The Potomac Yard Land Bay E

Arlington, VA

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Construction Management

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AE Senior Thesis Final Report

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The Pennsylvania State University Department of Architectural Engineering Senior Thesis

THE POTOMAC YARD LAND BAY E

ARLINGTON, VA

Contractor- James G. Davis Construction
Owner- The Meridian Group
Architect- Davis, Carter, Scott LTD.
Civil Engineer- Christopher Consultants
Structural Engineer- Smislova, Kehnemui & Assoc.
MEP Engineer- Allen & Shariff Corporation
Landscape Architect- Lewis Scully Gionet
Delivery Method- Design-Bid-Build, GMP
Cost- $75 Million
Duration- 20 Months, 1/2/2008 – 9/30/2009

Electrical:

- 277/480V, 3 Phase, 4W with 3,000A Breaker Service to Both Buildings
- (36) Lighting Fixtures throughout the Buildings Operating on 277V or 120V
- (10) Lighting Fixtures throughout the Parking Levels Operating on 277V or 120V

Mechanical:

- (8) AHU Ranging from 16,400-20,400 CFM on 480/3
- (3) Cooling Towers Ranging from 5,970-13,790lb Operating Weight
- (2) 350 Ton Chillers
- VAV used on Typical Floors to Regulate Temperature
- Fire Alarm System Rated for a Maximum Working Pressure of 175 PSI
- Utilization of Automatic Wet-type Class I Standpipe Systems, Wet and Dry Type Sprinkler Systems

Structural:

- 5,000 PSI Formed Slab and Beams
- 5” Thick Continuous Slab on Grade
- All Foundation Concrete Minimum of 28 Days 5,000 PSI Compressive Strength
- 12’-5” Typical Floor Height
- Typical Bay Size 28’ x 34’
- 10” Concrete Roof Slab
- Roof Structural Floor System is One-Way Conventional Reinforced Concrete Slab
- Roof Supported by Shallow Wide Post Tension Concrete Beams

Architecture:

- Office Building
- 9 Stories and a penthouse
- Two Buildings – 369,300 SF
- 235,000 SF Underground Parking Garage
- Pre-Certified as LEED Gold
- White TPO Roofing Membrane
- Precast Building Façade
- LA Fitness Facility
- 1.35 Acre Site
- Precast Wall Panels

DREW HEILMAN - CONSTRUCTION MANAGEMENT
THE PENNSYLVANIA STATE UNIVERSITY – DEPARTMENT OF ARCHITECTURAL ENGINEERING
http://www.engr.psu.edu/ae/thesis/portfolios/2010/deh5022/index.html

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2 Acknowledgements:

Throughout my college career I have faced many challenges and accomplished many great things. Over the past five years I have grown both scholastically and socially by completing the Architectural Engineering curriculum. By pursuing this major at Penn State University I was able to meet and work with a variety of accomplished individuals both in industry and on the faculty. As my senior year nears the end I have many people to thank for their assistance in completing one of my final college milestones. I would like to thank the following for their help:

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Solyndra

- Anthony Anello

TSI/ Exterior Wall Systems, Inc.

- Mike Callahan

Enclos Corporation

- Brian O’Connell

Arban & Carosi, Inc

- Nick Carosi IV

PACE Roundtable Industry Members

3 Executive Summary:

The 2009 PACE Roundtable event discussed many issues involving the current construction industry. Two important topics discussed during the event where sustainable construction and efficient project management. Today's owners are looking for a building design that incorporates sustainable features to benefit there building throughout its lifespan and efficient construction methods to deliver projects on-time and on-budget. The following analyses intend to offer ideas on reducing building operating costs through energy savings and efficient construction through prefabricated materials.

The first analysis looks at the implementation of a Solyndra PV system on the existing white TPO roof of both buildings. Solyndra claims that the implementation of their product with a reflective roof will optimize energy production. The study shows that the proposed system will provide a savings of $38,650 during the first year after installation. When using a 5% cost of energy increase per year it was determined that the system will pay for itself with in 22 years of operation. This is within the 25-year warranty period, in fact, by the end of the warranty the owner will save $402,622.63 in energy costs.

The second analysis involves implementing a unitized curtain wall system in place of the existing architectural precast and punched window façade. This was proposed to shorten the schedule and provide more natural daylight to the interior space. This study showed that the total project schedule would be shortened by 23 days and reduces the general conditions by 1.75%. This translates into a savings of $106,701.30 for the project. However, it was determined that the curtain wall system would cost 31% higher than the existing system and would more than double the cooling load on the building by solar heat gain through the increased glazing. This would dramatically increase the energy cost placed upon this building because the glazing is one of the largest factors in the cooling load of an office building.

The third analysis incorporated replacing the current all air mechanical system with a more energy efficient chilled beam mechanical system. This analysis only involved the comparison between the distribution equipment and supply material. This analysis showed used the decreased ceiling plenum height to translate into savings for the building. From this analysis it was determined that by implementing this system the owner would save 52.7 CY of concrete, which translates to a $67,390.13 cost savings on CIP concrete for the structural columns. The owner would also save 5.22% of conditioned air volume in the building to allow for a higher percentage of ventilated air in the building. However, when comparing the duration of installation and initial cost the new system cost approximately 45% more to install and take 54% longer time to complete. Although the proposed system is projected to cost more and take longer to install than the current system typically, chilled beam mechanical systems have around a 23% yearly energy savings compared to an all air system. From these annual savings the average chilled beam system pays for itself with in 7-10 years of installation.

4 Project Introduction:

The Potomac Yard Land Bay E is a 369,000 square foot base building with a 235,000 square foot underground parking garage located next to US Route 1 and the George Washington Memorial Parkway in Arlington Virginia. Land Bay E is positioned near Reagan National Airport and south of Crystal City Virginia. The project is located on an old train yard that has been converted into commercial land development. Land Bay E sits on a 15-acre complex that is owned by The Meridian Group which houses a variety of buildings that range from hotel, office, residential and retail space.

Upon completion of the project it is to have achieved a LEED Gold Certification. The construction site is constrained to 1.35 acres and houses two tower cranes, two material hoists and management office trailer. The deliveries, excavation and construction are able to take place with out disturbing the surrounding traffic flow and operations. Construction on the project is projected to take 20 months beginning on January 2, 2008 and it's scheduled to be completed by September 30, 2009.

The project includes new construction of a three level underground parking garage which will house 600 parking spots and two building towers that reach 9 stories of office space. The project also includes the construction of an outdoor interim space that consists of a landscaped park with a one-story building structure that will house either a small restaurant or a retail store. This space will fill the void between Land Bay E buildings East and West.

The building envelope of the Potomac Yard Land Bay E project consists of two types of systems. One of the systems is a curved curtain wall system and the other consists of architectural precast panels with punch windows. The other building envelope system used on the project is a unitized curtain wall system that covers the northern and southern facades of both towers. The southern façade of building B is covered with a curved curtain wall system that looks onto US RT.1. Other key features of the project include: the structural system consisting of cast in place concrete (CIP), courtyard area above portion of the parking garage, white TPO roofing and man high end finishes.

Figure 1: View from US Rte.1

5 Project Team Overview:

5.1 Client Information:

The owner of the Potomac Yard Land Bay E buildings is The Meridian Group that is located in Bethesda Maryland. They are a large real estate and investment development firm that has complete over $2.8 billion in transactions. The Meridian Group maintains a focus on the Washington DC Metropolitan area and also has assets in Baltimore, MD, Charlotte, SC and West Palm Beach, FL. The company has successfully acquired over 7 million SF of industrial and office space and 439 acres since 1993. Property is acquired, structured, constructed, capitalized and managed by the Meridian Group. All of these qualities make this client very experienced with construction practices.

The Potomac Yard Land Bay E buildings are high-class office spaces with class-A materials to attract high-end tenants. On the plaza level of the eastern building there are a variety of special features catered to LA Fitness like basketball courts and other fitness rooms. On the P1 level of the western building there is a swimming pool, basketball court and more fitness club space. The Lobbies of the buildings boast elaborate wood and stone decorative wall and floor coverings. The elevators are covered in stainless steel and are illuminated with high-class lighting fixtures.

The owner for this project was concerned about many issues. Some of the issues that the concerned the owner was to make sure that they were obtaining a quality product for the best value. The owner was also concerned keeping the construction process on schedule without sacrificing safety. The schedule was very important to the owner of the Land Bay E project because the sooner the construction of the buildings were completed the sooner they could rent out the space and begin making money on their investment. Finally the materials that were used on the project were of concern to the owner because they wanted to house high-end clients in their buildings. For this reason they had selected higher end finishes to be installed throughout the buildings.

5.2 Project Delivery Systems:

The Potomac Yard Land Bay E Project has many key players in delivering this project successfully as shown in the previous project delivery diagram. On this project there is the owner, which is The Meridian Group that is based out of Bethesda, MD. The Meridian Group is constructing this project with a goal of renting it for mainly office space with the ground floor being a health club. As of now there are two tenants that are LA Fitness and Wachovia/ Wells Fargo Bank. The Land Bay E project is delivered as a design-bid-build with a negotiated GMP contract.

The general contractor on the Land Bay E project is James G. Davis Construction Corporation and the architect is Davis, Carter, Scott LTD. DCS LTD. has contracted several other firms to help with the design process. Christopher Consultants was hired to perform the civil engineering for the project and the site work design. The structural engineer hired for this job was a company based out of Fairfax, VA that was called

Smislova, Kehnemui & Associates. The Allen and Shariff Corporation in charge of designing all of the mechanical, electrical and plumbing systems for the Land Bay E project and Lewis Scully Gionet was the landscape architect hired to design the finishes outside the building complex.

The subcontractors that DAVIS Construction used for the Land Bay E project were selected on a BAFO, best and final offer of the lowest offer with the comprehensive scope. DAVIS bonds all of the subcontractors over $150,000 for both payment and performance. For this project DAVIS did purchase liability insurance for work performed on the Land Bay E project. The main subcontractors that were selected for the project are listed below in figure 2.

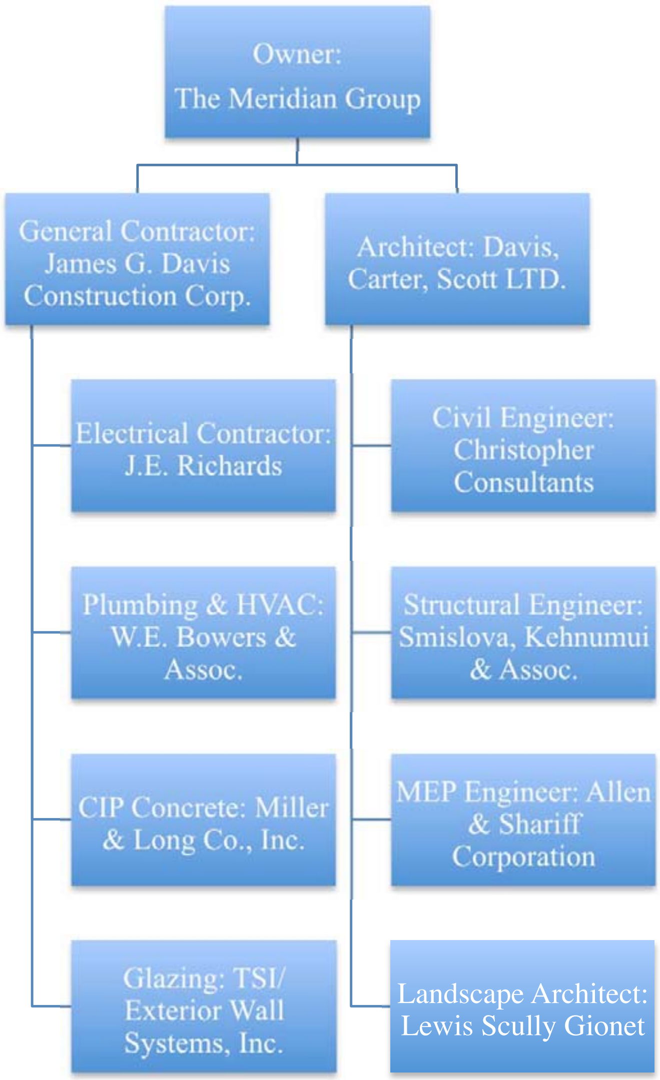


Figure 2: Project Delivery

5.3 Project Staffing Plan:

James G. Davis Construction has placed both management and field members on the Land Bay E project to accommodate the size and scope of the project. Throughout the project the personnel needs to change in order to accommodate different stages of construction. During some stages of the project more personnel with a variety of expertise will be needed. Overall the project staffing structure looks similar to figure three shown below.

Assistant Project Manager:

The assistant project manager is responsible for posting and submitting RFIs and submittals. Also the APM is in charge of tracking change documents and shop drawings.

Assistant Superintendent:

The assistant superintendent is responsible for updating the schedule and dealing with subcontractors on a daily basis. The assistant superintendent is also in charge of helping with the site coordination.

Project Manager:

The project manager is responsible for the completion of his or her portion of the project. They must keep track of change orders, ticket items, make payments ensure that budget items are met.

Superintendent:

The superintendent is responsible for maintaining the schedule by making sure that the field labor is producing the required amount of work to complete the project on time. Additionally the superintendent is responsible for managing and coordinating the work force on the job site, preparing for deliveries and ensuring site safety.

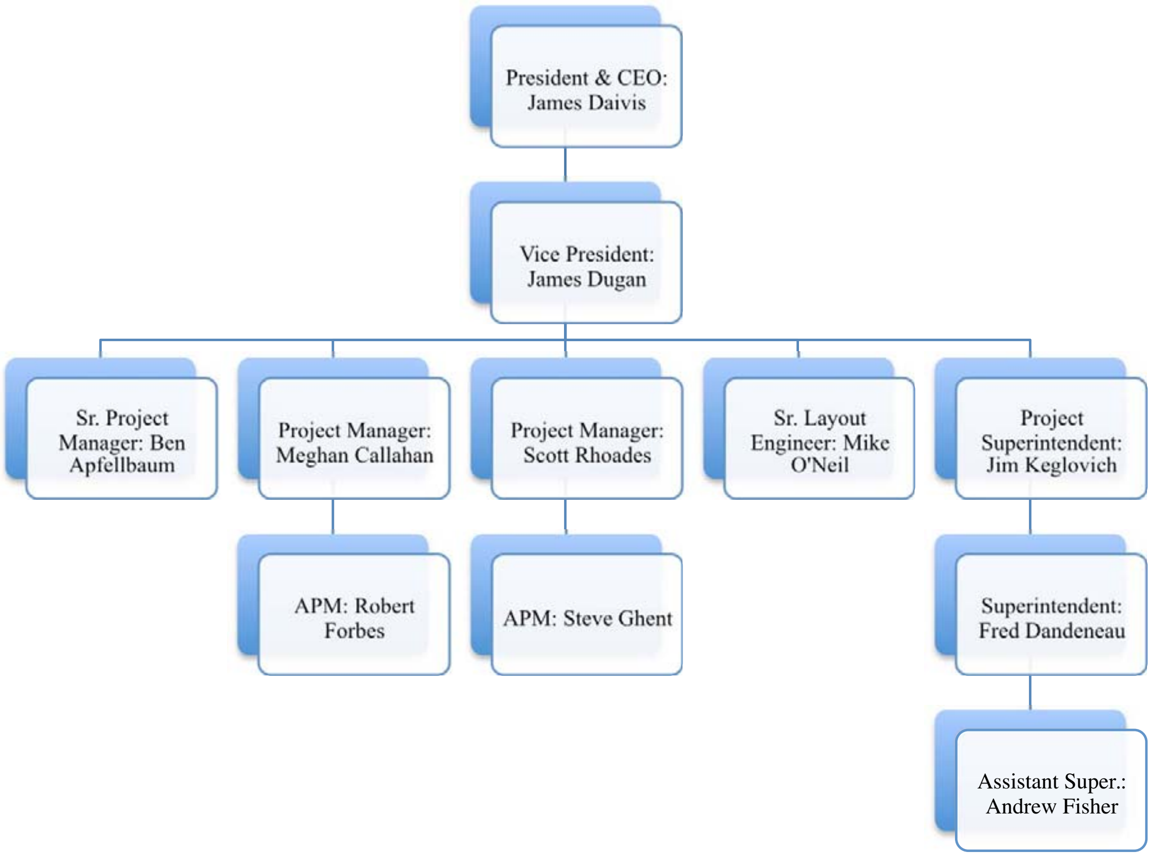


Figure 3: Project Staffing Chart

6 Existing Conditions

Figure 4: Existing Conditions

6.1 Design Overview:

Demolition:

The Potomac Yard Land Bay E project required no demolition because its prior use as a train yard. This site was relatively level with minimal structures. The project is one of many buildings that the owner is having built on their 15 acre facility. There has been previous construction on the 15-acre lot therefore making the Land Bay E site of 1.35 acres ready for construction to begin.

Structural Steel:

The Land Bay E project has minimal structural steel due to the fact that it is predominately a concrete structural system with post-tensioning elevated concrete slabs. The steel that is used in this project is cold-formed light steel that is used for some structural applications in the penthouse areas and also used for framing purposes. The structural steel studs on this project have minimum yield strengths of 50,000 psi for 16 gauge and thicker materials, and 33,000 psi for materials thinner than 16 gauge.

Cast In Place Concrete:

The Land Bay E project is mostly constructed with CIP concrete. It uses a variety of concrete strengths throughout the building. The building uses 5000 psi concrete for the slabs and beams, 4500 psi concrete for the slab on grade, 4000 psi concrete for the walls and piers, 5000 psi for the pile caps and 2500 psi concrete for CMU fill. All concrete ramps, parking levels, plaza levels and slabs shall have a minimum of 28 day curing time.

All of the typical floors in the buildings are constructed of elevated post tension concrete slabs. All of the reinforcing steel being used on this project shall be deformed billet steel conforming to ASTM A615, Grade 60. For any of the reinforcing steel that is being used on the Land Bay E project that is exposed to the elements is coated with an epoxy coating to retard the degradation of the product. The concrete placement was completed by a variety of methods like crane and bucket, concrete pump and Georgia buggies by Miller and Long. There were two tower cranes used in this process of placing the concrete, each located in one tower.

Figure 5: Architectural Precast

Precast Concrete:

There are two types of precast concrete used on the Land Bay E project. One of the types is prestressed concrete that is used for structural purposes as the piles. The reason for the use of piles on this project is due to the surrounding soil types and the depth of the water table. This project is within a small distance of the water table thus requiring a different type of foundation and a dewatering system. The piles that are used on the Potomac Yard Land Bay E project are 14'x14' that can resist 125 tons of force. These piles were driven into the ground to bear on natural soil which was on average about 30' below the lowest floor. The other type of precast concrete that was utilized on this project was used for architectural purposes as seen in figure 5 above. These panels are used on the façade of the buildings and are designed to anchor onto the structural concrete frame. The precast panels must also resist a force of 6000 pounds and not fail.

Mechanical System:

The mechanical contractor involved on the Land Bay E project is W.E. Bowers and Associates. The mechanical system in the Land Bay E buildings consist of 8 AHUs, 3 cooling towers, 2 chillers, both wet and dry sprinkler systems and VAV units that operate on every floor to regulate the air temperature. Between the two towers of the Land Bay E project there are 9 elevators, 8 of which service all of the floors including the parking levels. The other elevator is a hydraulic elevator that sole purpose is to serve the LA Fitness center. In the parking levels there are two garage air intake shafts and two garage air exhaust shafts. The building houses mechanical rooms on all of the floors except for the two lower P-levels. The combine size of the penthouses for both of the buildings for the Land Bay E project total is 15,430 SF which house the (2) chillers, (3) cooling towers, (8) AHUs and chilled water pumps.

Electrical System:

The electrical contractors involved on the Land Bay E project are MCLA and J.E. Richards. The electrical system that serves both of the buildings of the Potomac Yard Land Bay E project consists of a 277/480V, phase, 4W with a 3000A breaker service. The main service to the buildings is brought inside on the north face of the building system on the P1 level. The main electrical room is situated on the P1 level near the loading dock. Throughout the project there are 36 different lighting fixtures in the buildings A and B and there are 10 different lighting fixtures that are installed throughout the P-levels.

Masonry:

The masonry in this project is strictly used for load bearing purposes. There is no brick or architectural stone usage on the buildings. The concrete masonry units used on this project are to be placed with type N mortar joints and type S mortar joints for exterior walls. The masonry cells in the buildings are to be filled continuously with grout and reinforced. Wall ties were also used when being connected to steel beams.

Curtain Wall:

A curtain wall system was used for the curved portion of building B's façade and between both buildings A and B as seen in figure 6 below. On the larger portion of the project a precast architectural panel system with a punch out window glazing system would be put into place.

Figure 6: Curtain Wall System

Support of Excavation:

The design and installation of support of excavation was required for the Land Bay E project due to the soil and water conditions. The site was supported by sheet piling system to protect against caving. The excavation supports were not removed from the site until the structural system was braced. Once the excavation system was removed then proper backfilling of the site was completed.

LEED:

This project is projected to achieve a LEED certification of gold by the completion of the construction. There were many items that were used on the Land Bay E project that helped to achieve this status. Some of the materials and methods that were used on the project was a white TPO roofing membrane, recycling stations placed on every typical floor, recycling disposal service, additional bicycle racks added to the parking levels, local building materials and local transportation access. The reason that more bicycle racks were added is because of the large number of motor vehicle parking spots. Two contractors on this project provided the recycling service. The two contractors involved were American Disposal and Miller & Long/ NOVA. These two companies sorted land debris, asphalt, concrete and masonry, metals, drywall, wood, cardboard, paper, plastic and non-disposable materials. From this process there was 1,422.86 tons of recycled material and there was 93.94% of trash diverted from landfills.

6.2 Building Systems Summary:

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

Table 1: Buildings Systems Summary

6.3 Local Conditions:

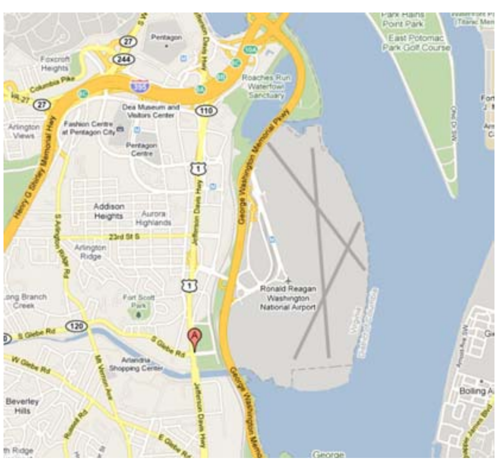


Figure 7: Local Map

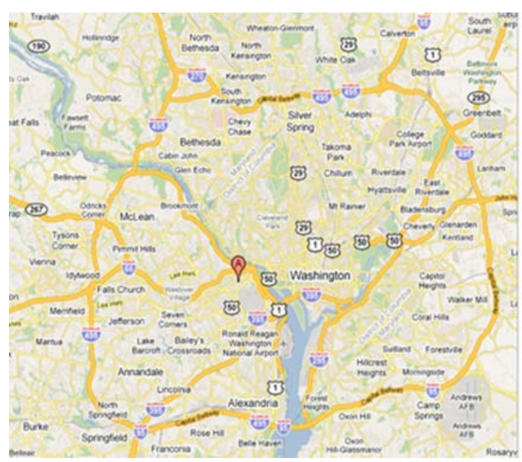


Figure 8: DC Area Map

The construction industry in the Washington DC metro areas is most commonly Cast in Place Concrete (CIP). To complete the structural system along with the CIP is most commonly post tension concrete slabs. The reason for the use of concrete structures in this area is due to the height restrictions placed within the District. Although these height restrictions do not apply to the surrounding cities this form of construction is highly adopted as a common practice. With the high demand for concrete structures in this area it limits the possibilities for steel erectors to become as profitable.

The project is located in an area of Arlington that predominately houses commercial office buildings along with some residential condos. Due to the condense area parking lots are at a minimum thus most buildings utilize parking decks and underground parking. Luckily during construction there is ample room on the northern portion of the sight for workers and management personnel to park outside the construction site. Although there is parking spots available it is appreciated that carpooling occur.

The type of projects that usually occur in the Washington DC metro area is predominately government buildings and related structures along with private office buildings. Being that Washington DC is the nation's capitol there is a lot of large businesses in the surrounding area like BAE Systems, Northrupp Grumman and Innovative Defense Tech that require large scale sophisticated buildings. Along with big business are the tourist attractions all over the area both government and historically related like the Pentagon and the Washington Monument. Both of these businesses require hotels, retail, residential and office space which the National Gateway at Potomac Yard provides.

Currently in the country's economic state of recovering from a recession there is unfortunately a reduced need for large office space. As of now there are two occupants that plan to move into the Land Bay E buildings. These two companies include LA Fitness and Wachovia/ Wells Fargo Bank. The rest of the building is currently awaiting occupancy.

The Potomac Yard site contains soft and compressible Stratum B1 soils that do not support the usage of shallow foundations like spread footings and mat slabs. Instead the use of deep foundations like precast concrete piles was recommended with a compressive strength of at least 4,000 psi. The piles are recommended to be of 30 feet in length below the lowest floor level. The water table was found to be at elevations of 0 to +15 feet thus the use of dewatering systems during construction were utilized. After construction pumping systems will still need to be used like sump pumps stations that are located in the lower P-levels.

6.4 Site Plan of Existing Conditions:

Please see Appendix A for site plan of existing conditions

The Potomac Yard Land Bay E project is located in Arlington, VA along US Route 1 and Glebe Road. The Land Bay E West project is one of eight buildings that are part the Potomac Yard complex. Land Bay E has two buildings that border to the north, one to the east and one to the south. All of the buildings names are Land Bay with different letters A-F. The buildings that surround Land Bay E West range from a variety of uses that consist of residential, office, retail and hotel.

The existing utilities around the site were run on the south border of the site while the new utilities were brought in on the northern border. There are several new light poles that will be installed surrounding the building along with new walkways. Once the parking deck the parking was completed Center Park was installed on top.

