

The Marriott Hotel at Penn Square and Lancaster County Convention Center

Trevor Sullivan
Penn State University
5th Year AE – CM Option



Project Introduction

- Problem Statement
- Proposal
- Laser Scanning Research
- Plumbing Redesign
- Minipile Research
- Structural Breadth
 - Retaining Wall Design
 - Floor System Redesign
- Construction Sequencing
- Conclusions and Acknowledgments

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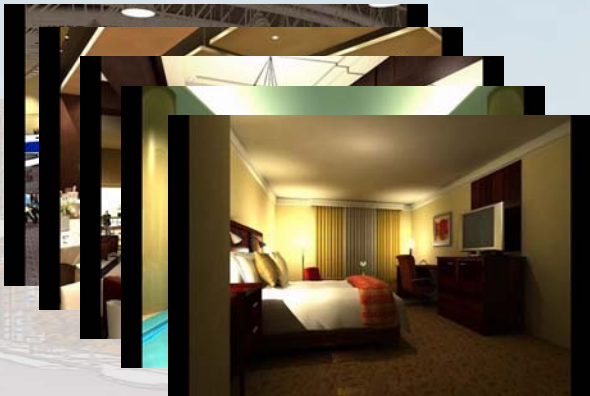


Images courtesy of: <http://www.lancasterconventioncenter.com/>

Trevor Sullivan

The Pennsylvania State University
Architectural Engineering
Construction Management Option
Fifth Year Thesis Presentation
April 15th 2008





Structural:

- 200 caissons : 36"-90" diameter
- Cast-in-place concrete structure (post-tensioned for hotel tower)
- 153' bow string metal trusses span the large exhibit level floor

Mechanical:

- Combination air and water system
- (8) large boilers, (2) cooling towers, (2) water cooled chillers

Electrical:

- 2 main service points, each 4000 amp, 480Y/277 volts, 3PH., 4W.
- 2000 HP backup generator with a 2000 gallon diesel storage tank

Project Information:

- Location: Penn Square – Lancaster, PA
- Total Cost: \$170 million
- Construction Cost: \$105 million
- Total Area: 412,079 SF, 19 Stories
- Convention Center: 220,000 SF
- Marriott Hotel : 300 rooms

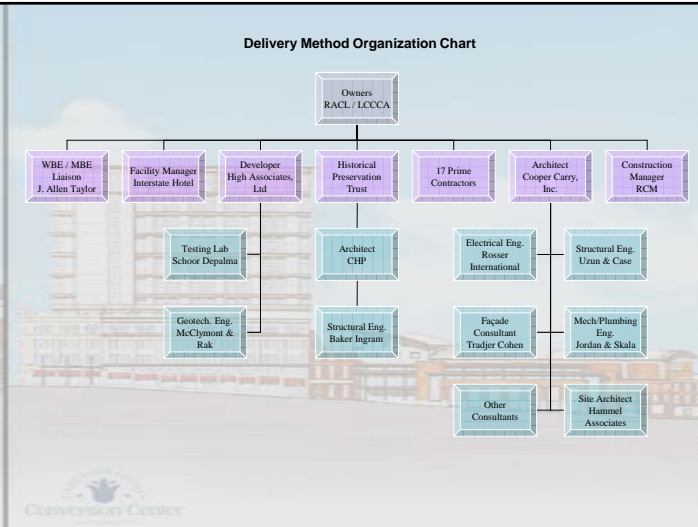
Construction:

- Phase 1: Site Prep: May 2006 – Oct. 2006 (6 Months)
- Phase 2: Construction: Oct. 2006 – Dec. 2008 (26 Months)

Historical:

- Façade stabilization and restoration of the 109 year old Watt & Shand façade
- 4 surrounding historical structures to be incorporated into the project as museums.





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Problem Statement

❑ **Natural Spring Encountered:** An underground spring was encountered during excavation in the museum level. This directly effected the ability to place the museum level SOG and thus proceed with the construction of the concrete structure.

