Architectural Engineering 2013 Senior Thesis

Senior Thesis Final Report

Reston Station Phase 1 Garage | Reston, VA

Jonathan A Fisher

Apr. 3, 2013

Advisor: Dr. Robert Leicht

Building Overview

Project Name	Reston Station Phase 1 Garage
Location	Reston, Virginia
Building Owner	Comstock & Fairfax County
Occupancy Type	Below Grade Parking Structure
Approximate Size	1.3 Million Square Feet
Building Height	7 levels below grade
Dates of Construction	April 2011—July 2013
Total Cost	$92 Million
Delivery Method	GMP CM at risk

Project Team

Land Lessee: Comstock Partners Ltd.

Land Lessor: Fairfax County, Virginia

Architect: DCS Design

MEP Engineer: Jordan & Skala

Structural Engineer: Luis Fernandez & Associates

Construction Manager: DAVIS Construction

Building Systems

- Traditionally Reinforced Concrete Structure
- Concrete encased steel beams (Elephant Stand) spans 60' bay at garage entrance.
- Over 1.4 million cubic feet of air cycled per minute by over 100 fans.
- Computer Room Air Conditioning Units
- LED Lighting fixtures illuminate drive aisles
- 4' deep planters on plaza for living decoration
- Soldier piles and lagging used for excavation support system

Construction

- Negotiated GMP Contract with a CM at-risk
- Temporary pumps required for deep excavation
- Site previously used as bus station, temporarily relocated to other location for project duration
- Fast tracked construction sequence
- Coordination of 5 above ground buildings with the underground garage structure
- 600,000 Cubic Yards of excavation
- BIM clash detection for MEP coordination

http://www.engr.psu.edu/ae/thesis/portfolios/2013/jaf5277/index.html

Executive Summary

The purpose of this report is to present the findings of four construction analysis topics pertaining to the Reston Station Phase 1 Parking Garage. The garage consists of 1.3 million square feet of parking space making it the largest parking structure east of the Mississippi River. Planned future developments include 3 office buildings, a hotel, and a large apartment building on the above ground levels of the structure. The construction schedule duration was 28 months and the project budget was $93 million.

The first analysis presents the findings of research regarding the use of public-private partnerships in the construction industry. The members of the partnership at Reston Station are Comstock Partners (private owner) and Fairfax County (public owner). Public private partnerships are relatively common in infrastructure construction related to transit and utility needs but are rare in commercial construction settings. The investigation into the partnership at Reston Station and other public private partnerships revealed a weak point when it comes to decision making but also found that the best solution is early determination of a decision making model for the project.

The second analysis investigates the use of bonded warehouses to mitigate risks encountered with onsite storage of equipment. It was found that a short term month-to-month logistics service would be far more cost effective that leasing an entire ware house over an extended period of time. In the case of Reston Station, it would have cost $6,000 per month to store equipment in a third part facility and $48,000 per month to rent an entire warehouse facility under their operation.

The third analysis sought to determine the benefits and costs associated with the use of short interval production scheduling (SIPS). From this, a structural engineering analysis was also done to evaluate the reshoring requirements for the garage slabs. Results were analyzed by incorporating SIPS sequencing and redesigning the slab so that reshore requirements allowed for 2 framed slabs with 2 reshored slabs. This resulted in finish sequence completion date 85 days earlier than the baseline schedule at a structural redesign cost of $200,000

The fourth and final analysis concentrated on one of the design coordination issues faced on the project due to the participation of 3 separate design teams on various projects on site. Specifically, the addition of mechanical chases was evaluated to ease the tight coordination requirements with slab penetrations between current construction and future buildings still being designed. The size of the main building drains for both storm and sanitary waste for each of the future buildings was found in a mechanical engineering analysis and the chases were sized accordingly. It was found that the addition of chases would increase the project budget by $99,000 while core drilling when necessary would only cost $11,000.