6.5 Site Layout Planning:

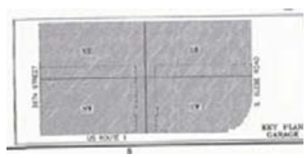


Figure 9: Garage Layout

The Potomac Yard Land Bay E project utilized a deep foundation system that involved the use of 14”x14” precast concrete piles at a length of 35 feet. Theses piles were driven into the site starting in the northwest quadrant of the site working their way around in a counter-clockwise direction finishing in the northeast quad. In total there were 1011 piles that were driven into the site to provide a stable foundation for the structure. There were 17 different types of pile caps that were constructed on this project that ranged from different size, shape and thickness. These pile caps were used to transfer the load from the columns in the building to the piles that distribute the weight of the structure and occupants to stable ground. For the excavation process of the project a retaining wall made of soldier beams a lagging was utilized to retain the surrounding soil while the construction of the foundation and garage levels was commencing.

To gain access to the excavated portion of the site there were two ramps that were constructed, one in the SE quadrant of the site and the second is located in the NE quadrant of the site. For organizational purposes each of the ramps permit one-way traffic. To enter and exit the site you must go down the SE ramp and go up the NE ramp. The CIP concrete garage structure was placed in the same sequence as the piles and pile caps were placed which was starting in the NW quadrant and proceeding counter-clockwise finishing in the NE quadrant. Once the entire placement of the garage structure was completed the building structural system was able to begin.

Please see Appendix B

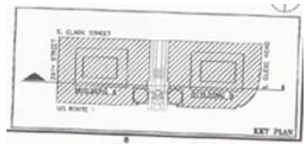


Figure 10: Building Layout

The CIP concrete structure for Building B begins on December 8, 2008 on the southern portion of the project. The placement of the concrete is broken up into three sequences per floor. Tower Crane #1 performs the placement of the concrete for Building B. Once the placement of concrete and some heavy picks are completed Tower Crane #1 may begin disassembly around April 2009. The CIP concrete structure for Building A begins on December 29, 2008. This building will have three similar floor sequences for placing the concrete as performed on Building B. Finally once the placement of concrete is completed for Building A and the heavy equipment is set the disassembly of Tower Crane #2 may begin around May 2009.

Please see Appendix C

7 Project Logistics

7.1 Project Schedule Summary:

Please see Appendix D for Project Schedule

The Land Bay E project was broken into three different phases. The three phases of the project were as follows: construction of the three parking levels, construction of building B and then the construction of building A. Although these three phases of construction started at separate times the work on all three of the phases was going on concurrently but at different stages.

Foundation Sequence

Due to the soil conditions and the site location's water table, shallow foundations like spread footings could not be used. Instead precast concrete piles had to be used for the foundation of this structure. Due to the larger footprint of the underground parking garage, a large area needed to be excavated to install a soldier beam and lagging soil retainage system to keep the excavation from caving during the pile installation. Once this was completed the garage structure was ready to commence.

Figure 11: Foundation

Structural Sequence

The structural sequencing of the project began with placing the cast in place columns for the parking levels and then placing the post tension concrete slabs for the parking decks. After the garage levels were completed the construction of building B began with the placing in the northern portion of the structure. Finally building A followed after building B started. Both of the buildings were having the concrete structure being placed simultaneously but at different stages.

Finish Sequence

After the structure of the buildings was completed the finishes could then proceed. Due to the fact that this project is just a base building and not a total interior fit out the buildings were not watertight when the core finishes begun. The reason for this is that only the building cores like the bathrooms, janitor closets, mechanical and electrical rooms which are located in the center of the buildings could be completed because they are isolated from the outside conditions. When installing the finishes in these areas the rooms were supplied with conditioned air. The lobby areas were also having the finishes installed before the building was sealed. This required the use of temporary doors, walls, air barricades and dehumidifiers.

7.2 Detailed Project Schedule:

Description	Date
Begin Construction	1/2/08
Complete Foundation	9/24/08
Permanent Power	7/27/09
Garage Complete	9/11/09
Project Complete	9/30/09

Table 2: Important Dates

The Potomac Yard Land Bay E project began its preconstruction activities during the summer of 2007 laying out the key plan for what the project was to become. The general contractor on the project was James G. Davis Construction Corporation that began its preconstruction activities in July of 2007. Around late August 2007 the design team released their final construction set of drawings to general contractor and the owner. After all of the preconstruction activities were completed the construction for the Land Bay E project began on January 2, 2008.

The detailed project schedule for the Potomac Yard Land Bay E project includes both preconstruction and construction activities with more of an emphasis on the construction phases. The detailed project schedule breaks down the three different phases of the project in detail for each trade. The three phases of this project include the garage levels, building B and Building A. In these three phases include various sequences that the construction process follows to ensure an organized approach to building the project.

Each phase of the building project is broken down into detail about the structural systems installation, MEP rough-in and trim out, finishes and exterior site work. The structural system for the garage levels starts in late August 2008, the MEP installation begins in late October 2008 and the finishes begin in December 2008. Next on the schedule Building B begins it's placing of structural concrete followed by the same sequence of events as the garage levels. After the structural concrete is placed for Building B, Building A begins its placement of structural concrete. While the placing of concrete is being completed for Building A the MEP work for Building B and the finishes for the garage levels is commencing simultaneously.

7.3 Project Cost Evaluation:

Cost Summary

Potomac Yard Land Bay E	Cost	Cost/SF
Construction Cost	$69,646,805	$112.53
Total Building Cost	$76,558,826	$123.70

Table 3: Construction and Building Cost

Building System Cost

Building System	Cost	Cost/SF
CIP Concrete	$15,700,000	$25.37
Precast	$2,570,000	$4.15
Glazing and Composite Panels	$11,070,000	$17.89
Elevators	$2,222,427	$3.59
HVAC/ Plumbing	$9,675,000	$15.63
Electrical	$5,450,730	$8.81
Fire Protection	$974,400	$1.57

Table 4: Building Systems

D4 Historical Data Estimate-

Please see Appendix E for D4 estimate sheets

Building Data

Name	Size	Floors	Bldg. Cost
Westchase Corporate Center	308,500	6	10,492,634
Ha-Lo Headquarters	267,334	7	37,643,382
Willow Oaks III	407,042	7	16,757,728

Table 5: Building Data

Parking Garage Data

Name	Size	Floors	Bldg. Cost
Park Place Parking Garage	129,024	5	3,158,033
Parking Garage	144,000	5	4,492,052
Renaissance Parking Garage	301,000	10	18,288,595
Mercy Health Parking Garage	220,000	4	6,581,720

Table 6: Parking Garage Data

When using D4 Cost Estimating Software for the Potomac Yard Land Bay E project the above projects where selected from the historical database. The reason for two estimates is because there were no projects that incorporated an underground parking garage with the building. The reason that the selected projects were used in the estimate is because they had the similar use, size and number of floors respectively. When obtaining the two estimates and adding them together to obtain the total project cost of $63,384,284. This total was about $13,174,542 short of the original project estimate.

RS Means Estimate-

Please see Appendix F for RS Means data sheets

	Building A	Building B	Parking Garage
Perimeter	333 LF	298 LF	647 LF
Square Footage	188,095 SF	181,997 SF	248,842 SF
Floor Height	12.5'	12.5'	10'
Elevators	4	5	8 (used in bldgs)

Table 7: SF Estimate

Building A

Base Unit Cost	$148.81	Adjustment	Notes
Story Adjust	.5	.69	Per 1Ft
Perimeter Adjust	247.95	-7.35	Per 100LF
Special Foundation		.49	
Elevators		0	Per Car
Subtotal:		142.64	
Location:	.93	132.66	Arlington, VA

Table 8: Building A Adjustments

Total Bldg. Cost: $24,951,719.84

Building B

Base Unit Cost	$149.18	Adjustment	Notes
Story Adjust	.5	.69	Per 1Ft
Perimeter Adjust	273.16	-8.40	Per 100LF
Special Foundation		.49	
Elevators	1	3.66	Per Car
Subtotal:		145.62	
Location:	.93	135.43	Arlington, VA

Table 9: Building B Adjustments

Total Bldg. Cost: $24,644,526.39

Parking Garage

Base Unit Cost	$148.81	Adjustment	Notes
Story Adjust	0	0	Per 1Ft
Perimeter Adjust	247.95	-3.96	Per 100LF
Special Foundation		.57	
Elevators		0	Per Car
Subtotal:		67.14	
Location:	.93	62.44	Arlington, VA

Table 10: Parking Garage Adjustments

Total Bldg. Cost: $15,537,744.25

Total Project Cost: $65,133,990.48

Comparison between D4 and RS Means

When comparing the two estimates for the Potomac Yard Land Bay E project it was determined that they were both over $10 million short from the original estimate. The reasons that the estimates could be inaccurate from the real project cost is:

- The foundation piles that needed to be driven into solid earth may not have been taken into account.
- The projects were not quite the same as the Land Bay E project in the sense that the buildings were built on top of the parking garage.
- The dewatering during excavation and the dewatering systems needed for permanent usage may not have been taken into account.
- Location factors seem to be a little low considering it is so close to Washington DC it would seem that it should be closer to 1.0 and not .93 for Arlington, VA.

7.4 Detailed Structural Systems Estimate:

The structural system for the Potomac Yard Land Bay E project consists of a deep foundation, CIP columns, CIP slabs, CIP walls and post tension concrete beams. There is virtually no steel used on the project except for reinforcing purposes and architectural purposes. The places that the miscellaneous metals are used are on the metal trellises, canopy and the metal roofs on the mechanical rooms. The use of concrete as a structural system in this area is very common. Two tower cranes, pump and Georgia buggies completed the entire concrete placement on this project.

To perform the structural concrete estimate for this project it was broken it into seven categories which include: concrete piles, pile caps, floor slabs, concrete walls, columns, beams and cranes. The deep foundations consisted of concrete piles that were 14"x14" with a length of 35'. There were 17 pile caps that ranged in size, shape and depth. All of these conditions were taken into account to obtain a total cubic yard amount of concrete. The floor slabs varies in thickness, so to determine the total amount of concrete used in them the thickness was multiplied by the total area of the slabs. The total volume of concrete for the columns and beams was determined from the cross sectional area multiplied by the total length of the beam. The structural drawings were used to complete the concrete take off for all three parts of the project. Once the take off was completed the total structural estimate was determined by using the cost data provided by 2009 RS Means sources. Once the project total was achieved it was then multiplied by the .93 location factor for Arlington Virginia. After obtaining the adjusted total amount for the location of the project the cost per square foot was obtained by taking the total and dividing it by the total area of the project.

Code	Description	Cost
31 62 13.23	Prestressed Piles	$1,185,397.50
03 30 53.40	Pile Caps	$769,587.00
03 30 53.40	Floor Slabs	$9,420,722.00
03 30 53.40	Garage Walls	$487,600.00
03 30 53.40	Columns	$1,396890.00
03 30 53.40	Beams	$5,029,752.00
01 54 19.50	(2)Cranes 12 Mo	$2,737,500.00
	Total:	$21,027,448.50
	Adjusted:	$19,555,527.11
	Cost/SF:	$31.59

Table 11: Structural Summary

The total structural systems estimate came to $19,555,527.11 that is only about $1,285,854 over the estimate that was provided by the general contractor. This is only about 4.7% over the original estimate for the structural system of the project. The reason for the accuracy of the estimate could be due to the common building type of the project. RS Means may compare similar projects for cost data in the reference books. Another factor that helped the accuracy of estimate is that the structure is predominately made up of structural concrete instead of a variety of different structural materials.

7.5 General Conditions Estimate:

Total General Conditions	**$6,110,382.88**
% Total Contract Value	7.98
Cost per Month	$305,519.14
Cost per Week	$71,050.96

Table 12: General Conditions Summary

Above is a summary of the General Conditions estimate for the Potomac Yard Land Bay E project. This summary takes into account for the project staff, permits, insurance, fee, construction facilities and equipment and temporary utilities. This estimate was prepared by using 2009 RS Means data and pricing along with the current industry unit costs provided by James G. Davis Construction Corporation. The largest portions of the General Conditions estimate are comprised from the project staff costs and the contractor's fee. The general contractor's project staff estimate was calculated by the industry rate for that position multiplied by the percentage of time a week the individual spent on the project. Some items that are normally included on a GC estimate like a crane and material hoist were not provided in this estimate because they were part of the subcontractor's bid package.

Please see Appendix G for General Conditions Estimate

8 Proposals for Analyses:

The Potomac Yard Land Bay E project located in Arlington Virginia is currently striving to reach a LEED Gold certification upon its final completion. As the economy and needs of building owners have changed over the past decade, so has the way construction is being performed. Energy prices have increased dramatically over the past few years and are intended to rise even more. Building owners want to build buildings and occupy them as soon as possible. Having all of these changing conditions in the industry the main goals of new construction is to build faster, smarter and more energy efficient products.

The 2009 PACE Roundtable Event was focused on a variety of issues that include: a panel of industry members that discuss how the industry is changing due to the economic circumstances and stimulus package, a breakout session that involved a problem identification and solution development, and a student panel discussing the communication patterns of the Now Generation. The breakout sessions had three different topics to choose from to attend. The three topics that were offered this year were Energy and the Building Industry, BIM Execution Planning and Business Networking. From attending the Energy and the Building Industry session one could learn about new and exciting technologies that are being utilized in the industry today and lastly and to become more familiar with the direction the industry is moving involving LEED and its applications.

There are many reasons for concern regarding the commercial energy consumption with in the United States. Some of the main concerns involve the environment, deregulation for competition, developing nations, federal and state incentives, life cycle costs, marketing image and national security for energy independence. To reduce energy consumption in the United States many alternate forms of energy resources are being utilized like: wind, solar, geotherm, nuclear, wave/tidal and biomass fuel. On a building and construction scale many new technologies and systems are being implemented like: space age insulation, LED lighting, BAS systems, office interior systems, hydronic heating and cooling systems, reuse/ deconstruction of materials and combine heat and power peak response systems.

As previously stated the construction industry is striving to build smarter, faster and more energy efficient projects. In doing so many different technologies and methods are being implemented. The focus of these thesis analyses will incorporate the reduction of energy consumption by the use of supplemental energy sources, schedule acceleration by the use of a solid unitized curtain wall system and energy conservation by the implementation of a chilled beam mechanical system.

9 Supplemental Energy (Electrical Breadth)

9.1 Opportunity Statement:

The United States is one of the world's highest energy consumers for which over 50% of the country's energy consumption is used by commercial buildings. The building industry is under much scrutiny to produce more energy efficient buildings in order to reduce the country's energy consumption. In the United States there is approximately 30 billion square feet of commercial roof area that could be used for placement of supplemental solar energy harvesting. The Potomac Yard Land Bay E could utilize a solar collection system to supplement its energy consumption provided by the United States energy suppliers.

9.2 Goal:

By placing solar panel systems on the roof, which consists of a large area of unusable space, the commercial building energy consumption could be reduced. The current roof system that is utilized on the Potomac Yard Land Bay E project is a white TPO roofing membrane that is designed to reflect large amounts of the sun's energy instead of transferring it into the building. By adding a supplemental solar panel system to the 43,800 SF roof of this building would result in optimum performance for harvesting energy and a reduction of energy consumption from nation's energy supply. By performing this analysis a comparison of energy created by the PV system will be compared to the building's total energy consumption and the energy cost savings will be determined.

9.3 Methodology:

- Contact a Solyndra representative to determine systems capabilities
- Obtain information about applications on cool roofs
- Look at other buildings with the Solydra application
- Look at current construction documents for the roof of the Potomac Yard project to determine the layout and how many panels may be used
- Calculate the initial cost of material and installation
- Calculate duration of installation
- Calculate current energy load on the building
    - Calculate mechanical equipment
    - Calculate lighting load
    - Calculate receptacle load
- Determine energy savings
- Determine payback period
- Draw conclusions and make recommendations concerning application

9.4 Tools and Resources:

- Solyndra website
- Solyndra sales personnel
- Construction documents

- DAVIS project team
- ASHRAE 90.1

9.5 Expected Outcome:

Solyndra PV panels are a very efficient design for harvesting the sun's solar energy and converting it into a valuable resource for the building. The PV system should produce enough energy savings to payback the system's initial cost within a reasonable amount of time. The structural impact caused from the PV system on the building should be minimal because the design of the anchoring system is very lightweight and easy to install. The reason for its lightweight frame is because of the shape of the panels. The panels consist of many long tubular shaped solar collectors that allow the air to flow around and between the arrays that reduces the amount of wind resistance. Another feature that the system possesses is that it is mounted horizontally, parallel with the roof's surface, which would reduce the uplift affect. Maintenance walkways may need to be considered for access to clean the panels along with proper waterproofing around the roof penetrations for anchoring. The installation of these solar collectors should not impede the schedule of the project because they can be installed as other work on the building is progressing without interruption. All of these features and the enhancement of green technology image for the building will probably outweigh the initial cost and installation of the product.

9.6 Research:

The installation of Solyndra PV panels would add to the sustainable image of the Potomac Yard Land Bay E building and will help to reduce the energy consumption from the electric grid. Since this is a new technology of harvesting the sun's energy from 360 degrees by absorbing direct, reflected and diffuse sunlight. This is made possible by installing the solar array on top of the existing white Thermo Plastic Olefin (TPO) roofing membrane.

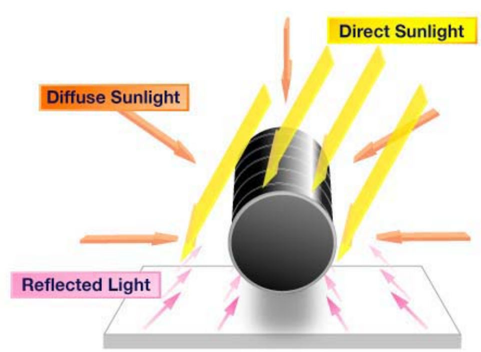


Figure 12: Solyndra Cell Diagram

The building orientation in regards to the sun's path is very minimal in effecting the system's energy production performance. In most cases when the system is used on a cool roof application the system is able to produce approximately 99% of the maximum power output regardless of the orientation. The wind performance of this system is also superior to a conventional PV system due to its lightweight design and natural gaps between the solar modules on the panels. This design allows the wind to pass under and between the units creating minimal uplift on the system.

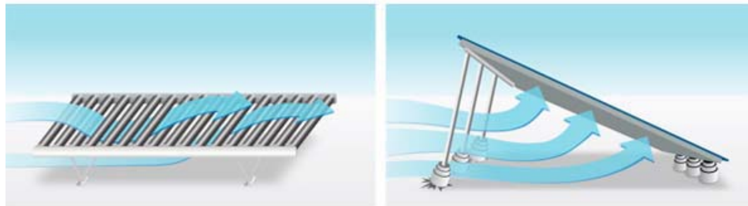


Figure 13: Solyndra vs. Conventional Wind Performance

There are many reasons to place a Solyndra PV system on cool roof application. When a Solyndra system is applied on a cool roof surface the power production of the PV system will be enhanced unlike a conventional flat-paneled system. The Solyndra system is very lightweight that will impose a minimal impact to the roof structure. An individual panel and mounting system will only place a force of 3.3 lb/ft^2 on the roof system. Solyndra panels do not require any anchoring devices, which results in no roof penetrations. Instead, a self-ballasting material holds down the system to the roofing membrane. Solyndra's solar panels have been tested and certified for use in winds up to 130 MPH. Typically each panel is capable of producing 200 watts/hr when used on a cool roof. Each panel comes with a 25-year power warranty and a 5-year product warranty. Another advantage to placing a Solyndra PV system on a white roof application is the qualification for a 30% Investment Tax Credit (ITC) that may be applied to the roof cost. The 30% credit may be applied to all of the following:

- Installation labor
- Reflective roof material
- Fasteners and adhesive agents
- Insulation
- Supporting materials

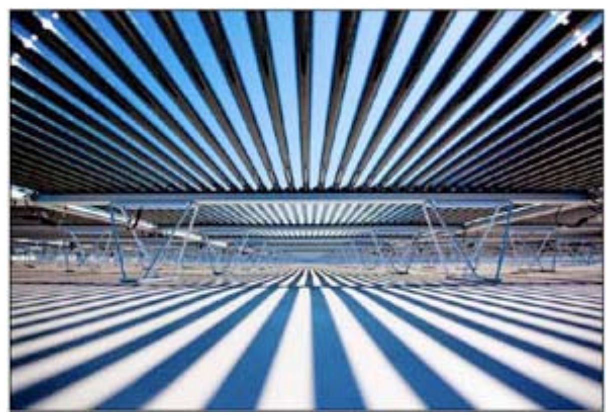


Figure 14: Functioning Solyndra Panels

When considering the implementation of the Solyndra PV system there are many advantages that can be factored while comparing to only one real disadvantage, the initial cost of the product. Many of the advantages include:

- High energy production
- 30% ITC on cool roof with use of a Solyndra system
- 25 year power warranty
- No roof penetrations, self ballasted
- Lightweight design
- Superior wind performance
- Flat angle installation, larger utilization of rooftop space
- 3x faster installation
- 50% reduction in installation cost

9.7 Application:

When trying to apply the Solyndra PV system to the current roof of the Potomac Yard Land Bay E project the construction documents for the building and the product specifications for the PV system was referenced. The determination of how many Solyndra panels many fit on top of the rooftop could not simply be determined by taking the total roof area divided by the area of one panel. Because there is a mechanical penthouse and an architecture dome on each of the two towers the layout and number of panels had to be strategically place upon the rooftop of this project. When laying out the locations of the panels, considerations where made for access paths through the arrays for maintenance and cleaning. The average sizes of the pathways are around two feet in width. When layout the system on the roof of both towers of the building it was determined that 531 panels could be placed on the roof of building A and 499 panels could be place on building B. The total number of panels that could be used on this project is 1030.

Figure15: Solyndra Mounting Bracket

Figure16: Solyndra Panel Spacing

9.8 Energy Comparison:

An energy comparison was conducted using the construction documents of the building and the product data supplied by Solyndra. In order to compare the energy consumption of the building to the energy production by the Solyndra PV system proposed for the roof, calculations involving the electrical and mechanical equipment were performed. To determine the power consumption for the building's mechanical equipment the mechanical schedules were utilized to determine the total kilowatt-hours consumed per year by the equipment. For those pieces of equipment that were rated in horsepower a conversion of 745.7 watts = 1 HP was used to determine the amount of kilowatts consumed. To determine the energy cost for each piece of equipment the following was used:

- 261 work-days in 2010
- 16 hours/day operation
- 4176 hours per work year
- Avg. Energy cost Balt. Wash. 2009: $.137/KWH
  http://www.bls.gov/ro3/apwb.htm

Parking Garage Mechanical Equipment			
Descripton	Quantity	Power (HP)	Power (KW)
O.A. Water Cooled AC Unit	1.00	0.50	0.37
Supply Fan	5.00	5.00	18.64
Supply Fan	5.00	3.00	11.19
Supply Fan	2.00	0.50	0.75
Supply Fan	2.00	0.25	0.37
Supply Fan	3.00	0.08	0.19
Supply Fan	2.00	1.00	1.49
Supply Fan	1.00	0.03	0.02
Exhaust Fan	10.00	5.00	37.29
Exhaust Fan	6.00	1.00	4.47
Exhaust Fan	3.00	0.25	0.56
Exhaust Fan	1.00	0.50	0.37
Exhaust Fan	3.00	0.08	0.19
Exhaust Fan	2.00	0.10	0.15
Electric Heater	2.00		10.00
Electric Heater	1.00		3.00
Electric Heater	1.00		10.00
Electric Heater	1.00		20.00
Split System	1.00		3.52
Split System	1.00		10.55
Plenum Heater	1.00		2.00
Plenum Heater Fan	1.00	0.33	0.25
	Parking Garage Total:		135.36

Table 13: P-Levels Mechanical Power

Building A Mechanical Equipment			
Descripton	Quantity	Power (HP)	Power (KW)
AHU Fan	3.00	25.00	55.93
Self Cont. AC Unit	1.00	1.50	1.12
VAV w/ Heat Fan	1.00	0.17	0.12
VAV w/ Heat Heater	1.00		3.00
VAV w/ Heat Fan	1.00	0.50	0.37
VAV w/ Heat Heater	1.00		4.00
VAV w/ Heat Fan	1.00	1.00	0.75
VAV w/ Heat Heater	1.00		5.00
Cooling Tower Sump Heater	2.00		12.00
Cooling Tower Motor	2.00	10.00	14.91
Cooling Tower Sump Heater	1.00		6.00
Cooling Tower Motor	1.00	7.50	5.59
Plenum Heater Fan	1.00	0.33	0.25
Plenum Heater	1.00		2.00
Make Up Air Unit Fan	1.00	20.00	14.91
Make Up Air Unit	1.00		420.00
Chiller Evaporator	1.00		1230.90
Chiller Condensor	1.00		317.00
Supply Fan	2.00	5.00	7.46
Supply Fan	2.00	0.50	0.75
Supply Fan	1.00	0.25	0.19
Exhaust Fan	1.00	1.00	0.75
Exhaust Fan	2.00	3.00	4.47
Exhaust Fan	1.00	0.50	0.37
Electric Heater	2.00		10.00
Electric Heater	1.00		3.00
Electric Heater	1.00		20.00
Split System	1.00		3.52
Pump	1.00	30.00	22.37
Pump	1.00	25.00	18.64
Pump	1.00	50.00	37.29
Pump	2.00	15.00	22.37
Solid Seperator	1.00	5.00	3.73
Oil Pump	1.00	0.50	0.37
Solid Seperator	1.00	3.00	2.24
	Building A Total:		2251.36

