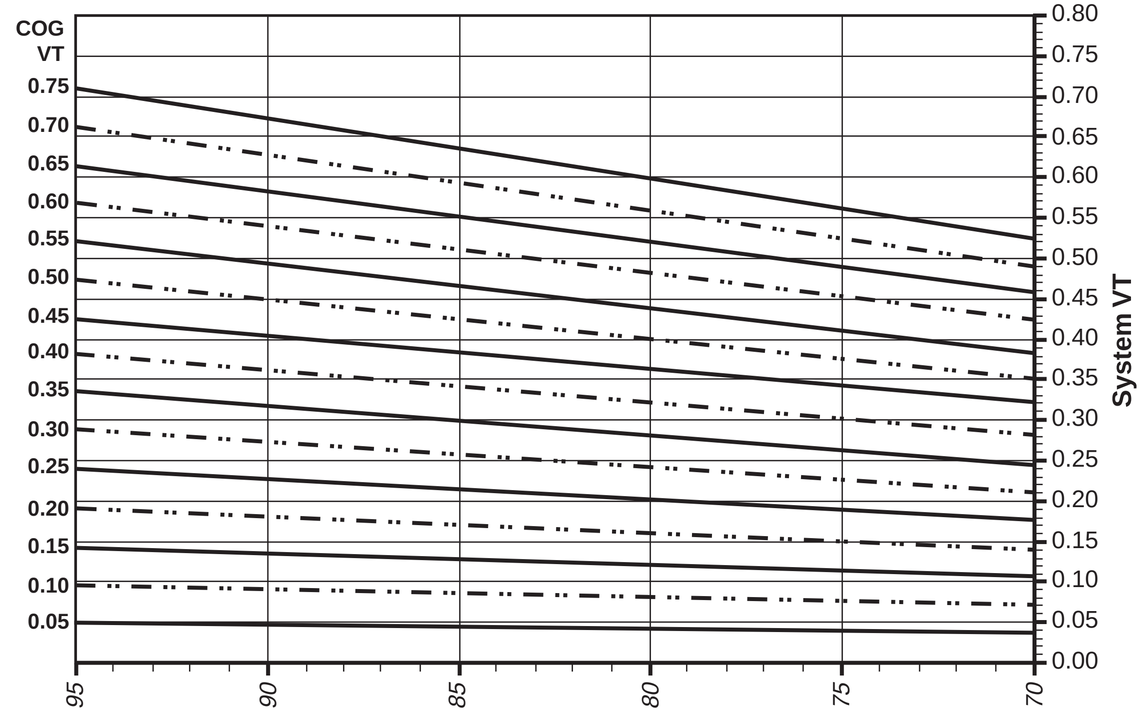
System Solar Heat Gain Coefficient (SHGC) vs Percent of Vision Area



Charts are generated per AAMA 507

4 Side Captured

Visible Transmittance (VT) vs Percent of Vision Area



Laws and building and safety codes governing the design and use of glazed entrance, window, and curtain wall products vary widely. Kawneer does not control the selection of product configurations, operating hardware, or glazing materials, and assumes no responsibility therefor.

Kawneer reserves the right to change configuration without prior notice when deemed necessary for product improvement.

4 Side Captured

Thermal Transmittance[1] (BTU/hr • ft ^{2} • °F)

Glass U-Factor [3]	Overall U-Factor [4]
0.48	0.65
0.46	0.63
0.44	0.62
0.42	0.60
0.40	0.59
0.38	0.57
0.36	0.55
0.34	0.54
0.32	0.52
0.30	0.51
0.28	0.49
0.26	0.48
0.24	0.46
0.22	0.44
0.20	0.43

SHGC Matrix [2]

Glass SHGC [3]	Overall SHGC [4]
0.75	0.68
0.70	0.63
0.65	0.59
0.60	0.55
0.55	0.50
0.50	0.46
0.45	0.41
0.40	0.37
0.35	0.33
0.30	0.28
0.25	0.24
0.20	0.19
0.15	0.15
0.10	0.11
0.05	0.06

Visible Transmittance [2]

Glass VT [3]	Overall VT [4]
0.75	0.66
0.70	0.61
0.65	0.57
0.60	0.53
0.55	0.48
0.50	0.44
0.45	0.39
0.40	0.35
0.35	0.31
0.30	0.26
0.25	0.22
0.20	0.18
0.15	0.13
0.10	0.09
0.05	0.04

NOTE: For glass values that are not listed, linear interpolation is permitted.

1. U-Factors are determined in accordance with NFRC 100.
2. SHGC and VT values are determined in accordance with NFRC 200.
3. Glass properties are based on center of glass values and are obtained from your glass supplier.
4. Overall U-Factor, SHGC, and VT Matricies are based on the standard NFRC specimen size of 2000mm wide by 2000mm high (78-3/4" by 78-3/4").

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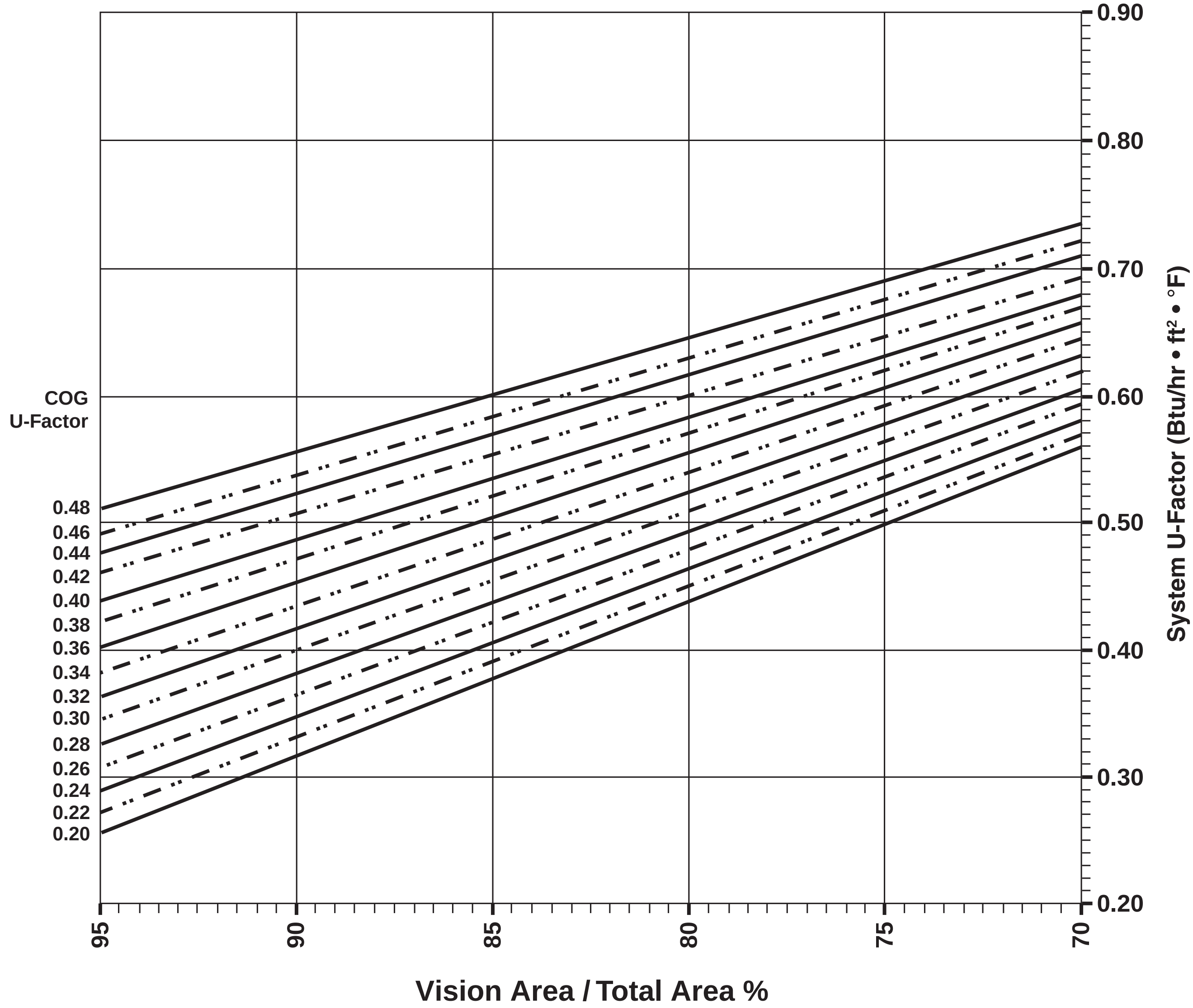
Vertical SSG

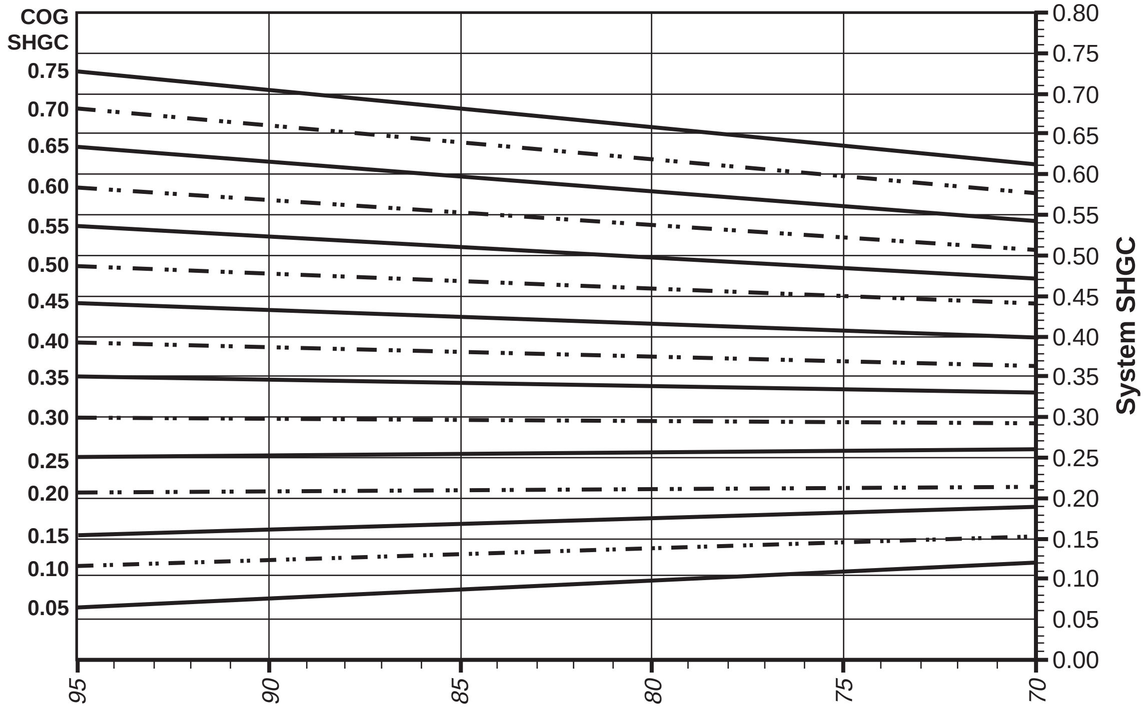
System U-Factor vs Percent of Glass Area



Notes for System U-Factor, SHGC and VT charts:
For glass values that are not listed, linear interpolation is permitted.
Glass properties are based on center of glass values and are obtained from your glass supplier.

Vertical SSG

System Solar Heat Gain Coefficient (SHGC) vs Percent of Vision Area

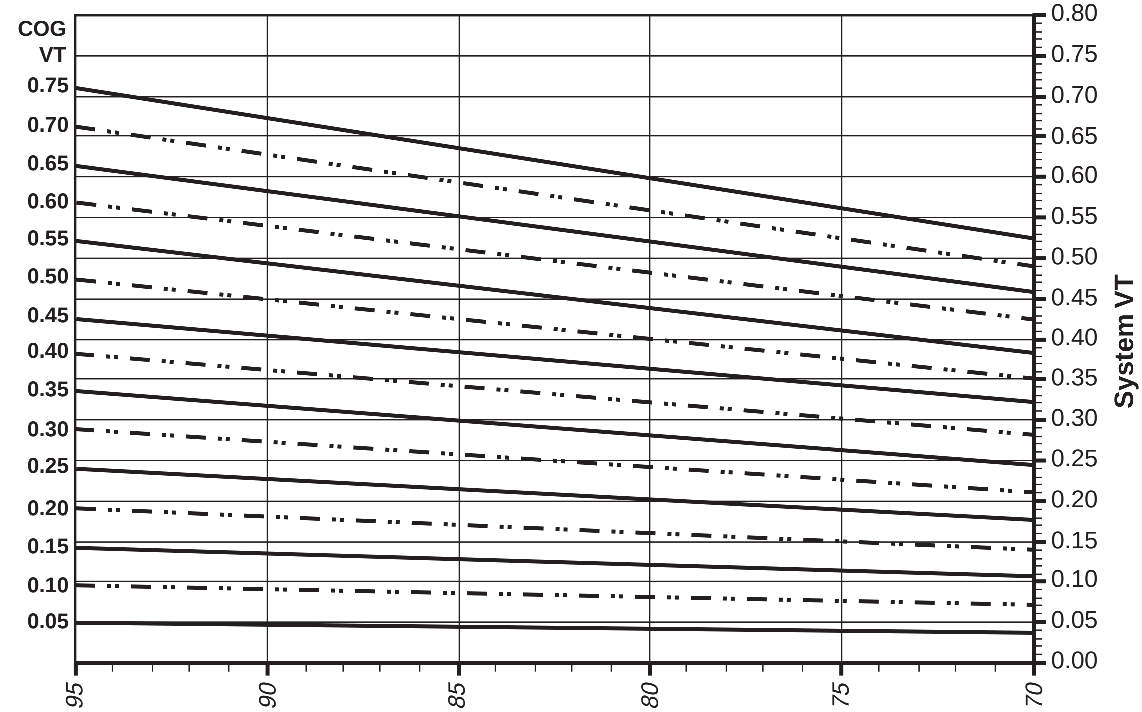


Vision Area / Total Area %
(Total Daylight Opening / Projected Area)

Charts are generated per AAMA 507

Vertical SSG

Visible Transmittance (VT) vs Percent of Vision Area



Vision Area / Total Area %
(Total Daylight Opening / Projected Area)

Vertical SSG

Thermal Transmittance[1] (BTU/hr • ft ^{2} • °F)

Glass U-Factor [3]	Overall U-Factor [4]
0.48	0.57
0.46	0.56
0.44	0.54
0.42	0.53
0.40	0.51
0.38	0.49
0.36	0.48
0.34	0.46
0.32	0.44
0.30	0.43
0.28	0.41
0.26	0.40
0.24	0.38
0.22	0.36
0.20	0.35

SHGC Matrix [2]

Glass SHGC [3]	Overall SHGC [4]
0.75	0.69
0.70	0.65
0.65	0.61
0.60	0.56
0.55	0.52
0.50	0.47
0.45	0.43
0.40	0.39
0.35	0.34
0.30	0.30
0.25	0.25
0.20	0.21
0.15	0.17
0.10	0.12
0.05	0.08

Visible Transmittance [2]

Glass VT [3]	Overall VT [4]
0.75	0.66
0.70	0.61
0.65	0.57
0.60	0.53
0.55	0.48
0.50	0.44
0.45	0.39
0.40	0.35
0.35	0.31
0.30	0.26
0.25	0.22
0.20	0.18
0.15	0.13
0.10	0.09
0.05	0.04

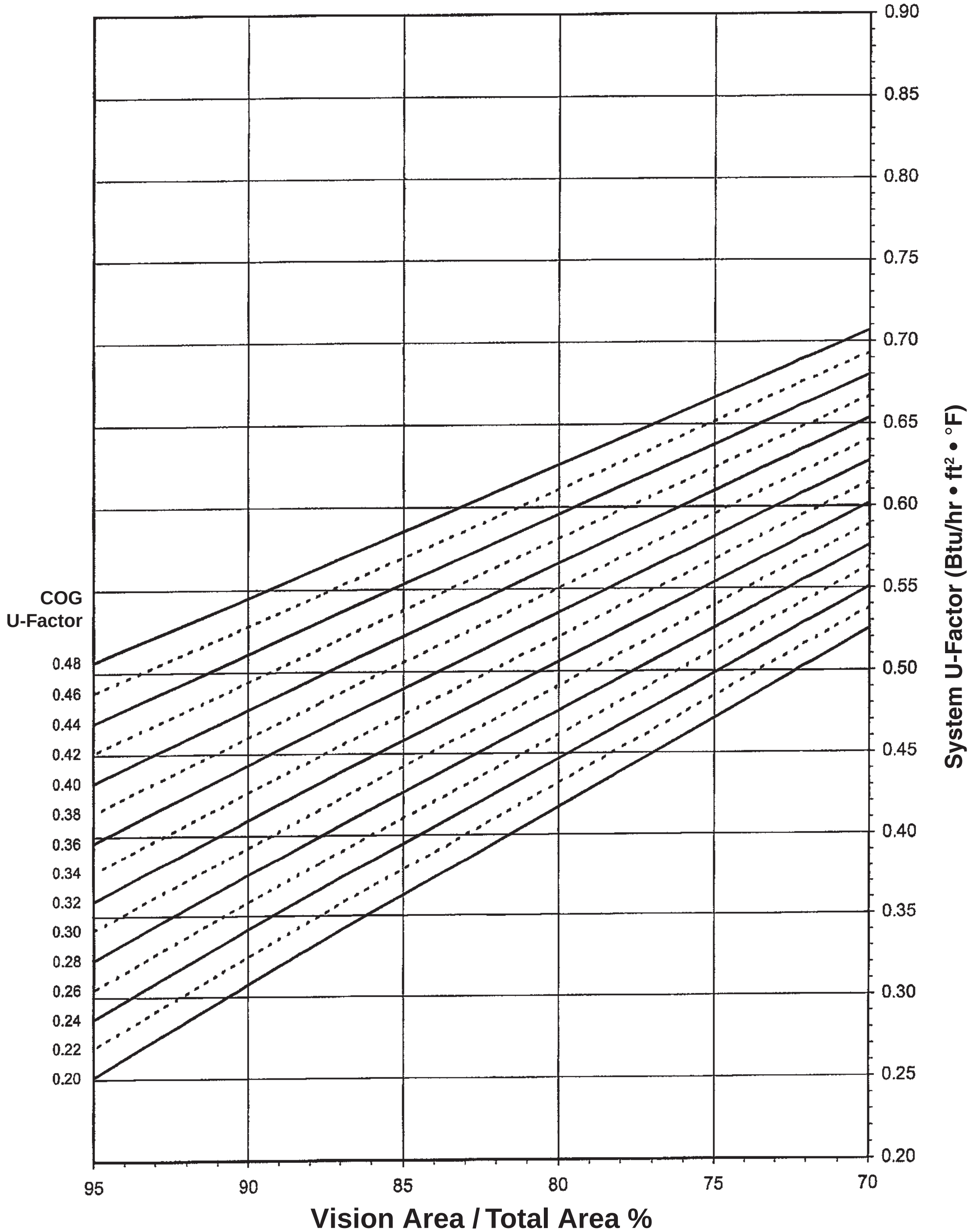
NOTE: For glass values that are not listed, linear interpolation is permitted.