Acknowledgements

Acadmeic Anknowledgements:

Penn State Department of Architectural Engineering

Dr. Robert Leicht – Senior Thesis Advisor

Industry Acknowledgements:

Special Thanks to:

Davis Project Team

Matt Dabrowski

Jeremy Sibert

Friends and Family:

Lindsey Kissinger, Mom, Dad, Andrew Voorhees, Sarah Bednarcik, Sean Felton, Jon Gallis, Cheuk Tsang, and Dan Bodde

Table of Contents

Table of Figures

Project Background

In December of 2010 Davis Construction signed a contract to construct the 1.3 million square foot Reston Station Phase 1 Parking Garage. Construction began on April 4th of 2011 and the 100 million dollar garage is scheduled to be complete on July 18th, 2013. This garage was the first of three phases in the construction of a complex known as Reston Station, developed by Comstock Partners LC. While Comstock is the developer of the future buildings, Fairfax County is the owner of the property and has developed a public private partnership with Comstock in the construction of the garage. The complex is made up of an underground garage and 5 buildings above grade each between 15 and 20 stories in height. The complex contains 2 office buildings, a 500,000 square foot apartment, a 200 room hotel, and a mixed office/amenities building.

The garage and development is being built in order to take advantage of the new Silver Line Metro railway being constructed along route 267 to Dulles Airport. The county's original intention was to build a 7 level garage with funds provided by the Department of Transportation for the sole purpose of providing commuters with 2300 parking spaces and a bus depot within walking distance of the train platform. Comstock approached the county about a future development project and obtained a 99 year lease on the above ground areas of the garage. Comstock also holds the contract with Davis for the construction of the garage itself but a majority of the funds are being provided by Fairfax County.

The construction of the project is a negotiated guaranteed maximum price contract. The construction schedule has been fast-tracked with design to allow for expedited construction delivery. This caused significant delay is the construction schedule as a result of design release delays. The project budget has also been heavily affected by changes in design and in order to meet the July 19th date of substantial completion, an additional cost of between $200,000 and $300,000 will be incurred.

Client Information

Figure 1: Fairfax County Seal

The primary incentive for the construction of the Reston Station civic complex is the arrival of the new Metrorail Silver Line. The Wiehle Avenue Station will be located in between the east and west bound lanes of the Dulles Toll Road (Rte. 267) just a hundred feet to the south of the Reston Station site. Fairfax County has taken an opportunity to expand the limited parking to the north of the toll road into a large public parking garage with capacity for many rail commuters. Realizing the opportunity for a commercial, residential, and retail development, Comstock Partners agreed to the terms of a 99 year lease on the private development of the above ground space of the garage. It is worth noting that traditionally, 99 year leases are assumed to be permanent and the 99 year term is considered a formality. Comstock has been in design development of 3 office buildings, a hotel, and an apartment building to be built up from the plaza of the garage.

The owner team of the Reston Station project is unique due to the public-private partnership structure between Comstock Partners and Fairfax County, Virginia. The agreement between Comstock and Fairfax County divides the cost of construction according to the number of public versus private parking spaces available in the garage. There are a total of 2,630 parking spaces being constructed in the current phase of construction. Out of those spots, 2,318 (roughly 88%) are available to the public for commuting on both metro rail and metro bus services. As a result, the approximate $92 million dollar cost of construction was divided into two portions of roughly $80 million and $12 million to be paid by Fairfax County and Comstock respectfully. In addition to the split cost of construction, Comstock is to pay a monthly rent on the property for the entire duration of the lease.

On-time completion of the project is very important for the ownership of the project. Even though the substantial completion date is 6 months prior to the planned opening of the silver line, testing must be done and gains can be made from the Metro bus terminal and parking fees in the garage immediately after the garage is opened.