Table 14: Building A Mechanical Power

Building B Mechanical Equipment			
Descripton	Quantity	Power (HP)	Power (KW)
AHU Fan	2.00	25.00	37.29
AHU Fan	1.00	30.00	22.37
Self Cont. AC Unit	1.00	1.50	1.12
VAV w/ Heat Fan	1.00	0.17	0.12
VAV w/ Heat Heater	1.00		3.00
VAV w/ Heat Fan	1.00	0.50	0.37
VAV w/ Heat Heater	1.00		4.00
VAV w/ Heat Fan	1.00	1.00	0.75
VAV w/ Heat Heater	1.00		5.00
Cooling Tower Sump Heater	2.00		12.00
Cooling Tower Motor	2.00	10.00	14.91
Cooling Tower Sump Heater	2.00		12.00
Cooling Tower Motor	2.00	10.00	14.91
Cooling Tower Sump Heater	1.00		6.00
Cooling Tower Motor	1.00	10.00	7.46
Plenum Heater Fan	2.00	0.33	0.50
Plenum Heater	2.00		4.00
Make Up Air Unit Fan	1.00	20.00	14.91
Make Up Air Unit	1.00		400.00
Chiller Evaporator	1.00		1230.90
Chiller Condensor	1.00		317.00
Supply Fan	2.00	5.00	7.46
Supply Fan	2.00	0.50	0.75
Supply Fan	1.00	0.25	0.19
Exhaust Fan	1.00	1.00	0.75
Exhaust Fan	2.00	3.00	4.47
Exhaust Fan	1.00	0.50	0.37
Electric Heater	2.00		10.00
Electric Heater	1.00		3.00
Electric Heater	1.00		10.00
Split System	1.00		3.52
Split System	1.00		3.52
Pump	1.00	30.00	22.37
Pump	3.00	25.00	55.93
Pump	1.00	50.00	37.29
Solid Seperator	1.00	5.00	3.73
Oil Pump	1.00	0.50	0.37
Solid Seperator	1.00	5.00	3.73
	Building B Total:		2215.27

Table 15: Building B Mechanical Power

Mechanical Equipment Power Cost					
	Total KW	Use (Hr/Yr)	KWH/Yr	Cost (KWH)	Total Cost
Building A	2251.36	2610.00	5876049.60	$0.14	$805,018.80
Building B	2215.27	2610.00	5781854.70	$0.14	$792,114.09
P-Levels	135.36	2610.00	353289.60	$0.14	$48,400.68
		Consumption:	12011193.90	Total Cost:	$1,645,533.56

Table x16: Mechanical Equipment Total

The Potomac Yard Land Bay E project is currently a base building that consists of a core and shell construction. This means that the final building's occupants have not been determined yet, which makes the current lighting and receptacle load unreasonable for accurate energy consumption. So in order to accurately represent the lighting load for the occupied building in its intended use the Lighting Power Density from ASHRAE 90.1 was used to determine the maximum lighting load. The LPD is an estimate of the W/ft^2 for a typical occupied space, so in order to determine the amount energy used in the building the LPD was multiplied by the floor area. To determine the energy cost of the lighting system the following was used:

- 261 work-days in 2010
- 10 hours/day operation
- 2610 hours per work year
- Avg. Energy cost Balt. Wash. 2009: $.137/KWH
  http://www.bls.gov/ro3/apwb.htm

Lighting Power Density ASHRAE 90.1 Table 9.5.1				
	Area (SF)	Building Type	LPD (W/ft^2)	Total KW
Building A	188095.00	Office	1.00	188.10
Building B	181977.00	Office	1.00	181.98
P-Levels	248842.00	Parking Garage	0.30	74.65
			Project Total:	444.72

Table 17: Lighting Power Density

Lighting Cost					
	Total KW	Use (Hr/Yr)	KWH/Yr	Cost (KWH)	Total Cost
Building A	188.10	2610	490941	$0.14	$67,258.92
Building B	181.98	2610	474967.8	$0.14	$65,070.59
P-Levels	74.65	2610	194836.50	$0.14	$26,692.60
					$159,022.11

Table 18: Lighting Cost

Please See Appendix H for LPD

When determining the receptacle load on the building the following was used:

- Add up all receptacles in the building
- Sum volt*amps
- Duplex receptacle = 180VA
- Double duplex = 360VA
- 1VA = 1 Watt
- NEC 2008 Table 20.44 Article 220: Branch Circuit-Feeder & Service
    - 1st 10 KVA – 100%
    - After 10 KVA – 50%
- 261 work-days in 2010
- 10 hours/day operation
- 2610 hours per work year
- Avg. Energy cost Balt. Wash. 2009: $.137/KWH
  http://www.bls.gov/ro3/apwb.htm

Receptacle Load			
	# Receptacles	Volt*Amps	Total KW
Building A	155.00	180.00	27.90
	8.00	360.00	2.88
Building B	159.00	180.00	28.62
	8.00	360.00	2.88
P-Levels	81.00	180.00	14.58
		Project Total:	76.86

Table 19: Receptacle Load

Receptacle Cost					
	Total KW	Use (Hr/Yr)	KWH/Yr	Cost (KWH)	Total Cost
1st 10 KVA	10	2610	26100	$0.14	$3,575.70
After 10KVA	33.43	2610	87252.3	$0.14	$11,953.57
		Total:	113352.3	Total:	$15,529.27

Table 20: Receptacle Cost

Annual Building Consumption & Energy Cost		
	Consumption per Year (KWH)	Cost ($)
Mechanical	19217910.24	$2,632,853.70
Lighting	1160731.21	$159,020.18
Receptacles	113352.30	$15,529.27
Totals:	20491993.75	$2,807,403.15

Table 21: Energy Consumption

After determining the building's total energy consumption per year the total energy production from the Solyndra PV system was calculated. In order to determine the amount of energy each panel can produce the insolation value for the Arlington Virginia area was referenced. Insolation is the amount of solar radiation that is absorbed in a given surface area over a certain amount of time. This value is typically expressed in KWH/m^2 per day. This value may also be known as the Earth's solar irradiance at a given location on the planet. This value is measured by the direct absorption perpendicular to the surface. This value changes throughout the year due to the angle of the sun, distance from the sun and disruptions in the atmosphere like: dirt particulates, clouds, moisture content and other impurities.

In order to determine the power output for each panel for a year the number of sun hours per day must be used. The insolaton value is equal to the number of sun hours per day that the panel can absorb, so in order to determine the power output for each panel the number of sun hours for each month must be multiplied by the number of days in that month and the power rating for a panel. Finally to determine the percentage of total power output for the system, the application conditions must be considered. For this project the system is being implemented on a white TPO roofing membrane, which has a reflectivity of 88%. When comparing the reflectivity to the Solyndra Energy Yield chart, the energy yield for the system should be 99% of the optimum production.

Please see Appendix I for Reflectivity vs. Annual Energy Yield chart

Month	Days/Month	Insolation (kWh/m^2/day)	Sun Hours/Day	Max Power Rating/Panel (Wp)	Output/Panel kWH/Panel)
January	31	1.87	1.87	200	11.594
February	28	2.61	2.61	200	14.616
March	31	3.58	3.58	200	22.196
April	30	4.61	4.61	200	27.66
May	31	5.27	5.27	200	32.674
June	30	5.75	5.75	200	34.5
July	31	5.65	5.65	200	35.03
August	31	5.08	5.08	200	31.496
September	30	4.11	4.11	200	24.66
October	31	3.14	3.14	200	19.468
November	30	2.1	2.1	200	12.6
December	31	1.64	1.64	200	10.168
		Power Output/Panel/Year (KWH/panel/year)			276.662
		Total Power Output 100%:			284961.86
		Total Power Output On White TPO Roof 99%:			282112.24

Table 22: GAISMA Insolaton

Once both the building consumption and Solyndra production was determined the energy savings could be found by comparing the two values. With the installation of this type of PV system the Potomac Yard Land Bay E building could have an annual energy savings of **1.38%** that translates into a **$38,650** savings for the first year. When deciding whether or not to install a supplemental energy system of this size an owner would most likely like to know how many years it will take for the system to pay for itself. To determine the payback period of the Solyndra system the initial cost of the system must be determined. The cost and installation of each panel was determined by pricing information that was provided by a representative of Solyndra. Each panel was found to cost approximately $1,400 installed. The roof of the project can accommodate 1030 panels. The total cost of the system for the Potomac Yard is approximately **$1,442,00** and would take about **22 years for 100% payback**. The payback was determined by a 5% energy cost increase annually. It was determined that by year 25, the end of the warranty period, the system would have saved the owner **$402,622.63** in energy costs.

Please see Appendix J for Solyndra Payback

9.9 Cost and Schedule Impacts:

The installation of this system should not interfere with any of the other construction activities on the project. This system may begin its installation after the roofing contractor has finished placing the roofing membrane. Once the roofing is completed installation technicians may bring the necessary materials on the rooftop to begin the panel set up. The panels are packaged in small, lightweight and easy to maneuver crates. All of the other rack connectors and tools used for installation are minimal because the supports simply snap onto the outer edge of the panel.

The mechanical installation process is fast and simple and includes:

- Connect the mounting hardware to the solar collector
- Transport the panel to the desired location on roof
- Plug in the DC connectors and the grounding cable
- Install lateral clip to connect all panels
- Place ballast material on mounting hardware

The mechanical installation of this system on the Potomac Yard Land Bay E project would be faster than the electrical installation. The mechanical installation of the panels on the rooftop would take approximately five qualified workers two eight-hour days. This includes delivery, setup and electrical connections for the panels for the electrician to connect to the building.

The electrical installation for this system is slightly more complex and would take a little longer than the panel installation. Typically the electrician on the project, J.E. Richards, can perform the electrical installation and connection of the panels to the building’s electrical system. Normally it would take approximately two men five to ten working days to run the wire and install the switching mechanisms and inverter to convert the DC power to AC power. All of these activities may take place without interrupting the progress of the other construction activities.

As previously mentioned the owner will incur a large initial cost by implementing the use of the Solyndra system. Each panel costs approximately $1,400 dollars including installation and the roof of the building can support 1,030 Solyndra panels. The total cost of implementing this system on the Potomac Yard project would come in at approximately $1,442,000. Although the system is quite pricey upfront it does however generate good returns, which is $38,650 for the first year with energy prices at $.137kWh.

9.10 Conclusions and Recommendations:

While conducting research for this analysis many sources and project archives have showed that the Solyndra solar collection system is the most efficient way of harvesting the sun's solar energy. The logic behind the way this system works makes perfect sense. By using a highly reflective roof surface and the Solyndra PV panels the sun's energy is to be harvested from 360 degrees. By absorbing the sun's energy from all directions instead of a single angle would make sense that the system would produce a great amount of supplemental energy for the building.

Before the owner or a representative of the owner for the Potomac Yard project could make a decision on whether or not to implement the system or not they would have to look at some cost and system data. Although the owner probably would not be too willing to pay nearly $1.5 million dollars up front for a system that is fairly new, other factors need to be considered. The owner would want to look at the payback period, benefits, savings and marketability.

When looking at the payback period of the system the owner may think that 22 years is a long time for the system to pay for itself, but it will have paid for itself before the 25-year warranty has expired. By the end of the 25-year warranty the owner would have saved $402,622.63 on energy costs. Another consideration would be that yes the company receives a lot of positive publicity but they have only been in business since 2005. The question would then be how long would this system last, long enough to pay for itself. Although there are some definite concerns about installing such a new system as a long-term investment however, there are far more advantages to owning this wonderful technology. Some of the advantages that would probably peek the owner's interest is:

- High energy production
- 30% ITC on cool roof with use of a Solyndra system
- 25 year power warranty
- No roof penetrations, self ballasted
- Lightweight design
- Superior wind performance, tested and certified for up to 130 MPH
- Flat angle installation, larger utilization of rooftop space
- 3x faster installation
- 50% reduction in installation cost
- Marketability
- Annual energy savings of $38,650

After performing this study of the Solyndra PV system I would recommend this system to the owner of the Potomac Yard Land Bay E project however, the application of this system would be better suited for low rise buildings with a large amount of flat roof area. The reason for this is because there would be much more roof area for the panels to produce energy in comparison to the occupiable space of the building, which would result in a much faster payback period. There are many reasons why the implementation of this system would benefit the building and the owner. For instance the system would help enhance green image for the public and make the building more environmentally friendly. This could increase the marketability to introduce new clients or higher rent for the office space. Also by installing this product the owner would benefit from being part of a cutting edge technology that will more than likely become even more popular in the future. Lastly, the owner will be proud to know that they are helping the energy crisis by reducing the demand for the burning of fossil fuels in order to support the energy needs of the country.

10 Solid Curtain Wall Implementation

10.1 Opportunity Statement:

The current building envelope system used on the Potomac Yard Land Bay E project consists of both an architectural precast façade with punched windows along with a curved curtain wall system on the ends of the buildings. Using two different types of building envelope systems for a project causes delivery issues and site congestion while storing the variety of materials before use on the building. By switching to a single building envelope system the duration of installation for the building may become shorter due to the repetitive activities and familiarity of connections. A reoccurring trend in the construction industry is the usage of prefabricated materials. By changing the building envelope for the Potomac Yard from two systems to a single glass curtain wall system that consists of prefabricated glazed panels would help speed up construction. This would help to reduce the use of varying materials that would speed up the installation period for the building envelope thus reducing the total project schedule.

10.2 Goal:

There will be many advantages to changing the building envelope from architectural precast and punched windows to a solid unitized curtain wall system. It will be determined how much shorter the project schedule may be reduced by implementing this type of building envelope system. By implementing this system the building's occupants should receive more natural daylight into their workspaces.

10.3 Methodology:

- Contact a window and glazing contractor
- Determine benefits of a solid curtain wall system
- Run calculations for the increased solar gain on the building
- Determine cost for curtain wall system
- Compare cost of curtain wall system to original
- Determine installation duration for curtain wall system
- Compare durations for schedule impact
- Explore methods of installation
- Draw conclusions and make recommendations concerning application

10.4 Tools and Resources:

- Construction documents
- Enclos and TSI project managers
- DAVIS project team
- Viracon website for product data

10.5 Expected Outcome:

The proposed curtain wall system would most likely reduce the schedule of the project because of the standardized use of materials and connections for the building envelope, prefabricated panels, placing methods and repetition of anchoring. The prefabricated panels will eliminate on site assembly and will just involve lifting and securing the materials on the building façade. If the monorail or floor crane system is chosen the site will become less congested and will allow for the curtain wall to begin installation before the structure is topped out and will allow for early removal of the tower cranes. While reducing the site congestion the typical floor will likely become crowded with panel layout. The floor staging will have to be considered because it may impede some ceiling work from being performed.

Other positive outcomes that may arise from switching to the curtain wall system will be the increased amount of natural daylight that enters into the typical floor space because of the floor to ceiling glazing which may result in higher rent for the owner. It has been proven that employees that work in conditions with increased amount of nature daylight have a positive effect on productivity. Along with the increased natural daylight in the building includes an increased amount of solar gain. The consideration of the increased cooling load on the building will also have to be considered because of the likelihood of it increasing.

10.6 Research:

Curtain Wall-

Curtain wall systems are becoming very popular for office building envelopes in today's society. The main purpose for a curtain wall system is to keep the outdoor weather conditions out of the interior space of a building. Curtain wall systems are lightweight designs that provide absolutely no structural support to the building it is covering. This type of building envelope system typically spans multiple floors that increases the efficiency of installation and seals the entire building not allowing for any opening sections unless infill windows are implemented. A curtain wall system is typically connected to the building structure through either the columns or floor slabs. Typically curtain wall systems are made up of predominantly glass that is supported by an extruded aluminum framing system. The framing system contains components of seals, rails, mullions and connections to the structure.

There are many advantages that a curtain wall system offers to a building and its occupants. However, despite all of the advantages that the system provides strong consideration concerning the increased amount of solar heat gain must be address. This topic will be analyzed further in this analysis. Many of the advantages of a curtain wall system include the following:

- Architects can make curtain wall systems aesthetically pleasing depending on design
- Natural day lighting increase
- Units assembled in factor controlled conditions
- Units contain all necessary parts
- Does not require external access for installation
- Speeds up construction
- Various outer coatings available

- Units package in easily maneuverable crates

Installation of a curtain wall system typically can be performed pretty efficiently. Normally the preparation of installing the connections into the floor system or columns of the building takes a long time. After all of the preparation for the units is completed the installation process is able to begin and become very efficient as the activity progresses. There are four common methods used when installing a curtain wall system on a building that include, floor crane, monorail system, mobile crane and tower crane. The use of a tower crane is convenient because the device is already set up and ready for use however, in most cases it is being used for many other activities like topping out the building or lifting other heavy pieces of equipment into position. The problem with using a tower crane to install a curtain wall system is that it makes it more difficult to overlap other activities that involve the use of the crane, which will prolong the duration of the project. When using a crawler crane or a hydraulic rubber tired crane to install a curtain wall system the subcontractor must be concerned about several variables:

- Site congestion
- Staging from the ground
- Leveling
- Cost, operator and rental
- Transportation permits

A monorail system is another typical means of installation for a curtain wall system. A monorail system typically helps to speed up the process of installing the units over a crane because there is no time needed for repositioning. This system is made up of several parts, which include a lifting mechanism, tubular channels mounted to the roof structure and a means of attachment. When using this system the contractor does not have to worry about site congestion because the units are staged from their corresponding floor location. Typically the units are lifted into position from the floor that they will be covering by the monorail system above on the roof. As the installation progresses across the building's façade the lifting mechanism is easily moved along the roof by means of the tubular channels. There are also many other factors that must be considered while using this installation method:

- Reinforcement of roof structure for mounting of cantilever brackets
- Connection of lifting mechanism to rails
- Distance between work area and lifting mechanism
- Not affected by wind
- Work multiple elevations at once
- Not weather dependent

The last typical installation device used for a curtain wall system is a floor crane. This is a very common installation method among contractors because they are easy to use, not very expensive, easy set up and are very maneuverable. This mechanism is much like an engine hoist. It consists of a wheeled base structure that is able to support the overhanging weight of the curtain wall

Figure x: Floor Crane 1

unit, a movable boom and lifting device that typically uses an electrical motor and steel cable. This type of mechanism is the preferred choice for installation of curtain wall units for both companies interviewed for this analysis. The typical sequence of installing a panel using a floor crane includes distributing the crates of units on the corresponding floor, setting up the crane two floors above the installation area, placing a unit on a wheeled cart in order to move to slab edge, attach lifting mechanism, slide out and lift into position and finally secure to connection.

The proposed curtain wall system for the Potomac Yard Land Bay E project would utilize a Viracon glazing system that comes with a 20-year warranty. Despite the generous warranty duration for the product there are still some cleaning and maintenance considerations that need to be noted. The curtain wall glazing must be cleaned inside and out frequently in order to maintain clear visibility. The aluminum rails and mullions must be cleaned upon the owner's request. If the aluminum is coated with a powder coating or some other protective covering cleaning may not need to be performed. All seals and gaskets should be examined during frequent cleanings for areas of possible water penetration. After approximately 20 years all seals including the perimeter seals, glazing seals and gaskets should be replaced. Removal and replacement of all sealant devices involve the use of proper tools and skills to ensure optimum performance from the product.

Heat Gain-

Space heat gain is the rate at which heat enters into or is generated within a space at a given period of time. There are several ways in which heat may enter a space:

- Solar radiation through glazing
- Heat conduction through interior partitions
- Heat conduction through exterior walls and roof
- Heat generated within the space by occupants, lights, appliances, and equipment
- Loads as a result of ventilation and infiltration of outdoor air

There are two types of heat gain that include sensible and latent. Sensible heat gain is the energy added to the space by conduction, convection and radiation. Sensible heat load can be attributed to by the following:

- Heat transmitted thru floors, ceilings and walls
- Occupant's body heat
- Appliance and light heat
- Solar heat gain thru glass
- Infiltration of outside air
- Air introduced by ventilation

Latent heat gain is the energy added to the space when moisture is added to the space by means of vapor emitted by the occupants, generated by a process or through air infiltration from outside or adjacent areas. Latent heat load can be attributed to by the following:

- Moisture from outside air thru infiltration and ventilation

- Occupant respiration and activities
- Moisture from equipment and appliances

Total window heat gain = solar heat gain + conduction heat gain

Cooling Load-

Space cooling load is the rate at which energy must be removed from a space to maintain a constant space air temperature. The building's total cooling load consists of both internal and external loads. External loads consist of those that are transferred through the building envelope while internal loads are the loads that are generated by the building's occupants, equipment and lights. Space heat gain differs from space cooling load because the heat received from the sources described does not always immediately go into heating the interior space. For example during the day the sun's solar radiation transfers through the windows of the building heating the surrounding materials and when the sun goes down the energy absorbed throughout the day in those materials is still releasing heat into the space.

CLTD/SCL/CLF Method-

In order to determine the total solar heat gain from the proposed curtain wall system and compare it to the original precast and punched window system the CLTD/SCL/CLF method will be utilized. This method stands for Cooling Load Temperature Difference/Solar Cooling Load/Cooling Load Factor Method. This is a hand calculation method that takes into account the lag-time in conductive heat gain through opaque exterior surfaces and the time delay by thermal storage in converting radiant heat gain to cooling load. This approach allows the calculation of the cooling load to be calculated by using the three factors CLTD, CLF and SCL. CLTD factors are used to adjust for the conductive heat gains, or external loads from the building envelope. CLF factors are used to adjust for the heat gains form the internal loads of the building. SCL factors are used to adjust the transmission heat gains from the glazing. The following steps will be used to calculate the solar and conductive heat gain through the glazing on the east and west building facades.

Conductive:

Q = U A *CLTD

1. Determine U – Value
2. Select CLTD for time of interest (Ch. 28 ASHRAE Table 34)
3. Corrections:
   CLTD = [CLTD + (78-TR) + (TM-85)]
   Where
   - (78-TR) = indoor design temp corr.
   - (TM-85) = outdoor design temp corr.
   - TR = Indoor room temp
   - TM = Mean outdoor temp
   - Tmax = Maximum outdoor temp
   - TM = Tmax-(Daily Range)/2

4. Calculate glass area (A) from architectural plans
5. Q = U A *CLTD

Solar:

Q = A* (SC) * (SCL)

1. Determine shading coefficient (SC) from Viracon data sheet
2. Determine zone type from ASHRAE 1997 CH. 28, Table 35 B
3. Determine solar cooling load factor (SCL) from ASHRAE 1997 CH. 28, Table 36
4. Calculate glass area (A) from architectural plans
5. Q = A* (SC) * (SCL)

10.7 Solar Heat Gain Comparison:

In order to complete this analysis many values for computation were referenced in the 1997 ASHRAE Handbook Fundamentals I-P Edition. The following will be the method of determining the comparison of heat gain through the glazing of one side of the building. All of the other sides of the building will be shown in a summary at the end of the analysis. This analysis is strictly analyzing the solar heat gain through the glazing of the building during a 24-hour period. All other factors that affect heat gain are assumed to be constant like equipment, lighting, occupants, ect… At the end of the analysis a summary of the total difference in heat gained in a 24-hour period due to the change of building envelope will be given as a comparison of the total difference in cooling load upon the building. The weather data for Arlington Virginia was provided by Weatherbase.com and is as follows:

Arlington Virgina

- Elevation: 720 feet
- Latitude: 37 38N
- Longitude: 078 56W
- Indoor Room Temperature: 70 assumed
- Maximum outdoor temperature: 87 in July
- Mean daily range: 20

Note: The following calculations have been performed with ASHRAE values at 40N Latitude instead of the Arlington Virginia 37 38N. The values used in the computations are relevant to the month of July, which is the warmest month for the area. These numbers will be worst-case scenario. There were no other values to use that were any closer to the location.

Please see Appendix K for glazing information

Cooling Load for Existing Punched Windows on East Façade Building A-

Conductive:

Q = U A *CLTD

U-value: .26

Area of exposed glass: 6,122.55 sf

CLTD = [CLTD + (78-TR) + (TM-85)]

TM = 87-(20/2) = 77

CLTD at noon = 9 Table 34 Ch. 28

CLTD = [9 + (78-70) + (77-85)] = 9

Q = .26 (6,122.55) (9) = **14,327 Btu/h**

Solar:

Q = A* (SC) * (SCL)

Area of exposed glass: 6,122.55 sf

SC: .44 from Viracon data table

Zone Type: A

SCL: 67 at Noon

Q = 6,122.55 * (.44) * (67) = **180,493 Btu/h**

Qtotal = conductive + solar = 14,327 Btu/h + 180,493 Btu/h = **194,820 Btu/h**

Cooling Load for Proposed Curtain Wall on East Façade Building A-

Conductive:

Q = U A *CLTD

U-value: .26

Area of exposed glass: 12,168.33 sf

CLTD = [CLTD + (78-TR) + (TM-85)]

TM = 87-(20/2) = 77

CLTD at noon = 9 Table 34 Ch. 28

CLTD = [9 + (78-70) + (77-85)] = 9

Q = .26 (12,168.33) (9) = **28,474 Btu/h**

Solar:

Q = A* (SC) * (SCL)

Area of exposed glass: 12,168.33 sf

SC: .44 from Viracon data table

Zone Type: A

SCL: 67 at Noon

Q = 12,168.33 * (.44) * (67) = **358,722 Btu/h**

Qtotal = conductive + solar = 28,474 Btu/h + 358,722 Btu/h = **387,196 Btu/h**

Comparison: (387,196 / 194,820) * 100 = 99% Increase

Whole Building Comparison-

Please see Appendix L for individual façade Conductive and Solar Cooling Loads

Conductive Q		
	Punched Windows	Curtain Wall
	994922.50	2011262.50
Solar Q		
Elevation	Punched Windows	Curtain Wall
North	914353.44	2120210.40
East	6325277.20	12571004.00
South	681801.84	1580979.40
West	5693007.80	11314214.00
Total:	**14609362.78**	**29597670.30**
% Increase:		**202.59%**

Table 23: Cooling Load Comparison

The cooling load comparison above shows the difference in cooling load due to fenestration through the building's glazing. The comparison takes into account both the conductive and solar heat gains. This comparison specifically focuses on the difference in cooling load between the existing punched window and architectural precast building façade to the proposed unitized curtain wall system. The increase in energy will cost approximately:

14,988,307.5 BTU * (.000293 kWh) = 4,391 kWh

4,391 kWh * ($.137) = $601 in the worst circumstances during the summer

10.8 Cost and Schedule Impacts:

In order to determine the cost implications of implementing the use of a unitized curtain wall system instead of the existing punched window and architectural precast panels the curtain wall contractor, TSI Exterior Wall Systems, and the architectural precast contractor, Arban & Carosi, were consulted. The pricing information provided by TSI was broken down into material and installation/delivery. The material cost was $54.30 s.f. and installation and delivery $20.28 s.f. The pricing information provided by Arban & Carosi was a combination of material and installation, which was approximately $20 s.f.