1. U-Factors are determined in accordance with NFRC 100.
2. SHGC and VT values are determined in accordance with NFRC 200.
3. Glass properties are based on center of glass values and are obtained from your glass supplier.
4. Overall U-Factor, SHGC, and VT Matricies are based on the standard NFRC specimen size of 2000mm wide by 2000mm high (78-3/4" by 78-3/4").

Note:
Values in parentheses are metric.
COG = Center of Glass.
Charts are generated per AMMA 507

4 Side SSG

System U-Factor vs Percent of Glass Area



Notes for System U-Factor, SHGC and VT charts:
For glass values that are not listed, linear interpolation is permitted.
Glass properties are based on center of glass values and are obtained from your glass supplier.

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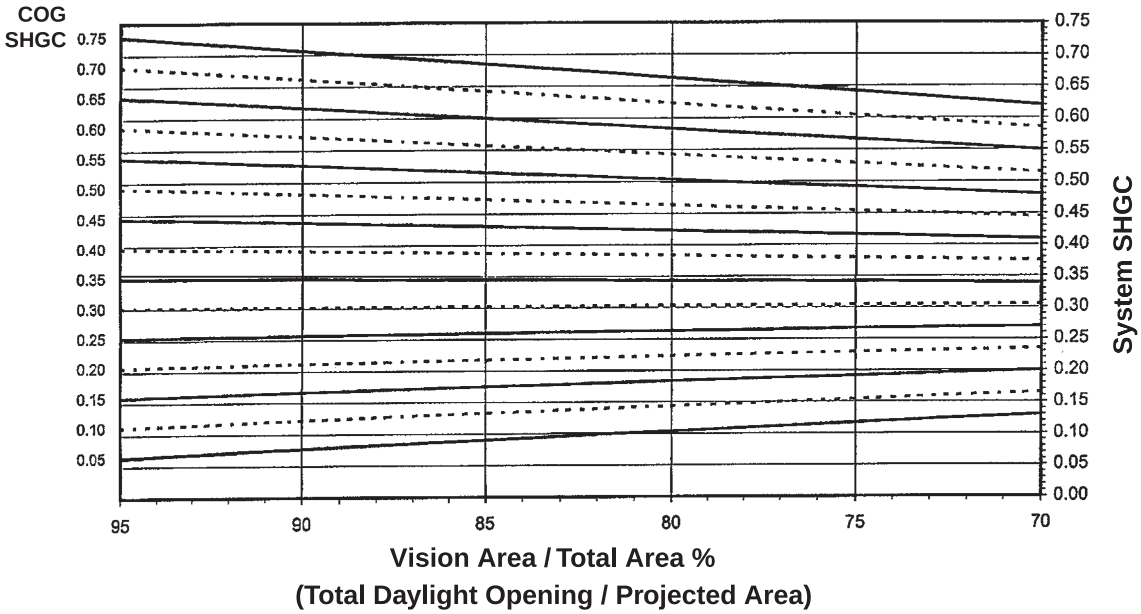
4 Side SSG

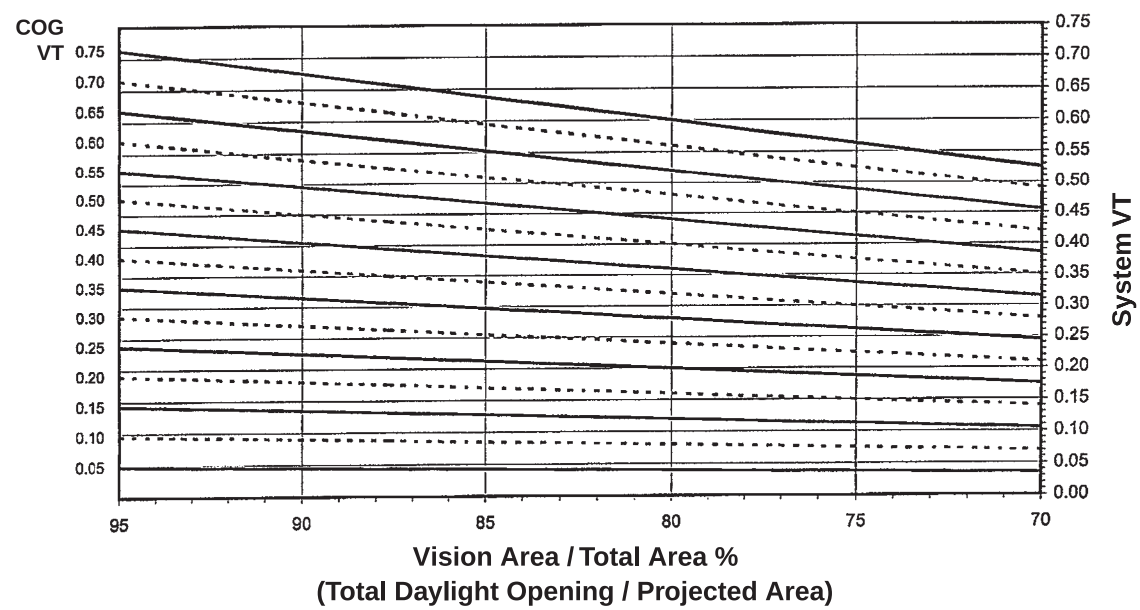
System Solar Heat Gain Coefficient (SHGC) vs Percent of Vision Area



Charts are generated per AAMA 507

4 Side SSG

Visible Transmittance (VT) vs Percent of Vision Area



4 Side SSG

Thermal Transmittance[1] (BTU/hr • ft ^{2} • °F)

Glass U-Factor [3]	Overall U-Factor [4]
0.48	0.56
0.46	0.55
0.44	0.53
0.42	0.51
0.40	0.50
0.38	0.48
0.36	0.46
0.34	0.45
0.32	0.43
0.30	0.42
0.28	0.40
0.26	0.38
0.24	0.37
0.22	0.35
0.20	0.33

SHGC Matrix [2]

Glass SHGC [3]	Overall SHGC [4]
0.75	0.70
0.70	0.65
0.65	0.61
0.60	0.57
0.55	0.52
0.50	0.48
0.45	0.43
0.40	0.39
0.35	0.35
0.30	0.30
0.25	0.26
0.20	0.21
0.15	0.17
0.10	0.13
0.05	0.08

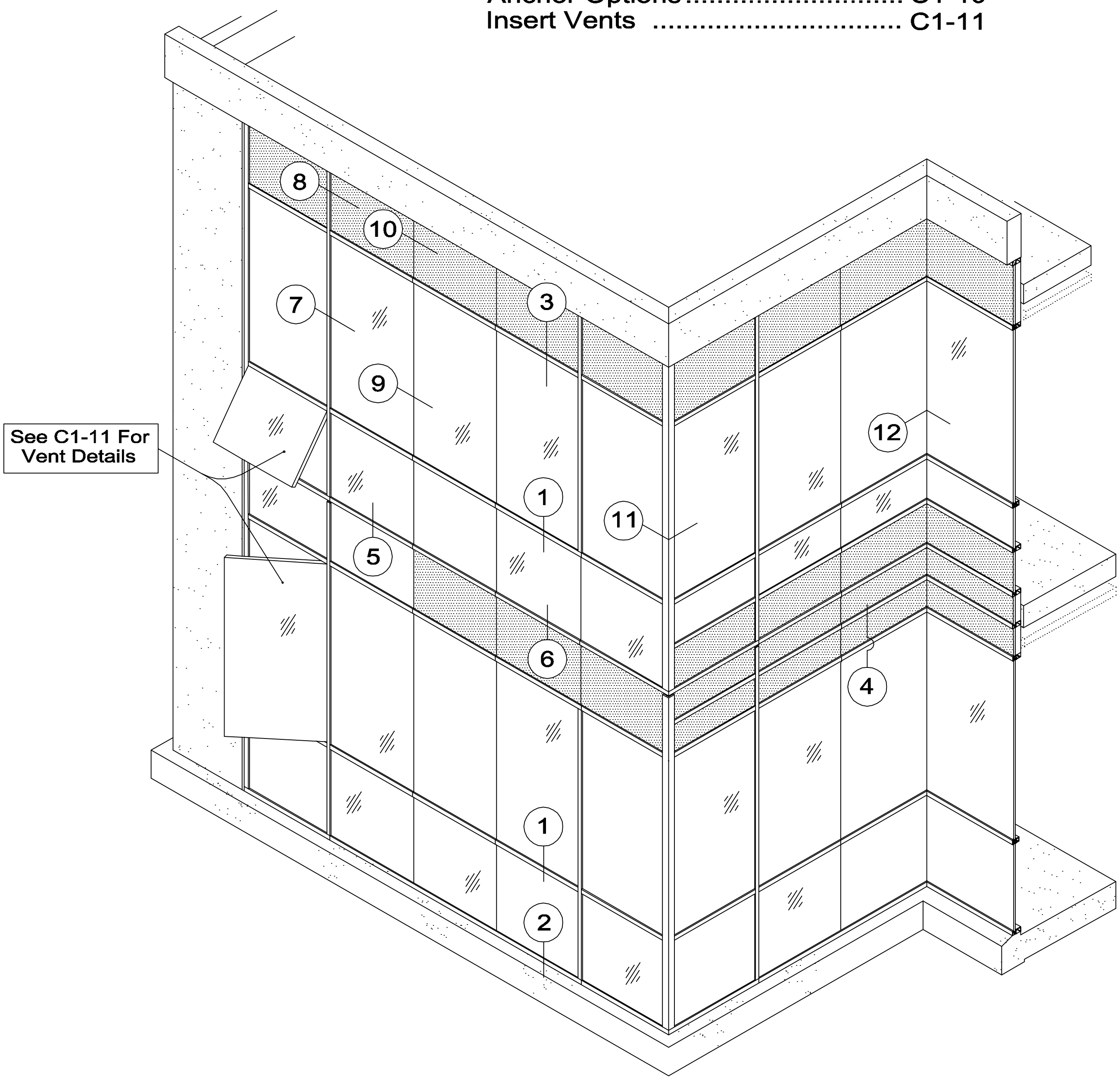
Visible Transmittance [2]

Glass VT [3]	Overall VT [4]
0.75	0.66
0.70	0.61
0.65	0.57
0.60	0.53
0.55	0.48
0.50	0.44
0.45	0.39
0.40	0.35
0.35	0.31
0.30	0.26
0.25	0.22
0.20	0.18
0.15	0.13
0.10	0.09
0.05	0.04

NOTE: For glass values that are not listed, linear interpolation is permitted.

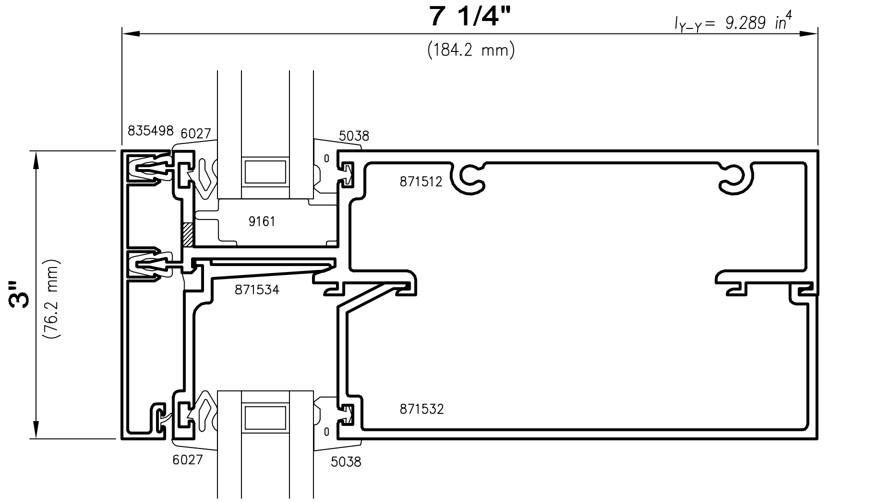
1. U-Factors are determined in accordance with NFRC 100.
2. SHGC and VT values are determined in accordance with NFRC 200.
3. Glass properties are based on center of glass values and are obtained from your glass supplier.
4. Overall U-Factor, SHGC, and VT Matricies are based on the standard NFRC specimen size of 2000mm wide by 2000mm high (78-3/4" by 78-3/4").

APPENDIX 3-B – WAUSAU WINDOW AND WALL SYSTEMS – 7250-UW SERIES TECHNICAL DATA

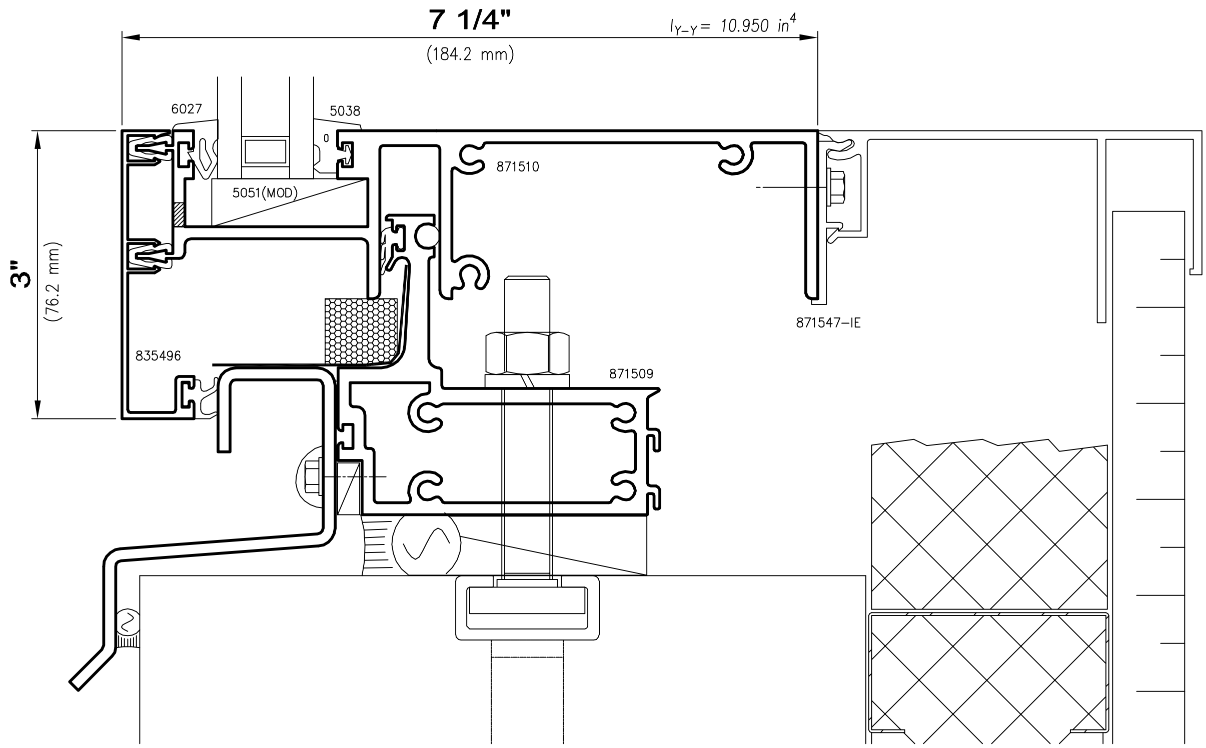


7250-UW

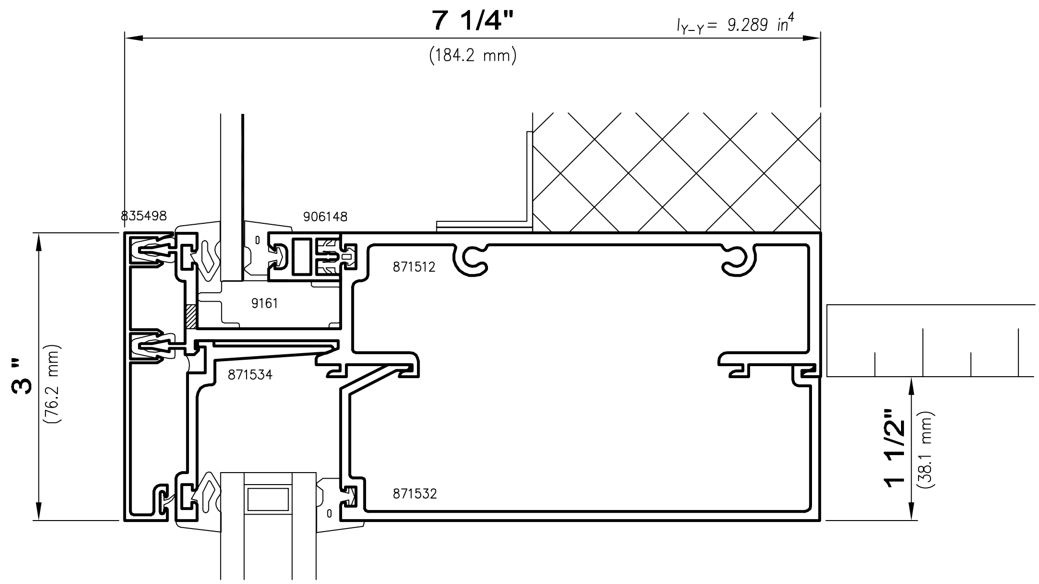
Non-stocked items shown – Minimum order quantity may apply