❑ **Façade Issues:** During construction the existing Watt & Shand façade was discovered to not be straight nor plumb – The caissons could not be drilled where needed and thus changed the column locations and edge of slab locations for the entire tower. 3 months of redesign/revision work to drawings to completely rectify the problem.

Convention Entry Construction



Excavation Process



Proposed Solutions

❑ **Implement Laser Scanning Technology:** Use Laser Scanning to survey the Watt & Shand façade (not traditional methods).

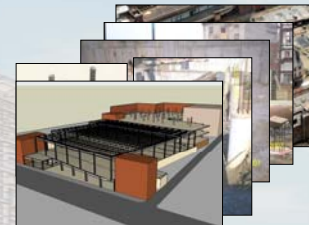
❑ **Foundation Redesign:** Implement a combination caisson and minipile foundation system.

❑ **Plumbing Redesign:** Increase the capacity of the groundwater lift station to handle the additional flow requirements.

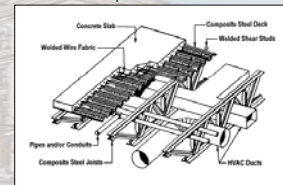
❑ **Structural Redesigns:**
 ❑ Foundation Wall Redesign
 ❑ Convention Center Structural System Redesign

❑ **Construction Re-Sequencing Analysis:** to implement the proposed changes.

The Goal: Decrease Construction Schedule!



Composite Joist Detail



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Existing Watt & Shand Façade:

- To be stabilized, restored, and integrated into the new building
- Parts of the façade are 109 years old



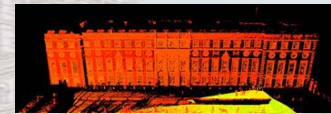
Façade Issues:

- Limited surveying data points obtained
- Façade not straight or plumb
- Caissons near the façade could not be drilled due to conflicts. The result:
 - The columns needed to be moved
 - The edge of slab locations changed
 - Changes needed to be reflected on all the drawings – took 3 months to complete.

Laser Scan Survey Comparison

	Initial Cost	Additional Costs due to Redesign	Delays due to Redesign	Savings
Traditional	\$500	\$40,000	3 months	-
Laser Scan	\$27,500	-	-	\$13,000

Typical Laser Scanning Equipment



Laser Scanning Computer Output for a Façade

Photos courtesy of: <http://www.arctron.com/pix/vermessung/3scanner>

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Plumbing Redesign Summary

Item	Existing	Proposed
Pump Sizes	1 HP	15 HP
Pump Capacity	60 GPM	340 GPM
Pump Arrangement	Duplex	Triplex
Total Capacity	120 GPM	1020 GPM
Underslab Drainage	4" PVC	6" PVC
Ontop of Footing Drainage	6" PVC	10" PVC



Pump Calculation Summary	
Total Discharge Head TDH	= 18.95 ft
Gallons per Minute GPM	= 340 gal/min
Total Head Developed H	= 58.0 ft
Brake Horsepower BHP	= 13.7 HP _{pump}

- Under-slab drainage installation (above)
- Pre-cast basin installation: Sanitary on left, Ground water on right (left)

Groundwater Piping Design Estimate					
Item	Description	Size	Quantity	Unit Cost	Cost
Pipe*					
Carbon Steel	Plain Sch. 40	8"	LF	\$85.00	\$6,800
Carbon Steel	Plain Sch. 40	4"	175	\$30.00	\$5,250
PVC	Sch 40 Perforated	6"	825	\$10.00	\$8,250
PVC	Sch 40 Perforated	8"	250	\$15.00	\$3,750
Equipment					
Pre-cast Basin	96" diameter		1	\$5,000.00	\$5,000
Submersible Pumps	340 GPM		3	\$15,000.00	\$45,000
Total					\$74,050

* includes an allowance in the unit price for fittings.