In order to determine the approximate pricing for both of the systems the following was used:

- Size of punched window units provided by subcontractor
- Architectural plans, building elevations to determine wall area
- Size of architectural precast panels
- Pricing information provided by both subcontractors

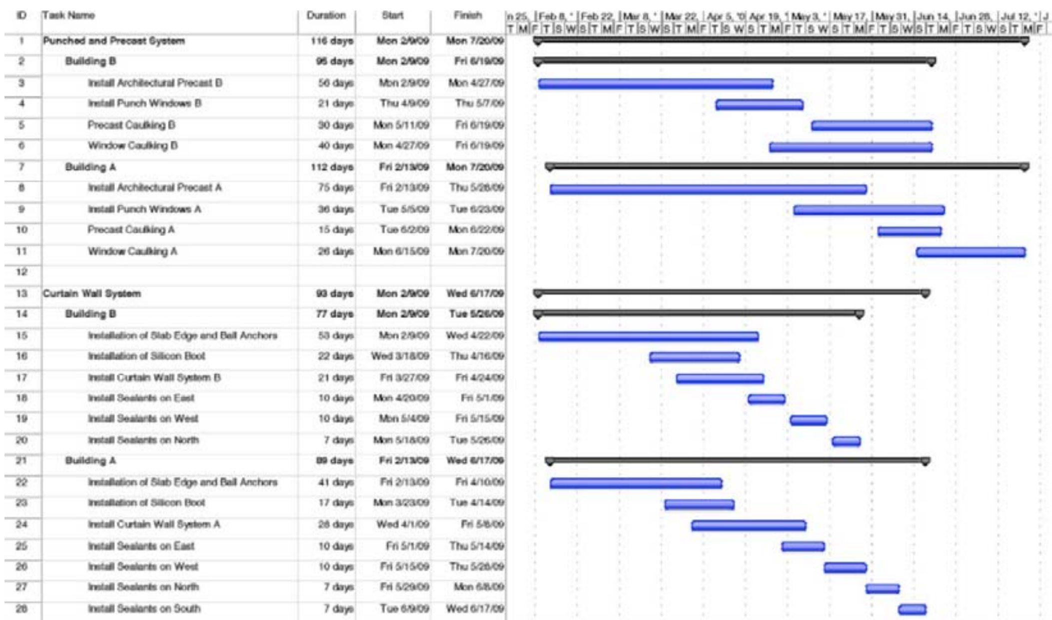
Architectural Precast and Punched Window Cost				
	Elevation	Type	Area (ft^2)	Cost ($)
Building A	West	Glazing	6122.00	$456,620.00
	West	Precast	6046.00	$241,832.00
	East	Glazing	6122.00	$456,620.00
	East	Precast	6046.00	$241,832.00
	North	Glazing	2449.00	$182,648.00
	North	Precast	2766.00	$110,639.00
	South	Glazing	2449.00	$182,648.00
	South	Precast	2766.00	$110,639.00
Building B	West	Glazing	4898.00	$365,266.00
	West	Precast	4837.00	$193,467.00
	East	Glazing	6122.00	$456,620.00
	East	Precast	6045.00	$241,832.00
	North	Glazing	2449.00	$182,648.00
	North	Precast	2766.00	$110,639.00
	South	Glazing	none	none
	South	Precast	none	none
			Total:	**$3,533,950.00**

Table 24: Architectural Precast and Punched Window Cost

Curtain Wall				
	Elevation	Type	Area (ft^2)	Cost ($)
Building A	West	Glazing	12168.00	$907,515.00
	East	Glazing	12168.00	$907,515.00
	North	Glazing	5215.00	$388,935.00
	South	Glazing	5215.00	$388,935.00
Building B	West	Glazing	9735.00	$726,012.00
	East	Glazing	12168.00	$907,515.00
	North	Glazing	5215.00	$388,935.00
	South	Glazing	none	none
			Total:	**$4,615,362.00**

Table 25: Curtain Wall Cost

After determining the approximate estimates for each of the systems it was proven that the proposed curtain wall system would cost more than the existing architectural precast and punched window system. The curtain wall systems totals $4,615,362 while the existing system totals $3,533,950. This increase in building envelope cost is approximately a 31% increase over the existing system.



ID	Task Name	Duration	Start	Finish
1	**Punched and Precast System**	**116 days**	**Mon 2/9/09**	**Mon 7/20/09**
2	**Building B**	**95 days**	**Mon 2/9/09**	**Fri 6/19/09**
3	Install Architectural Precast B	56 days	Mon 2/9/09	Mon 4/27/09
4	Install Punch Windows B	21 days	Thu 4/9/09	Thu 5/7/09
5	Precast Caulking B	30 days	Mon 5/11/09	Fri 6/19/09
6	Window Caulking B	40 days	Mon 4/27/09	Fri 6/19/09
7	**Building A**	**112 days**	**Fri 2/13/09**	**Mon 7/20/09**
8	Install Architectural Precast A	75 days	Fri 2/13/09	Thu 5/28/09
9	Install Punch Windows A	36 days	Tue 5/5/09	Tue 6/23/09
10	Precast Caulking A	15 days	Tue 6/2/09	Mon 6/22/09
11	Window Caulking A	26 days	Mon 6/15/09	Mon 7/20/09
12				
13	**Curtain Wall System**	**93 days**	**Mon 2/9/09**	**Wed 6/17/09**
14	**Building B**	**77 days**	**Mon 2/9/09**	**Tue 5/26/09**
15	Installation of Slab Edge and Ball Anchors	53 days	Mon 2/9/09	Wed 4/22/09
16	Installation of Silicon Boot	22 days	Wed 3/18/09	Thu 4/16/09
17	Install Curtain Wall System B	21 days	Fri 3/27/09	Fri 4/24/09
18	Install Sealants on East	10 days	Mon 4/20/09	Fri 5/1/09
19	Install Sealants on West	10 days	Mon 5/4/09	Fri 5/15/09
20	Install Sealants on North	7 days	Mon 5/18/09	Tue 5/26/09
21	**Building A**	**89 days**	**Fri 2/13/09**	**Wed 6/17/09**
22	Installation of Slab Edge and Ball Anchors	41 days	Fri 2/13/09	Fri 4/10/09
23	Installation of Silicon Boot	17 days	Mon 3/23/09	Tue 4/14/09
24	Install Curtain Wall System A	28 days	Wed 4/1/09	Fri 5/8/09
25	Install Sealants on East	10 days	Fri 5/1/09	Thu 5/14/09
26	Install Sealants on West	10 days	Fri 5/15/09	Thu 5/28/09
27	Install Sealants on North	7 days	Fri 5/29/09	Mon 6/8/09
28	Install Sealants on South	7 days	Tue 6/9/09	Wed 6/17/09

Figure 17: Façade Comparison Schedule

The figure above is a schedule comparison between the proposed curtain wall system and the existing punched window and architectural precast system. As you can see the curtain wall system saves approximately 23 days off of the project schedule. The curtain wall sequence and time durations were determined by consulting TSI, the glazing contractor for the Potomac Yard project. A base installation value of 50 units per day was used to give the durations for the installation of all activities. To determine the exact time of installation the construction documents and the individual unit size of 5.25' wide were consulted. It was determined that each tower will have a crew performing curtain wall tasks simultaneously.

Each activity was calculated from the following information. For one crew it takes approximately three men installing slab edge anchors and ball anchor. These items are used to set the units onto. Two of the men are actually installing the pieces of material while the third man is shooting elevation to make sure that the installation is correct. This duration is approximately 5days for 50 units. Following the anchors is one worker installing a silicon boot on top of the ball and anchor bedding. This activity takes approximately 2 days per 50 units. After the preparation work is completed the installation of the curtain wall panels may begin. One installation crew involves 8 total workers. Typically two men are operating the floor crane two floors above the floor the curtain wall units are being installed. Three men are used to distribute the curtain wall units from the truck onto the corresponding floor location to be ready for installation. Finally, three men are used to set the units into place and secure them to the connection points.

The general conditions estimate may also be reduced do to the shortening of the schedule as a result of implementing a unitized curtain wall system on this project. The building envelope system was on the critical path for the project's completion during the construction of the Potomac Yard Land Bay E. By implementing a curtain wall system the project schedule could be reduced by **23 days**. As a result of the decreased schedule the general conditions could be reduced from **$6,110,382.88 to $6,003,681.58**, which is a **total savings of $106,701.30.** The percent of contract value could be reduced from **7.98% to 7.84%** and the cost per week could be reduced from **$71,050.96 to $69,810.25**. This is approximately a **1.75% reduction** in general conditions cost for the project.

Please see Appendix M for general conditions reduction

10.9 Conclusions and Recommendations:

While conducting research for this analysis it was determined that curtain wall systems have many benefits, which include aesthetically pleasing designs, increased amounts of natural day lighting, units are assembled in controlled factory environments, units contain all necessary parts, doesn't require external access for installation, speed of installation and numerous outer coatings. Throughout the research on this analysis it has been determined that there are two major disadvantages to this building envelope system. One of the major disadvantages is that the initial cost of the system is more expensive than other types of building envelope systems. The second major disadvantage to a curtain wall system is that acquires a large increase in building heat gain through fenestration.

Before the owner could make a decision whether or not to use this type of building envelope system on their building they would have to consider the following:

- Reduction in project time equals a 1.75% reduction in general conditions
- Increased cooling load on the building by 102%

- Increased initial cost of system by 31%

After performing this analysis and taking these three major factors into consideration I would not choose to implement a unitized curtain wall system on the Potomac Yard Land Bay E project. I do not believe that the reduction in the project schedule and general conditions is enough to outweigh the dramatic increase in the building's cooling load and the increase in initial cost. Simply, the architectural precast and punched window system is a better bang for your buck system when looking at the bottom line figures.

11 Chilled Beam Implementation

11.1 Opportunity Statement:

During the 2009 PACE Roundtable event there were many topics discussed. One of the most important topics discussed during this event was the energy consumption of commercial buildings in the United States. During this breakout session many new technologies were identified to be possible ways to reduce the amount of energy consumed by commercial buildings. Many of the items discussed where automated building systems, LED lighting, new types of insulation, reuse of materials and hydronic heating and cooling systems. Over the past ten years Europe and Australia have been using a new technology called a chilled beam mechanical system to heat and cool certain spaces. Most recently the United States has began to use this energy efficient system.

The current mechanical system used on the Potomac Yard Land Bay E project is a typical forced air VAV distribution system. The disadvantage with this system is that it uses large ductwork to distribute its forced air throughout the building's floor areas. The Potomac Yard Land Bay E project is also projected to achieve a LEED Gold rating upon completion. A way to further reduce energy consumption on this project would be to replace the current mechanical system with a more efficient system. To help reduce the energy consumption of this building the implementation of a chilled beam mechanical system could be used. The advantages for using this type of mechanical system is that the floor-to-floor height will be reduced thus reducing the area of conditioned space and the amount of concrete used in the structure. Another advantage of using this type of mechanical distribution system is that it consumes less energy than a forced air system, which would help with the building's total energy consumption.

11.2 Goal:

The purpose of this study is to determine the different types of chilled beam systems available on the market today and discover the advantages and disadvantages to using this system over a conventional VAV metal duct system. Also when implementing chilled beams on this project it will be determined if the decreased floor to floor height will help decrease the amount of conditioned air in the building and structural concrete. Finally, it will be determined if the installation process of the supply lines, supply air and beams for this new system would be more efficient than the existing system.

11.3 Methodology:

- Research the advantages and disadvantages of a chilled beam system
- Research different types of chilled beams
- Determine best product for use
- Contact Trox for product data
- Determine height savings
- Determine reduction in conditioned space
- Compare durations of installation for forced air and hydronic systems
- Compare costs of two systems

- Draw conclusions and make recommendations concerning application

11.4 Tools and Resources:

- Construction documents
- Trox sales representative
- DAVIS Constitution Center project team
- Internet articles and online sources

11.5 Expected Outcome:

When comparing the initial cost of the two systems I expect that the chilled beam mechanical system will cost more than the traditional VAV system. When looking further into my study I believe that it will take more time to run hydronic piping in comparison to the larger forced air metal ductwork that will probably increase the schedule for the mechanical installation. Due to the reduction in floor-to-floor height the amount of conditioned space should be reduced lowering the demand on the mechanical equipment to condition the air in the building. Also by reducing the floor-to-floor height the building height will be reduced which will reduce the amount of concrete used to construct the building's columns.

11.6 Research:

Traditionally in years past, commercial buildings in the United States have delivered cool air to its interior spaces to condition the occupied space. In recent years an emerging technology that has been used in foreign countries like Australia and European nations has been gaining popularity in the United States. Chilled beam mechanical systems are very efficient tools to control a building's indoor temperature for the building's occupants. This system utilizes chilled water to cool the building's interior spaces by transporting the energy through small water pipes to ceiling units. The reason that this method of cooling is so efficient is because the distribution of energy is much better through water than through forced air. It has been determined that a 1" diameter water distribution pipe can transport the same cooling energy throughout the building as an 18" square metal ductwork supply.

The reason that in years past the chilled beam mechanical system was not used in the United States was because it was too expensive for owners to install in their buildings. The reason that this system was so expensive is because all of the manufacturers of these items were made overseas and were very costly to transport over long distances. Another reason that this system was not common in the States is because contractors were not familiar with the installation methods for this system. For those that did try and install them they were not very fast and had to learn along the way, thus costing the owner an additional amount of money. Of lately due to the increased demand for energy conservation these mechanical systems are becoming much more popular and easier to install in the United States. There are three common types of chilled beams that are being used in the United States today, which include passive, active and multifunction chilled beams.

Passive Chilled Beams-

Passive chilled beams are the simplest type of chilled beam on the market with an average cooling capacity of 50Btuh/sf. The reason for this is because it requires less material to supply the beam and it has no moving parts within the unit. The maintenance on this unit is minimal due to the simplicity of its design. The way this system works is it is supplied with chilled water through small piping that flows into the unit and reaches a series of coils, typically made of either aluminum or copper. Once the fluid passes through the cooling coils in the unit it then moves into the return piping to be chilled again at a central location. The passive chilled beam relies on the natural convection process. Convection is the process by which energy is transferred through a common medium like a gas or a fluid.

In order for natural convection to work the chilled beam unit must be mounted close to the ceiling leaving enough space for the warmer buoyant air to reach the underside of the mounting surface and then drop into the top of the chilled beam. Once the air enters the unit it is cooled by the series of fins and tubes that make up the inside of the unit. After the air is cooled it exits the beam on the underside and falls to the floor level to cool the occupants and the equipment. Once the air is then reheated by the occupants and equipment the air rises and starts the process all over again.

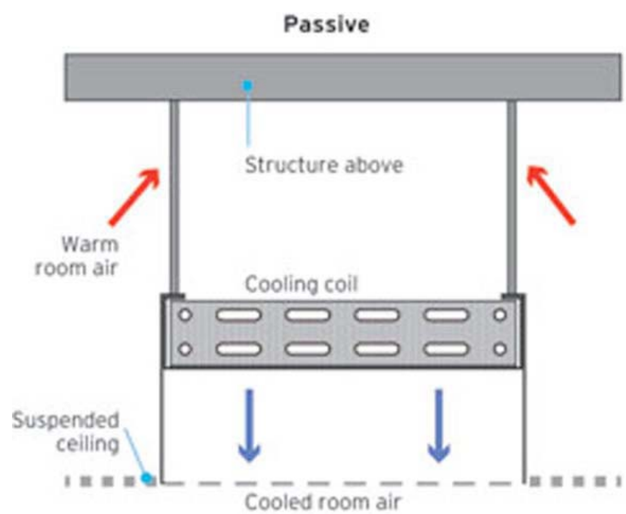


Figure 18: Passive Chilled Beam

As stated before there are no moving parts in a passive chilled beam, it runs solely on the natural process of convection, which prevents need for fans or any other circulating equipment. For these reasons the operation of this unit is virtually silent and comfortable to be around. This system actually is more comfortable because there is not any forced air creating a draft in the occupied space. Passive chilled beams do not use any ventilation to the conditioned space so additional ventilation must be required to serve the occupied space. Although this would require some ductwork it is much smaller and not as extensive as an all air system.

The installation of a passive chilled beam may be either hung by itself like a pendant light fixture, stand alone or mounted flush with an acoustical ceiling. When installing the beams it is critical to place them in the appropriate locations. Optimum locations for placement are parallel and adjacent to exterior perimeter walls because the solar gain from the windows will help with the natural convection process. The heat generated from the windows will rise faster and increase the flow of air through the unit. Locations that are not best suited for beam placement are above workstations, copiers and kitchen appliances. A chilled beam should not be placed above a workstation because the draft from the unit may be disruptive to the worker. Placement of a unit above a copier or other heat generators will counteract the flow of air from the unit from reaching the building occupants.

Figure 19: Trox Passive Beam w/ Fluid Lines

Passive chilled beams may be used in all types of climates with some considerations in mind. This system may even be used in hot and humid environments if the building is sealed from the outside air and the humidity is controlled. Along with controlling the humidity in the building it is important that the supply of chilled water to the unit is kept approximately 2 degrees above the room's dew point in order to prevent condensation off the pipes and mold growth around the insulation. Typically the chilled water used to supply the passive system is warmer than typical chilled water so the size of the building's chillers may be reduced. In some circumstances ground water may be used to supply chilled water to the units thus reducing the building's energy consumption even further.

Active Chilled Beams-

Active chilled beams are more complex units than an active chilled beam mechanical system and have an average cooling capacity of 80 Btuh/sf. Active chilled beams use much of the same concepts as the passive ones but with one major difference, the active beams integrate the use of ventilation air supply. This system still relies on the assistance of natural convection throughout the floor space to circulate the air but also incorporate the dehumidified supply air from a central location in the building. This eliminates the need for another fresh air system like the one required for the passive system. Another great feature of the active chilled beam system is that is may be used for either heating or cooling. This is accomplished by the temperature of the water being supplied to the coils within the unit and the velocity of the ventilated air leaving the unit.

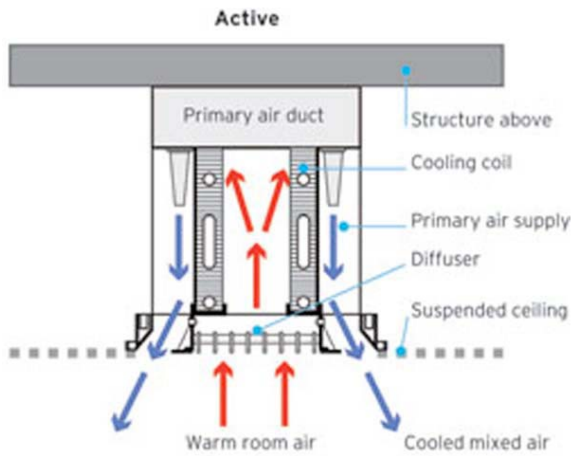


Figure 20: Active Chilled Beam

Active chilled beams can be installed up against the mounting structure as seen from the figure above. This system operates with the help of natural convection within the space it is conditioning. Warm air rises from the floor up to the beam and is drawn into the bottom of the unit by the temperature differential that is supplied by the heat exchanger inside. Once the air is inside the unit it is cooled by the heat exchanger coils and then mixed with the ventilated air supply. The ventilated supply air is introduced into the chamber at a high velocity to thoroughly mix with the cooled air. After mixing the air it is discharged into the room through a diffuser located on the bottom of the unit. Again like the passive system the cool air proceeds to fall to the floor to cool the occupants and equipment. After the air is heated it then rises towards the induction chamber of the unit and then the process is repeated.

Like passive chilled beams, active systems require very little maintenance because there are very few moving parts in comparison to a conventional VAV mechanical system. Even though the active system incorporates a supply of ventilated air to the process it still requires a much smaller volume of air in comparison to an all air system. Active systems are able to produce a high cooling potential than the passive systems because of the high velocity of the ventilated air being mixed within the beam. This allows the discharge temperature of the air leaving the unit to be higher than a traditional all air system allowing for a more comfortable room atmosphere. Because the active system utilizes a small volume of high velocity air the total volume of forced air used is approximately 50-75% lower than a conventional air conditioning system.

Installations of active systems are typically flush mounted units that are incorporated with an acoustical ceiling tile system. When installing an active system in a building the ceiling height is used to determine the spacing of the units to achieve optimum performance from the system. Active chilled beams may be installed to act independently or in a zone. Unlike the passive chilled beam placement of the units above a heat generator or workstation is not a concern. The reason for this is that the warm air is inducted into the unit through the bottom center of the beam and the conditioned air is dispersed through a diffuser at angles greater than 30 degrees from vertical directly below the unit.

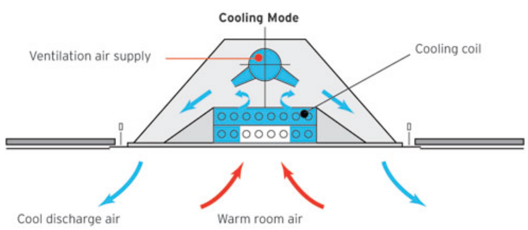


Figure 21: Active Beam Cooling Mode

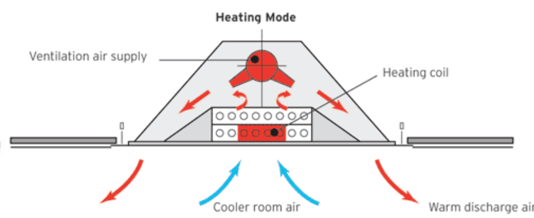


Figure 22: Active Beam Heating Mode

Active systems also have another advantage over the passive systems, which is the ability to supply heat and cooling to a space. This is accomplished because of the integration of the ventilated air supply into the beams. When the heating mode is desired the supply water into the unit must be at a higher temperature in order to warm the heat exchanger to transfer the heat into the inducted air. Once the air is heated it is then mixed and forced out of the unit towards the occupied space by the high velocity supply air. An active chilled beam that has the function for both heating and cooling will typically have four pipes connected to the unit. Two of the pipes will be the supply, one for hot water and one for chilled water. The other two pipes are the returns for both the hot and chilled water. Along with the piping of water being connected to the unit there will be a connection for the forced air supply in the top of the unit. The temperature of the water being supplied to the beams depends on the thermostat that controls a particular zone. Different zones in a building may perform separate tasks like in one zone the thermostat may call for heat and the beams will produce heat while in another zone the thermostat may call for cooling and the beams will cool the space.

Multiservice Chilled Beam-

Multiservice chilled beams may be either active or passive systems. This type of chilled beam incorporates other building systems with it in one prefabricated unit. Typically larger than the other two systems, it may contain a variety of building systems, which include:

- Lighting
- Sprinklers
- Public Address System
- Motion detector and other BA Systems

- Wire ways

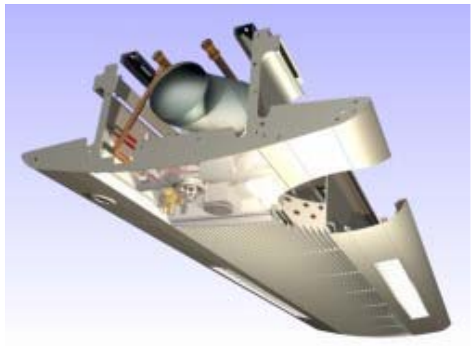


Figure 23: Trox Multi-Service Chilled Beam

These units are obviously much larger than the single function systems and much more expensive. However, these units are very compact in comparison to all of the individual systems it houses. By having the variety of components within the unit, construction may be shortened dramatically. The need for drop ceilings is an option because all of the components for the building to operate are in a compact area. This may reduce the cost of hangers and installation materials.

Advantages-

Chilled beams have many advantages over conventional all air mechanical systems. Chilled beam systems use approximately 50-75% less air ventilated air than forced air systems. This is achieved by using water as a transportation medium for cooling a space. Water is much more dense than air, which allows it to be more efficient for transferring energy throughout a building. In many case studies it has been determined that by using a chilled beam mechanical system over a conventional VAV system a building will consume much less energy. An example of this is the Constitution Center in Washington DC. This is a 1.4 million square feet office building-remodeling job that is being fitted out with all new construction materials and is projected to achieve a LEED Silver Certification. This building is utilizing active chilled beams on all of the typical floors. The mechanical designers of the building project that the building will consume approximately 23% less energy than a typical all air mechanical system compliant with ASHRAE 90.1 standard.

The comfort of the conditioned space for the building occupants is much better than a conventional all air system. The lower discharge air velocity coming from the units improves comfort in the occupied area. The conditioned air is mixed much better inside of the unit before it is discharged into the room unlike all air systems that mix the air after entering the room. Chilled beams also reduce the size of metal ductwork for forced air in the building. This is accomplished because the need for ventilated air is dramatically reduced, thus reducing overall ductwork, air handlers and fan energy. By reducing the size of the ductwork used on a building two things may happen, the floor-to-floor height may be reduced or the floor to ceiling height may be increased. By increasing the ceiling height architects may add larger lights and other amenities to the building that may increase occupant comfort. By lowering the floor-to-floor height many things may be achieved:

- Less structural material consumed
- Decreased volume of conditioned space
- Higher percentage of outside air, creating healthier indoor environment
- Allow for more floors to be added where height restrictions are enforced

Chilled beams also require less maintenance than conventional all air systems, which reduces the life-cycle cost of the system. This system only requires periodic vacuuming of the coils within the unit approximately every five years to ensure optimum performance. Because of the chilled beam's lack of moving parts there are virtually no parts of the system that will fail if installed properly. Chilled beams have virtually no noise of operation due to the lack of moving parts. Passive chilled beams are virtually silent while active beams produce a small amount of noise, less than 30 dB, from the high velocity ventilated air.

Other advantages to implementing a chilled beam mechanical system is that there are no electrical connections involved with the beams. This can dramatically reduce electrical installation and wire costs during construction. Controls for a chilled beam system are far less complex than the ones used on all air systems containing VAV boxes. Commissioning for a chilled beam system are much less complicated and time consuming when compared to a typical mechanical system. Only small adjustments through the water balancing valves and primary air balancing dampers through easy pressure readings are needed to complete the system's commissioning.