Figure 2: Logo of Comstock Partners

COMSTOCK PARTNERS™

Local Conditions

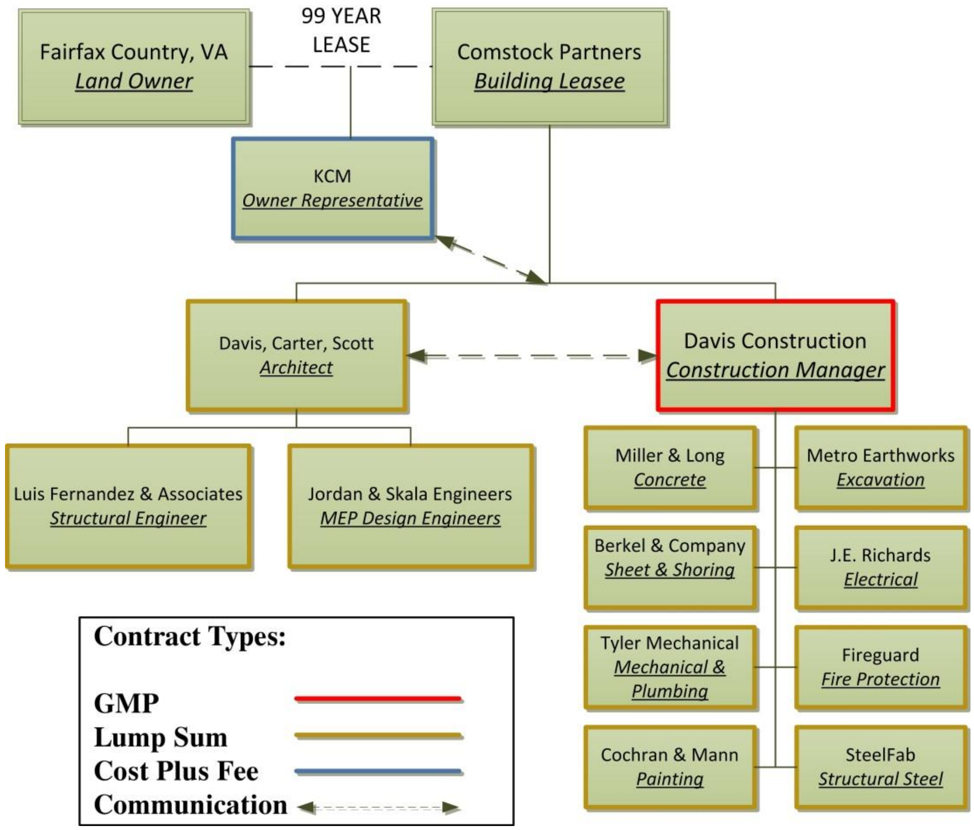
There are several unique challenges and opportunities that are a result of the project's location in Reston, Virginia. Reston is a planned community of approximately 80,000 residents in northern Fairfax County. The zoning guidelines and enforcement in the area is controlled by the Fairfax County Planning Office. The property was originally zoned for industrial use so rezoning had to be achieved for mixed use office, retail, and residential. A local organization known as the Reston Association has their own planning and zoning committee but does not have statutory authority and only acts as an advisory board to other government authorities.

Soils and water conditions at the Reston Station project are incredibly important given the depth and volume of excavation needed for the construction of the garage. Data from a total of 33 test bores was taken into account when determining building foundations and considerations for the water level in excavation. Test results concluded that the design water table elevation was to begin at 370 feet above sea level (plaza level is at 410'). The lowest footings go down to a depth 37' beneath the designed water level in the soil. This requires water management with pumps and dewatering wells to lower the water table level.

The acquiring of permits was modified from traditional methods in the construction of the garage because of the fast-track method of construction. Since complete drawings were not available when construction was due to begin a building permit was approved up to the G4 level only. Later on, a full building permit was approved midway through construction. An added benefit to the project's DC metro location was the wealth of concrete experience and ability available.