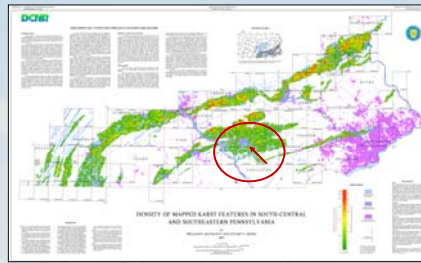
Additional Plumbing Costs Total \$74,050

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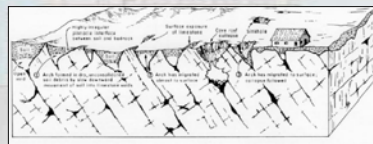
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Minipile Foundation Design Summary	
Design Input	
1) Grout Strength	$f_c = 3$ ksi
2) Grout Factor Safety	$FS_g = 3$
3) Cross Sectional Area of Grout	$A_g = 38.48$ in ²
4) Steel Yield Strength	$F_{y,steel} = 60$ ksi
5) Steel Factor of Safety	$FS_{y,steel} = 0.47$
6) Bar Diameter	$A_b = 1.25$ in ²
7) Cross Sectional Area of Casing	$A_{casing} = 11.82$ in ²
Design Output	
1) Allowable Axial Stress	$F_a = 128$ ksi
2) Axial Compression	$P_{c-allowable} = 300$ k



- Caisson casing shafts creating site congestion (above)
- Karst topography map of PA (upper left)
- Karst topography section (lower left)
- Minipile to caisson load comparison Chart (below)

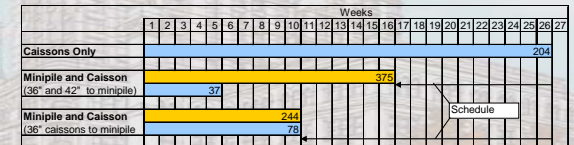


Caisson Diameter	Min. Required Capacity	8' Minipile Load Capacity	# of Minipiles per Group
36"	569K	300K	2
42"	779K	300K	3
54"	1200K	300K	4
60"	1500K	300K	5
66"	1900K	300K	7
72"	2260K	300K	8
84"	3080K	300K	11
90"	3535K	300K	12

Images courtesy of: www.delminisociety.net fwie.fw.vt.edu

Minipile and Caisson Analysis Summary				
Description	Cost	Cost Difference	Schedule (weeks)	Schedule Difference
All caissons (existing system)	\$1,084,140	---	26	---
36" caissons converted to minipiles	\$1,466,160	\$382,020	10	-16
36" and 42" caissons converted to minipiles	\$1,783,980	\$699,840	16	-10

Minipile and Caisson Schedule Analysis



Legend
■ Caisson Duration (with quantity)
■ Minipile Duration (with quantity)

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Structural Redesigns:

- **Foundation Wall Rede**Utilize an ivany block cantilevered retaining wall over the current cast-in-place concrete pinned foundation wall design to save time and increase space on site.
- **Convention Center Structural System Redesign:** Utilize a steel system over the current cast-in-place concrete system to save time. Specifically a composite joist floor system.

Location of Retaining Walls

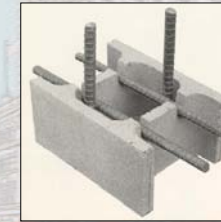


Ivany Block:

- Reduces Formwork
- Fast Rebar Installation

Cantilevered Design:

- Allows for full height backfilling
 - saving time
 - more room on site



Ivany Block Detail

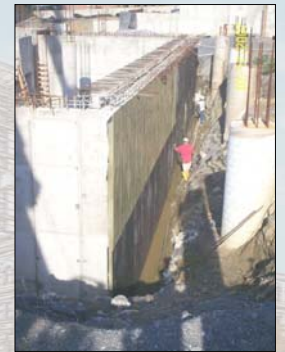
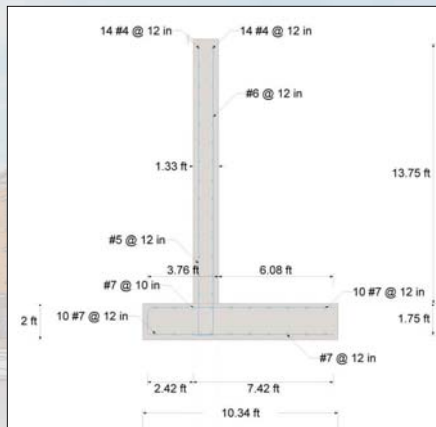
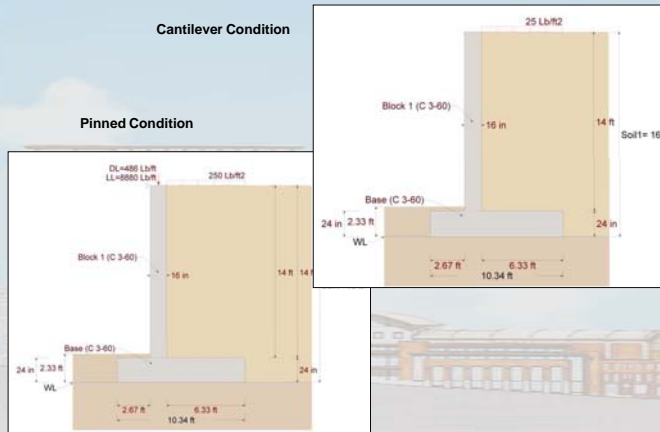


Photo of construction for the existing retaining wall design

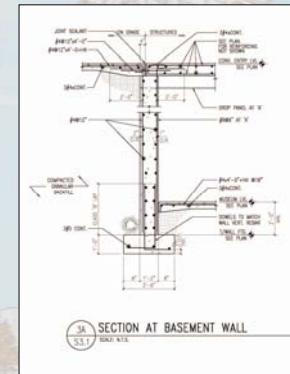
Proposed Wall Detailing



Cantilever Condition



Existing Design Detail



Retaining Wall Estimate Summary			
Utilized Cast-in-Place Concrete Wall System			
Foundation wall, cast in place, pumped, 14" high, 12" thick			
Quantity (LF)	S/LF	Total	
2250	650	\$1,462,500	
Proposed Ivory Block Wall System			
Ivory Block Wall, 14" high, 16" thick, filled solid, pumped.			
Quantity (LF)	Height (ft)	Area (SF)	Cost per SF
2250	14	31500	37.25
			\$1,173,375
Ivory Block System Saves:		\$289,125	(-20%)

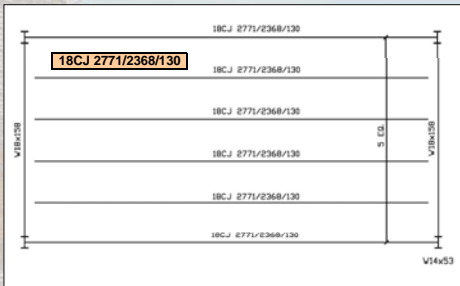
- Major Differences:**
- 14" concrete to 16" block
 - Footing increase

Note: Estimate excludes excavation difference.

**Exhibit Hall Level
Floor System**

Typical Bay 20 x 40

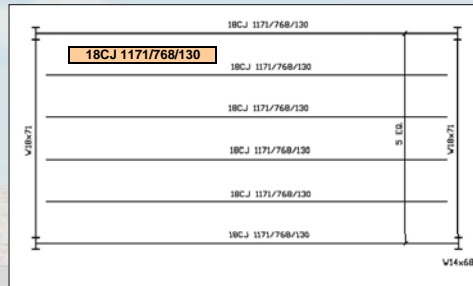
350 PSF Live Load
(693 PSF Total Factored Load)



**Convention Entry Level
Floor System**

Typical Bay 20 x 40

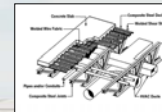
100 PSF Live Load
(293 PSF Total Factored Load)



**Convention Entry
Construction**



Composite Joist Detail



Structural System Estimate Summary

Steel System

Column Total:	\$34,816
Base Plate Total:	\$708
Beam Total:	\$127,204
Joist Total:	\$579,720
Metal Decking w/ Slab:	\$385,250
Spray Fire Proofing:	\$77,050
Total:	\$1,204,748