Disadvantages-

The major disadvantage of a chilled beam mechanical system is the high initial cost of material and installation. There are many reasons for the increased initial cost of this system. One major factor to the increased price is the unfamiliarity of contractor's installation methods. Another reason for the high cost of the material is that most of the products come from overseas. Although metal ductwork decreases when implementing this system other items are needed. Some of the increased cost for this system is attributed to the cost of the unit, the need for piping, insulation for water pipes and pumps to circulate the water.

There are many applications that chilled beams are not suited for like spaces with high ceilings and rooms with high humidity. Humidity must be monitored closely to ensure that mold and condensation does not form. Buildings that use this mechanical system must be sealed and dehumidified; operable windows and other means of allowing unconditioned outside air into the occupied space are unacceptable. Locations that are not well suited for the use of chilled beams are lobbies, exercise rooms, indoor pools and kitchens.

11.7 Conditioned Air Volume and CIP Savings:

Conditioned Air Volume Difference								
	Floor	Area (SF)	Floor Height (ft)	Plenum Diff. (ft)	VAV (CF)	CB (CF)	Difference (CF)	Savings %
Building A	Ground	15469.00	15.67	0.67	242399.23	232086.56	10312.67	4.25%
	2	22325.00	12.42	0.67	277200.60	262317.26	14883.33	5.37%
	3	23567.00	12.42	0.67	292622.01	276910.68	15711.33	5.37%
	4	23567.00	12.42	0.67	292622.01	276910.68	15711.33	5.37%
	5	23567.00	12.42	0.67	292622.01	276910.68	15711.33	5.37%
	6	23567.00	12.42	0.67	292622.01	276910.68	15711.33	5.37%
	7	23567.00	12.42	0.67	292622.01	276910.68	15711.33	5.37%
	8	23567.00	12.42	0.67	292622.01	276910.68	15711.33	5.37%
	9	21620.00	12.75	0.67	275655.00	261241.67	14413.33	5.23%
Building B	Ground	22823.00	15.67	0.67	357636.41	342421.08	15215.33	4.25%
	2	21485.00	12.42	0.67	266770.65	252447.32	14323.33	5.37%
	3	22642.00	12.42	0.67	281136.66	266041.99	15094.67	5.37%
	4	22642.00	12.42	0.67	281136.66	266041.99	15094.67	5.37%
	5	22642.00	12.42	0.67	281136.66	266041.99	15094.67	5.37%
	6	22642.00	12.42	0.67	281136.66	266041.99	15094.67	5.37%
	7	22642.00	12.42	0.67	281136.66	266041.99	15094.67	5.37%
	8	22642.00	12.42	0.67	281136.66	266041.99	15094.67	5.37%
	9	21209.00	12.75	0.67	270414.75	256275.42	14139.33	5.23%
Totals:					5132628.65	4864505.32	268123.33	5.22%

Table 26: Conditioned Air Volume Savings

The table above depicts the amount of conditioned air volume that would be saved if a chilled beam mechanical system was used on the Potomac Yard Land Bay E project. The conditioned air volume savings is made possible by the decreased ceiling plenum space required for the chilled beam system and its components, which resulted in a lower floor-to-floor height on a typical floor. The advantage of having a lower floor-to-floor height is the decease in the amount of conditioned air in the building, which in most cases will result in a higher percentage of ventilated air making the building a healthier work environment.

The difference in air volume for this project was determined by using the current construction documents to find the required ceiling plenum for the VAV system. In order to determine the required ceiling plenum for a chilled beam mechanical system the construction management team on the Constitution Center project was consulted. This team is in the process of implementing on of the largest active chilled beams systems to date in a commercial office building in the United States. It was determined that the difference in the ceiling plenum requirements between the two systems to be 8”. This difference was then subtracted from the original floor-to-floor height to find the new floor height. This number was then multiplied by the floor area of each floor and then compared to the original floor volume. The total conditioned air volume savings was 268,123 CF, which resulted in approximately a 5.22% reduction in total conditioned air space.

Concrete Savings				
Strenght (PSI)	Original (CY)	Proposed (CY)	Savings (CY)	Savings (%)
5000	215.49	203.98	11.51	5.34%
6000	800.43	759.24	41.19	5.15%
		Total Savings:	52.70	5.19%

Table 27: Cast-in-place Concrete Savings

The table above summarizes the amount of cast-in-place structural concrete saved when implementing a chilled beam mechanical system compared to a typical all air system. The CIP concrete savings is a result of the lower floor-to-floor heights required to support the proposed system. All of the concrete savings occur within the column construction of the building. The total amount of concrete savings is approximately **52.7CY** of concrete, which is about **5.19%** of the total concrete used for all of the columns in the building. Assuming that each concrete truck holds approximately 9CY of concrete, there will be a savings of six truck loads of concrete brought to the site thus freeing up a portion of the site for other deliveries.

Please see Appendix N for Concrete Savings

Cost Savings $1375/CY			
Strenght (PSI)	Original ($)	Proposed ($)	Savings ($)
5000	$296,298.75	$280,472.50	$15,826.25
6000	$1,100,591.25	$1,043,955.00	$56,636.25
		Total Savings:	$72,462.50
		Adjusted (.93):	$67,390.13

The table above summarizes the cost savings of CIP concrete for the columns in the building. RS Means provided the pricing information for the CIP concrete. This price includes material, placement and delivery. The total cost savings for CIP concrete from the implementation of a chilled beam mechanical system is **$72,462.50**. When this value is adjusted for location, Arlington Virginia, the total savings amounts to **$67,390.13**.

11.8 Cost and Schedule Impacts:

The cost and schedule considerations compared in this analysis involve the comparison between the VAV and chilled beam units and supply air ducts and water piping material for both systems. In order to determine the cost differential between the two systems the following information was used:

Chilled Beam System- information provided by DAVIS mechanical team at Constitution Center

- Union labor rate $54
- 1” pipe $600/100’ including fittings
- 1 hour for beam installation
- 30hours/100’ of pipe
- 25”x5” trunk duct
- $1800/100’ duct
- 25 hours to fabricate and install duct
- $30 flex duct supplying individual unit
- Chilled beam cost $800
- 18 beams for 2700s.f.

Building A Typical Floor:

Ductwork-

- Material: $9,216
- Installation: $6,912

1” piping-

- Material: $12,288
- Installation: $33,178

Chilled Beams-

- Material: $125,600
- Installation: $8,478

Total Per Floor = $195,672

Total Building A, Floors 2-9 = **$1,565,376**

Building B Typical Floor:

Ductwork-

- Material: $8,280
- Installation: $6,480

1” piping-

- Material: $11,520
- Installation: $31,104

Chilled Beams-

- Material: $120,000
- Installation: $8,100

Total Per Floor = $185,484

Total Building B, Floors 2-9 = **$1,483,872**

Total Building Cost = $3,049,248

This number only includes typical office space floors, which are floors 2-9. The ground floor and P-levels are not suitable for chilled beam implementation because of function and ceiling height. Again this is an estimate only involving the unit itself and the material needed to supply the units, not the whole mechanical system.

VAV System- information provided by DAVIS mechanical team at Constitution Center

- Union labor $54
- Assuming average duct size 2’x3’
- Material $240/12’
- 3 hours fabrication for 12’
- 10 hours installation for 12’
- VAV $2500 including local controls
- 4 hours for VAV installation

Building A Typical Floor:

Ductwork-

- Material: $9,520
- Installation: $27,846

VAV w/ controls-

- Material: $90,000
- Installation: $7,776

Total Per Floor = $135,142

Total Building A, Floors 2-9 = **$1,081,136**

Building B Typical Floor:

Ductwork-

- Material: $9,200
- Installation: $26,910

VAV w/ controls-

- Material: $85,000
- Installation: $7,344

Total Per Floor = $128,454

Total Building B, Floors 2-9 = **$1,027,632**

Total Building Cost = $2,108,768

When comparing the two systems the chilled beam system is **45% higher** than the VAV system. This is higher than the more common 20-30% increase in cost between the two systems. The reason that this is so high is because is because the cost savings for air handlers, fans and controls were not taken into consideration during this analysis. Given more time and the appropriate resources to determine the total system cost differences it would have been found that the chilled beam system would have been in the range of 20-30% more than the all air system. However, the initial cost is one important consideration when looking at implementing a new system but the payback period is just as important. Typically, a chilled beam mechanical system should pay for itself in energy savings in approximately **7-10 years**, said a member of the Constitution Center mechanical team. After the system has paid for itself it will continue to save money throughout its lifecycle, which could amount to significant dollars especially with energy inflation near 5% a year.

When taking into consideration the schedule impacts of implementing a chilled beam mechanical system to the Potomac Yard Land Bay E project, the duration of installing this system is not critical to the project's completion. However, it is still important to take into account how long it will take to install the components of this system. When comparing the installation of just the ductwork and VAV units to the ductwork, piping and chilled beams the proposed system takes approximately **54% longer** to install. The traditional all air system would take approximately **102 days** to complete while the chilled beam system would take approximately **157 days** to complete. The information used to determine the original systems duration was the schedule for the project. The Constitution Center mechanical team provided the information used to determine the duration for the chilled beam system. The assumptions used where the following:

- 5 men crew
- Ductwork: 19hr/100'
- Piping: 30hr/100'
- Beams: 1hr/beam

Please see Appendix O for Schedule Comparison between chilled beam system and all air system.

11.9 Conclusions and Recommendations:

After conducting research for this analysis it has been determined that chilled beam technology is a more efficient mechanical system than an all air mechanical system. Chilled beams utilize water as the means of transporting the cooling energy throughout the building. Water is much more dense than traditionally used air, this means that water may transfer much more energy in a smaller volume. As stated before a 1" water pipe contains the same cooling capacity as an 18' air duct. This eliminates the need for large amounts of metal ductwork servicing buildings, which allows for a reduced ceiling plenum. As previously stated there are many benefits to installing a chilled beam mechanical system, which include:

- Increased energy savings
- Higher floor-to-ceiling height
- Lower floor-to-floor height
    - Concrete savings
    - Conditioned air volume savings
    - Higher percentage of outside air
    - Allows for more floors in height restricted regions
- Increased occupant comfort, better air dispersion

Before the owner could make a decision whether or not to implement a chilled beam mechanical system on their project instead of the existing system they would have to consider the cost and schedule implications. If the owner where to switch to a chilled beam system they would decrease the total amount of conditioned air volume with in the building by 5.22%. This would increase the percentage of ventilated air into the occupied floors and reduce the load on the mechanical system. The owner would also benefit from a 5.19% savings in structural concrete in the columns. This translates to 52.7CY of concrete and a cost savings of $67,390.13. When comparing the initial cost of the two systems the chilled beam system will cost approximately 45% higher than the all air system. If a study of the reduction in AHUs, fans and controls where performed the percentage difference would become smaller. There is not a need to be concerned about the schedule because the mechanical rough in is not on the critical path of this project. However, to install this system it would take approximately 54% longer duration to complete when compared to the VAV system.

After reviewing the findings of this analysis I would recommend this system to the ownership of the Potomac Yard Land Bay E project. By installing this system they will receive many benefits that will be noticed immediately and some that will ongoing throughout the life of the building. As time progresses and this technology becomes more popular within the United States contractors will become more familiar with installation methods and the prices of the units will fall as more competition enters the market hoping to capitalize on a piece of the action.

12 Conclusions:

After conducting all three analyses many advantages and disadvantages have been discovered. From an owner's perspective they are looking for fast, efficient, cost effective and quality construction for their project. These analyses look at saving the owner money by making the building more efficient and shortening the construction process by using prefabricated materials. The first analysis looks at the addition of a supplemental energy source on the rooftop of the existing white TPO roof. The last two analyses look at comparing existing building systems to other commonly used systems on new construction today.

The first analysis looks at the implementation of a Solyndra PV system on the roof of both buildings. The study shows that the proposed system will provide a savings of $38,650 during the first year after installation. When using a 5% cost of energy increase per year it was determined that the system will pay for itself with in 22 years of operation. This is within the 25-year warranty period, in fact, by the end of the warranty the owner will save $402,622.63 in energy costs.

The second analysis involves implementing a unitized curtain wall system in place of the existing architectural precast and punched window façade. This was proposed to shorten the schedule and provide more natural daylight to the interior space. This study showed that the total project schedule would be shortened by 23 days and reduces the general conditions by 1.75%. This translates into a savings of $106,701.30 for the project. However, it was determined that the curtain wall system would cost 31% higher than the existing system and would more than double the cooling load on the building by solar heat gain through the increased glazing.

The third analysis incorporated replacing the current all air mechanical system with a more energy efficient chilled beam mechanical system. This analysis only involved the comparison between the distribution equipment and supply material. From this analysis it was determined that by implementing this system the owner would save 52.7 CY of concrete, which translates to a $67,390.13 cost savings on CIP concrete for the columns. The owner would also save 5.22% of conditioned air volume in the building to allow for a higher percentage of ventilated air in the building. However, when comparing the duration of installation and initial cost the new system cost approximately 45% more to install and take 54% longer time to complete.

After looking over the findings for each of the three analyses it was determined that the first and third analyses would be good decisions for the owner to implement. By implementing these two systems to the building the owner would achieve a more sustainable image to the public and LEED officials. Assuming that the owner keeps the building and does not perform any major renovations for forty years they will be saving tremendous amounts of money through energy savings. Energy prices are only going to skyrocket due to the current energy crisis. Assuming that energy costs rise at a constant rate of 5% in the DC metro area the cost of energy may reach $.92 per kWh. At the future price of $.92/kWh the energy savings for the Solydra panels alone would reach $3,226,836.

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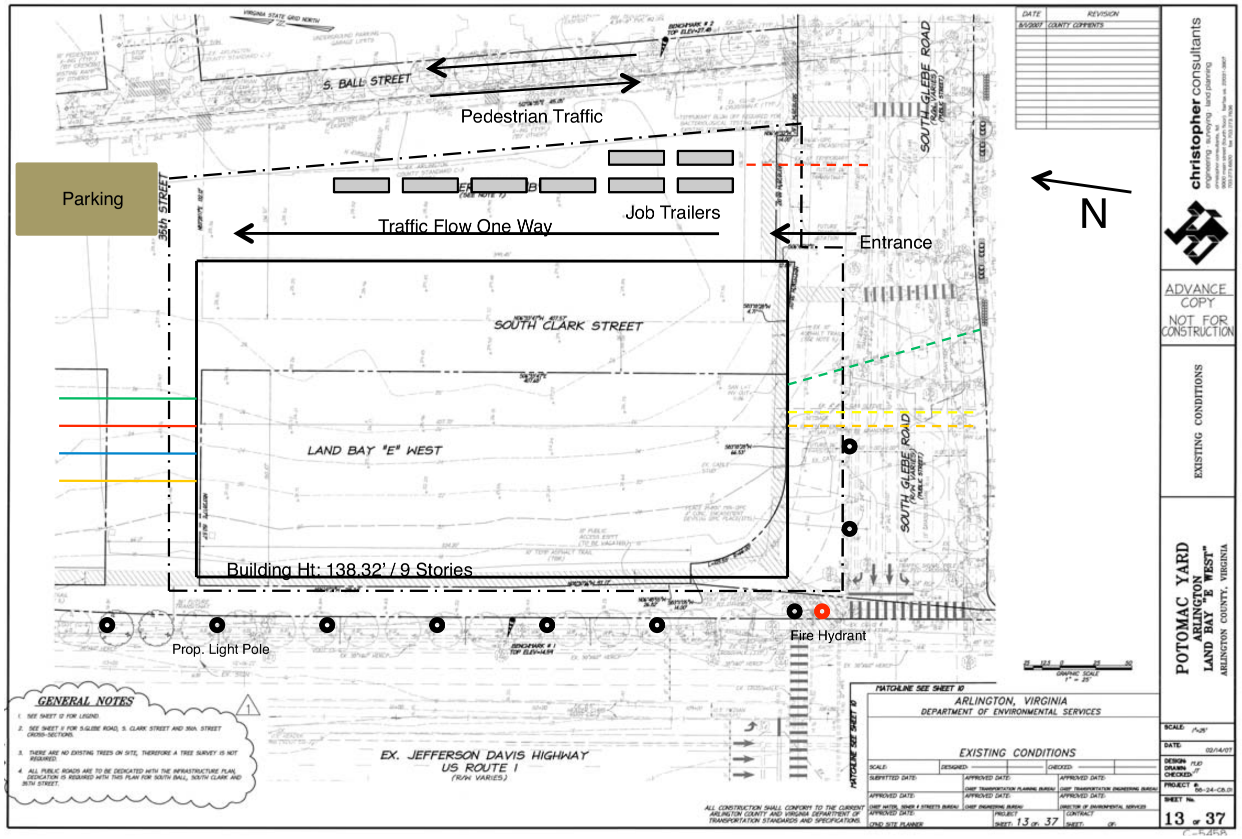
Wikipedia. Insolation. February 2010 http://en.wikipedia.org/wiki/Insolation

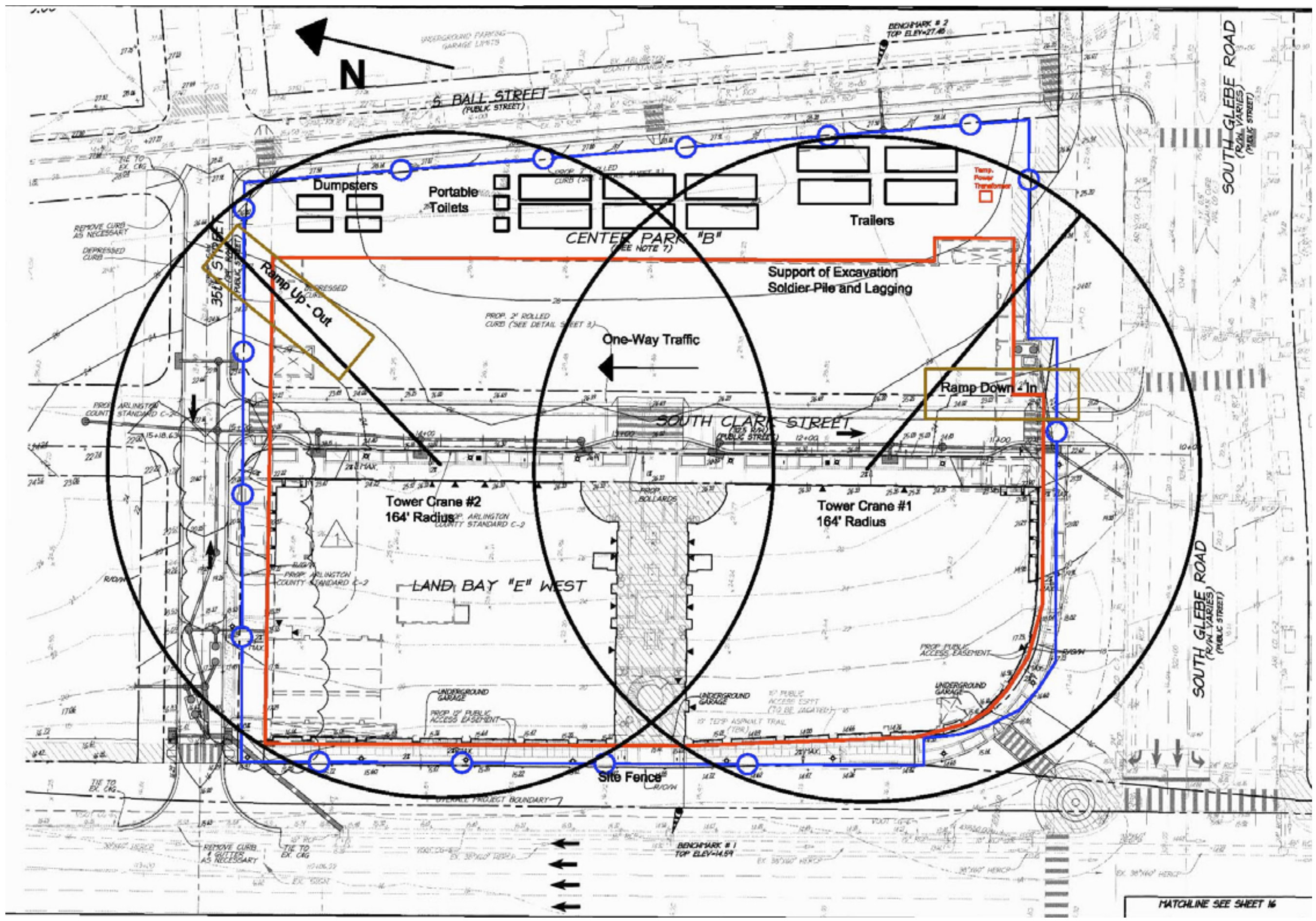
14 Appendix A:



Building Perimeter w/ Parking	Exist. Sanitary	Exist. Gas	Electric	Water
Property Line & Construction Fence	Exist. Communication	Sanitary	Gas	Temp. Electric