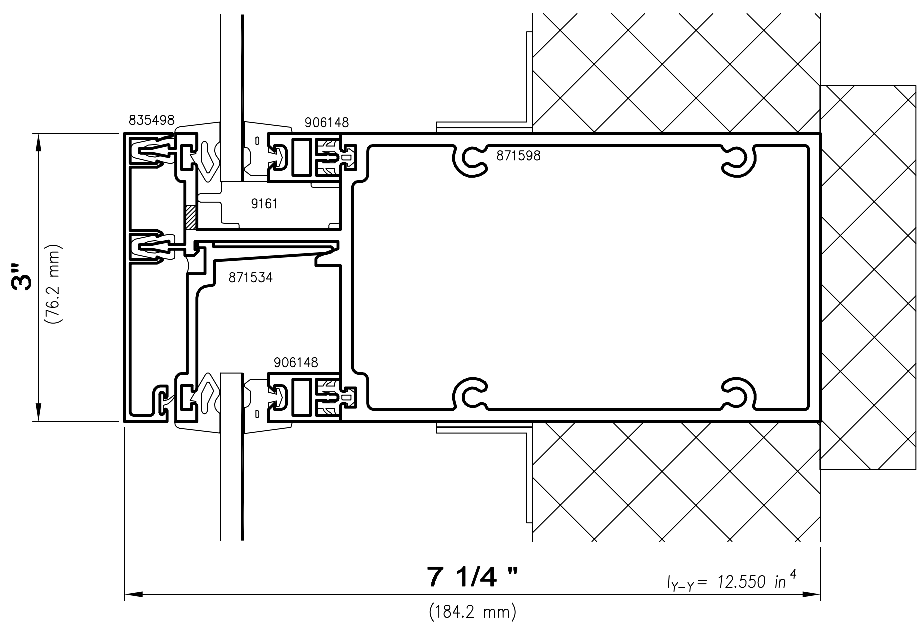
1 Vision/Vision Horizontal Intermediate



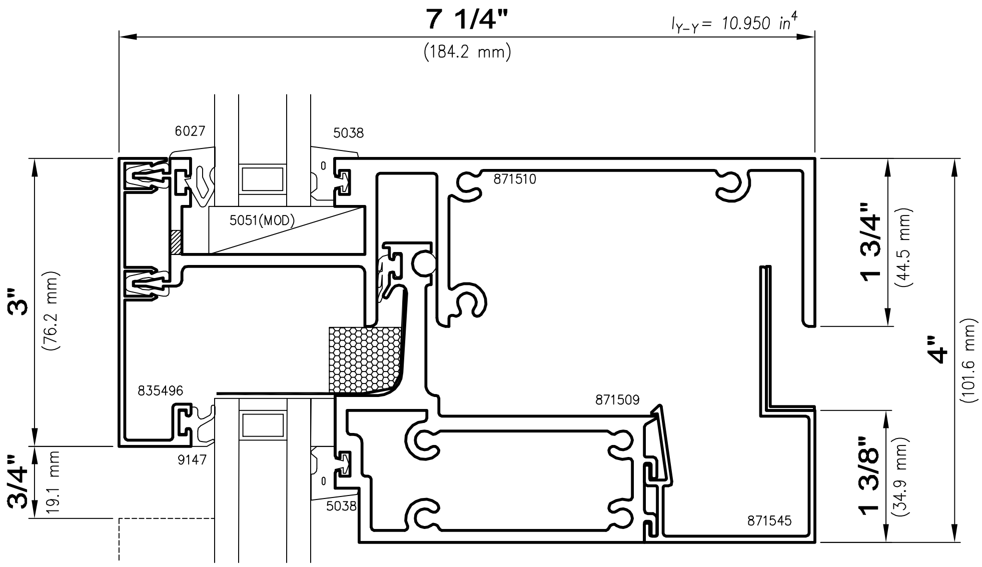
2 Vision Sill



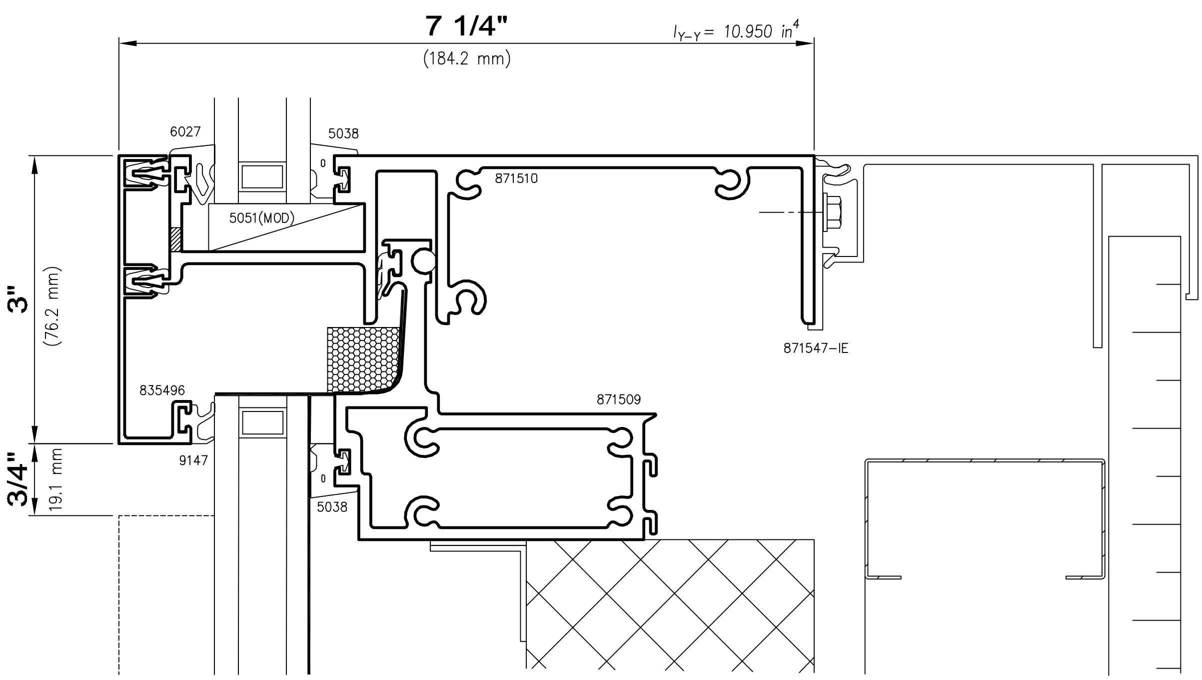
3 Spandrel/Vision
Horizontal Intermediate



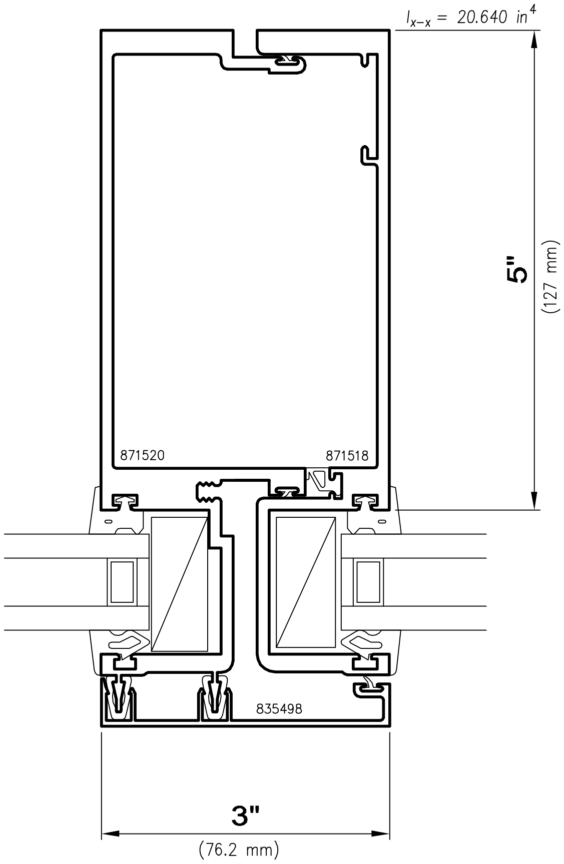
4 Spandrel/Spandrel
Horizontal Intermediate