Concrete System

Concrete:	\$363,214
Formwork:	\$535,515
Shoring:	\$14,694
Reshoring:	\$53,600
Rebar:	\$121,111
Finishing:	\$14,254
Total:	\$1,102,388

Steel Cost an Additional: \$102,360 (+9%)

Less Site Congestion



The congestion from shoring and re-shoring of a concrete structure makes it difficult to work around

No Change in Ceiling Height

14'-0"	Floor to floor height
- 5"	Decking and slab on deck
- 18"	Joists (and girders)
- 16"	Duct (deepest used on the floor)
- 6"	Ceiling (drywall with high-hat light fixtures)
10'-3"	Ceiling height = No Change



Existing 30x30 column grid:

Floor plan diagram showing a 30x30 column grid. The grid is represented by a regular pattern of dots. The building footprint is outlined, and the grid lines are shown as a series of small squares. The building has a complex shape with several rooms and a central area.

Proposed 40x20 column grid:

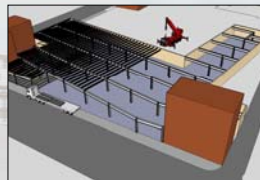
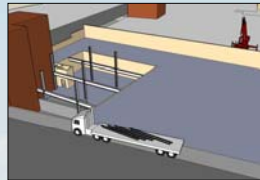
- Provides more open space with the same floor plan.
- Only minor conflicts requiring changes to the floor plan; i.e., door relocation.

Floor plan diagram showing a proposed 40x20 column grid. The grid is represented by a regular pattern of dots. The building footprint is outlined, and the grid lines are shown as a series of small squares. Two red circles highlight specific areas where the grid lines intersect with the building's structure, indicating minor conflicts.

Proposed Steel Erection Sequencing



Photo from tower crane of crane erecting convention center steel.



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Key points for schedule reduction:

- A portion of the SOG left out to allow for the crane path during steel erection.

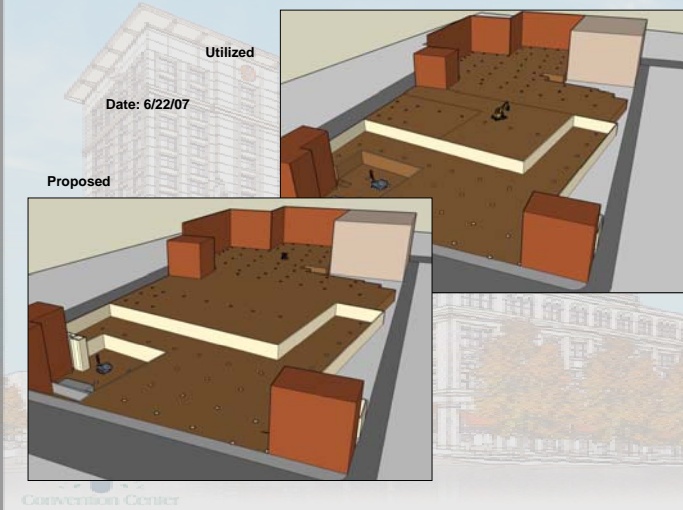


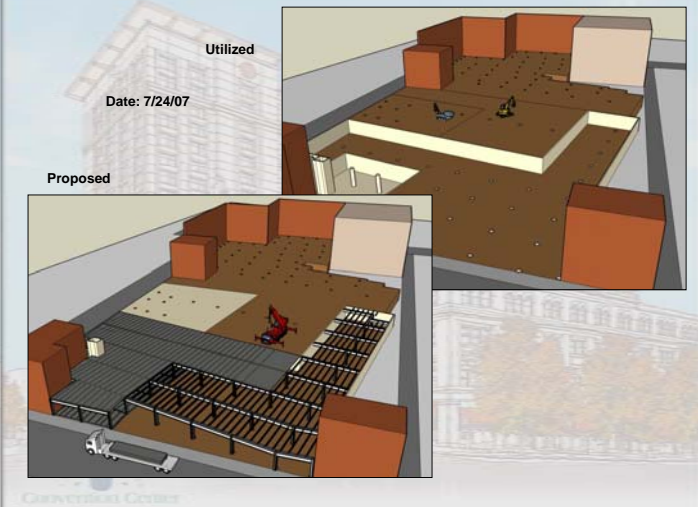
- For concrete construction the museum level SOG needs to be placed first.