Potomac Yard Land Bay E	Existing Conditions	Drew Heilman	10/05/09

14 Appendix B:



Potomac Yard Land Bay E
Arlington, VA

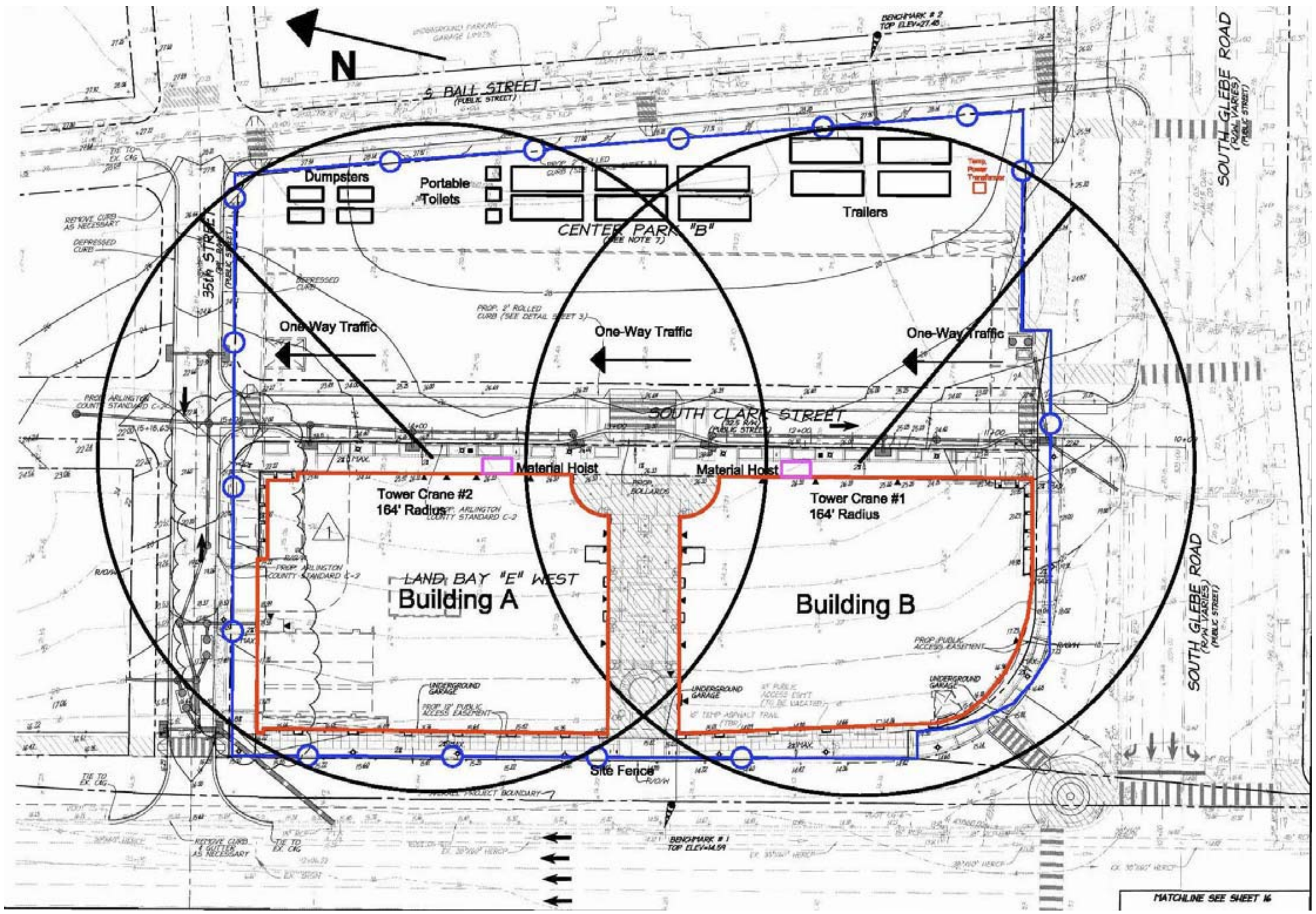
Structural Sequence: Garage Levels

By: Drew Heilman

Tech 2

Date: October 28, 2009

14 Appendix C:



Potomac Yard Land Bay E

Arlington, VA

Structural Sequence: Buildings A&B

By: Drew Heilman

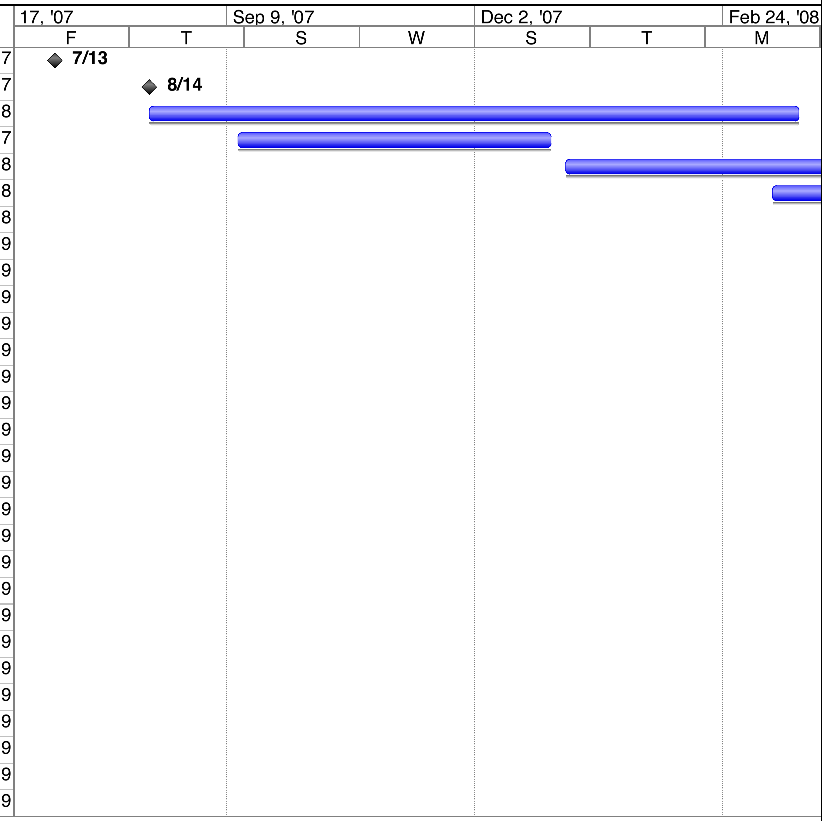
Tech 2

Date: October 28, 2009

14 Appendix D:

Project Summary Schedule

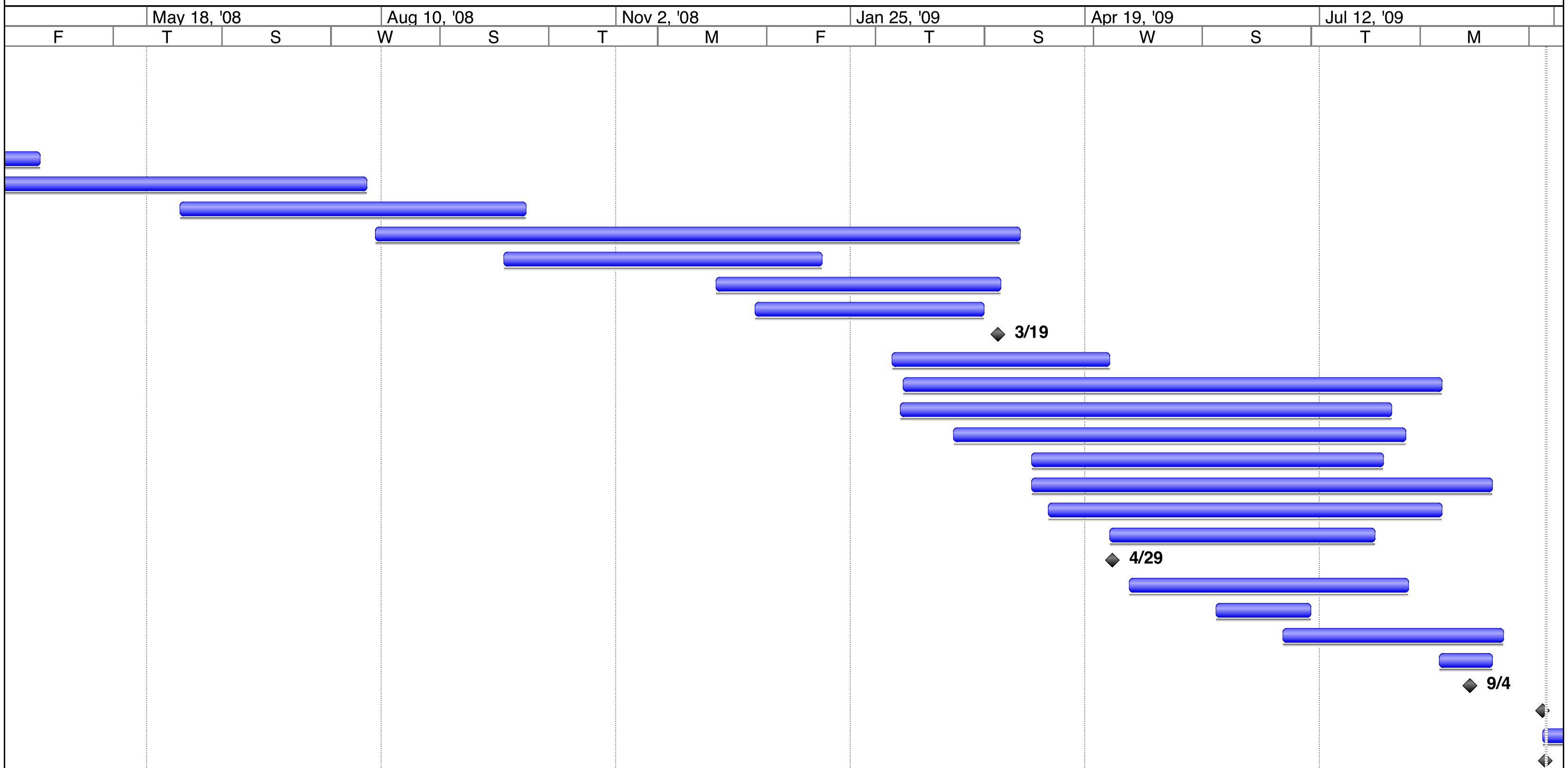
ID	Task Name	Duration	Start	Finish
1	Proposal to Owner	0 days	Fri 7/13/07	Fri 7/13/07
2	Notice to Proceed	0 days	Tue 8/14/07	Tue 8/14/07
3	Preconstruction	158 days	Tue 8/14/07	Thu 3/20/08
4	Owner Receiving Permits	76 days	Thu 9/13/07	Thu 12/27/07
5	Site Development	71 days	Wed 1/2/08	Wed 4/9/08
6	Sheeting/ Shoring	104 days	Wed 3/12/08	Mon 8/4/08
7	Foundation Piles/ Pile Caps	88 days	Fri 5/30/08	Tue 9/30/08
8	Site Utilities	165 days	Fri 8/8/08	Thu 3/26/09
9	Ground Floor Concrete	82 days	Tue 9/23/08	Wed 1/14/09
10	Above Grade Concrete Structure B	74 days	Mon 12/8/08	Thu 3/19/09
11	Above Grade Concrete Structure A	60 days	Mon 12/22/08	Fri 3/13/09
12	Top Out Building B	0 days	Thu 3/19/09	Thu 3/19/09
13	Arch Precast Bldg B	56 days	Mon 2/9/09	Mon 4/27/09
14	Building B Core Finishes	137 days	Fri 2/13/09	Mon 8/24/09
15	Main Lobby Interior Bldg B	126 days	Thu 2/12/09	Thu 8/6/09
16	Building A Core Finishes	116 days	Tue 3/3/09	Tue 8/11/09
17	MEP and Sprikler Bldg B	90 days	Tue 3/31/09	Mon 8/3/09
18	Elevators Bldg B	119 days	Tue 3/31/09	Fri 9/11/09
19	Elevators Bldg A	101 days	Mon 4/6/09	Mon 8/24/09
20	MEP and Sprinkler Bldg A	69 days	Tue 4/28/09	Fri 7/31/09
21	Top Out Building A	0 days	Wed 4/29/09	Wed 4/29/09
22	Arch Precast Bldg A	72 days	Tue 5/5/09	Wed 8/12/09
23	MEP Garage Levels	24 days	Fri 6/5/09	Wed 7/8/09
24	Site Work/ Landscaping	57 days	Mon 6/29/09	Tue 9/15/09
25	Inspections	15 days	Mon 8/24/09	Fri 9/11/09
26	Building A&B Watertight	0 days	Fri 9/4/09	Fri 9/4/09
27	Substaintial Completion	0 days	Wed 9/30/09	Wed 9/30/09
28	Punchlist	10 days	Wed 9/30/09	Tue 10/13/09
29	Project Completion	0 days	Thu 10/1/09	Thu 10/1/09



Drew Heilman
AE Senior Thesis

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

Project Summary Schedule



Drew Heilman AE Senior Thesis	Task		Milestone		External Tasks	
	Split		Summary		External Milestone	
	Progress		Project Summary		Deadline	

14 Appendix E:

Statement of Probable Cost

Land Bay E - Oct 2008 - VA - Arlington

Prepared By: **Drew Heilman**
AE Senior Thesis 2010
The Pennsylvania State University
University Park, Pa 16802
717.873.1210 Fax:

Prepared For: **Penn State AE Department**
104 EUA
University Park, Pa 16802
Fax:

Building Sq. Size:	**369300**	Site Sq. Size:	**216643**
Bid Date:		Building use:	**Office**
No. of floors:	**9**	Foundation:	**PIL**
No. of buildings:	**2**	Exterior Walls:	**PRE**
Project Height:	**138.32**	Interior Walls:	
1st Floor Height:		Roof Type:	**MEM**
1st Floor Size:		Floor Type:	**CON**
		Project Type:	**NEW**

Division		Percent	Sq. Cost	Amount
00	**Bidding Requirements**	**3.15**	**3.87**	**1,430,841**
	Bidding Requirements	3.15	3.87	1,430,841
01	**General Requirements**	**12.05**	**14.83**	**5,476,682**
	General Requirements	12.05	14.83	5,476,682
02	**Site Work**	**5.76**	**7.09**	**2,619,383**
	Site Work	5.76	7.09	2,619,383
03	**Concrete**	**23.48**	**28.90**	**10,672,842**
	Concrete	23.48	28.90	10,672,842
04	**Masonry**	**1.54**	**1.89**	**699,400**
	Masonry	1.54	1.89	699,400
05	**Metals**	**7.60**	**9.35**	**3,452,036**
	Metals	7.60	9.35	3,452,036
06	**Wood & Plastics**	**0.31**	**0.39**	**142,375**
	Wood & Plastics	0.31	0.39	142,375
07	**Thermal & Moisture Protection**	**1.36**	**1.67**	**617,607**
	Thermal & Moisture Protection	1.36	1.67	617,607
08	**Doors & Windows**	**15.30**	**18.82**	**6,951,740**
	Doors & Windows	15.30	18.82	6,951,740
09	**Finishes**	**3.59**	**4.42**	**1,632,282**
	Finishes	3.59	4.42	1,632,282
10	**Specialties**	**1.89**	**2.33**	**860,576**
	Specialties	1.89	2.33	860,576
11	**Equipment**	**0.08**	**0.10**	**35,856**
	Equipment	0.08	0.10	35,856
12	**Furnishings**	**1.06**	**1.31**	**482,962**
	Furnishings	1.06	1.31	482,962
14	**Conveying Systems**	**4.13**	**5.08**	**1,875,990**
	Conveying Systems	4.13	5.08	1,875,990
15	**Mechanical**	**12.02**	**14.79**	**5,461,850**
	Mechanical	12.02	14.79	5,461,850
16	**Electrical**	**6.68**	**8.22**	**3,036,306**
	Electrical	6.68	8.22	3,036,306
Total Building Costs		**100.00**	**123.07**	**45,448,726**
Total Non-Building Costs		**100.00**	**0.00**	**0**

Total Project Costs	**--**	**--**	**45,448,726**

Statement of Probable Cost

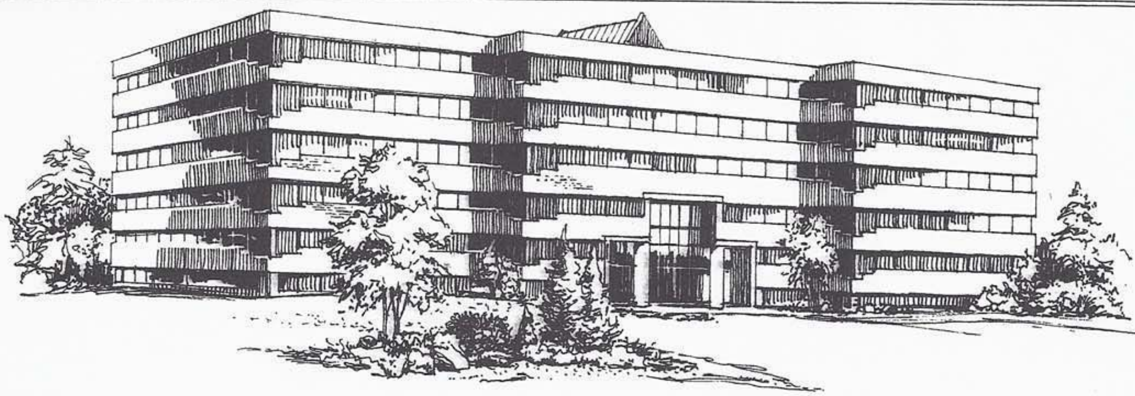
Land Bay E Parking - Oct 2008 - VA - Arlington

Prepared By:	**Drew Heilman** **AE Senior Thesis 2010** **The Pennsylvania State University** **University Park, Pa 16802** **717.873.1210 Fax:**	Prepared For:	**Penn State AE Department** **104 EUA** **University Park, Pa 16802** **Fax:**
Building Sq. Size:	**235000**	Site Sq. Size:	**23677**
Bid Date:		Building use:	**Commercial**
No. of floors:	**3**	Foundation:	**PIL**
No. of buildings:	**1**	Exterior Walls:	**CON**
Project Height:		Interior Walls:	
1st Floor Height:		Roof Type:	
1st Floor Size:		Floor Type:	**CON**
		Project Type:	**NEW**

Division		Percent	Sq. Cost	Amount
00	**Procurement and Contracting Require**	**4.74**	**3.62**	**850,145**
	Procurement and Contracting Require	4.74	3.62	850,145
01	**General Requirements**	**3.65**	**2.78**	**654,152**
	General Requirements	3.65	2.78	654,152
02	**Site Work**	**10.64**	**8.12**	**1,907,629**
	Site Work	10.64	8.12	1,907,629
03	**Concrete**	**52.89**	**40.36**	**9,485,701**
	Concrete	52.89	40.36	9,485,701
04	**Masonry**	**0.39**	**0.29**	**69,281**
	Masonry	0.39	0.29	69,281
05	**Metals**	**4.47**	**3.41**	**802,395**
	Metals	4.47	3.41	802,395
06	**Wood & Plastics**	**0.06**	**0.04**	**10,052**
	Wood & Plastics	0.06	0.04	10,052
07	**Thermal & Moisture Protection**	**1.83**	**1.40**	**328,018**
	Thermal & Moisture Protection	1.83	1.40	328,018
08	**Doors & Windows**	**6.68**	**5.10**	**1,197,760**
	Doors & Windows	6.68	5.10	1,197,760
09	**Finishes**	**0.59**	**0.45**	**105,647**
	Finishes	0.59	0.45	105,647
10	**Specialties**	**0.37**	**0.28**	**66,427**
	Specialties	0.37	0.28	66,427
11	**Equipment**	**0.73**	**0.55**	**130,198**
	Equipment	0.73	0.55	130,198
14	**Conveying Systems**	**1.76**	**1.35**	**316,147**
	Conveying Systems	1.76	1.35	316,147
15	**Mechanical**	**3.89**	**2.97**	**698,528**
	Mechanical	3.89	2.97	698,528
16	**Electrical**	**4.60**	**3.51**	**825,422**
	Electrical	4.60	3.51	825,422
21	**Fire Suppression**	**0.37**	**0.28**	**65,725**
	Fire Suppression	0.37	0.28	65,725
22	**Plumbing**	**0.52**	**0.40**	**93,706**
	Plumbing	0.52	0.40	93,706
26	**Electrical**	**1.83**	**1.40**	**328,625**
	Electrical	1.83	1.40	328,625

Total Building Costs	**100.00**	**76.32**	**17,935,558**
Total Non-Building Costs	**100.00**	**0.00**	**0**
Total Project Costs	**--**	**--**	**17,935,558**

14 Appendix F:



Costs per square foot of floor area

Exterior Wall	S.F. Area	20000	40000	60000	80000	100000	150000	200000	250000	300000
	L.F. Perimeter	260	360	400	420	460	520	600	640	700
Precast Concrete Panel	Steel Frame	219.75	191.10	176.00	167.10	162.85	155.70	152.70	150.00	148.55
	R/Conc. Frame	215.70	186.70	171.55	162.60	158.30	151.10	148.10	145.40	143.95
Face Brick with Concrete Block Back-up	Steel Frame	212.30	185.15	171.35	163.35	159.45	152.90	150.15	147.80	146.45
	R/Conc. Frame	205.90	179.90	166.50	158.65	154.85	148.55	145.85	143.50	142.20
Limestone Panel Concrete Block Back-up	Steel Frame	256.90	216.70	194.95	182.05	175.95	165.60	161.20	157.30	155.20
	R/Conc. Frame	252.25	212.05	190.25	177.40	171.25	160.90	156.55	152.65	150.55
Perimeter Adj., Add or Deduct	Per 100 L.F.	27.40	13.65	9.10	6.80	5.50	3.65	2.75	2.25	1.90
Story Hgt. Adj., Add or Deduct	Per 1 Ft.	5.70	3.90	2.90	2.30	2.05	1.50	1.35	1.15	1.05

***For Basement**, add $36.40 per square foot of basement area*

The above costs were calculated using the basic specifications shown on the facing page. These costs should be adjusted where necessary for design alternatives and owner's requirements. Reported completed project costs, for this type of structure, range from $74.60 to $219.35 per S.F.

Common additives

Description	Unit	$ Cost
Clock System		
20 room	Each	16,000
50 room	Each	39,100
Closed Circuit Surveillance, One station		
Camera and monitor	Each	1850
For additional camera stations, add	Each	1000
Directory Boards, Plastic, glass covered		
30" x 20"	Each	595
36" x 48"	Each	1450
Aluminum, 24" x 18"	Each	600
36" x 24"	Each	675
48" x 32"	Each	980
48" x 60"	Each	2025
Elevators, Electric passenger, 5 stops		
2000# capacity	Each	158,700
3500# capacity	Each	167,200
5000# capacity	Each	170,700
Additional stop, add	Each	13,600
Emergency Lighting, 25 watt, battery operated		
Lead battery	Each	282
Nickel cadmium	Each	805

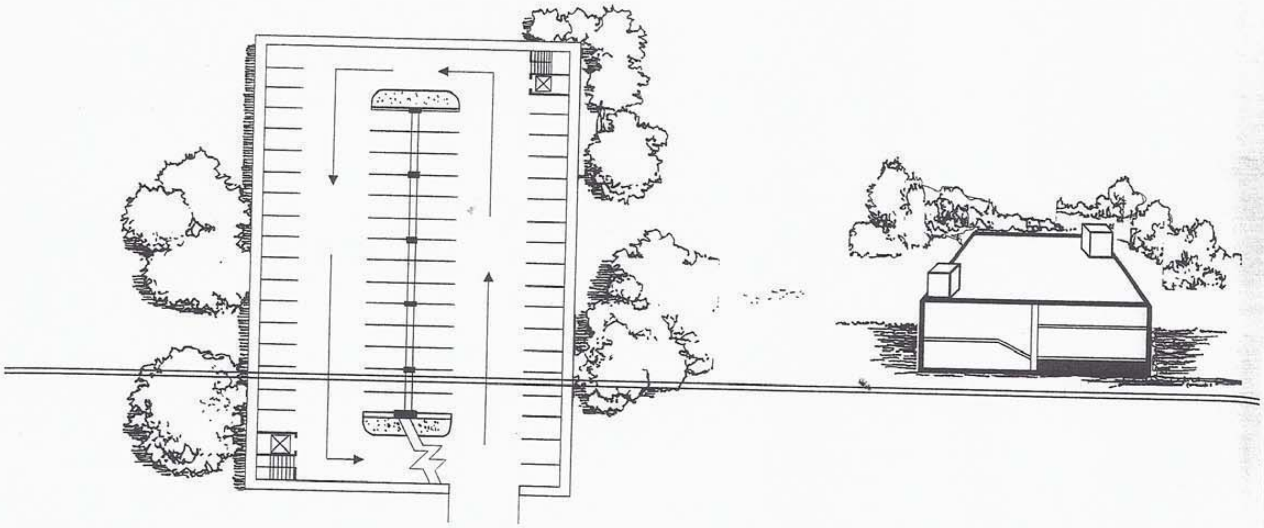
Description	Unit	$ Cost
Intercom System, 25 station capacity		
Master station	Each	2650
Intercom outlets	Each	169
Handset	Each	470
Smoke Detectors		
Ceiling type	Each	187
Duct type	Each	480
Sound System		
Amplifier, 250 watts	Each	2350
Speaker, ceiling or wall	Each	191
Trumpet	Each	365
TV Antenna, Master system, 12 oulet	Outlet	315
30 outlet	Outlet	203
100 outlet	Outlet	194

Important: See the Reference Section for Location Factors

Model costs calculated for a 8 story building with 12′ story height and 80,000 square feet of floor area

Office, 5-10 Story

			Unit	Unit Cost	Cost Per S.F.	% Of Sub-Total
A. SUBSTRUCTURE						
1010	Standard Foundations	Poured concrete; strip and spread footings	S.F. Ground	12.08	1.51	
1020	Special Foundations	N/A	—	—	2.00 Assumed	
1030	Slab on Grade	4″ reinforced concrete with vapor barrier and granular base	S.F. Slab	4.74	.59	2.1%
2010	Basement Excavation	Site preparation for slab and trench for foundation wall and footing	S.F. Ground	.26	.03	
2020	Basement Walls	4′ foundation wall	L.F. Wall	78	.53	
B. SHELL						
	B10 Superstructure					
1010	Floor Construction	Concrete slab with metal deck and beams	S.F. Floor	26.25	22.97	19.0%
1020	Roof Construction	Metal deck, open web steel joists, interior columns	S.F. Roof	8.08	1.01	
	B20 Exterior Enclosure					
2010	Exterior Walls	Precast concrete panels *80% of wall*	S.F. Wall	38.24	15.42	
2020	Exterior Windows	Vertical pivoted steel *20% of wall*	Each	552	3.71	15.3%
2030	Exterior Doors	Double aluminum and glass doors and entrance with transoms	Each	3542	.22	
	B30 Roofing					
3010	Roof Coverings	Built-up tar and gravel with flashing; perlite/EPS composite insulation	S.F. Roof	5.52	.69	0.5%
3020	Roof Openings	N/A	—	—	—	
C. INTERIORS						
1010	Partitions	Gypsum board on metal studs *30 S.F. Floor/L.F. Partition*	S.F. Partition	9.09	3.03	
1020	Interior Doors	Single leaf hollow metal *400 S.F. Floor/Door*	Each	875	2.19	
1030	Fittings	Toilet Partitions	S.F. Floor	.73	.73	
2010	Stair Construction	Concrete filled metal pan	Flight	15,800	3.36	19.2%
3010	Wall Finishes	60% vinyl wall covering, 40% paint	S.F. Surface	1.35	.90	
3020	Floor Finishes	60% carpet, 30% vinyl composition tile, 10% ceramic tile	S.F. Floor	7.62	7.62	
3030	Ceiling Finishes	Mineral fiber tile on concealed zee bars	S.F. Ceiling	6.38	6.38	
D. SERVICES						
	D10 Conveying					
1010	Elevators & Lifts	Four geared passenger elevators	Each	292,600	14.63	11.6%
1020	Escalators & Moving Walks	N/A	—	—	—	
	D20 Plumbing					
2010	Plumbing Fixtures	Toilet and service fixtures, supply and drainage *1 Fixture/1370 S.F. Floor*	Each	2781	2.03	
2020	Domestic Water Distribution	Gas fired water heater	S.F. Floor	.42	.42	2.1%
2040	Rain Water Drainage	Roof drains	S.F. Roof	1.84	.23	
	D30 HVAC					
3010	Energy Supply	N/A	—	—	—	
3020	Heat Generating Systems	Included in D3050	—	—	—	
3030	Cooling Generating Systems	N/A	—	—	—	12.3 %
3050	Terminal & Package Units	Multizone unit gas heating, electric cooling	S.F. Floor	15.50	15.50	
3090	Other HVAC Sys. & Equipment	N/A	—	—	—	
	D40 Fire Protection					
4010	Sprinklers	Wet pipe sprinkler system	S.F. Floor	2.33	2.33	2.7%
4020	Standpipes	Standpipes and hose systems	S.F. Floor	1.07	1.07	
	D50 Electrical					
5010	Electrical Service/Distribution	1600 ampere service, panel board and feeders	S.F. Floor	1.86	1.86	
5020	Lighting & Branch Wiring	High efficiency fluorescent fixtures, receptacles, switches, A.C. and misc. power	S.F. Floor	11.11	11.11	15.1%
5030	Communications & Security	Addressable alarm systems, internet and phone wiring, emergency lighting	S.F. Floor	5.05	5.05	
5090	Other Electrical Systems	Emergency generator, 100 kW, uninterruptible power supply	S.F. Floor	1.02	1.02	
E. EQUIPMENT & FURNISHINGS						
1010	Commercial Equipment	N/A	—	—	—	
1020	Institutional Equipment	N/A	—	—	—	0.0 %
1030	Vehicular Equipment	N/A	—	—	—	
1090	Other Equipment	N/A	—	—	—	
F. SPECIAL CONSTRUCTION						
1020	Integrated Construction	N/A	—	—	—	0.0 %
1040	Special Facilities	N/A	—	—	—	
G. BUILDING SITEWORK		N/A				
				Sub-Total	126.14	100%
		CONTRACTOR FEES (General Requirements: 10%, Overhead: 5%, Profit: 10%)		25%	31.50	
		ARCHITECT FEES		6%	9.46	
				Total Building Cost	**167.10**	



Costs per square foot of floor area

Exterior Wall	S.F. Area	20000	30000	40000	50000	75000	100000	125000	150000	175000
	L.F. Perimeter	400	500	600	650	775	900	1000	1100	1185
Reinforced Concrete	R/Conc. Frame	93.55	87.50	84.45	81.60	77.70	75.80	74.35	73.50	72.75
Perimeter Adj., Add or Deduct	Per 100 L.F.	5.40	3.60	2.65	2.15	1.45	1.10	0.90	0.70	0.65
Story Hgt. Adj., Add or Deduct	Per 1 Ft.	2.05	1.65	1.55	1.30	1.05	0.85	0.90	0.75	0.70
Basement—Not Applicable										

The above costs were calculated using the basic specifications shown on the facing page. These costs should be adjusted where necessary for design alternatives and owner's requirements. Reported completed project costs, for this type of structure, range from $46.60 to $111.05 per S.F.