Project Delivery

Figure 3: Contract Structure of Delivery Method

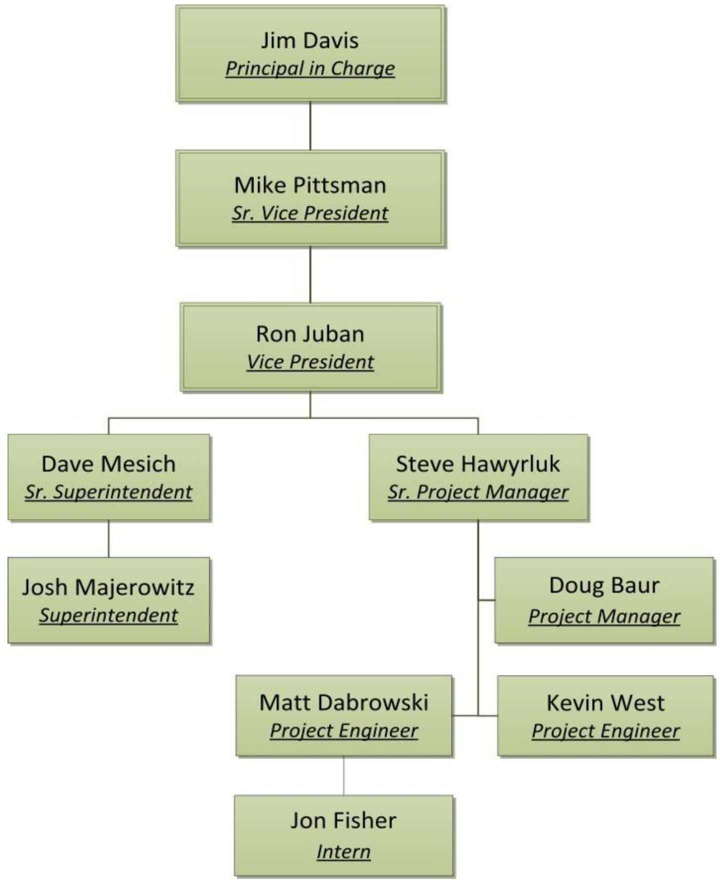


The project delivery method for the construction of the Reston Station Phase 1 Garage project was a negotiated GMP with DAVIS Construction as CM at-risk. DAVIS was chosen by Comstock in a large part due to their experience with DAVIS on another similar project at Louden Station in Louden County, VA. This project consisted of 3 large condominium facilities and it is of similar nature to Reston Station in many regards. To assist with project team communication KCM served as an owner representative to both Comstock and Fairfax County.

The biggest challenge in the delivery method has proved to be the design process in the fast track construction schedule. Due to changing designs of above buildings, structural design fell behind the construction schedule and progress had to slow on site while waiting for updated drawings. The issues resulting from the delays has quickly compounded into higher prices than were originally projected in almost every aspect of the project.

Staffing Plan

Figure 4: Project Staffing Diagram



The project team at Reston Station is typical of other projects led by DAVIS Construction. A Vice President (Ron Juban) serves as project executive and oversees the operations of the project as well as several other large northern Virginia projects. The Sr. Vice President (Mike Pittsman) and company President (Jim Davis) are involved in leadership meetings on a bi-weekly basis but are not involved in day to day operations.

The full time personnel on site are divided into a field and a project management staff. A senior project manager is responsible for the project budget and schedule, he leads the project trailer. The project manager deals with day-to-day communications with the owner and project cost and schedule controls. Two project engineers split the management of trade work and the processing of submittals, RFI's, pay applications, and BIM integration. The field staff is led by a Sr. Superintendent (Dave Mesich) who is responsible for the safe and efficient construction of the garage. An additional superintendent and two layout engineers assist with the construction coordination of the garage. .

Building Systems

Building Systems Checklist		
YES	NO	Building System
X		Demolition
X		Structural Steel
X		Cast in Place Concrete
	X	Precast Concrete
X		Mechanical System
X		Electrical System
X		Masonry
X		Curtain Wall
X		Support of Excavation

Demolition

The demolition at the Reston Station site consisted of the removal of an existing parking lot that was at grade level. There were also several utility lines that required relocation or removal. The parking lot was an approximate area of 170,000 square feet and was predominately asphalt with concrete 8" curbs. The demolition of the lot was performed with excavators, front end loaders, and other typical excavation equipment. Figure 5 shows active demolition of the asphalt lot.

Figure 5: Demolition of Parking

There are several considerations for existing utilities that must be removed or relocated in the excavation process as well. An underground electrical and cable television line running up the east side of the site must be safely relocated. In addition, an abandon water line to the southeast of the site needs to be removed.