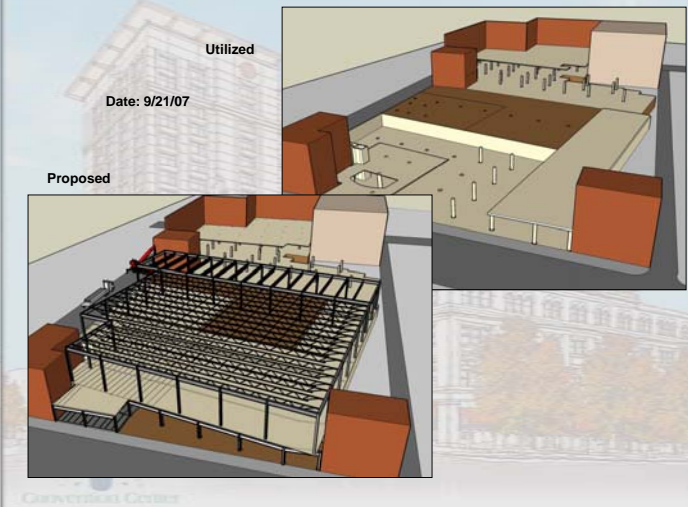
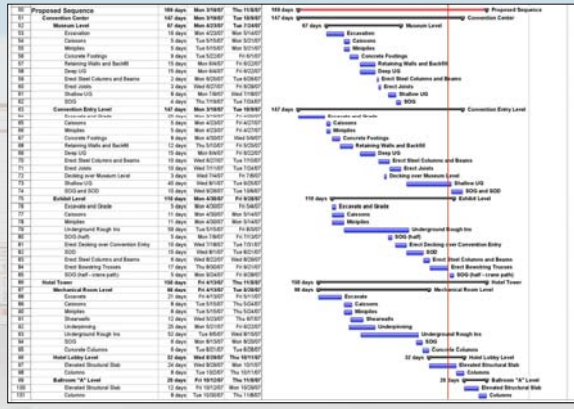
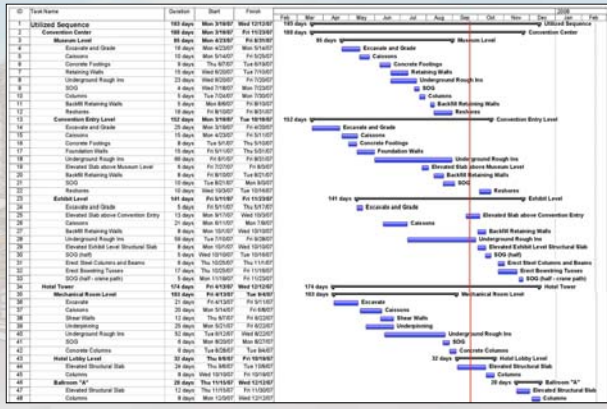