Common additives

Description	Unit	$ Cost
Elevators, Hydraulic passenger, 2 stops		
1500# capacity	Each	62,800
2500# capacity	Each	66,300
3500# capacity	Each	69,800
Barrier gate w/programmable controller	Each	4000
Booth for attendant, average	Each	12,400
Fee computer	Each	15,000
Ticket spitter with time/date stamp	Each	7450
Mag strip encoding	Each	21,000
Collection station, pay on foot	Each	126,000
Parking control software	Each	25,200 - 108,500
Painting, Parking stalls	Stall	13.25
Parking Barriers		
Timber with saddles, 4" x 4"	L.F.	7.10
Precast concrete, 6" x 10" x 6'	Each	81
Traffic Signs, directional, 12" x 18"	Each	84.50

Model costs calculated for a 2 story building with 10' story height and 100,000 square feet of floor area

Garage, Underground Parking

			Unit	Unit Cost	Cost Per S.F.	% Of Sub-Total
A. SUBSTRUCTURE						
1010	Standard Foundations	Poured concrete; strip and spread footings and waterproofing	S.F. Ground	7.86	3.93	
1020	Special Foundations	N/A	—	—	4.50 Assumed	
1030	Slab on Grade	5" reinforced concrete with vapor barrier and granular base	S.F. Slab	6.27	3.14	20.4%
2010	Basement Excavation	Excavation 24' deep	S.F. Ground	8.80	4.40	
2020	Basement Walls	N/A	—	—	—	
B. SHELL						
	B10 Superstructure					
1010	Floor Construction	Cast-in-place concrete beam and slab, concrete columns	S.F. Floor	28.40	14.20	48.7%
1020	Roof Construction	Cast-in-place concrete beam and slab, concrete columns	S.F. Roof	26.32	13.16	
	B20 Exterior Enclosure					
2010	Exterior Walls	Cast-in place concrete	S.F. Wall	20.44	3.68	
2020	Exterior Windows	N/A	—	—	—	6.9%
2030	Exterior Doors	Steel overhead, hollow metal	Each	3965	.17	
	B30 Roofing					
3010	Roof Coverings	Neoprene membrane traffic deck	S.F. Roof	4.22	2.11	3.8%
3020	Roof Openings	N/A	—	—	—	
C. INTERIORS						
1010	Partitions	Concrete block	S.F. Partition	38.48	.74	
1020	Interior Doors	Hollow metal	Each	7000	.07	
1030	Fittings	N/A	—	—	—	
2010	Stair Construction	Concrete	Flight	6400	.32	2.2%
3010	Wall Finishes	Paint	S.F. Surface	2.34	.09	
3020	Floor Finishes	N/A	—	—	—	
3030	Ceiling Finishes	N/A	—	—	—	
D. SERVICES						
	D10 Conveying					
1010	Elevators & Lifts	Two hydraulic passenger elevators	Each	81,000	1.62	2.9%
1020	Escalators & Moving Walks	N/A	—	—	—	
	D20 Plumbing					
2010	Plumbing Fixtures	Drainage in parking areas, toilets, & service fixtures 1 Fixture/5000 S.F. Floor	Each	.04	.04	
2020	Domestic Water Distribution	Electric water heater	S.F. Floor	.10	.10	2.0%
2040	Rain Water Drainage	Roof drains	S.F. Roof	2	1	
	D30 HVAC					
3010	Energy Supply	N/A	—	—	—	
3020	Heat Generating Systems	N/A	—	—	—	
3030	Cooling Generating Systems	N/A	—	—	—	0.3 %
3050	Terminal & Package Units	Exhaust fans	S.F. Floor	.15	.15	
3090	Other HVAC Sys. & Equipment	N/A	—	—	—	
	D40 Fire Protection					
4010	Sprinklers	Dry pipe sprinkler system	S.F. Floor	3.33	3.33	6.2%
4020	Standpipes	Dry standpipe system, class 3	S.F. Floor	.13	.13	
	D50 Electrical					
5010	Electrical Service/Distribution	200 ampere service, panel board and feeders	S.F. Floor	.13	.13	
5020	Lighting & Branch Wiring	T-8 fluorescent fixtures, receptacles, switches and misc. power	S.F. Floor	3.06	3.06	6.0%
5030	Communications & Security	Addressable alarm systems and emergency lighting	S.F. Floor	.14	.14	
5090	Other Electrical Systems	Emergency generator, 11.5 kW	S.F. Floor	.06	.06	
E. EQUIPMENT & FURNISHINGS						
1010	Commercial Equipment	N/A	—	—	—	
1020	Institutional Equipment	N/A	—	—	—	0.6 %
1030	Vehicular Equipment	Ticket dispensers, booths, automatic gates	S.F. Floor	.36	.36	
1090	Other Equipment	N/A	—	—	—	
F. SPECIAL CONSTRUCTION						
1020	Integrated Construction	N/A	—	—	—	0.0 %
1040	Special Facilities	N/A	—	—	—	
G. BUILDING SITEWORK	**N/A**					
				Sub-Total	56.13	**100%**
	CONTRACTOR FEES (General Requirements: 10%, Overhead: 5%, Profit: 10%)			25%	14.06	
	ARCHITECT FEES			8%	5.61	
				Total Building Cost	**75.80**	

Location Factors

STATE/ZIP	CITY	Residential	Commercial
UTAH (CONT'd)			
845	Price	.70	.78
846-847	Provo	.80	.87
VERMONT			
050	White River Jct.	.76	.80
051	Bellows Falls	.78	.82
052	Bennington	.80	.83
053	Brattleboro	.80	.84
054	Burlington	.81	.86
056	Montpelier	.82	.84
057	Rutland	.81	.85
058	St. Johnsbury	.78	.80
059	Guildhall	.77	.79
VIRGINIA			
220-221	Fairfax	1.02	.93
222	Arlington	1.03	.93
223	Alexandria	1.07	.95
224-225	Fredericksburg	.94	.88
226	Winchester	.91	.86
227	Culpeper	.99	.88
228	Harrisonburg	.89	.86
229	Charlottesville	.90	.86
230-232	Richmond	.98	.88
233-235	Norfolk	1.00	.89
236	Newport News	.99	.88
237	Portsmouth	.92	.86
238	Petersburg	.96	.87
239	Farmville	.88	.81
240-241	Roanoke	.97	.85
242	Bristol	.85	.81
243	Pulaski	.83	.80
244	Staunton	.90	.84
245	Lynchburg	.95	.86
246	Grundy	.83	.80
WASHINGTON			
980-981,987	Seattle	1.02	1.04
982	Everett	1.04	1.02
983-984	Tacoma	1.02	1.03
985	Olympia	1.01	1.02
986	Vancouver	.97	1.01
988	Wenatchee	.92	.95
989	Yakima	.96	.98
990-992	Spokane	.99	.95
993	Richland	.97	.96
994	Clarkston	.96	.94
WEST VIRGINIA			
247-248	Bluefield	.88	.89
249	Lewisburg	.90	.92
250-253	Charleston	.95	.95
254	Martinsburg	.86	.90
255-257	Huntington	.96	.96
258-259	Beckley	.90	.93
260	Wheeling	.92	.96
261	Parkersburg	.91	.95
262	Buckhannon	.91	.95
263-264	Clarksburg	.91	.95
265	Morgantown	.92	.95
266	Gassaway	.91	.95
267	Romney	.89	.92
268	Petersburg	.91	.93
WISCONSIN			
530,532	Milwaukee	1.07	1.03
531	Kenosha	1.03	1.00
534	Racine	1.02	1.00
535	Beloit	.98	.97
537	Madison	.98	.98
538	Lancaster	.97	.94
539	Portage	.96	.95
540	New Richmond	.99	.95
541-543	Green Bay	1.00	.96
544	Wausau	.94	.92
545	Rhinelander	.94	.94
546	La Crosse	.94	.94
547	Eau Claire	.97	.95
548	Superior	.98	.96
549	Oshkosh	.94	.93
WYOMING			
820	Cheyenne	.82	.86
821	Yellowstone Nat. Pk.	.74	.81
822	Wheatland	.74	.82

STATE/ZIP	CITY	Residential	Commercial
WYOMING (CONT'd)			
823	Rawlins	.75	.83
824	Worland	.74	.81
825	Riverton	.73	.81
826	Casper	.76	.83
827	Newcastle	.74	.81
828	Sheridan	.79	.84
829-831	Rock Springs	.78	.83
CANADIAN FACTORS (reflect Canadian currency)			
ALBERTA			
	Calgary	1.14	1.14
	Edmonton	1.13	1.14
	Fort McMurray	1.14	1.13
	Lethbridge	1.11	1.09
	Lloydminster	1.06	1.05
	Medicine Hat	1.07	1.05
	Red Deer	1.07	1.05
BRITISH COLUMBIA			
	Kamloops	1.05	1.06
	Prince George	1.05	1.07
	Vancouver	1.06	1.11
	Victoria	.99	1.02
MANITOBA			
	Brandon	1.02	1.00
	Portage la Prairie	1.02	.99
	Winnipeg	1.02	1.04
NEW BRUNSWICK			
	Bathurst	.94	.95
	Dalhousie	.94	.95
	Fredericton	1.01	.98
	Moncton	.95	.96
	Newcastle	.94	.95
	St. John	1.01	.98
NEWFOUNDLAND			
	Corner Brook	.96	.98
	St. Johns	.98	.99
NORTHWEST TERRITORIES			
	Yellowknife	1.07	1.06
NOVA SCOTIA			
	Bridgewater	.97	.99
	Dartmouth	.98	1.00
	Halifax	1.00	1.02
	New Glasgow	.97	.99
	Sydney	.96	.97
	Truro	.97	.99
	Yarmouth	.97	.99
ONTARIO			
	Barrie	1.13	1.08
	Brantford	1.14	1.09
	Cornwall	1.14	1.08
	Hamilton	1.16	1.12
	Kingston	1.14	1.09
	Kitchener	1.09	1.05
	London	1.14	1.10
	North Bay	1.11	1.07
	Oshawa	1.13	1.08
	Ottawa	1.16	1.11
	Owen Sound	1.11	1.08
	Peterborough	1.12	1.08
	Sarnia	1.14	1.09
	Sault Ste Marie	1.07	1.04
	St. Catharines	1.10	1.05
	Sudbury	1.07	1.04
	Thunder Bay	1.12	1.05
	Timmins	1.11	1.07
	Toronto	1.17	1.14
	Windsor	1.11	1.05
PRINCE EDWARD ISLAND			
	Charlottetown	.92	.95
	Summerside	.92	.95
QUEBEC			
	Cap-de-la-Madeleine	1.13	1.04
	Charlesbourg	1.13	1.04
	Chicoutimi	1.16	1.05
	Gatineau	1.12	1.03

14 Appendix G:

General Contrator Staff					
Description	Time on Job	Quantity	Unit	Unit Price	Total
Project Executive	30%	86	week	$1,144.00	$98,384.00
Senior Project Manager	80%	86	week	$2,653.00	$182,526.40
Project Managers (2)	100%	86	week	$2,083.00	$358,276.00
Assistant Project Managers (2)	100%	86	week	$1,555.00	$267,460.00
Superintendents (2)	100%	86	week	$3,345.00	$575,340.00
Assistant Superintendents (1)	100%	86	week	$2,465.00	$211,990.00
Safety	10%	86	week	$161.00	$13,846.00
Layout Engineer	60%	86	week	$1,373.00	$118,078.00
				Total Cost	$1,825,900.40

Temporary Utilities					
Description	Quantity	Unit	Duration	Unit Price	Total
Heat	1	CSF/week	20	$12.50	$154,750.00
Lighting	1	CSF		$29.42	$18,210.98
Power	1	CSF		$51.70	$32,002.30
Toilets	8	Month	20	$162.00	$25,920.00
				Total Cost	$230,883.28

Construction Facilities and Equipment					
Description	Quantity	Unit	Duration	Unit Price	Total
Trailers	4	EA/month	10	$410.00	$16,400.00
Storage Boxes	3	EA/month	10	$79.00	$2,370.00
Field Office Equipment Rental	4	Month	10	$171.00	$6,840.00
Office Supplies	4	Month	10	$93.50	$3,740.00
Field Office Lights & HVAC	4	Month	10	$165.00	$6,600.00
Scaffolding	30	CSF		$124.00	$3,720.00
Fencing	808	LF		$11.15	$9,009.20
Signage	100	SF		$25.00	$2,500.00
Dumpsters	4	Week	86	$620.00	$213,280.00
Tower Crane/ Material Hoist (Trades)					$0.00
Testing and Inspections (Owner)					$0.00
				Total Cost	$264,459.20

Permits, Insurance and Fee				
Description	Quantity	Unit	Unit Price	Total
Permits	1	LS	$383,000.00	$383,000.00
Building Permit and others (Owner)				$0.00
Payment and Performance Bond	1	LS	$459,600.00	$459,600.00
General Liability Insurance	1	LS	$183,840.00	$183,840.00
Builder's Risk Insurance (Owner)				$0.00
Contractors Fee	1	LS	$2,762,700.00	$2,762,700.00
			Total Cost	$3,789,140.00

Total General Conditions	**$6,110,382.88**
% Total Contract Value	7.98
Cost per Month	$305,519.14
Cost per Week	$71,050.96

14 Appendix H:

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	*LPD* (W/ft^2)
Automotive facility	0.9
Convention center	1.2
Courthouse	1.2
Dining: bar lounge/leisure	1.3
Dining: cafeteria/fast food	1.4
Dining: family	1.6
Dormitory	1.0
Exercise center	1.0
Gymnasium	1.1
Health-care clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing facility	1.3
Motel	1.0
Motion picture theater	1.2
Multifamily	0.7
Museum	1.1
Office	1.0
Parking garage	0.3
Penitentiary	1.0
Performing arts theater	1.6
Police/fire station	1.0
Post office	1.1
Religious building	1.3
Retail	1.5
School/university	1.2
Sports arena	1.1
Town hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

[a] In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

c. Multiply the gross lighted floor areas of the building area type(s) times the *LPD*.

d. The *interior lighting power allowance* for the building is the sum of the *lighting power allowances* of all building area types. Trade-offs among building area types are permitted provided that the total *installed interior lighting power* does not exceed the *interior lighting power allowance*.

9.6 Alternative Compliance Path: Space-by-Space Method

9.6.1 Space-by-Space Method of Calculating Interior Lighting Power Allowance. Use the following steps to determine the interior lighting power allowance by the Space-by-Space Method:

a. Determine the appropriate building type from Table 9.6.1. For building types not listed, selection of a reasonably equivalent type shall be permitted.

b. For each space enclosed by partitions 80% or greater than ceiling height, determine the gross interior floor area by measuring to the center of the partition wall. Include the floor area of balconies or other projections. Retail spaces do not have to comply with the 80% partition height requirements.

c. Determine the *interior lighting power allowance* by using the columns designated Space-by-Space Method in Table 9.6.1. Multiply the floor area(s) of the space(s) times the allowed *LPD* for the space type that most closely represents the proposed use of the space(s). The product is the *lighting power allowance* for the space(s). For space types not listed, selection of a reasonable equivalent category shall be permitted.

d. The *interior lighting power allowance* is the sum of *lighting power allowances* of all spaces. Trade-offs among spaces are permitted provided that the total *installed interior lighting power* does not exceed the *interior lighting power allowance.*

9.6.2 Additional Interior Lighting Power. When using the Space-by-Space Method, an increase in the *interior lighting power allowance* is allowed for specific lighting functions. Additional power shall be allowed only if the specified lighting is installed and automatically controlled, separately from the general lighting, to be turned off during nonbusiness hours. This additional power shall be used only for the specified *luminaires* and shall not be used for any other purpose.

An increase in the *interior lighting power allowance* is permitted in the following cases:

a. For spaces in which lighting is specified to be installed in addition to the general lighting for the purpose of decorative appearance, such as chandelier-type luminaries or sconces or for highlighting art or exhibits, provided that the additional lighting power shall not exceed 1.0 W/ft^2 of such spaces.

b. For lighting equipment installed in sales areas and specifically designed and directed to highlight merchandise, calculate the additional lighting power as follows:

$$\text{Additional Interior Lighting Power Allowance} = 1000 \text{ watts} + (\text{Retail Area 1} \times 1.0 \text{ W/ft}^2) + (\text{Retail Area 2} \times 1.7 \text{ W/ft}^2) + (\text{Retail Area 3} \times 2.6 \text{ W/ft}^2) + (\text{Retail Area 4} \times 4.2 \text{ W/ft}^2),$$

where

Retail Area 1 = the floor area for all products not listed in Retail Areas 2, 3, or 4;

Retail Area 2 = the floor area used for the sale of vehicles, sporting goods, and small electronics;

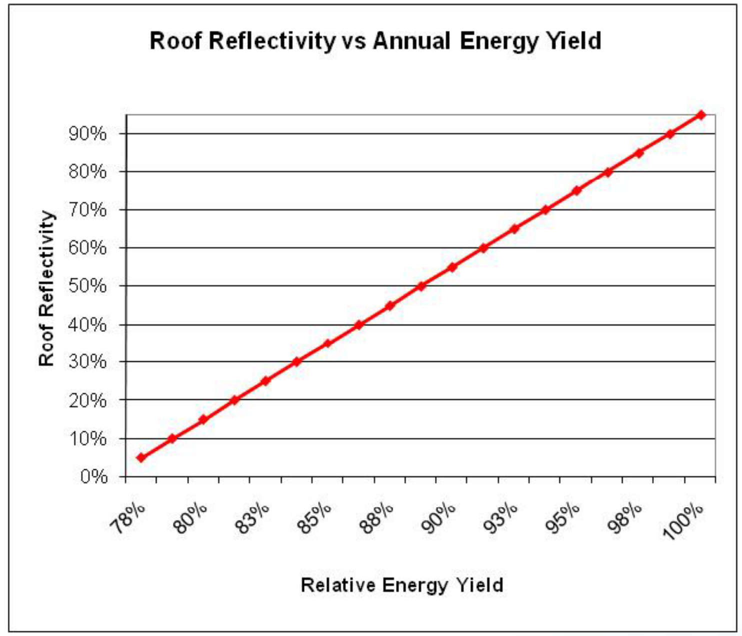
Retail Area 3 = the floor area used for the sale of furniture, clothing, cosmetics, and artwork; and

14 Appendix I:

Albedo Reflectivity vs. Annual Energy Yield

- Energy with White Membrane: 80% Top / 20% Bottom
- Rule of thumb: 4% drop in reflectivity = 1% annual energy yield loss

Example Roof Types	Roof Reflectivity	Annual Energy Yield
White "Cool Roof" Membrane	95%	100%
or Reflective Field Applied	90%	99%
Coatings	85%	98%
	80%	96%
	75%	95%
	70%	94%
Tan Membrane	65%	93%
	60%	91%
Light Grey Membrane	55%	90%
Light Green Membrane	50%	89%
Metal	45%	88%
	40%	86%
Dark Green Membrane	35%	85%
Grey Membrane	30%	84%
Dark Grey Bitumen	25%	83%
	20%	81%
	15%	80%
Tar / Black EPDM	10%	79%
	5%	78%
	1%	77%



Graph is for demonstration purposes, not actual data

14 Appendix J:

Solyndra Payback Period					
Year	Cost Increase/y	Energy Cost	Energy Produc	Cost Savings	Savings To-date
1		$0.14	282112.24	$38,649.38	$38,649.38
2	1.05	$0.14	564224.48	$40,581.85	$79,231.22
3	1.05	$0.15	846336.72	$42,610.94	$121,842.16
4	1.05	$0.16	1128448.96	$44,741.48	$166,583.65
5	1.05	$0.17	1410561.20	$46,978.56	$213,562.20
6	1.05	$0.17	1692673.44	$49,327.49	$262,889.69
7	1.05	$0.18	1974785.68	$51,793.86	$314,683.55
8	1.05	$0.19	2256897.92	$54,383.55	$369,067.11
9	1.05	$0.20	2539010.16	$57,102.73	$426,169.84
10	1.05	$0.21	2821122.40	$59,957.87	$486,127.71
11	1.05	$0.22	3103234.64	$62,955.76	$549,083.47
12	1.05	$0.23	3385346.88	$66,103.55	$615,187.02
13	1.05	$0.25	3667459.12	$69,408.73	$684,595.75
14	1.05	$0.26	3949571.36	$72,879.16	$757,474.91
15	1.05	$0.27	4231683.60	$76,523.12	$833,998.04
16	1.05	$0.28	4513795.84	$80,349.28	$914,347.32
17	1.05	$0.30	4795908.08	$84,366.74	$998,714.06
18	1.05	$0.31	5078020.32	$88,585.08	$1,087,299.14
19	1.05	$0.33	5360132.56	$93,014.33	$1,180,313.47
20	1.05	$0.35	5642244.80	$97,665.05	$1,277,978.52
21	1.05	$0.36	5924357.04	$102,548.30	$1,380,526.83
22	1.05	$0.38	6206469.28	$107,675.72	$1,488,202.54
23	1.05	$0.40	6488581.52	$113,059.50	$1,601,262.05
24	1.05	$0.42	6770693.76	$118,712.48	$1,719,974.53
25	1.05	$0.44	7052806.00	$124,648.10	$1,844,622.63
				Initial Cost:	$1,442,000.00
				Yr. 25 Savings:	**$402,622.63**

14 Appendix K:

Performance Data:

Solarscreen Low-E (VE) Insulating Glass

1" (25mm) overall

View: Metric | English

Product Code	Transmittance		Reflectance		U-Value		Shading Coefficient	SHGC	LSG	Silk-screen	Viraspan Color	Argon	PVB
	Visible	U-V	Vis-Out	Vis-In	Winter	Summer							
VE 1-2M	70%	10%	11%	12%	0.29	0.26	0.44	0.38	1.84	-	-	-	-
VE 1-40	36%	10%	15%	19%	0.31	0.29	0.32	0.28	1.30	-	-	-	-
VE 1-42	37%	16%	19%	14%	0.31	0.29	0.36	0.31	1.20	-	-	-	-
VE 1-48	47%	19%	17%	11%	0.31	0.29	0.43	0.37	1.27	-	-	-	-
VE 1-52	50%	21%	16%	11%	0.32	0.29	0.46	0.40	1.24	-	-	-	-
VE 1-55	47%	13%	11%	16%	0.31	0.29	0.40	0.35	1.34	-	-	-	-
VE 1-85	76%	26%	12%	13%	0.31	0.29	0.63	0.54	1.40	-	-	-	-
VE 2-2M	60%	6%	9%	11%	0.29	0.26	0.36	0.31	1.94	-	-	-	-
VE 2-40	32%	5%	12%	19%	0.31	0.29	0.26	0.22	1.44	-	-	-	-
VE 2-42	31%	8%	15%	14%	0.31	0.29	0.27	0.23	1.37	-	-	-	-
VE 2-48	39%	9%	13%	11%	0.31	0.29	0.31	0.27	1.44	-	-	-	-
VE 2-52	43%	10%	12%	11%	0.32	0.29	0.34	0.29	1.50	-	-	-	-
VE 2-55	40%	7%	10%	16%	0.31	0.29	0.30	0.26	1.53	-	-	-	-
VE 2-85	65%	13%	10%	12%	0.31	0.29	0.45	0.39	1.67	-	-	-	-
VE 3-2M	35%	4%	6%	10%	0.29	0.26	0.28	0.24	1.45	-	-	-	-
VE 3-40	18%	4%	7%	19%	0.31	0.29	0.22	0.19	0.96	-	-	-	-
VE 3-42	19%	7%	8%	14%	0.31	0.29	0.25	0.21	0.89	-	-	-	-
VE 3-48	24%	9%	7%	10%	0.31	0.29	0.28	0.24	1.00	-	-	-	-
VE 3-52	25%	8%	7%	10%	0.32	0.29	0.29	0.25	0.99	-	-	-	-
VE 3-55	23%	6%	6%	15%	0.31	0.29	0.26	0.23	1.01	-	-	-	-
VE 3-85	38%	11%	7%	10%	0.31	0.29	0.38	0.33	1.15	-	-	-	-
VE 4-2M	41%	5%	7%	10%	0.29	0.26	0.31	0.26	1.59	-	-	-	-
VE 4-40	22%	4%	8%	19%	0.31	0.29	0.24	0.21	1.04	-	-	-	-
VE 4-42	22%	7%	10%	14%	0.31	0.29	0.27	0.23	0.97	-	-	-	-
VE 4-48	28%	8%	9%	10%	0.31	0.29	0.31	0.27	1.04	-	-	-	-
VE 4-52	30%	9%	8%	10%	0.32	0.29	0.33	0.28	1.05	-	-	-	-
VE 4-55	27%	6%	7%	15%	0.31	0.29	0.29	0.25	1.10	-	-	-	-
VE 4-85	45%	11%	7%	11%	0.31	0.29	0.43	0.37	1.20	-	-	-	-

14 Appendix L:

Conductive Punched Windows					
Time (Hour)	U Value	Area(SF)	CLTD (F)	CLTD Corr.	Q (Btu/h)
1.00	0.26	30613	1	1	7959.38
2.00	0.26	30613	0	0	0
3.00	0.26	30613	-1	-1	-7959.38
4.00	0.26	30613	-2	-2	-15918.76
5.00	0.26	30613	-2	-2	-15918.76
6.00	0.26	30613	-2	-2	-15918.76
7.00	0.26	30613	-2	-2	-15918.76
8.00	0.26	30613	0	0	0
9.00	0.26	30613	2	2	15918.76
10.00	0.26	30613	4	4	31837.52
11.00	0.26	30613	7	7	55715.66
12.00	0.26	30613	9	9	71634.42
13.00	0.26	30613	12	12	95512.56
14.00	0.26	30613	13	13	103471.94
15.00	0.26	30613	14	14	111431.32
16.00	0.26	30613	14	14	111431.32
17.00	0.26	30613	13	13	103471.94
18.00	0.26	30613	12	12	95512.56
19.00	0.26	30613	10	10	79593.8
20.00	0.26	30613	8	8	63675.04
21.00	0.26	30613	6	6	47756.28
22.00	0.26	30613	4	4	31837.52
23.00	0.26	30613	3	3	23878.14
24.00	0.26	30613	2	2	15918.76
				Total:	**994922.5**