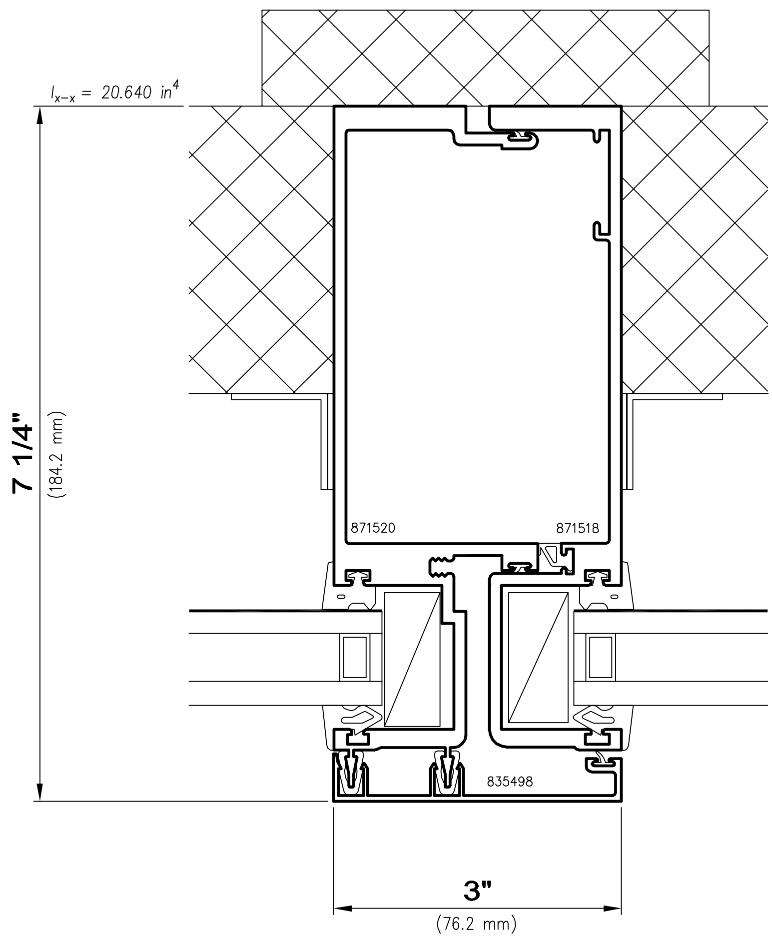
5 Vision/Vision Horizontal Stack



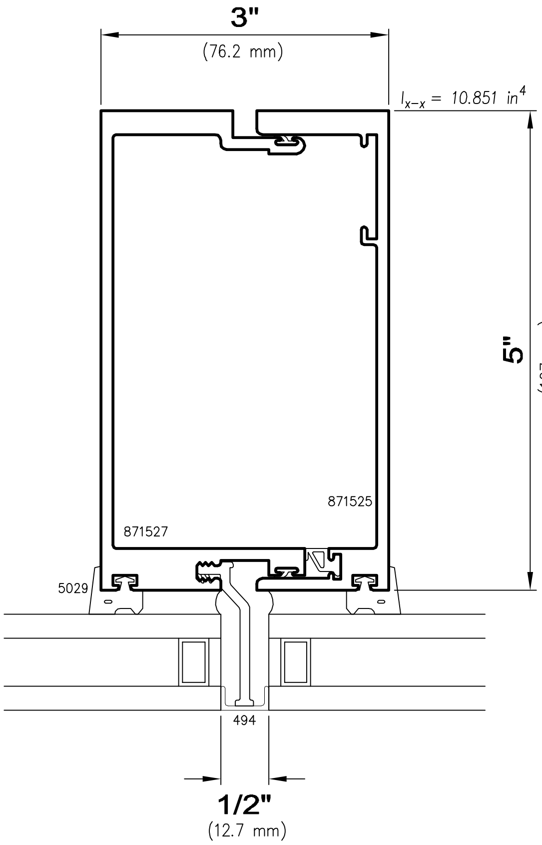
6 Vision/Spandrel Horizontal Stack



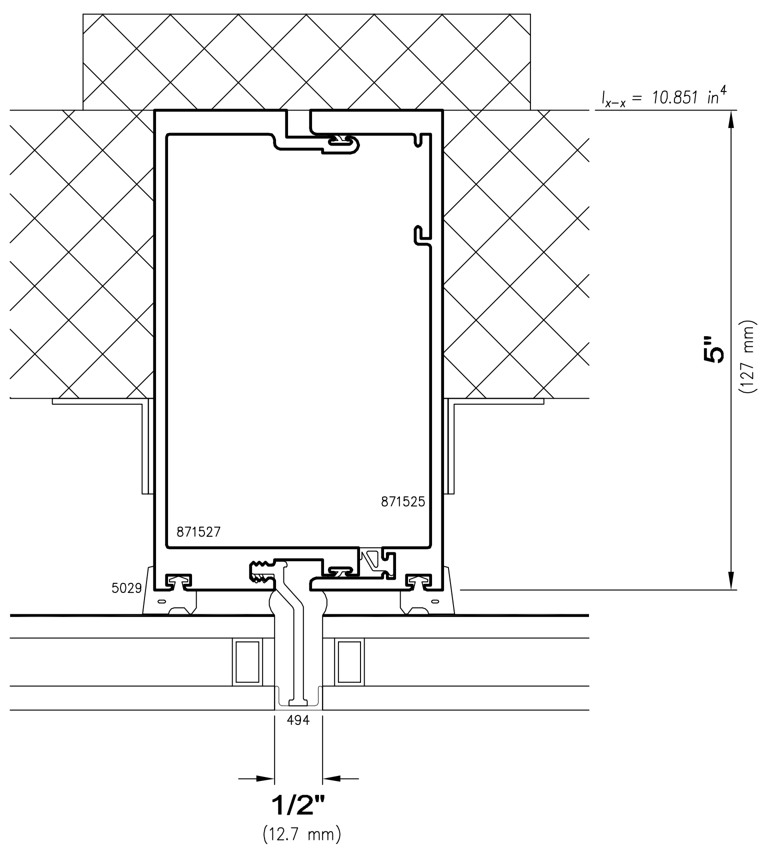
7 Vision/Vision Mullion Stack



8 Spandrel/Spandrel Mullion Stack

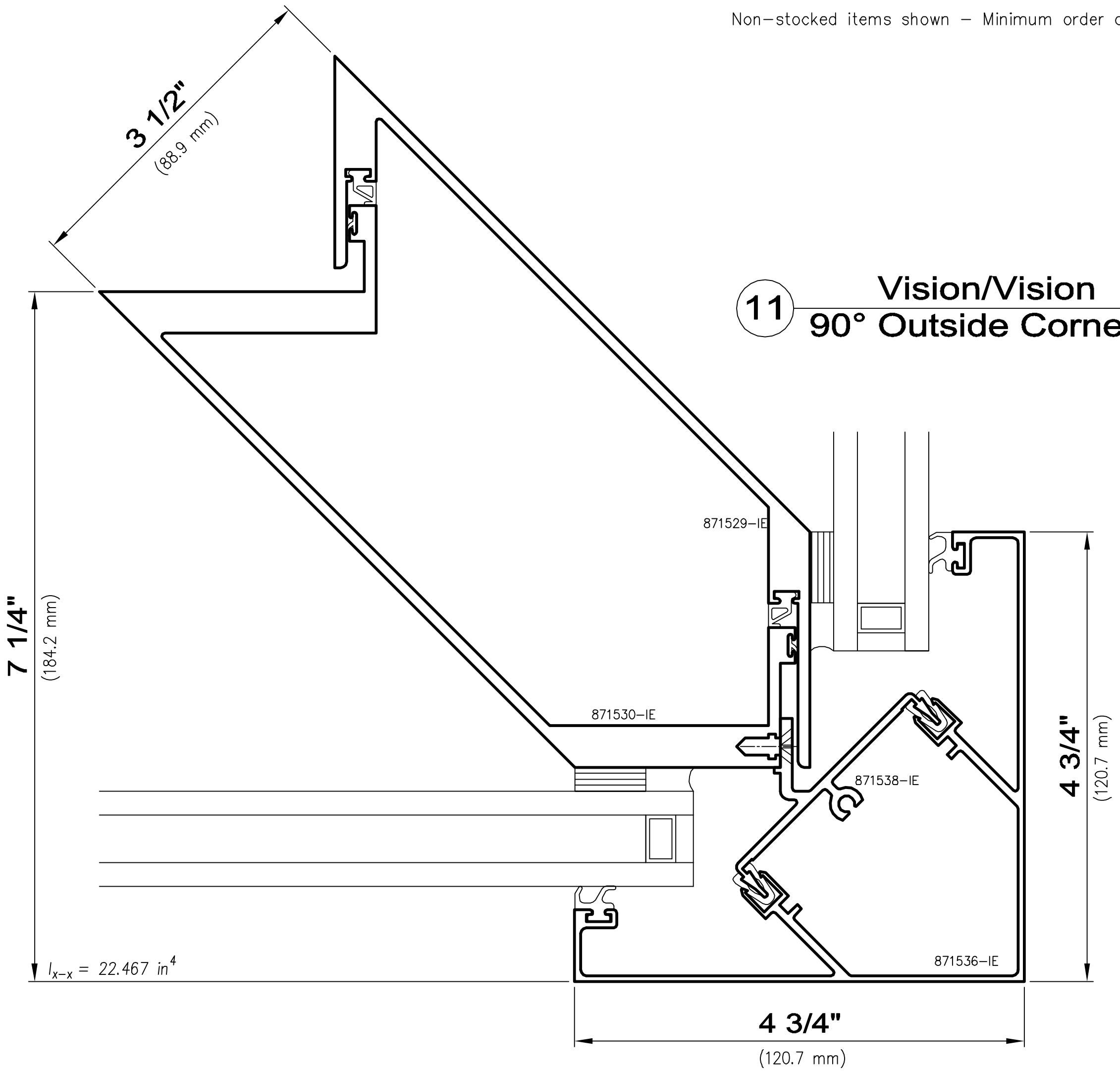


9 Vision/Vision Mullion Stack

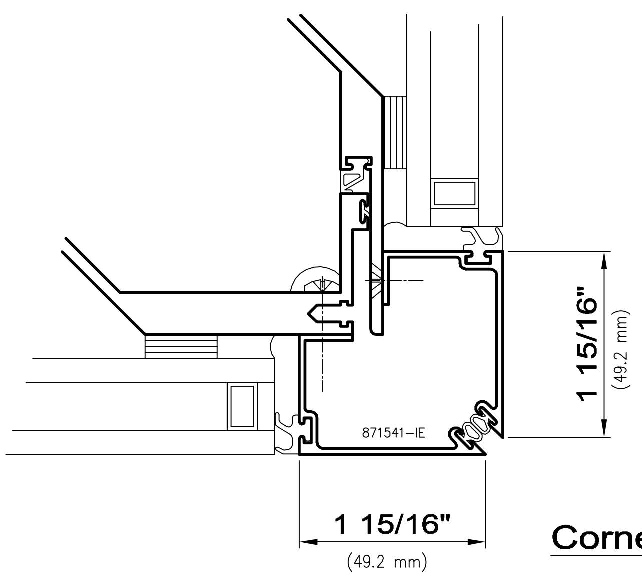


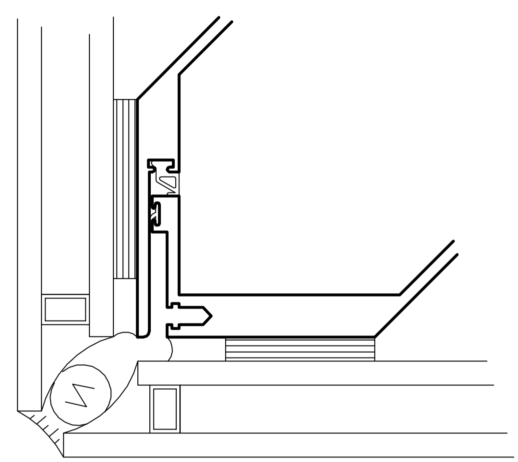
10 Spandrel/Spandrel Mullion Stack

Non-stocked items shown – Minimum order quantity may apply



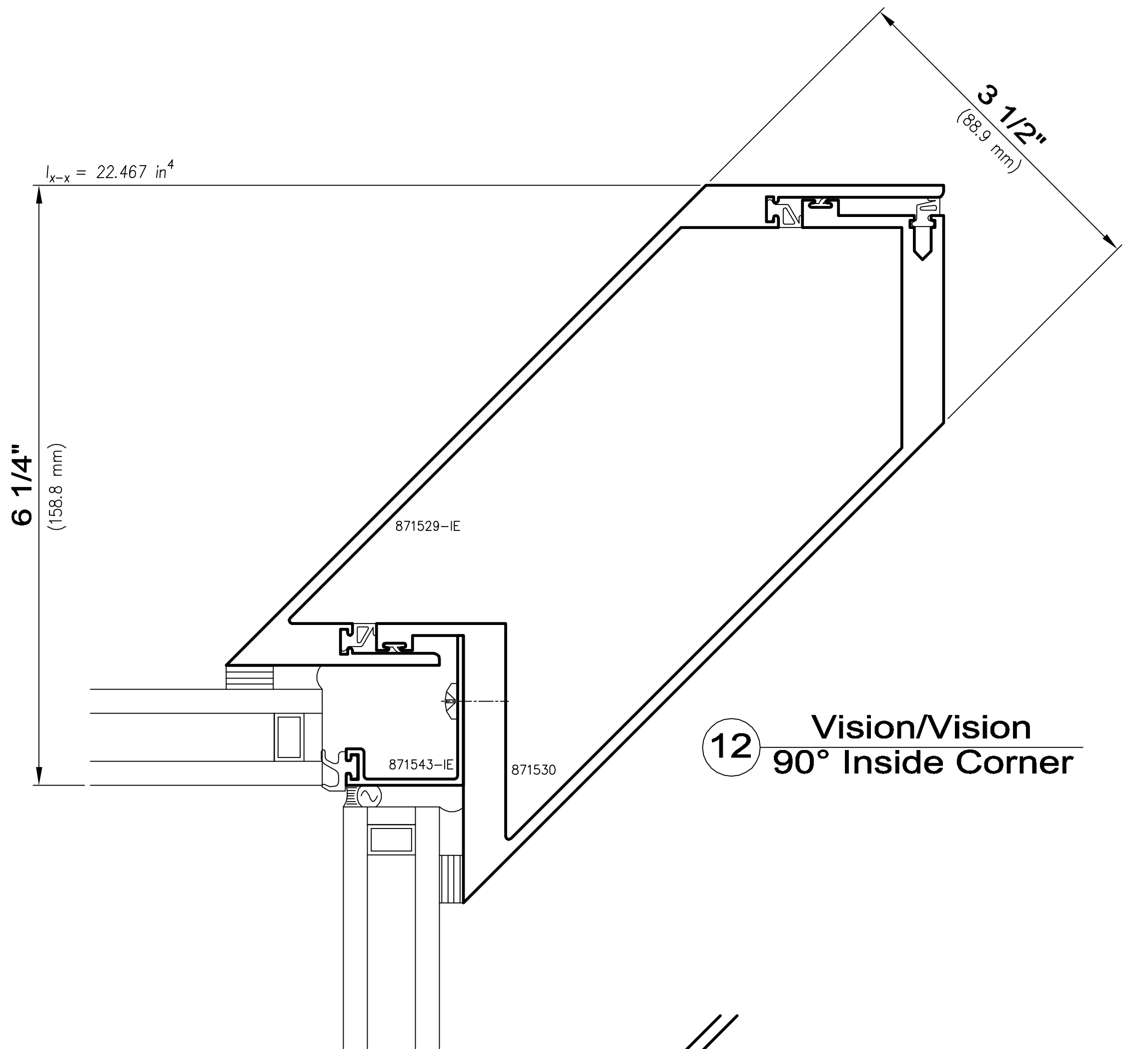
11 Vision/Vision 90° Outside Corner



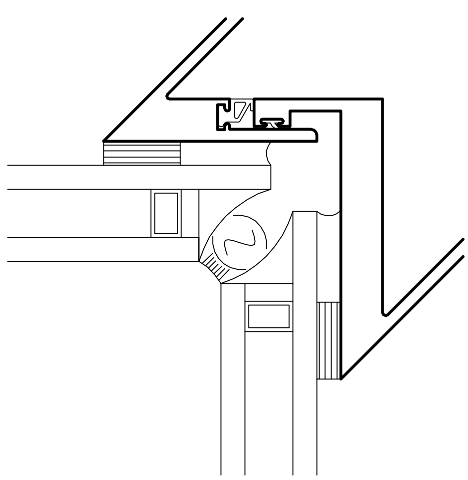


Corner Options

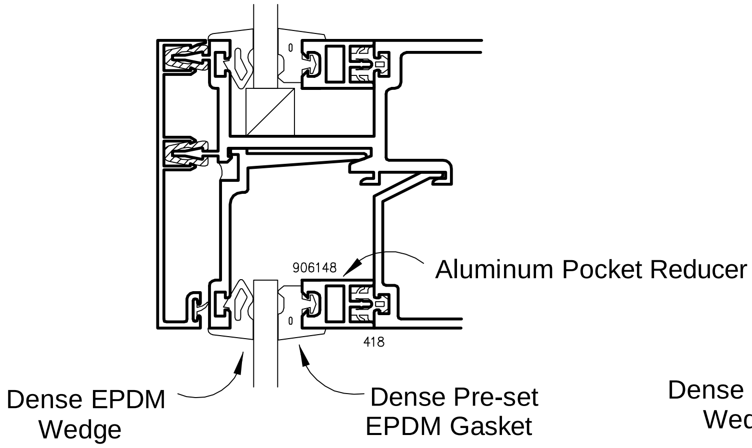
Non-stocked items shown – Minimum order quantity may apply



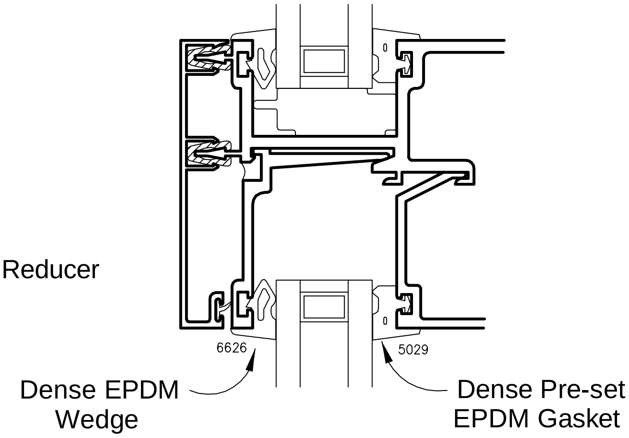
12 Vision/Vision 90° Inside Corner



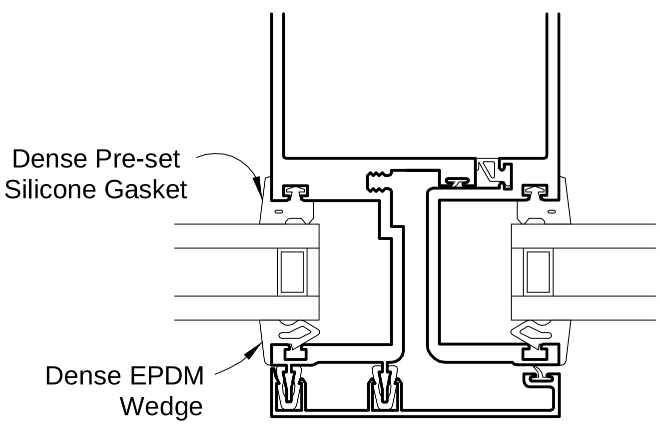
Corner Option



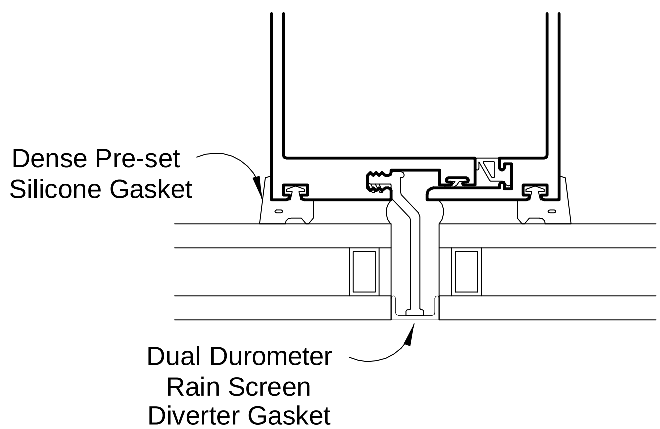
1/4" Monolithic Glass
Interior or Exterior Glazed



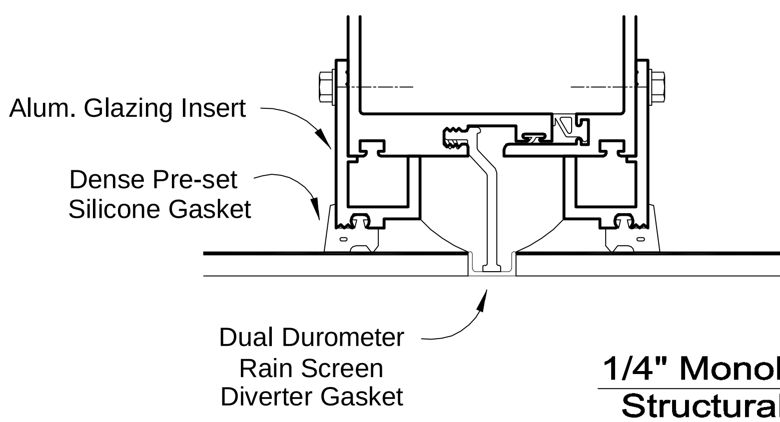
1" Insulating Glass
Interior or Exterior Glazed



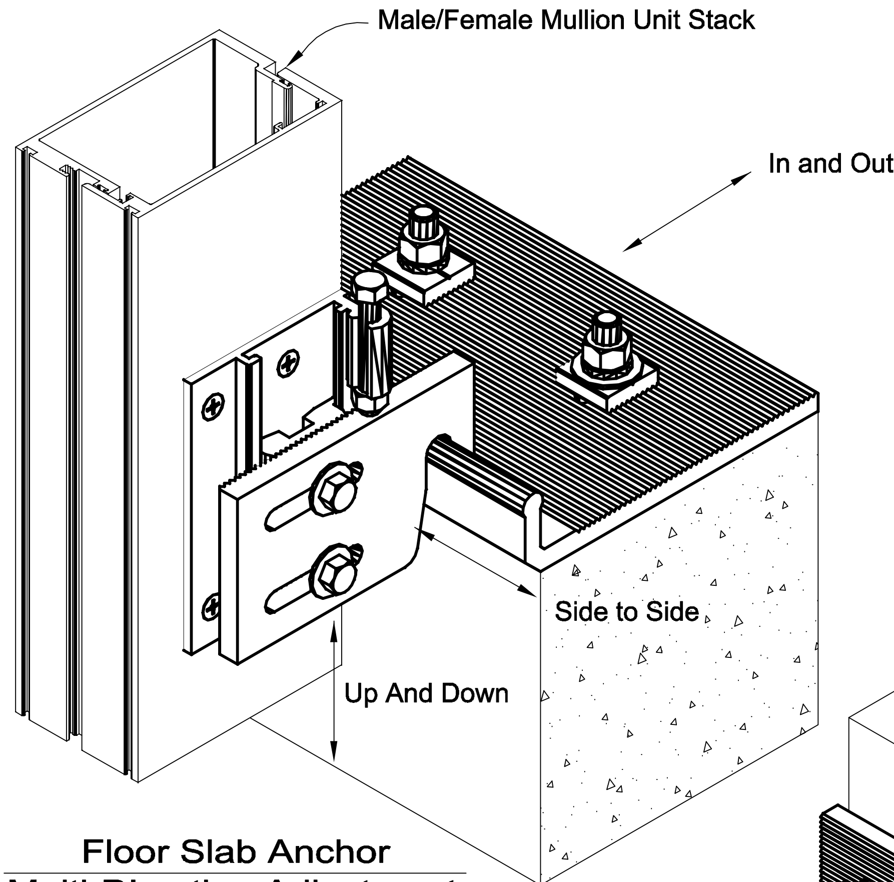
1" Insulating Glass
Captured Glazed



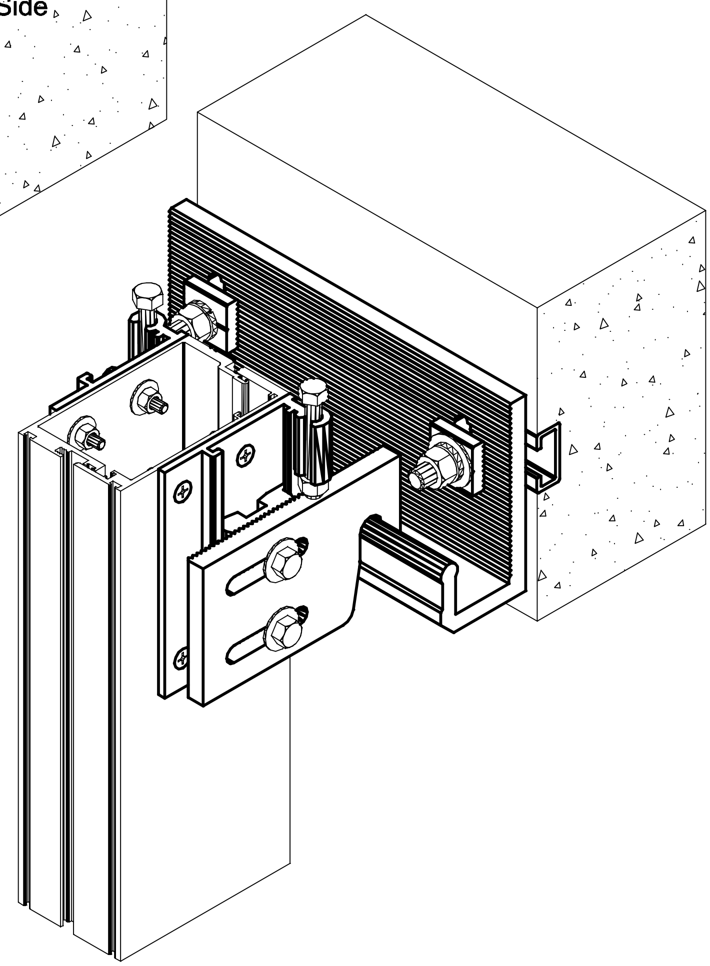
1" Insulating Glass
Structural Glazed



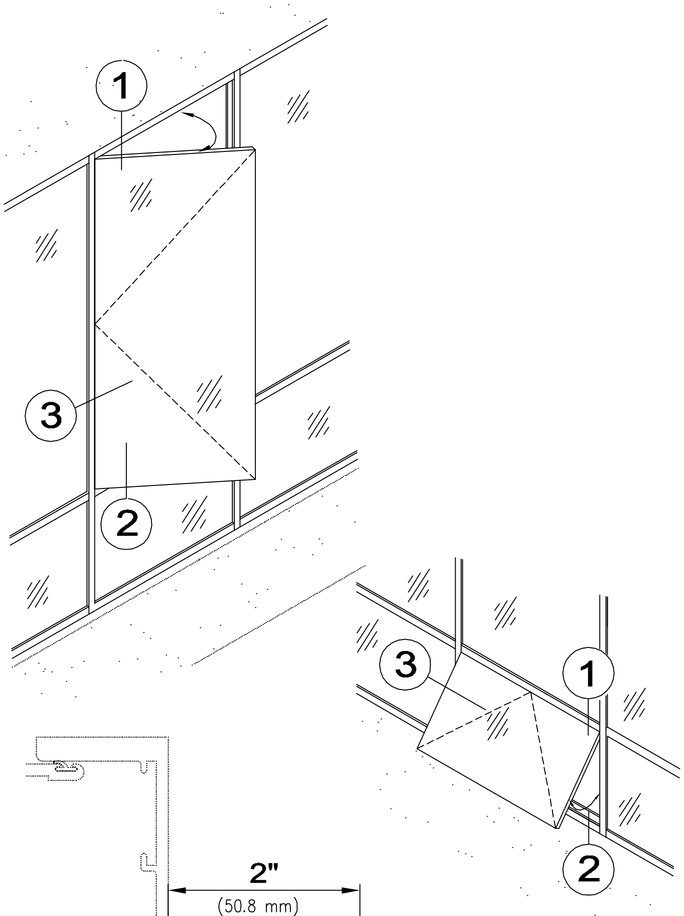
1/4" Monolithic Spandrel
Structural Glazed