Task Name	Duration	Start	Finish	Predecessors	Resources
Utilized Sequence	180 Days	Mon 5/14/07	Mon 12/12/07		
Concealed Ceiling	180 Days	Mon 5/14/07	Fri 12/12/07		
Museum Level	80 Days	Mon 5/21/07	Fri 8/10/07		
Concrete and Slab	15 Days	Mon 5/21/07	Mon 5/28/07		
Columns	15 Days	Mon 5/21/07	Mon 5/28/07		
Concrete Footings	15 Days	Mon 5/21/07	Mon 5/28/07		
Reinforcing Walls	15 Days	Wed 5/23/07	Tue 5/29/07		
Underground Rough Ins	20 Days	Wed 5/23/07	Fri 6/8/07		
SOB	4 Days	Wed 5/23/07	Mon 5/29/07		
Columns	4 Days	Tue 5/29/07	Mon 5/30/07		
Health Retaining Walls	4 Days	Mon 5/28/07	Fri 6/1/07		
Reinforce	16 Days	Fri 6/1/07	Mon 6/11/07		
Convention Entry Level	160 Days	Mon 5/14/07	Tue 11/20/07		
Concrete and Slab	20 Days	Mon 5/14/07	Fri 6/8/07		
Columns	10 Days	Mon 5/21/07	Mon 5/28/07		
Concrete Footings	10 Days	Tue 5/22/07	Tue 5/29/07		
Foundation Walls	10 Days	Fri 5/25/07	Fri 6/1/07		
Underground Rough Ins	40 Days	Fri 5/25/07	Mon 7/23/07		
Reinforced Slab above Museum Level	4 Days	Fri 5/25/07	Fri 5/25/07		
Health Retaining Walls	4 Days	Fri 5/25/07	Tue 5/29/07		
SOB	10 Days	Tue 5/29/07	Mon 6/4/07		
Reinforce	10 Days	Wed 5/30/07	Mon 6/11/07		
Exhibit Level	140 Days	Fri 5/18/07	Fri 11/23/07		
Concrete and Slab	4 Days	Fri 5/18/07	Thu 5/17/07		
Reinforced Slab above Convention Entry	12 Days	Mon 5/21/07	Wed 5/23/07		
Columns	20 Days	Mon 5/21/07	Mon 6/4/07		
Health Retaining Walls	8 Days	Mon 5/21/07	Mon 5/28/07		
Underground Rough Ins	80 Days	Tue 5/22/07	Mon 7/23/07		
Reinforced Exhibit Level Structural Slab	4 Days	Mon 5/21/07	Mon 5/21/07		
SOB	4 Days	Mon 5/21/07	Tue 5/22/07		
Steel Steel Columns and Beams	4 Days	Thu 5/24/07	Thu 5/24/07		
Steel Bracing Trusses	4 Days	Thu 5/24/07	Thu 5/24/07		
SOB (not - same path)	4 Days	Mon 5/14/07	Fri 11/23/07		
Hall Tower	170 Days	Fri 5/18/07	Mon 11/26/07		
Mechanical Room Level	160 Days	Fri 5/18/07	Tue 11/20/07		
Concrete	20 Days	Fri 5/18/07	Fri 6/8/07		
Columns	20 Days	Mon 5/21/07	Fri 6/8/07		
Reinforcing Walls	20 Days	Tue 5/22/07	Fri 6/8/07		
Underpinning	10 Days	Mon 5/21/07	Fri 6/8/07		
Underground Rough Ins	10 Days	Tue 5/22/07	Mon 6/11/07		
SOB	4 Days	Mon 5/21/07	Mon 5/28/07		
Concrete Columns	10 Days	Tue 5/22/07	Tue 5/29/07		
Water Lobby Level	30 Days	Thu 5/24/07	Fri 6/8/07		
Structural Structural Slab	20 Days	Thu 5/24/07	Tue 5/29/07		
Columns	20 Days	Thu 5/24/07	Fri 6/8/07		
Balkons "A" Level	20 Days	Thu 5/24/07	Mon 6/11/07		
Reinforced Structural Slab	12 Days	Thu 5/24/07	Mon 5/28/07		
Columns	4 Days	Mon 5/28/07	Mon 5/28/07		

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Was the goal met?

The Goal: Decrease Construction Schedule!

Yes – Save 5 weeks!

QUESTIONS?

Summary Table

Item	Cost	Schedule
Structural Redesign		
C.I.P. Concrete to Steel Joists	\$102,361	
C.I.P. Concrete to Block Retaining Walls	-\$289,125	
Plumbing (Groundwater Lift Station) Redesign		
Duplex 120GPM to Triplex 1020 GPM Capacity	\$74,050	
Research		
Laser Scanning Technology	-\$17,500	
Minipile and Caisson Foundation System	\$382,020	
CM Study		
Resequencing	-	- 5 Weeks
Total	\$251,806	- 5 Weeks

Additional Cost of \$251,806 (+0.15% to Total Project Cost) Saves 5 Weeks

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