Conductive Curtain Wall					
Time (Hour)	U Value	Area(SF)	CLTD (F)	CLTD Corr.	Q (Btu/h)
1.00	0.26	61885	1	1	16090.1
2.00	0.26	61885	0	0	0
3.00	0.26	61885	-1	-1	-16090.1
4.00	0.26	61885	-2	-2	-32180.2
5.00	0.26	61885	-2	-2	-32180.2
6.00	0.26	61885	-2	-2	-32180.2
7.00	0.26	61885	-2	-2	-32180.2
8.00	0.26	61885	0	0	0
9.00	0.26	61885	2	2	32180.2
10.00	0.26	61885	4	4	64360.4
11.00	0.26	61885	7	7	112630.7
12.00	0.26	61885	9	9	144810.9
13.00	0.26	61885	12	12	193081.2
14.00	0.26	61885	13	13	209171.3
15.00	0.26	61885	14	14	225261.4
16.00	0.26	61885	14	14	225261.4
17.00	0.26	61885	13	13	209171.3
18.00	0.26	61885	12	12	193081.2
19.00	0.26	61885	10	10	160901
20.00	0.26	61885	8	8	128720.8
21.00	0.26	61885	6	6	96540.6
22.00	0.26	61885	4	4	64360.4
23.00	0.26	61885	3	3	48270.3
24.00	0.26	61885	2	2	32180.2
				Total:	**2011262.5**

Solar Punched Windows North				
Time (Hours)	Area (SF)	SC	SCL	Q (Btu/h)
1.00	4498	0.44	0	0
2.00	4498	0.44	0	0
3.00	4498	0.44	0	0
4.00	4498	0.44	0	0
5.00	4498	0.44	1	1979.12
6.00	4498	0.44	25	49478
7.00	4498	0.44	27	53436.24
8.00	4498	0.44	28	55415.36
9.00	4498	0.44	32	63331.84
10.00	4498	0.44	35	69269.2
11.00	4498	0.44	38	75206.56
12.00	4498	0.44	40	79164.8
13.00	4498	0.44	40	79164.8
14.00	4498	0.44	39	77185.68
15.00	4498	0.44	36	71248.32
16.00	4498	0.44	31	61352.72
17.00	4498	0.44	31	61352.72
18.00	4498	0.44	36	71248.32
19.00	4498	0.44	12	23749.44
20.00	4498	0.44	6	11874.72
21.00	4498	0.44	3	5937.36
22.00	4498	0.44	1	1979.12
23.00	4498	0.44	1	1979.12
24.00	4498	0.44	0	0
			Total:	**914353.44**

Solar Punched Windows East				
Time (Hours)	Area (SF)	SC	SCL	Q (Btu/h)
1.00	12245	0.44	0	0
2.00	12245	0.44	0	0
3.00	12245	0.44	0	0
4.00	12245	0.44	0	0
5.00	12245	0.44	2	10775.6
6.00	12245	0.44	93	501065.4
7.00	12245	0.44	157	845884.6
8.00	12245	0.44	185	996743
9.00	12245	0.44	183	985967.4
10.00	12245	0.44	154	829721.2
11.00	12245	0.44	106	571106.8
12.00	12245	0.44	67	360982.6
13.00	12245	0.44	53	285553.4
14.00	12245	0.44	45	242451
15.00	12245	0.44	39	210124.2
16.00	12245	0.44	33	177797.4
17.00	12245	0.44	26	140082.8
18.00	12245	0.44	18	96980.4
19.00	12245	0.44	7	37714.6
20.00	12245	0.44	3	16163.4
21.00	12245	0.44	2	10775.6
22.00	12245	0.44	1	5387.8
23.00	12245	0.44	0	0
24.00	12245	0.44	0	0
			Total:	**6325277.2**

Solar Punched Windows South				
Time (Hours)	Area (SF)	SC	SCL	Q (Btu/h)
1.00	2249	0.44	0	0
2.00	2249	0.44	0	0
3.00	2249	0.44	0	0
4.00	2249	0.44	0	0
5.00	2249	0.44	0	0
6.00	2249	0.44	9	8906.04
7.00	2249	0.44	17	16822.52
8.00	2249	0.44	25	24739
9.00	2249	0.44	41	40571.96
10.00	2249	0.44	64	63331.84
11.00	2249	0.44	85	84112.6
12.00	2249	0.44	97	95987.32
13.00	2249	0.44	96	94997.76
14.00	2249	0.44	84	83123.04
15.00	2249	0.44	63	62342.28
16.00	2249	0.44	42	41561.52
17.00	2249	0.44	31	30676.36
18.00	2249	0.44	20	19791.2
19.00	2249	0.44	8	7916.48
20.00	2249	0.44	4	3958.24
21.00	2249	0.44	2	1979.12
22.00	2249	0.44	1	989.56
23.00	2249	0.44	0	0
24.00	2249	0.44	0	0
			Total:	**681806.84**

Solar Punched Windows West				
Time (Hours)	Area (SF)	SC	SCL	Q (Btu/h)
1.00	11021	0.44	1	4849.24
2.00	11021	0.44	0	0
3.00	11021	0.44	0	0
4.00	11021	0.44	0	0
5.00	11021	0.44	0	0
6.00	11021	0.44	9	43643.16
7.00	11021	0.44	17	82437.08
8.00	11021	0.44	24	116381.76
9.00	11021	0.44	30	145477.2
10.00	11021	0.44	35	169723.4
11.00	11021	0.44	38	184271.12
12.00	11021	0.44	40	193969.6
13.00	11021	0.44	65	315200.6
14.00	11021	0.44	114	552813.36
15.00	11021	0.44	158	766179.92
16.00	11021	0.44	187	906807.88
17.00	11021	0.44	192	931054.08
18.00	11021	0.44	156	756481.44
19.00	11021	0.44	57	276406.68
20.00	11021	0.44	27	130929.48
21.00	11021	0.44	13	63040.12
22.00	11021	0.44	6	29095.44
23.00	11021	0.44	3	14547.72
24.00	11021	0.44	2	9698.48
			Total:	**5693007.8**

Solar Curtain Wall North				
Time (Hours)	Area (SF)	SC	SCL	Q (Btu/h)
1.00	10430	0.44	0	0
2.00	10430	0.44	0	0
3.00	10430	0.44	0	0
4.00	10430	0.44	0	0
5.00	10430	0.44	1	4589.2
6.00	10430	0.44	25	114730
7.00	10430	0.44	27	123908.4
8.00	10430	0.44	28	128497.6
9.00	10430	0.44	32	146854.4
10.00	10430	0.44	35	160622
11.00	10430	0.44	38	174389.6
12.00	10430	0.44	40	183568
13.00	10430	0.44	40	183568
14.00	10430	0.44	39	178978.8
15.00	10430	0.44	36	165211.2
16.00	10430	0.44	31	142265.2
17.00	10430	0.44	31	142265.2
18.00	10430	0.44	36	165211.2
19.00	10430	0.44	12	55070.4
20.00	10430	0.44	6	27535.2
21.00	10430	0.44	3	13767.6
22.00	10430	0.44	1	4589.2
23.00	10430	0.44	1	4589.2
24.00	10430	0.44	0	0
			Total:	**2120210.4**

Solar Curtain Wall East				
Time (Hours)	Area (SF)	SC	SCL	Q (Btu/h)
1.00	24336	0.44	0	0
2.00	24336	0.44	0	0
3.00	24336	0.44	0	0
4.00	24336	0.44	0	0
5.00	24336	0.44	2	21415.68
6.00	24336	0.44	93	995829.12
7.00	24336	0.44	157	1681130.88
8.00	24336	0.44	185	1980950.4
9.00	24336	0.44	183	1959534.72
10.00	24336	0.44	154	1649007.36
11.00	24336	0.44	106	1135031.04
12.00	24336	0.44	67	717425.28
13.00	24336	0.44	53	567515.52
14.00	24336	0.44	45	481852.8
15.00	24336	0.44	39	417605.76
16.00	24336	0.44	33	353358.72
17.00	24336	0.44	26	278403.84
18.00	24336	0.44	18	192741.12
19.00	24336	0.44	7	74954.88
20.00	24336	0.44	3	32123.52
21.00	24336	0.44	2	21415.68
22.00	24336	0.44	1	10707.84
23.00	24336	0.44	0	0
24.00	24336	0.44	0	0
			Total:	**12571004**

Solar Curtain Wall South				
Time (Hours)	Area (SF)	SC	SCL	Q (Btu/h)
1.00	5215	0.44	0	0
2.00	5215	0.44	0	0
3.00	5215	0.44	0	0
4.00	5215	0.44	0	0
5.00	5215	0.44	0	0
6.00	5215	0.44	9	20651.4
7.00	5215	0.44	17	39008.2
8.00	5215	0.44	25	57365
9.00	5215	0.44	41	94078.6
10.00	5215	0.44	64	146854.4
11.00	5215	0.44	85	195041
12.00	5215	0.44	97	222576.2
13.00	5215	0.44	96	220281.6
14.00	5215	0.44	84	192746.4
15.00	5215	0.44	63	144559.8
16.00	5215	0.44	42	96373.2
17.00	5215	0.44	31	71132.6
18.00	5215	0.44	20	45892
19.00	5215	0.44	8	18356.8
20.00	5215	0.44	4	9178.4
21.00	5215	0.44	2	4589.2
22.00	5215	0.44	1	2294.6
23.00	5215	0.44	0	0
24.00	5215	0.44	0	0
			Total:	**1580979.4**

Solar Curtain Wall West				
Time (Hours)	Area (SF)	SC	SCL	Q (Btu/h)
1.00	21903	0.44	1	9637.32
2.00	21903	0.44	0	0
3.00	21903	0.44	0	0
4.00	21903	0.44	0	0
5.00	21903	0.44	0	0
6.00	21903	0.44	9	86735.88
7.00	21903	0.44	17	163834.44
8.00	21903	0.44	24	231295.68
9.00	21903	0.44	30	289119.6
10.00	21903	0.44	35	337306.2
11.00	21903	0.44	38	366218.16
12.00	21903	0.44	40	385492.8
13.00	21903	0.44	65	626425.8
14.00	21903	0.44	114	1098654.48
15.00	21903	0.44	158	1522696.56
16.00	21903	0.44	187	1802178.84
17.00	21903	0.44	192	1850365.44
18.00	21903	0.44	156	1503421.92
19.00	21903	0.44	57	549327.24
20.00	21903	0.44	27	260207.64
21.00	21903	0.44	13	125285.16
22.00	21903	0.44	6	57823.92
23.00	21903	0.44	3	28911.96
24.00	21903	0.44	2	19274.64
			Total:	**11314214**

14 Appendix M:

General Contrator Staff					
Description	Time on Job	Quantity	Unit	Unit Price	Total
Project Executive	30%	81.5	week	$1,144.00	$93,236.00
Senior Project Manager	80%	81.5	week	$2,653.00	$172,975.60
Project Managers (2)	100%	81.5	week	$2,083.00	$339,529.00
Assistant Project Managers (2)	100%	81.5	week	$1,555.00	$253,465.00
Superintendents (2)	100%	81.5	week	$3,345.00	$545,235.00
Assistant Superintendents (1)	100%	81.5	week	$2,465.00	$200,897.50
Safety	10%	81.5	week	$161.00	$13,121.50
Layout Engineer	60%	81.5	week	$1,373.00	$111,899.50
				Total Cost	$1,730,359.10

Temporary Utilities					
Description	Quantity	Unit	Duration	Unit Price	Total
Heat	1	CSF/week	20	$12.50	$154,750.00
Lighting	1	CSF		$29.42	$18,210.98
Power	1	CSF		$51.70	$32,002.30
Toilets	8	Month	20	$162.00	$25,920.00
				Total Cost	$230,883.28

Construction Facilities and Equipment					
Description	Quantity	Unit	Duration	Unit Price	Total
Trailers	4	EA/month	10	$410.00	$16,400.00
Storage Boxes	3	EA/month	10	$79.00	$2,370.00
Field Office Equipment Rental	4	Month	10	$171.00	$6,840.00
Office Supplies	4	Month	10	$93.50	$3,740.00
Field Office Lights & HVAC	4	Month	10	$165.00	$6,600.00
Scaffolding	30	CSF		$124.00	$3,720.00
Fencing	808	LF		$11.15	$9,009.20
Signage	100	SF		$25.00	$2,500.00
Dumpsters	4	Week	81.5	$620.00	$202,120.00
Tower Crane/ Material Hoist (Trades)					$0.00
Testing and Inspections (Owner)					$0.00
				Total Cost	$253,299.20

Permits, Insurance and Fee				
Description	Quantity	Unit	Unit Price	Total
Permits	1	LS	$383,000.00	$383,000.00
Building Permit and others (Owner)				$0.00
Payment and Performance Bond	1	LS	$459,600.00	$459,600.00
General Liability Insurance	1	LS	$183,840.00	$183,840.00
Builder's Risk Insurance (Owner)				$0.00
Contractors Fee	1	LS	$2,762,700.00	$2,762,700.00
			Total Cost	$3,789,140.00

Total General Conditions	**$6,003,681.58**
% Total Contract Value	7.84
Cost per Month	$300,184.08
Cost per Week	$69,810.25

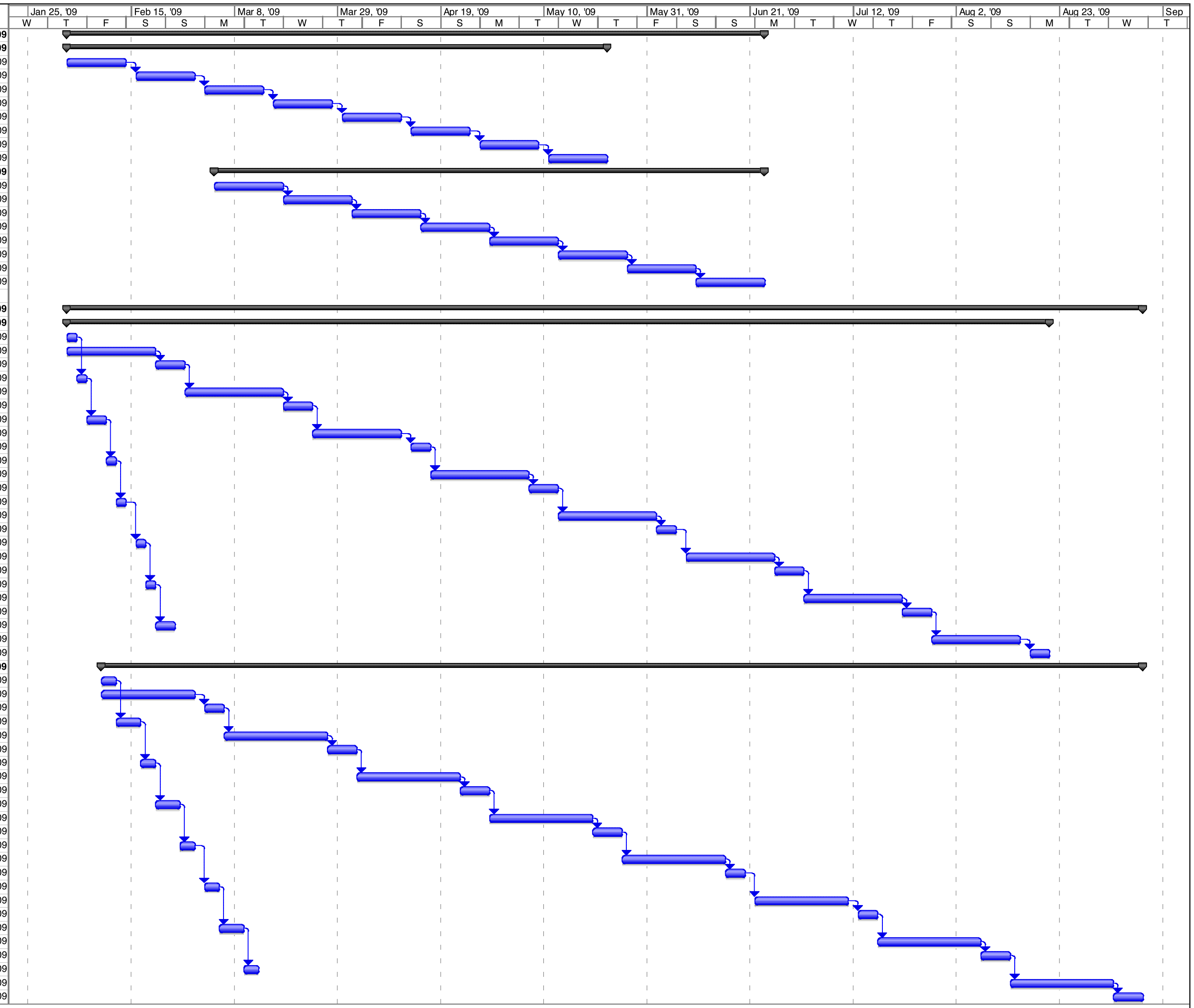
14 Appendix N:

Original Columns					
Floor/Building	Description	Quantity	Floor Height	Cubic Yards	Strength (psi)
1st A	24x24	23.00	15.67	53.39	6000.00
1st A	24x30	14.00	15.67	40.63	6000.00
1st A	36x36	4.00	15.67	20.89	6000.00
2nd A	24x24	24.00	12.42	44.16	6000.00
2nd A	24x30	12.00	12.42	27.60	6000.00
2nd A	36x36	1.00	12.42	4.14	6000.00
3rd A	24x24	25.00	12.42	46.00	6000.00
3rd A	24x30	12.00	12.42	27.60	6000.00
4-7 A	24x24	148.00	12.42	272.32	6000.00
8th A	24x24	38.00	12.42	69.92	5000.00
9th A	24x24	19.00	12.75	35.89	5000.00
1st B	24x24	27.00	15.67	62.68	6000.00
1st B	24x30	12.00	15.67		6000.00
1st B	36x36	1.00	15.67		6000.00
2nd B	24x24	20.00	12.42	36.80	6000.00
2nd B	24x30	12.00	12.42	27.60	6000.00
2nd B	36x36	1.00	12.42	4.14	6000.00
3rd B	24x24	21.00	12.42	38.64	6000.00
3rd B	24x30	12.00	12.42	27.60	6000.00
4-7 B	24x24	36.00	12.42	66.24	6000.00
8th B	24x24	36.00	12.42	66.24	5000.00
9th B	24x24	23.00	12.75	43.44	5000.00
			Sub 6000:	800.43	
			Sub 5000:	215.49	

Proposed Columns					
Floor/Building	Description	Quantity	Floor Height	Cubic Yards	Strength (psi)
1st A	24x24	23.00	15.00	51.11	6000.00
1st A	24x30	14.00	15.00	38.89	6000.00
1st A	36x36	4.00	15.00	20.00	6000.00
2nd A	24x24	24.00	11.75	41.78	6000.00
2nd A	24x30	12.00	11.75	26.11	6000.00
2nd A	36x36	1.00	11.75	3.92	6000.00
3rd A	24x24	25.00	11.75	43.52	6000.00
3rd A	24x30	12.00	11.75	26.11	6000.00
4-7 A	24x24	148.00	11.75	257.63	6000.00
8th A	24x24	38.00	11.75	66.15	5000.00
9th A	24x24	19.00	12.08	34.00	5000.00
1st B	24x24	27.00	15.00	60.00	6000.00
1st B	24x30	12.00	15.00		6000.00
1st B	36x36	1.00	15.00		6000.00
2nd B	24x24	20.00	11.75	34.81	6000.00
2nd B	24x30	12.00	11.75	26.11	6000.00
2nd B	36x36	1.00	11.75	3.92	6000.00
3rd B	24x24	21.00	11.75	36.56	6000.00
3rd B	24x30	12.00	11.75	26.11	6000.00
4-7 B	24x24	36.00	11.75	62.67	6000.00
8th B	24x24	36.00	11.75	62.67	5000.00
9th B	24x24	23.00	12.08	41.16	5000.00
			Sub 6000:	759.24	
			Sub 5000:	203.98	

14 Appendix O:

ID	Task Name	Duration	Start	Finish
1	**VAV System**	**102 days**	**Mon 2/2/09**	**Tue 6/23/09**
2	**Building B**	**80 days**	**Mon 2/2/09**	**Fri 5/22/09**
3	2nd Floor Ductwork and VAV	10 days	Mon 2/2/09	Fri 2/13/09
4	3rd Floor Ductwork and VAV	10 days	Mon 2/16/09	Fri 2/27/09
5	4th Floor Ductwork and VAV	10 days	Mon 3/2/09	Fri 3/13/09
6	5th Floor Ductwork and VAV	10 days	Mon 3/16/09	Fri 3/27/09
7	6th Floor Ductwork and VAV	10 days	Mon 3/30/09	Fri 4/10/09
8	7th Floor Ductwork and VAV	10 days	Mon 4/13/09	Fri 4/24/09
9	8th Floor Ductwork and VAV	10 days	Mon 4/27/09	Fri 5/8/09
10	9th Floor Ductwork and VAV	10 days	Mon 5/11/09	Fri 5/22/09
11	**Building A**	**80 days**	**Wed 3/4/09**	**Tue 6/23/09**
12	2nd Floor Ductwork and VAV	10 days	Wed 3/4/09	Tue 3/17/09
13	3rd Floor Ductwork and VAV	10 days	Wed 3/18/09	Tue 3/31/09
14	4th Floor Ductwork and VAV	10 days	Wed 4/1/09	Tue 4/14/09
15	5th Floor Ductwork and VAV	10 days	Wed 4/15/09	Tue 4/28/09
16	6th Floor Ductwork and VAV	10 days	Wed 4/29/09	Tue 5/12/09
17	7th Floor Ductwork and VAV	10 days	Wed 5/13/09	Tue 5/26/09
18	8th Floor Ductwork and VAV	10 days	Wed 5/27/09	Tue 6/9/09
19	9th Floor Ductwork and VAV	10 days	Wed 6/10/09	Tue 6/23/09
20				
21	**Chilled Beam System**	**157 days**	**Mon 2/2/09**	**Tue 9/8/09**
22	**Building B**	**144 days**	**Mon 2/2/09**	**Thu 8/20/09**
23	2nd Floor Ductwork	2 days	Mon 2/2/09	Tue 2/3/09
24	2nd Floor Piping	14 days	Mon 2/2/09	Thu 2/19/09
25	2nd Floor Beams	4 days	Fri 2/20/09	Wed 2/25/09
26	3rd Floor Ductwork	2 days	Wed 2/4/09	Thu 2/5/09
27	3rd Floor Piping	14 days	Thu 2/26/09	Tue 3/17/09
28	3rd Floor Beams	4 days	Wed 3/18/09	Mon 3/23/09
29	4th Floor Ductwork	2 days	Fri 2/6/09	Mon 2/9/09
30	4th Floor Piping	14 days	Tue 3/24/09	Fri 4/10/09
31	4th Floor Beams	4 days	Mon 4/13/09	Thu 4/16/09
32	5th Floor Ductwork	2 days	Tue 2/10/09	Wed 2/11/09
33	5th Floor Piping	14 days	Fri 4/17/09	Wed 5/6/09
34	5th Floor Beams	4 days	Thu 5/7/09	Tue 5/12/09
35	6th Floor Ductwork	2 days	Thu 2/12/09	Fri 2/13/09
36	6th Floor Piping	14 days	Wed 5/13/09	Mon 6/1/09
37	6th Floor Beams	4 days	Tue 6/2/09	Fri 6/5/09
38	7th Floor Ductwork	2 days	Mon 2/16/09	Tue 2/17/09
39	7th Floor Piping	14 days	Mon 6/8/09	Thu 6/25/09
40	7th Floor Beams	4 days	Fri 6/26/09	Wed 7/1/09
41	8th Floor Ductwork	2 days	Wed 2/18/09	Thu 2/19/09
42	8th Floor Piping	14 days	Thu 7/2/09	Tue 7/21/09
43	8th Floor Beams	4 days	Wed 7/22/09	Mon 7/27/09
44	9th Floor Ductwork	2 days	Fri 2/20/09	Mon 2/23/09
45	9th Floor Piping	14 days	Tue 7/28/09	Fri 8/14/09
46	9th Floor Beams	4 days	Mon 8/17/09	Thu 8/20/09
47	**Building A**	**152 days**	**Mon 2/9/09**	**Tue 9/8/09**
48	2nd Floor Ductwork	3 days	Mon 2/9/09	Wed 2/11/09
49	2nd Floor Piping	15 days	Mon 2/9/09	Fri 2/27/09
50	2nd Floor Beams	4 days	Mon 3/2/09	Thu 3/5/09
51	3rd Floor Ductwork	3 days	Thu 2/12/09	Mon 2/16/09
52	3rd Floor Piping	15 days	Fri 3/6/09	Thu 3/26/09
53	3rd Floor Beams	4 days	Fri 3/27/09	Wed 4/1/09
54	4th Floor Ductwork	3 days	Tue 2/17/09	Thu 2/19/09
55	4th Floor Piping	15 days	Thu 4/2/09	Wed 4/22/09
56	4th Floor Beams	4 days	Thu 4/23/09	Tue 4/28/09
57	5th Floor Ductwork	3 days	Fri 2/20/09	Tue 2/24/09
58	5th Floor Piping	15 days	Wed 4/29/09	Tue 5/19/09
59	5th Floor Beams	4 days	Wed 5/20/09	Mon 5/25/09
60	6th Floor Ductwork	3 days	Wed 2/25/09	Fri 2/27/09
61	6th Floor Piping	15 days	Tue 5/26/09	Mon 6/15/09
62	6th Floor Beams	4 days	Tue 6/16/09	Fri 6/19/09
63	7th Floor Ductwork	3 days	Mon 3/2/09	Wed 3/4/09
64	7th Floor Piping	15 days	Mon 6/22/09	Fri 7/10/09
65	7th Floor Beams	4 days	Mon 7/13/09	Thu 7/16/09
66	8th Floor Ductwork	3 days	Thu 3/5/09	Mon 3/9/09
67	8th Floor Piping	15 days	Fri 7/17/09	Thu 8/6/09
68	8th Floor Beams	4 days	Fri 8/7/09	Wed 8/12/09
69	9th Floor Ductwork	3 days	Tue 3/10/09	Thu 3/12/09
70	9th Floor Piping	15 days	Thu 8/13/09	Wed 9/2/09
71	9th Floor Beams	4 days	Thu 9/3/09	Tue 9/8/09



Project: Chilled Beam VAV Comparison
Date: Tue 3/30/10

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