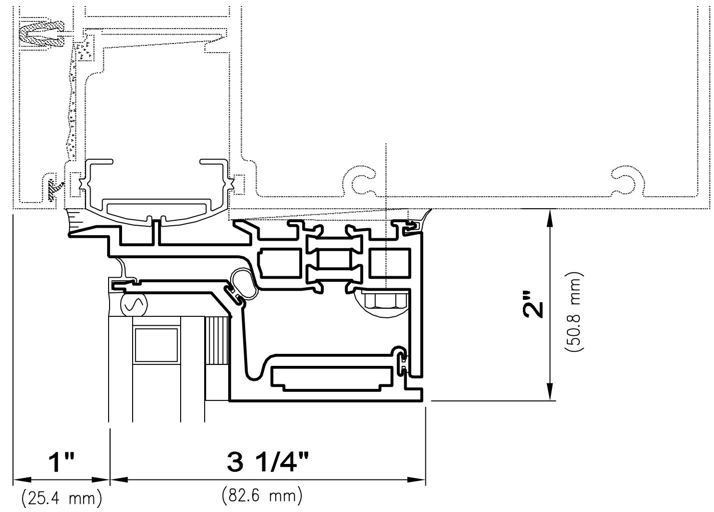


Floor Slab Anchor
Multi-Direction Adjustment

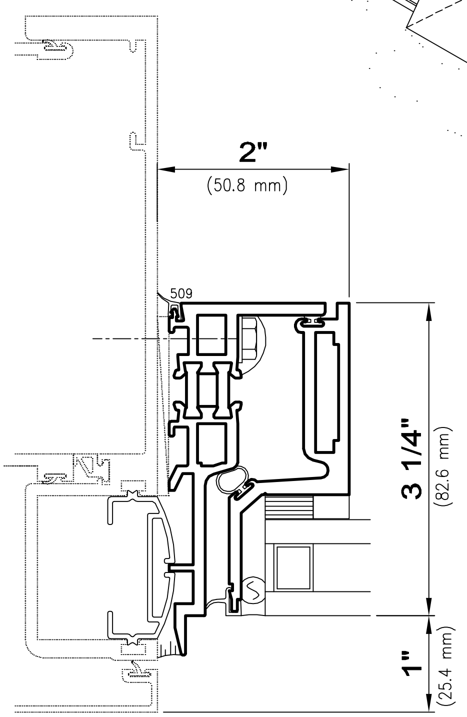


Face Mount Anchor
Multi-Direction Adjustment

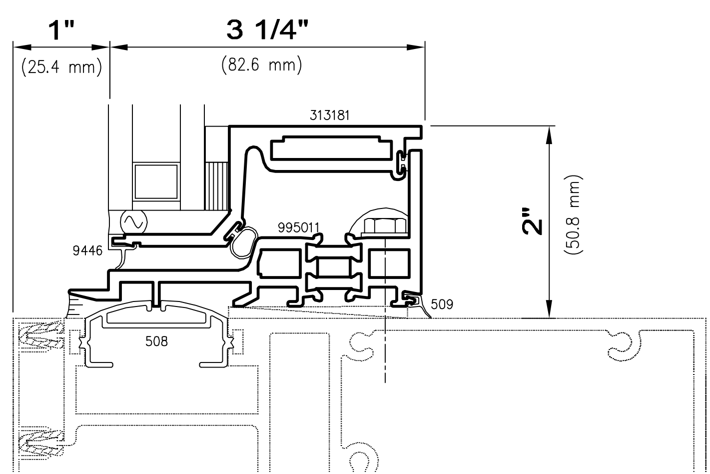

1
3
2
3
1
2


2"
(50.8 mm)
1"
(25.4 mm)
3 1/4"
(82.6 mm)

1


2"
(50.8 mm)
509
3 1/4"
(82.6 mm)
1"
(25.4 mm)

3


1"
(25.4 mm)
3 1/4"
(82.6 mm)
313181
995011
9446
509
508
2"
(50.8 mm)

2

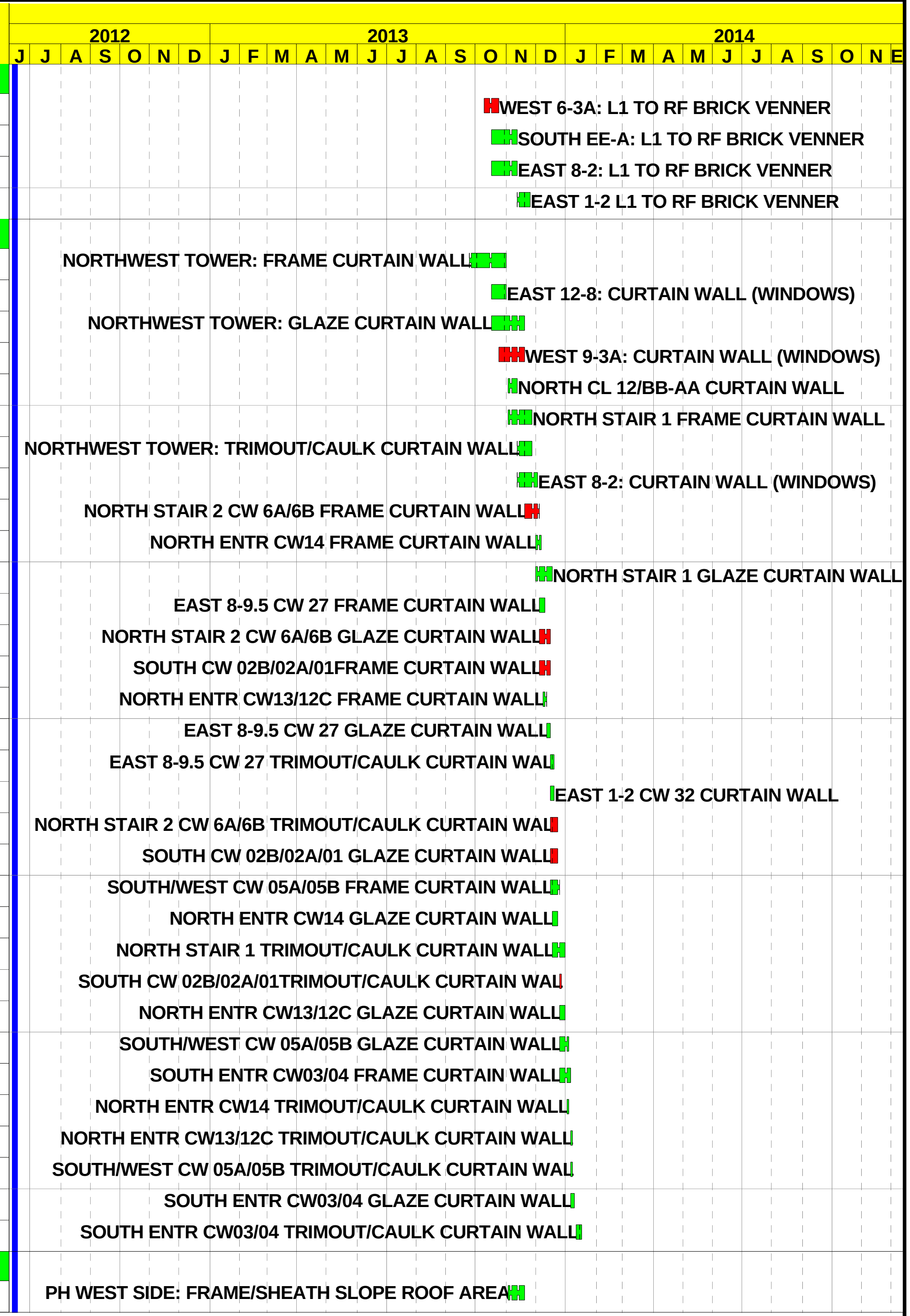
APPENDIX 3-C – CURTAIN WALL CALCULATIONS

Curtain Wall Panels				
Location	Size	SF	No. Panels	Total SF
CW 15A	2' - 7-1/2" x 15'-4"	40.25	25	1006.25
Cw 15A	2' - 7-1/2" x 21'-4"	56	50	2800
CW 36	1'-8" x 18'-10"	31.4	3	94.2
CW 15B	2' - 7-1/2" x 15'-4"	40.25	32	1288
CW 15B	2' - 7-1/2" x 20'-4"	53.4	64	3417.6
CW 15C	2' - 7-1/2" x 15'-4"	40.25	32	1288
CW 15C	2' - 7-1/2" x 20'-4"	53.4	64	3417.6
CW 15D	2' - 7-1/2" x 15'-4"	40.25	12	483
CW 15D	2' - 7-1/2" x 20'-4"	53.4	24	1281.6
CW 1	3'-0" x 15'-4"	46	3	138
CW 2A	2' - 7-1/2" x 15'-4"	40.25	9	362.25
CW 2B	2' - 7-1/2" x 15'-4"	40.25	9	362.25
CW 3	2' - 7-1/2" x 20'-0"	52.5	5	262.5
CW 4	2' - 7-1/2" x 15'-4"	40.25	4	161
CW 4	2' - 7-1/2" x 18'-0"	47.25	8	378
CW 6A	2' - 7-1/2" x 15'-4"	40.25	8	322
CW 6A	2' - 7-1/2" x 11'-4"	29.75	4	119
CW 6A	2' - 7-1/2" x 18'-0"	47.25	4	189
CW 6B	2' - 7-1/2" x 15'-4"	40.25	20	805
CW 6B	2' - 7-1/2" x 11'-4"	29.75	10	297.5
CW 6B	2' - 7-1/2" x 18'-0"	47.25	10	472.5
CW 7	2' - 7-1/2" x 15'-4"	40.25	4	161
CW 10	2' - 7-1/2" x 15'-4"	40.25	18	724.5
CW 11	2' - 7-1/2" x 15'-4"	40.25	9	362.25
CW 11	2' - 7-1/2" x 12'-4"	32.36	9	291.24
CW 13	2' - 7-1/2" x 16'-9"	44	11	484
CW 14	2' - 7-1/2" x 16'-9"	44	27	1188
CW 12A	2' - 7-1/2" x 14'-6"	38.06	27	1027.62
CW 12B	2' - 7-1/2" x 14'-6"	38.06	17	647.02
CW 12C	2' - 7-1/2" x 14'-6"	38.06	8	304.48
CW 16A	2' - 7-1/2" x 14'-8"	38.5	9	346.5
CW 16A	2' - 7-1/2" x 15'-4"	40.25	36	1449
CW 16B	2' - 7-1/2" x 14'-8"	38.5	5	192.5
CW 16B	2' - 7-1/2" x 15'-4"	40.25	20	805
CW 16C	2' - 7-1/2" x 14'-8"	38.5	4	154
CW 16C	2' - 7-1/2" x 15'-4"	40.25	16	644
CW 17, 18, 19	2' - 7-1/2" x 11'-4"	29.75	3	89.25
CW 41	4' - 10" x 12'-4"	59.6	1	59.6
CW 20	8' - 6" x 12'-4"	104	1	104
CW 21	1' - 9" x 15'-4"	26.83	4	107.32
CW 22	5' - 4" x 14'-9"	78.66	1	78.66
CW 23A	1' - 2-1/2" x 15'-4"	18.5	4	74
CW 23B	6' - 2-3/4" x 15'-4"	95.5	4	382
CW 24	5'-3" x 7'-0"	36.75	9	330.75
CW 25	5'-3" x 4'-6"	23.63	9	212.67
CW 25A	5'-3" x 4'-6"	23.63	9	212.67
CW 29	3'-0" x 15'-4"	46	4	184
CW 30A	5'-3" x 11'-8"	61.2	24	1468.8
CW 30B	5'-3" x 11'-8"	61.2	28	1713.6
CW 31	5'-3" x 7'-0"	36.75	11	404.25
CW 33	5'-3" x 7'-0"	36.75	10	367.5
CW 32	5'-3" x 4'-6"	23.63	21	496.23
CW 34	2' - 7-1/2" x 15'-4"	40.25	6	241.5
CW 35	2' - 7-1/2" x 11'-6"	30.12	14	421.68
Totals			**783**	**34675**

Cost Estimate			
	Cost/SF	SF	Total
Stick-Built	$ 180.00	34675	$ 6,241,500.00
Panel - Wausau 7250-UW	$ 153.00	34675	$ 5,305,275.00
Staging Crew	$ 9.35	34675	$ 324,211.25
		Variance	$ 5,629,486.25

APPENDIX 3-D – ORIGINAL PROJECTED CURTAIN WALL SCHEDULE

Activity ID	BDPK	Activity Description	OD	%	Early Start	Early Finish
EXTERIOR BRICK VENEER						
20410	B041	WEST 6-3A: L1 TO RF BRICK VENNER	10	0	10OCT13	24OCT13
20530	B041	SOUTH EE-A: L1 TO RF BRICK VENNER	15	0	18OCT13	11NOV13
20710	B041	EAST 8-2: L1 TO RF BRICK VENNER	15	0	18OCT13	11NOV13
20590	B041	EAST 1-2 L1 TO RF BRICK VENNER	8	0	12NOV13	25NOV13
EXTERIOR WINDOWS & CURTAIN WALLS						
22500	B081	NORTHWEST TOWER: FRAME CURTAIN WALL	25	0	24SEP13	01NOV13
22300	B081	EAST 12-8: CURTAIN WALL (WINDOWS)	10	0	18OCT13	01NOV13
22550	B081	NORTHWEST TOWER: GLAZE CURTAIN WALL	20	0	18OCT13	19NOV13
22000	B081	WEST 9-3A: CURTAIN WALL (WINDOWS)	15	0	25OCT13	19NOV13
22320	B081	NORTH CL 12/BB-AA CURTAIN WALL	5	0	04NOV13	11NOV13
22600	B081	NORTH STAIR 1 FRAME CURTAIN WALL	15	0	04NOV13	27NOV13
22560	B081	NORTHWEST TOWER: TRIMOUT/CAULK CURTAIN WALL	10	0	12NOV13	27NOV13
22340	B081	EAST 8-2: CURTAIN WALL (WINDOWS)	12	0	12NOV13	03DEC13
22100	B081	NORTH STAIR 2 CW 6A/6B FRAME CURTAIN WALL	8	0	21NOV13	05DEC13
22650	B081	NORTH ENTR CW14 FRAME CURTAIN WALL	4	0	02DEC13	06DEC13
22610	B081	NORTH STAIR 1 GLAZE CURTAIN WALL	10	0	02DEC13	17DEC13
22400	B081	EAST 8-9.5 CW 27 FRAME CURTAIN WALL	4	0	05DEC13	10DEC13
22110	B081	NORTH STAIR 2 CW 6A/6B GLAZE CURTAIN WALL	6	0	06DEC13	16DEC13
22150	B081	SOUTH CW 02B/02A/01FRAME CURTAIN WALL	6	0	06DEC13	16DEC13
22700	B081	NORTH ENTR CW13/12C FRAME CURTAIN WALL	3	0	09DEC13	12DEC13
22410	B081	EAST 8-9.5 CW 27 GLAZE CURTAIN WALL	3	0	12DEC13	16DEC13
22420	B081	EAST 8-9.5 CW 27 TRIMOUT/CAULK CURTAIN WAL	2	0	17DEC13	19DEC13
22450	B081	EAST 1-2 CW 32 CURTAIN WALL	3	0	17DEC13	19DEC13
22130	B081	NORTH STAIR 2 CW 6A/6B TRIMOUT/CAULK CURTAIN WAL	4	0	17DEC13	23DEC13
22160	B081	SOUTH CW 02B/02A/01 GLAZE CURTAIN WALL	4	0	17DEC13	23DEC13
22200	B081	SOUTH/WEST CW 05A/05B FRAME CURTAIN WALL	5	0	17DEC13	26DEC13
22660	B081	NORTH ENTR CW14 GLAZE CURTAIN WALL	3	0	19DEC13	23DEC13
22620	B081	NORTH STAIR 1 TRIMOUT/CAULK CURTAIN WALL	6	0	19DEC13	30DEC13
22180	B081	SOUTH CW 02B/02A/01TRIMOUT/CAULK CURTAIN WAL	2	0	26DEC13	27DEC13
22710	B081	NORTH ENTR CW13/12C GLAZE CURTAIN WALL	3	0	26DEC13	30DEC13
22210	B081	SOUTH/WEST CW 05A/05B GLAZE CURTAIN WALL	4	0	27DEC13	03JAN14
22850	B081	SOUTH ENTR CW03/04 FRAME CURTAIN WALL	5	0	27DEC13	06JAN14
22670	B081	NORTH ENTR CW14 TRIMOUT/CAULK CURTAIN WALL	2	0	02JAN14	03JAN14
22720	B081	NORTH ENTR CW13/12C TRIMOUT/CAULK CURTAIN WALL	2	0	06JAN14	07JAN14
22230	B081	SOUTH/WEST CW 05A/05B TRIMOUT/CAULK CURTAIN WAL	3	0	06JAN14	08JAN14
22860	B081	SOUTH ENTR CW03/04 GLAZE CURTAIN WALL	4	0	07JAN14	10JAN14
22870	B081	SOUTH ENTR CW03/04 TRIMOUT/CAULK CURTAIN WALL	3	0	13JAN14	16JAN14
PERIMETER METAL ROOFING AROUND PENTHOUSE						
23000	B091	PH WEST SIDE: FRAME/SHEATH SLOPE ROOF AREA	10	0	04NOV13	19NOV13



Start Date	01APR11
Finish Date	17NOV14
Data Date	15JUN12
Run Date	01AUG12 15:06

Early Bar
Progress Bar
Critical Activity

WIF4

BARTON MALOW
SCIENCE AND TECHNOLOGY CENTER
MASTER PROJECT

Date	Revision	Checked	Approved
14JUN12	MASTER PROJECT SCHEDULE for GMP #1 (BP 1)	RP	AWT
01AUG12	MASTER PROJECT SCHEDULE	AWT	BM

APPENDIX 4-A – MECHANICAL SYSTEM ESTIMATE REPORTS

Analysi 3 - Finned Tube Radiation System
Year 2013 Quarter 1
Unit Detail Report

Prepared By:
Nick Zitterbart
PSU

LineNumber	Description	Quantity	Unit	Daily Output	Total Incl. O&P	Ext. Total Incl. O&P
Division 22 Plumbing						
22071910000	Insulation waste, 5%	227.00	L.F.		$10.12	$2,297.24
220719107813	Insulation, pipe covering (price copper tube one size less than I.P.S.), finishes, .010" thick, for stainless steel jacket, add	4,536.00	S.F.	160.00	$10.12	$45,904.32
221113230000	Fittings add 15% of pipe, based on 4536' pipe	680.00	L.F.		$26.65	$18,122.00
221113232180	Pipe, copper, tubing, solder, 3/4" diameter, type L, includes coupling & clevis hanger assembly 10' O.C.	2,584.00	L.F.	76.00	$16.05	$41,473.20
221113232200	Pipe, copper, tubing, solder, 1" diameter, type L, includes coupling & clevis hanger assembly 10' O.C.	1,313.00	L.F.	68.00	$20.45	$26,850.85
221113232220	Pipe, copper, tubing, solder, 1-1/4" diameter, type L, includes coupling & clevis hanger assembly 10' O.C.	551.00	L.F.	58.00	$26.65	$14,684.15
221113232260	Pipe, copper, tubing, solder, 2" diameter, type L, includes coupling & clevis hanger assembly 10' O.C.	36.00	L.F.	42.00	$46.50	$1,674.00
221113232280	Pipe, copper, tubing, solder, 2-1/2" diameter, type L, includes coupling & clevis hanger assembly 10' O.C.	55.00	L.F.	62.00	$66.50	$3,657.50
Division 22 Plumbing Subtotal						**$154,663.26**
Division 23 Heating, Ventilating, and Air Conditioning (HVAC)						
232123131180	Pump, circulating, bronze, heated or chilled water application, in line, flanged joints, 1/4 H.P., 2-1/2" size	2.00	Ea.	5.00	$4,234.00	$8,468.00
238236101200	Hydronic heating, terminal units, fin tube, wall hung, 14" slope top cover, 1-1/4" copper tube, 4-1/4" aluminum fins, includes damper, excludes main supply pipe	1,550.00	L.F.	38.00	$79.00	$122,450.00
Division 23 Heating, Ventilating, and Air Conditioning (HVAC) Subtotal						**$130,918.00**
					TOTAL:	$285,581.26

Cost Effect on Boiler with reduced load:
Total decreased load from eliminating FTR = 358 MBH

Existing Boiler (B-3 = 3000MBH capacity) = $47,600 (Total O&P)
Installation Time = 179MH

New Boiler (2856 MBH) = $44,100 (Total O&P)
Installation Time = 160MH

Analysis 3 - Linear Diffusers
Year 2013 Quarter 1
Unit Detail Report

Prepared By:
Nick Zitterbart
PSU

LineNumber				Description	Quantity	Unit	Daily Output	Total Incl. O&P	Ext. Total Incl. O&P
Division 23 Heating, Ventilating, and Air Conditioning (HVAC)									
233113130160				Metal ductwork, fabricated rectangular, over 5000 lb., aluminum alloy 3003-H14, includes fittings, joints, supports and allow for a flexible conn. field sketches, excludes as-built dwgs. and insul.	6,046.00	Lb.	145.00	$14.93	$90,266.78
233713101040				Diffuser, aluminum, ceiling, rectangular, 1 to 4 way blow, 12" x 9", includes opposed blade damper	155.00	Ea.	14.00	$130.00	$20,150.00
Division 23 Heating, Ventilating, and Air Conditioning (HVAC) Subtotal									**$110,416.78**

Cost Effect on AHU with increased load:
Total increased load - AHU1 = 8162CFM, AHU2 = 2426CFM, AHU3 = 5977CFM

Existing AHU1 (23500CFM) = $41,975 (Total O&P), Installation Time = 40MH
Existing AHU2 (33000CFM) = $65,875 (Total O&P), Installation Time = 80MH
Existing AHU3 (44500CFM) = $65,875 (Total O&P), Installation Time = 80MH

New AHU1 (31700CFM) = $65,875 (Total O&P), Installation Time = 80MH
New AHU2 (35500CFM) = $65,875 (Total O&P), Installation Time = 80MH
New AHU3 (50500CFM) = $80,480 (Total O&P), Installation Time = 104 MH (extrapolation)

Variance:

AHU1 -> add $23,900 and 40MH
AHU2 -> no change
AHU3 -> $14,605 and 24MH

APPENDIX 4-B – MECHANICAL SYSTEM CALCULATIONS

Finned Tube Radiators Load

AHU-1 Area (North Floors 2-4)						AHU-2 Area (West Floors 1-4)			AHU-3 Area (East Floors 1-4)		
Unit No	*Capacity (MBH)*	*CFM conversion*	*Unit No*	*Capacity (MBH)*	*CFM conversion*	*Unit No*	*Capacity (MBH)*	*CFM conversion*	*Unit No*	*Capacity (MBH)*	*CFM conversion*
FTR-2-1	2	93	FTR-3-23	2.6	120	FTR-1-10	6	278	FTR-1-1	4	185
FTR-2-2	2	93	FTR-3-24	2.4	111	FTR-1-15	2.4	111	FTR-1-2	4	185
FTR-2-3	2	93	FTR-3-25	2.2	102	FTR-1-16	2	93	FTR-1-3	4	185
FTR-2-4	2	93	FTR-3-26	2	93	FTR-1-17	2	93	FTR-1-4	4	185
FTR-2-5	2	93	FTR-3-27	2	93	FTR-1-18	2	93	FTR-1-5	4	185
FTR-2-6	2	93	FTR-3-28	2	93	FTR-1-19	2	93	FTR-1-6	4	185
FTR-2-7	2	93	FTR-3-29	2	93	FTR-1-20	2	93	FTR-1-7	4	185
FTR-2-8	2	93	FTR-4-1	2	93	FTR-1-21	3	139	FTR-1-8	4	185
FTR-2-9	2	93	FTR-4-2	2	93	FTR-1-22	3	139	FTR-1-9	4	185
FTR-2-10	2	93	FTR-4-3	2	93	FTR-1-23	2	93	FTR-1-11	3	139
FTR-2-11	2	93	FTR-4-4	2	93	FTR-1-24	1	46	FTR-1-12	3	139
FTR-2-12	2.4	111	FTR-4-5	2	93	FTR-1-25	2	93	FTR-1-13	3	139
FTR-2-13	2	93	FTR-4-6	2	93	FTR-1-26	2	93	FTR-1-14	3	139
FTR-2-14	2	93	FTR-4-7	2	93	FTR-3-32	2	93	FTR-1-27	2	93
FTR-2-15	2	93	FTR-4-8	2	93	FTR-3-33	2	93	FTR-1-28	5	231
FTR-2-16	2	93	FTR-4-9	2	93	FTR-3-34	1	46	FTR-1-29	4	185
FTR-2-17	2	93	FTR-4-10	2	93	FTR-3-36	2	93	FTR-1-30	3	139
FTR-2-18	2	93	FTR-4-11	2	93	FTR-3-37	2	93	FTR-1-31	3	139
FTR-2-19	2	93	FTR-4-12	2	93	FTR-3-43	6	278	FTR-1-32	2	93
FTR-2-20	2	93	FTR-4-13	2	93	FTR-3-44	2	93	FTR-1-33	2	93
FTR-2-21	2.6	120	FTR-4-14	2	93	FTR-4-29	2	93	FTR-1-34	2	93
FTR-2-22	2.6	120	FTR-4-15	2	93	FTR-4-39	2	93	FTR-2-29	2.8	130
FTR-2-23	2	93	FTR-4-16	2	93				FTR-2-30	2.8	130
FTR-2-24	2	93	FTR-4-17	2	93				FTR-2-31	1.5	69
FTR-2-25	2	93	FTR-4-18	2	93				FTR-2-32	1.5	69
FTR-2-26	2	93	FTR-4-19	2	93				FTR-2-33	1.5	69
FTR-2-27	2	93	FTR-4-20	2.2	102				FTR-2-34	1.5	69
FTR-2-28	2	93	FTR-4-21	2.2	102				FTR-3-16	8	370
FTR-3-1	2	93	FTR-4-22	2.6	120				FTR-3-30	2	93
FTR-3-2	4	185	FTR-4-23	2.6	120				FTR-3-31	2	93
FTR-3-3	2	93	FTR-4-24	2	93				FTR-3-35	1.5	69
FTR-3-4	2	93	FTR-4-25	2.5	116				FTR-3-38	1.5	69
FTR-3-5	2	93	FTR-4-26	2.8	130				FTR-3-39	1.5	69
FTR-3-6	2	93	FTR-4-27	2	93				FTR-3-40	1.5	69
FTR-3-7	2	93	FTR-4-28	2	93				FTR-3-41	1.5	69
FTR-3-8	2	93							FTR-3-42	2	93
FTR-3-9	2	93							FTR-3-45	2	93
FTR-3-10	2	93							FTR-3-46	2	93
FTR-3-11	2	93							FTR-3-47	1	46
FTR-3-12	2	93							FTR-4-30	2	93
FTR-3-13	2	93							FTR-4-31	2	93
FTR-3-14	2	93							FTR-4-32	2	93
FTR-3-15	2	93							FTR-4-33	2	93
FTR-3-17	2	93							FTR-4-34	2	93
FTR-3-18	2	93							FTR-4-35	2	93
FTR-3-19	2	93							FTR-4-36	2	93
FTR-3-20	2	93							FTR-4-37	2	93
FTR-3-21	2	93							FTR-4-38	2	93
FTR-3-22	2.6	120							FTR-4-40	2	93
TOTAL	**102.2**	**4731**		**74.1**	**3431**		**52.4**	**2426**		**129.1**	**5977**

Calculating Duct Size for Equivalent FTR Load Output											
			Round Duct Size				Round Duct Size				Round Duct Size
FTR-1-24	1	46	5	FTR-3-12	2	93	7	FTR-4-35	2	93	7
FTR-3-34	1	46	5	FTR-3-13	2	93	7	FTR-4-36	2	93	7
FTR-3-47	1	46	5	FTR-3-14	2	93	7	FTR-4-37	2	93	7
FTR-2-31	1.5	69	6	FTR-3-15	2	93	7	FTR-4-38	2	93	7
FTR-2-32	1.5	69	6	FTR-3-17	2	93	7	FTR-4-39	2	93	7
FTR-2-33	1.5	69	6	FTR-3-18	2	93	7	FTR-4-4	2	93	7
FTR-2-34	1.5	69	6	FTR-3-19	2	93	7	FTR-4-40	2	93	7
FTR-3-35	1.5	69	6	FTR-3-20	2	93	7	FTR-4-5	2	93	7
FTR-3-38	1.5	69	6	FTR-3-21	2	93	7	FTR-4-6	2	93	7
FTR-3-39	1.5	69	6	FTR-3-26	2	93	7	FTR-4-7	2	93	7
FTR-3-40	1.5	69	6	FTR-3-27	2	93	7	FTR-4-8	2	93	7
FTR-3-41	1.5	69	6	FTR-3-28	2	93	7	FTR-4-9	2	93	7
FTR-1-16	2	93	7	FTR-3-29	2	93	7	FTR-3-25	2.2	102	7
FTR-1-17	2	93	7	FTR-3-3	2	93	7	FTR-4-20	2.2	102	7
FTR-1-18	2	93	7	FTR-3-30	2	93	7	FTR-4-21	2.2	102	7
FTR-1-19	2	93	7	FTR-3-31	2	93	7	FTR-1-15	2.4	111	7
FTR-1-20	2	93	7	FTR-3-32	2	93	7	FTR-2-12	2.4	111	7
FTR-1-23	2	93	7	FTR-3-33	2	93	7	FTR-3-24	2.4	111	7
FTR-1-25	2	93	7	FTR-3-36	2	93	7	FTR-4-25	2.5	116	7
FTR-1-26	2	93	7	FTR-3-37	2	93	7	FTR-2-21	2.6	120	7
FTR-1-27	2	93	7	FTR-3-4	2	93	7	FTR-2-22	2.6	120	7
FTR-1-32	2	93	7	FTR-3-42	2	93	7	FTR-3-22	2.6	120	7
FTR-1-33	2	93	7	FTR-3-44	2	93	7	FTR-3-23	2.6	120	7
FTR-1-34	2	93	7	FTR-3-45	2	93	7	FTR-4-22	2.6	120	7
FTR-2-1	2	93	7	FTR-3-46	2	93	7	FTR-4-23	2.6	120	7
FTR-2-10	2	93	7	FTR-3-5	2	93	7	FTR-2-29	2.8	130	8
FTR-2-11	2	93	7	FTR-3-6	2	93	7	FTR-2-30	2.8	130	8
FTR-2-13	2	93	7	FTR-3-7	2	93	7	FTR-4-26	2.8	130	8
FTR-2-14	2	93	7	FTR-3-8	2	93	7	FTR-1-11	3	139	8
FTR-2-15	2	93	7	FTR-3-9	2	93	7	FTR-1-12	3	139	8
FTR-2-16	2	93	7	FTR-4-1	2	93	7	FTR-1-13	3	139	8
FTR-2-17	2	93	7	FTR-4-10	2	93	7	FTR-1-14	3	139	8
FTR-2-18	2	93	7	FTR-4-11	2	93	7	FTR-1-21	3	139	8
FTR-2-19	2	93	7	FTR-4-12	2	93	7	FTR-1-22	3	139	8
FTR-2-2	2	93	7	FTR-4-13	2	93	7	FTR-1-30	3	139	8
FTR-2-20	2	93	7	FTR-4-14	2	93	7	FTR-1-31	3	139	8
FTR-2-23	2	93	7	FTR-4-15	2	93	7	FTR-1-1	4	185	9
FTR-2-24	2	93	7	FTR-4-16	2	93	7	FTR-1-2	4	185	9
FTR-2-25	2	93	7	FTR-4-17	2	93	7	FTR-1-29	4	185	9
FTR-2-26	2	93	7	FTR-4-18	2	93	7	FTR-1-3	4	185	9
FTR-2-27	2	93	7	FTR-4-19	2	93	7	FTR-1-4	4	185	9
FTR-2-28	2	93	7	FTR-4-2	2	93	7	FTR-1-5	4	185	9
FTR-2-3	2	93	7	FTR-4-24	2	93	7	FTR-1-6	4	185	9
FTR-2-4	2	93	7	FTR-4-27	2	93	7	FTR-1-7	4	185	9
FTR-2-5	2	93	7	FTR-4-28	2	93	7	FTR-1-8	4	185	9
FTR-2-6	2	93	7	FTR-4-29	2	93	7	FTR-1-9	4	185	9
FTR-2-7	2	93	7	FTR-4-3	2	93	7	FTR-3-2	4	185	9
FTR-2-8	2	93	7	FTR-4-30	2	93	7	FTR-1-28	5	231	9
FTR-2-9	2	93	7	FTR-4-31	2	93	7	FTR-1-10	6	278	10
FTR-3-1	2	93	7	FTR-4-32	2	93	7	FTR-3-43	6	278	10
FTR-3-10	2	93	7	FTR-4-33	2	93	7	FTR-3-16	8	370	12
FTR-3-11	2	93	7	FTR-4-34	2	93	7				

BTU/HR coversion to CFM to evaluate additional load on AHU's

$q=1.08CFM\Delta T$, where ΔT = 75-55 = 20 and q is BTU/HR totals listed above

Increased Load on AHU		Dec. on Boiler
	CFM	MBH
AHU-1	**8162**	**176**
AHU-2	**2426**	**52**
AHU-3	**5977**	**129**
Total	16565	358

Duration to install FTR	
3 per steamfitter per day	
Total FTR	155

Linear diffusers
Total of 155 added
Average of 15' of round duct necessary per diffuser based on plans
duct size determined by above CFm per diffuser

UNIT NO.	AREA SERVED	TOTAL CFM	MIN. OA CFM
AHU-1	NORTH FLOORS 2-4	23500	8000
AHU-2	WEST FLOORS 1-4	33000	25000
AHU-3	EAST FLOORS 1-4	44500	33000
AHU-4A/4B	LOWER LEVEL VIVARIUM	4500	4500
AHU-5	LOWER LEVEL	3400	2200
AHU-6	LECTURE HALL	3200	1600

Summary - Round Duct Size and Weights (24G)					
Duct Size (in.)	Qty (@15LF)	Tot LF	SA(ft2/ft)	Weight (24G)	Tot Weight (lb)
5	3	45	1.31	1.67	75.15
6	9	135	1.57	1.98	267.3
7	51	765	1.83	2.3	1759.5
8	11	165	2.09	2.61	430.65
9	12	180	2.36	2.93	527.4
10	2	30	2.62	3.34	100.2
12	1	15	3.14	3.97	59.55
				TOTAL WEIGHT	3220
			(Fittings, Turns)	10%	3542

Diameter (inches)	Surface Area (ft^2/ft)	Gage 26	Gage 24	Gage 22
		Weight (lbs/ft)		
4	1.05	1.02	1.36	1.59
5	1.31	1.25	1.67	1.95
6	1.57	1.49	1.98	2.32
7	1.83	1.72	2.30	2.69
8	2.09	1.96	2.61	3.06
9	2.36	2.20	2.93	3.42
10	2.62	2.51	3.34	3.91
11	2.88	2.74	3.66	4.28
12	3.14	2.98	3.97	4.64
13	3.40	3.21	4.28	5.01
14	3.67	3.45	4.60	5.38
15	3.93	3.68	4.91	5.75
16	4.19	3.92	5.23	6.12
17	4.45	4.16	5.54	6.48
18	4.72	4.39	5.85	6.85
19	4.98	4.63	6.17	7.22
20	5.24	4.94	6.58	7.70
21	5.50	5.18	6.90	8.07
22	5.75	5.41	7.21	8.44
23	6.02	5.64	7.53	8.80
24	6.28	5.88	7.84	9.17
25	6.54	6.12	8.15	9.54
26	6.80	6.35	8.47	9.91

FTR Piping QTO Summary			
WBS	**Description**	**Quantity 1**	
1" PHWR	Copper	452.12	ft
1" PHWS	Copper	860.74	ft
1-1/4" PHWR	Copper	312.61	ft
1-1/4" PHWS	Copper	238.39	ft
2" PHWR	Copper	35.58	ft
2-1/2" PHWR	Copper	55.10	ft
3/4" PHWR	Copper	1,150.08	ft
3/4" PHWS	Copper	1,434.09	ft

APPENDIX 5-A – DRIVEN STEEL H-PILE CALCULATIONS

Analysis 4 - Drive Steel H Piles
Year 2013 Quarter 1
Unit Detail Repor

Prepared By:
Nick Zitterbart
PSU

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 31 Earthwork					
316216130700	Steel piles, "H" Sections, 50' long, HP12 x 53, excludes mobilization or demobilization	2,079.00	V.L.F.	$41.58	$86,444.82
316216130800	Steel piles, "H" Sections, 50' long, HP12 x 74, excludes mobilization or demobilization	513.00	V.L.F.	$54.31	$27,861.03
316219102700	Timber piles, treated wood pile, mobilization, for 10,000 L.F. pile job	5,184.00	V.L.F.	$1.98	$10,264.32
Division 31 Earthwork Subtotal					**$124,570.17**

Note: HP12x74 were used in placed of HP12x84 for calculations based on availability in Reed Construction Data
Mobilization/Demobilization costs for timber and steel piles are the same per Reed Construction Data
Daily Output: H-Piles - 590 V.L.F, Mob/Demob - 3300 V.L.F

Footing: 4A-EE

Type: F2B Size: 6'-0" x 6'-0" x 1'-10"

Reinf: 10-#6 Each Way Bottom

Bearing Capacity: 14000 PSF (P= 504k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 6' [Per S001]

B= 6' [Per S001]

B Direction

S_B = B - 2*d_{min} = 3.5'

$N_B < S_B/3D$ → $N_B <$ 1.167

$N_B > S_B/10'$ → $N_B >$ 0.35

So N_B= 1 Two rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 3.5'

$N_L < S_L/3D$ → $N_L <$ 1.167

$N_L > S_L/10'$ → $N_L >$ 0.35

So N_L= 1 Two rows in 'L' direction

P = 504k (from column)

$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 4 = 624k

Is $P_{reaction,\ H\ pile\ total} > P$? Yes, therefore okay

4 - 12x53 Piles @ 27' will support this footing

Note: 27' is depth to bedrock per geotech report

Footing: 2D-FF, 2D-DD.9, 2C-FF, 2C-DD.9

Type: F11A   Size: 4'-0" x 4'-0" x 1'-0"

Reinf: 8-#4 Each Way Bottom

Bearing Capacity: 5000 PSF (P= 80k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 4' [Per S001]

B= 4' [Per S001]

B Direction

S_B = B - 2*d_{min} = 1.5'

$N_B < S_B/3D$ → $N_B < 0.5$

$N_B > S_B/10'$ → $N_B > 0.15$

So N_B= 0   One row in 'B' direction

L Direction

S_L = L - 2*d_{min} = 3.5'

$N_L < S_L/3D$ → $N_L < 0.5$

$N_L > S_L/10'$ → $N_L > 0.15$

So N_L= 0   One row in 'L' direction

P = 80k   (from column)

$P_{reaction, H pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction, H pile total}$= 156k * 1 = 156k

Is $P_{reaction, H pile total}$ > P ?   Yes, therefore okay

4 - 12x53 Piles @ 27' will support these four footings

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Footing: 2B-DD.2

Type: F1A Size: 5'-0" x 5'-0" x 1'-0"

Reinf: 6-#5 Each Way Bottom

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Bearing Capacity: 5000 PSF (P= 125k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 5' [Per S001]

B= 5' [Per S001]

B Direction

S_B = B - 2*d_{min} = 2.5'

$N_B < S_B/3D$ → $N_B <$ 0.83

$N_B > S_B/10'$ → $N_B >$ 0.25

So N_B= 0 One row in 'B' direction

L Direction

S_L = L - 2*d_{min} = 2.5'

$N_L < S_L/3D$ → $N_L <$ 0.83

$N_L > S_L/10'$ → $N_L >$ 0.25

So N_L= 0 One row in 'L' direction

P = 125k (from column)

$P_{reaction, H pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction, H pile total}$= 156k * 1 = 156k

Is $P_{reaction, H pile total}$ > P ? Yes, therefore okay

1 - 12x53 Pile @ 27' will support this footing

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Footing: 4A-DD

Part 2

Type: F9A   Size: 30'-0" x 4'-0" x 3'-0"

Reinf: #7 @12 o.c Each Way Top & Bottom

Bearing Capacity: 5000 PSF (P= 600k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 30' [Per S100b]

B= 4' [Per S100b]

B Direction

S_B = B - 2*d_{min} = 1.5'

$N_B < S_B/3D$ → $N_B <$ 0.5

$N_B > S_B/10'$ → $N_B >$ 0.15

So N_B= 0 One row in 'B' direction

L Direction

S_L = L - 2*d_{min} = 27.5'

$N_L < S_L/3D$ → $N_L <$ 9.17

$N_L > S_L/10'$ → $N_L >$ 2.75

So N_L= 4 Five rows in 'L' direction

P = 600k (from column)

$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 5 = 780k

Is $P_{reaction,\ H\ pile\ total} > P$? Yes, therefore okay

5 - 12x53 Piles @ 27' will support this part of footing

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Footing: 4-B

Type: F5B Size: 9'-0" x 9'-0" x 2'-8"

Reinf: 14-#8 Each Way Bottom

Bearing Capacity: 14000 PSF (P= 1134k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 9' [Per S001]

B= 9' [Per S001]

B Direction

S_B = B - 2*d_{min} = 6.5'

$N_B < S_B/3D$ → $N_B <$ 2.16

$N_B > S_B/10'$ → $N_B >$ 0.65

So N_B= 2 Three rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 6.5'

$N_L < S_L/3D$ → $N_L <$ 2.16

$N_L > S_L/10'$ → $N_L >$ 0.65

So N_L= 2 Three rows in 'L' direction

P = 1134k (from column)

$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 9 = 1404k

Is $P_{reaction,\ H\ pile\ total} > P$? Yes, therefore okay

9 - 12x53 Piles @ 27' will support this footing

Footing: 3- B to A Under Elevator shaft

Type: F10A Size: 42'-0" x 17'-0" x 4'-0"

Reinf: #10 @ 12" o.c. Each Way Top & Bottom

Bearing Capacity: 5000 PSF (P= 3570k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 84 → D= 12in and Bearing Capacity = 620 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 42' [Per S100b]

B= 17' [Per S100b]

B Direction

S_B = B - 2*d_{min} = 39.5'

$N_B < S_B/3D$ → $N_B <$ 13.16

$N_B > S_B/10'$ → $N_B >$ 3.95

So N_B= 4 Five rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 14.5'

$N_L < S_L/3D$ → $N_L <$ 4.83

$N_L > S_L/10'$ → $N_L >$ 1.45

So N_L= 2 Three rows in 'L' direction

P = 3570k (from column)

$P_{reaction,\ H\ pile}$= 620*0.4 (reduction factor) = 248k

$P_{reaction,\ H\ pile\ total}$= 248k * 15 = 3720k

Is $P_{reaction,\ H\ pile\ total}$ > P ? Yes, therefore okay

15 - 12x84 Piles @ 27' will support this footing

Footing: 2-A.1

Type: F7A   Size: 11'-0" x 11'-0" x 2'-4"

Reinf: 18-#7 Each Way Bottom

Bearing Capacity: 5000 PSF (P=605k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 11' [Per S001]

B= 11' [Per S001]

B Direction

S_B = B - 2*d_{min} = 8.5'

$N_B < S_B/3D$ → $N_B <$ 2.83

$N_B > S_B/10'$ → $N_B >$ 0.85

So N_B= 1 Two rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 8.5'

$N_L < S_L/3D$ → $N_L <$ 2.83

$N_L > S_L/10'$ → $N_L >$ 0.85

So N_L= 2 Three rows in 'L' direction

P = 605k (from column)

$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 6 = 936k

Is $P_{reaction,\ H\ pile\ total}$ > P ? Yes, therefore okay

6 - 12x53 Piles @ 27' will support this footing

Footing: 1-B

Type: F7A   Size: 11'-0" x 11'-0" x 2'-4"

Reinf: 18-#7 Each Way Bottom

Bearing Capacity: 5000 PSF (P=605k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 11' [Per S001]

B= 11' [Per S001]

B Direction

S_B = B - 2*d_{min} = 8.5'

$N_B < S_B/3D$ → $N_B <$ 2.83

$N_B > S_B/10'$ → $N_B >$ 0.85

So N_B= 1 Two rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 8.5'

$N_L < S_L/3D$ → $N_L <$ 2.83

$N_L > S_L/10'$ → $N_L >$ 0.85

So N_L= 2 Three rows in 'L' direction

P = 605k (from column)

$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 6 = 936k

Is $P_{reaction,\ H\ pile\ total} > P$? Yes, therefore okay

6 - 12x53 Piles @ 27' will support this footing

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Footing: 3A-EE

Type: F2A Size: 6'-0" x 6'-0" x 1'-2"

Reinf: 8-#6 Each Way Bottom

Bearing Capacity: 5000 PSF (P= 180k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 6' [Per S001]

B= 6' [Per S001]

B Direction

S_B = B - 2*d_{min} = 3.5'

$N_B < S_B/3D$ → $N_B <$ 1.167

$N_B > S_B/10'$ → $N_B >$ 0.35

So N_B= 1 Two rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 3.5'

$N_L < S_L/3D$ → $N_L <$ 1.167

$N_L > S_L/10'$ → $N_L >$ 0.35

So N_L= 1 Two rows in 'L' direction

P = 180k (from column)

$P_{reaction, H pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction, H pile total}$= 156k * 4 = 624k

Is $P_{reaction, H pile total}$ > P ? Yes, therefore okay

4 - 12x53 Piles @ 27' will support this footing

Footing: 2A-DD.9

Type: F11A   Size: 4'-0" x 4'-0" x 1'-0"

Reinf: 8-#4 Each Way Bottom

Bearing Capacity: 5000 PSF (P= 80k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 4' [Per S001]

B= 4' [Per S001]

B Direction

S_B = B - 2*d_{min} = 1.5'

$N_B < S_B/3D$ → $N_B <$ 0.5

$N_B > S_B/10'$ → $N_B >$ 0.15

So N_B= 0 One row in 'B' direction

L Direction

S_L = L - 2*d_{min} = 3.5'

$N_L < S_L/3D$ → $N_L <$ 0.5

$N_L > S_L/10'$ → $N_L >$ 0.15

So N_L= 0 One row in 'L' direction

P = 80k (from column)

$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 1 = 156k

Is $P_{reaction,\ H\ pile\ total}$ > P ? Yes, therefore okay

1 - 12x53 Pile @ 27' will support this footing

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Footing: 4A-DD

Part 1

Type: F9A Size: 15'-0" x 16'-0" x 3'-0"

Reinf: #7 @12 o.c Each Way Top & Bottom

Bearing Capacity: 5000 PSF (P= 1200k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 16' [Per S100b]

B= 15' [Per S100b]

B Direction

S_B = B - 2*d_{min} = 12.5'

$N_B < S_B/3D$ → $N_B <$ 4.16

$N_B > S_B/10'$ → $N_B >$ 1.25

So N_B= 2 Three rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 13.5'

$N_L < S_L/3D$ → $N_L <$ 4.5

$N_L > S_L/10'$ → $N_L >$ 1.35

So N_L= 3 Four rows in 'L' direction

P = 1200k (from column)

$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 12 = 1872k

Is $P_{reaction,\ H\ pile\ total}$ > P ? Yes, therefore okay

12 - 12x53 Piles @ 27' will support this part of footing

Footing: 4A-DD

Part 3

Type: F9A Size: 32'-0" x 9'-0" x 3'-0"

Reinf: #7 @12 o.c Each Way Top & Bottom

Bearing Capacity: 5000 PSF (P= 1440k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 32' [Per S100b]

B= 9' [Per S100b]

B Direction

S_B = B - 2*d_{min} = 6.5'

$N_B < S_B/3D$ → $N_B <$ 2.16

$N_B > S_B/10'$ → $N_B >$ 0.65

So N_B= 2 Three rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 29.5'

$N_L < S_L/3D$ → $N_L <$ 9.83

$N_L > S_L/10'$ → $N_L >$ 2.95

So N_L= 3 Four rows in 'L' direction

P = 1440k (from column)

$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 12 = 1872k

Is $P_{reaction,\ H\ pile\ total} > P$? Yes, therefore okay

12 - 12x53 Piles @ 27' will support this part of footing

Footing: 4-A.1

Type: F3B Size: 7'-0" x 7'-0" x 2'-4"

Reinf: 12-#7 Each Way Bottom

Bearing Capacity: 14000 PSF (P= 686k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 7' [Per S001]

B= 7' [Per S001]

B Direction

S_B = B - 2*d_{min} = 4.5'

$N_B < S_B/3D$ → $N_B <$ 1.5

$N_B > S_B/10'$ → $N_B >$ 0.45

So N_B= 1 Two rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 4.5'

$N_L < S_L/3D$ → $N_L <$ 1.5

$N_L > S_L/10'$ → $N_L >$ 0.45

So N_L= 1 Two rows in 'L' direction

P = 686k (from column)

$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 4 = 624k

Is $P_{reaction,\ H\ pile\ total}$ > P ? No, therefore increase pile to 12x84 (620k*0.4=248k)

Now, $P_{reaction}$ = 248*4 = 992k > P

4 - 12x84 Piles @ 27' will support this footing

Footing: 2-B

Type: F8A Size: 14'-0" x 14'-0" x 3'-0"

Reinf: 24-#8 Each Way Bottom

Bearing Capacity: 5000 PSF (P= 980k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min}$ + D/2 = 1.25'

L= 14' [Per S001]

B= 14' [Per S001]

B Direction

S_B = B - 2*d_{min} = 11.5'

$N_B < S_B/3D$ → $N_B <$ 3.83

$N_B > S_B/10'$ → $N_B >$ 1.15

So N_B= 2 Three rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 11.5'

$N_L < S_L/3D$ → $N_L <$ 3.83

$N_L > S_L/10'$ → $N_L >$ 1.15

So N_L= 2 Three rows in 'L' direction

P = 980k (from column)

$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 9 = 1404k

Is $P_{reaction,\ H\ pile\ total} > P$? Yes, therefore okay

9 - 12x53 Piles @ 27' will support this footing

Footing: 1-A.1

Type: F5A   Size: 9'-0" x 9'-0" x 1'-10"

Reinf: 12-#7 Each Way Bottom

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Bearing Capacity: 5000 PSF (P=405k)

Per Geotech Report: Spacing ≥ 3D, D = Dia. Of Pile

Spacing Parallel to P	Ded. Factor
≥8D	1
6D	0.8
4D	0.5
≤3D	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.

$Cover_{min}$= 9 in.

d_{min}= $Cover_{min} + D/2$ = 1.25'

L= 9' [Per S001]

B= 9' [Per S001]

B Direction

S_B = B - 2*d_{min} = 6.5'

$N_B < S_B/3D$ → $N_B <$ 2.16

$N_B > S_B/10'$ → $N_B >$ 0.65

So N_B= 1 Two rows in 'B' direction

L Direction

S_L = L - 2*d_{min} = 6.5'

$N_L < S_L/3D$ → $N_L <$ 2.16

$N_L > S_L/10'$ → $N_L >$ 0.65

So N_L= 1 Two rows in 'L' direction

P = 405k (from column)

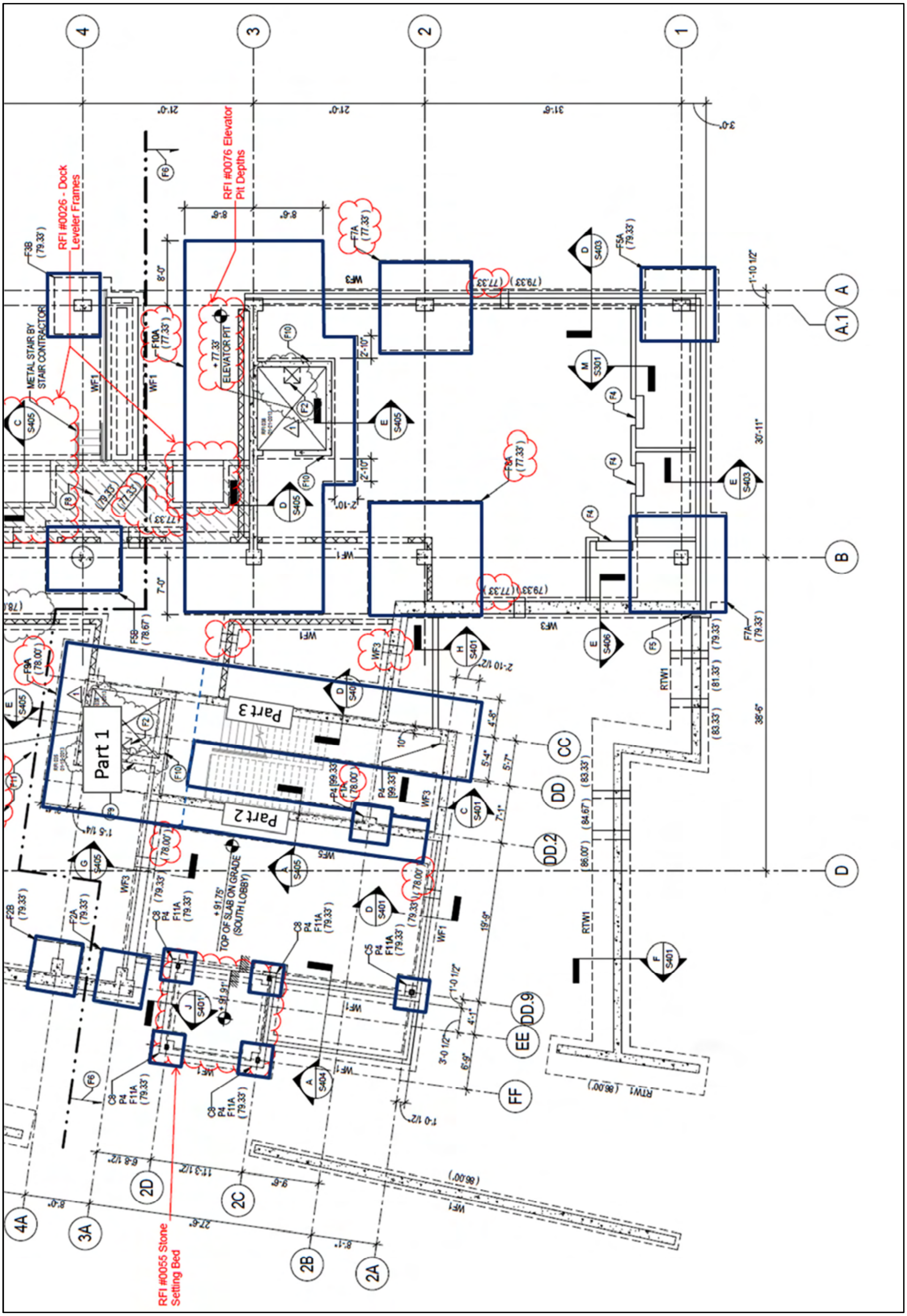
$P_{reaction,\ H\ pile}$= 390*0.4 (reduction factor) = 156k

$P_{reaction,\ H\ pile\ total}$= 156k * 4 = 624k

Is $P_{reaction,\ H\ pile\ total} > P$? Yes, therefore okay

4 - 12x53 Piles @ 27' will support this footing

Analysis 4 - Footing Locations - Reference Drawing S100b



APPENDIX 5-B – GEOTECHNICAL REPORT

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the subsurface conditions encountered, the site is considered suitable for the planned development. The following sections expound our Analysis, Conclusions and Recommendations based on the available limited geotechnical data.

6.1 Building

Based on the information provided, the finish floor elevations for the lower level and the first level of the proposed building are at 227.55 feet and 243.55 feet respectively.

Soil test borings were distributed within and in the vicinity of the footprint of the proposed structure based on access to test locations because of presence of existing residential structures. The subsurface conditions have been previously narrated in Section 4.0 and indicate subsurface material encountered can be grouped into the following strata:

- Stratum A – Existing Fill Material
- Stratum B - Residual (Sandy Silt/Clay/Silty Clay): SPT N-values 10 to 20 bpf
- Stratum C - Disintegrated Rock: SPT N-values > 51 bpf
- Stratum D - Bedrock

The following table presents the approximate elevations at the top of Stratum C and at the top of Bedrock.

Table No. 3: Approx. Top Elevation of Stratum "C" & Bedrock

Boring	Stratum "C"	Bedrock
B-01	227	214
B-02	233	223
B-03	236	226
B-04	253	239
B-05	246	237
B-06	237	218
B-07	232	213
B-08	215	203
B-09	211	201
B-10	215	209
B-11	226	211

The following subsurface conditions are noted within or in the vicinity of the proposed building:

- In **Borings B-02 to B-05** (located within approximately north one-third of building), **Stratum D (Bedrock)** was encountered either above the lower level FF elevation at Borings B-04 and B-05, or within 1.5 to 4.5 feet below the noted FF elevation at Borings B-02 and B-03. As such deep rock excavations of about 14 feet (from Elevation 239.0± to estimated Subgrade Elevation 226.5±) will be required to install slabs-on-grade. Additional excavation will be required to install spread footings to support the specified column loads mostly in the 1400-kips range per column. It is recommended to support the structure on spread and strip footings in the vicinity of these borings. For footings bearing on **Bedrock, they should be designed based on allowable bearing capacity of 35 ksf.**

- **Stratum C - Disintegrated Rock** (very dense silty sand) was observed from top elevations ranging from Elevation 211± to 253± feet. This stratum was underlain by bedrock that extended to the maximum depth of exploration. Stratum C was encountered within typical shallow spread footing embedment depths within Borings **B-01, B-06, B-07 and B-11.** Spread footings and strip footings can be placed within the very dense disintegrated rock encountered below Elevation 227± within these borings. Below this elevation at these borings, footings should be designed based on an **allowable bearing capacity of 14 ksf**.

- In the remaining Borings B-08 to B-10, **Stratum B** extended up to Elevations 211.0 to 215.0. Stratum B is expected to be encountered within potential footing embedment depths. At these depths, the bearing capacity of the soil is maximum 2 ksf which is deemed not enough to support the heavy loads of the walls and columns of the structure. However, bearing can be achieved at much deeper elevation below 200 feet. Spread footing at these depths are not feasible as they require deep excavations which require shoring, and would be cost-prohibitive. Hence, it is recommended to support the structure in the south one-third of the building (vicinity of Borings B-08 to B-10) on either deep foundation or intermediate foundations. **Stone columns/aggregate piers** can be used to increase the bearing capacity of the Stratum B - residual soils. Alternatively, deep foundations like **drilled shafts or driven Steel H-piles,** extending into the bedrock can be used as the support for the structure in this area. We understand that Value Engineering (VE) is being performed and were asked to provide these alternatives for VE evaluation.

    - **Stone Columns/Aggregate Piers** can be used to support footings in the vicinity of Borings B-08 to B-10. Stone Columns/Aggregate piers shall be installed to Elevations ranging from 211± to 215.0±. While the number of the Stone Column/Aggregate Pier elements will depend on the loads and sizes of the footings at each foundation element, it is recommended that the pier elements should cover at least 30% of the footprint of the supported footing.

The stone columns shall be designed in accordance with generally-accepted engineering practice. It is recommended that a specialty contractor provide a design for the stone columns/aggregate piers suitable for supporting spread and continuous footings. The design shall include detailed geotechnical design calculations, construction drawings, and shop drawings. The contractor shall provide the appropriate allowable bearing capacity on the stone columns/aggregate piers soil improvement system. An allowable bearing capacity of 5.0 ksf is recommended for preliminary design and estimating purposes. The bearing capacity is predicated on total and differential settlements being limited to maximum 1.0 inch and 0.5 inches respectively. The bearing capacity must be confirmed by the specialty contractor based on the service load bearing pressure determined by based on Modulus Load Test on the piers.

All plans and calculations shall be signed and sealed by a Professional Engineer (P.E.) licensed in the State of Maryland.

- **Driven Steel H-piles** – H-pile bearing resistance recommendations are based on the AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications and the in-situ subsurface soil/rock and groundwater conditions. The piles are recommended to be driven to practical refusal on top of bedrock. Accordingly, the pile capacity will be governed by the structural capacity of the pile. Using yield strength, Fy = 50 Ksi, and a Structural Resistance Factor, ϕs of 0.50 for structural design of steel H-piles in compression and subject to damage due to severe driving conditions where use of a pile driving shoes is necessary, the following table presents the Allowable bearing capacities for the suggested H-piles.

H-Pile Size	Allowable Capacity (kips)
12x53	390
12x84	620
14x117	860

The above table presents the results of the single pile analysis. Group pile analysis will be provided after pile layout has been determined. Due to the group effect, the lateral capacity of the individual piles cannot be fully developed if the piles are closer than 8D spacing, where, D is equal to the pile diameter in the direction parallel to the loading. Accordingly, the following deduction factors are recommended to be applied to the lateral resistance of individual piles:

Spacing in the Direction Parallel to Loading	Deduction Factor
=>8D	1.0
6D	0.8
4D	0.5
<=3D	0.4

As for axially loaded piles, a minimum spacing of 3D is recommended. Because of the hard pile driving that is anticipated within Stratum C (very dense disintegrated rock) and bedrock, driving shoes are recommended in order to prevent any damage to the piles.

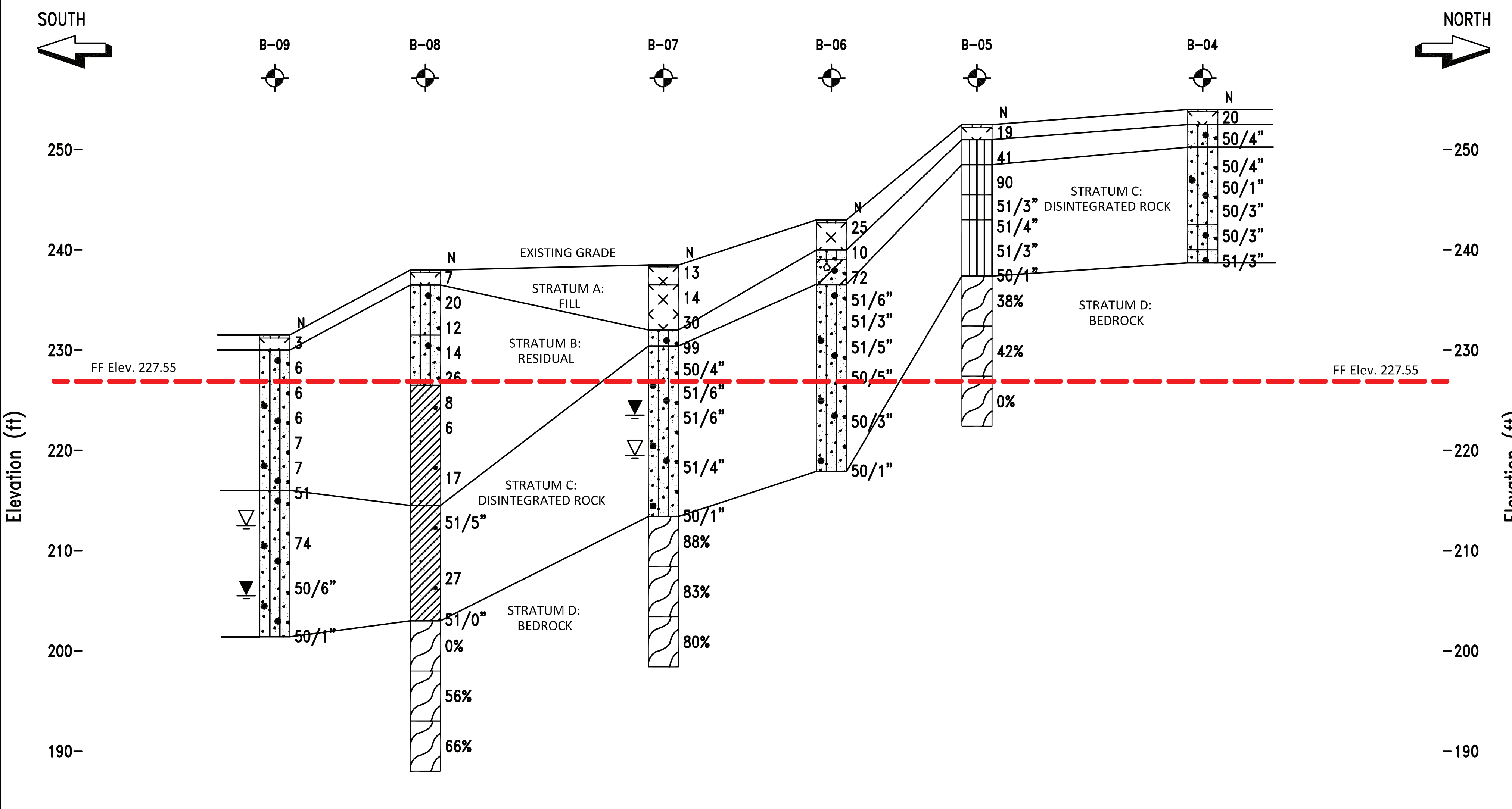
Alternatively, Drilled Shafts - Due to the potential differential settlement and stability considerations of the structure, it is suggested to use deep foundations in the vicinity of Boring B-08 and B-09. The drilled shafts shall be designed based on allowable Unit Side Friction of 0.45 ksf within the overburden (residual soil and disintegrated rock) and 8 ksf within bedrock, and allowable Unit End-Bearing of 100 ksf, where the bases of all drilled shafts are socketed into competent rock. It is recommended to install drilled shafts with their bases embedded at least 2 shaft diameters into competent rock. Competent bedrock is defined as rock with RQD greater than 35%. Drilled shafts of **36 inch diameter and socketed minimum 10 feet into bedrock** are required to support the proposed structure. It is imperative that drilled shafts be inspected by a Geotechnical Engineer or a Technician under the engineer's supervision.

6.2 Retaining Walls

The bottom of wall elevations, thus in front of wall, for the proposed retaining walls range from 230± feet to 245± feet. The following subsurface conditions are noted within or in the vicinity of the proposed retaining wall.

- In Boring RW-01, the bottom of wall is expected to be at Elevation 244.9 at which disintegrated rock was observed below conventional footing elevation. It is required to excavate at least 7 feet of Stratum C soil for footing placement. Footings in this area should be designed based on allowable bearing pressure of 14 ksf.
- Boring RW-02 consisted of fill material extending to Elevation 230.0 and with variable SPT N-values ranging from 10 to 47. Residual soils with SPT N-values ranging from 10 to 20 were logged below the fill to Elevation 219.5±. The bottom of wall in the vicinity of this boring is at Elevation 235.5, thus within the existing fill. Spread footings can be place in compacted existing fill below Elevation 233.5 or within the underlying residual soils. For footings in this area, an allowable bearing pressure of 3 ksf is recommended. This recommendation is predicated on the subgrade being prepared as recommended for footings bearing in compacted existing fill material.
- In Borings RW-03 and RW-04, suitable load bearing soils (Silty sand with rock fragments) were encountered below approximately Elevations 235± which are suitable to support the proposed retaining walls. At this elevation should be designed based on allowable bearing pressure of 14 ksf.

Stepped down and/or adjacent column footings should be positioned outside of a 2H:1V slope line extending outward from the underside of the nearest adjacent footings. Competent undisturbed natural soil, compacted structural fill, and/or compacted existing fill should exist



STRATUM A: FILL (Silty Sand/Sandy Clay)
STRATUM B: Residual (Clay/Silty Sand/Silt)
STRATUM C: Disintegrated Rock (Silty Sand/Silty Clay/Silt with rock fragments)
STRATUM D: Bedrock (Amphibolite Rock)

LEGEND

∇ – Depth water was encountered during drilling.

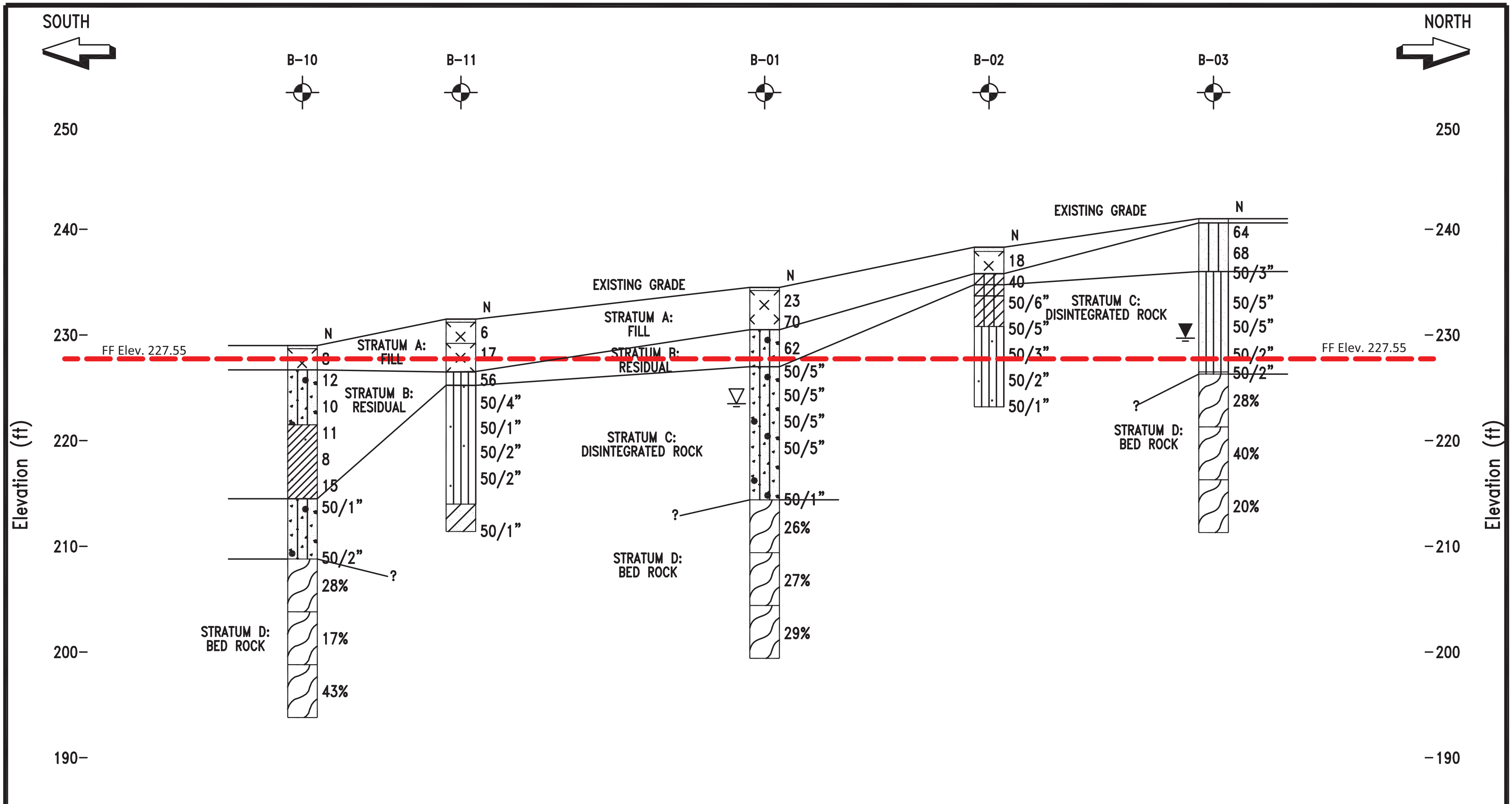
▼ – Groundwater depth monitored after boring completion or after 24 hours.

N – Standard Penetration test Resistance in Blows per foot or RQD (%)

Note: Strata changes shown on this profile represent generalizations based on average conditions indicated by soil test borings.

GENERALIZED SUBSURFACE PROFILE Section A–A'		
Scale: 1H = 4V	Date: 9/30/11	Drawn By: RG
Coppin State University Science and Technology Center Baltimore, MD		
T. L. B. ASSOCIATES, INC. Glen Burnie, Maryland 21061		Drawing No: 3

STRATIGRAPHY N GW LOGS.GPJ TLB.GDT 9/30/11



STRATUM A: FILL (Silty Sand/Silty Clay/Silt)
STRATUM B: Residual (Sandy Silt/Clay/Silty Clay)
STRATUM C: Disintegrated Rock (Silty Sand/Sandy Silt with rock fragments)
STRATUM D: Bedrock (Amphibolite Rock)

LEGEND

▽ – Depth water was encountered during drilling.

▼ – Groundwater depth monitored after boring completion or after 24 hours.

N – Standard Penetration test Resistance in Blows per foot or RQD (%)

Note: Strata changes shown on this profile represent generalizations based on average conditions indicated by soil test borings.

GENERALIZED SUBSURFACE PROFILE Section C-C'		
Scale: 1H = 4V	Date: 12/9/11	Drawn By: RG
Coppin State University Science and Technology Center Baltimore, MD		
T. L. B. ASSOCIATES, INC. Glen Burnie, Maryland 21061	Drawing No: 5	

STRATIGRAPHY N GW LOGS.GPJ TLB.GDT 12/9/11