Structural Steel

Figure 6: Composite Photo of Elephant Stand

Although the parking structure is a concrete two way slab system, there are unique instances in the structure where structural steel is utilized. In particular, a design feature known as the "elephant stand" is a network of transfer girders on the G1 level used to span a 60' by 60' area at the main vehicle entrance to the garage. The typical column spacing in the garage is 30' on center but at the elephant stand, two concentric squares made of W36x650 steel members are incased in 48"x48" concrete beams to span 60'. The steel members assembled in place prior to concrete encasement can be seen in Figure 6. The opening allows for easier car accessibility and allows for an extra lane to ease traffic build up in and out of the structure. The columns return to 30' on center continuing up from the elephant stand and transfer their building loads to the inner nodes of the steel frame. There are also two steel trusses at the P1 and P2 levels to support a vehicle ramp through the p2 level directly above the elephant stand steel.

Cast in Place Concrete

The cast in place concrete at Reston Station is the largest system on site in terms of both cost and schedule. The structural system is a 2-way, flat slab with banded beams system with several moment frames throughout the building. Slabs are typically 8 inches thick with drop panels of 10 inches thick. The slabs have a 1.5% to 3% slope to accommodate draining of water into floor drains. North-South oriented column lines are spaced 30' on center while East-West oriented column lines are 15' on center. The rebar used in the concrete slabs is epoxy coated to protect against corrosion from road salt brought into the garage via vehicle tires. The design of upper levels of the garage have been changed to include a large number of post tensioned beams to accommodate construction loads of the above ground buildings without closing operations of the below ground garage.

A building separation joint runs along the North-South 11 line of the building. This joint helps protect the structure against transferring loads and displacements from one portion of the garage to the entire structure. The exterior walls of the garage are 16 inches thick at the G7 (deepest) level and decrease in thickness as each higher level resists a decreasing load due to soil pressures. The minimum thickness at the G2 level is 12 inches. Figure 7 shows active construction of a concrete slabs at the eastern perimeter of the building.

Figure 7: Concrete Slab Construction

Mechanical System

Mechanically, the garage has a fairly simple system but carries heavy loads due to the large volume and floor area of the underground space. There are 4 exhaust shafts at the southern perimeter of the building and 16 exhaust fans per floor. The fans are each 1.5hp and can exhaust a combined, 1.4 million cubic feet of air per minute from the garage. Two air intake shafts at the northern perimeter of the building deliver air to each floor using 8 supply fans on each of the 5 lower levels. In terms of controlling air temperature, heating is provided in limited areas by electric terminal heaters. There are a total of 19 CRAC (computer room air-conditioning) units on floors G7 to G2 to deliver cooling to computer spaces. In addition, DX split-system units are utilized in ticket kiosks and other personnel locations on the upper levels. Plumbing systems within the project are devoted to properly draining rain water from the upper levels to surface water management vaults where they can be pumped back to storm water utilities. There are a few potable water supply and sanitary sewer systems to provide proper plumbing to bathrooms.

Electrical System

The electrical utility provider to the project is Dominion Power. A transformer is located on the G3 level of the garage and feeds approximately 1500KVA to the main electrical switch board. Card readers, CRAC units, and common power receptacles are fed by 208/120V panels, while lighting fixtures, dewatering pumps, supply fans, and exhaust fans are fed by 480/288V. All garage drive aisles and parking areas are illuminated by LED surface mounted fixtures as a result of energy saving initiatives. Some fluorescent lighting is used in wall sconces and stairwell light fixtures.

Masonry

The masonry walls in the garage are not load bearing and are used only for fire rating and veneer anchoring purposes. Stairwells, elevator shafts, and walls dividing two or more areas of different intended uses are required to have a 2 hour fire rating. Masonry walls are to be reinforced at 16" on center and each reinforced cell is to be filled with grout. In some situations decorative CMU is required because there are some situations in which the finish material is exposed CMU. In these cases, pigmented mortar is required and certain non-standard textured units must be used. Although LEED certification is not being sought for this project, there is still a requirement in the project specification that CMUs be manufactured within 500 miles of the project site.

Curtain Wall

The curtain walls on site are above grade and used to create an appealing architectural finish with an aluminum framed glazing system. Several storefronts will also be installed on the plaza level for several retail locations. Curtain walls are mostly found on the north elevation of the building but the elevator lobby and escalator landings are also encased in a curtain wall structure.

Support of Excavation

The 70 foot deep excavation for the garage left behind nearly 120,000 square feet of vertical soil surface area that had to be safely secured to allow for work to proceed in the site. The system used to support the excavation walls was soldier piles and lagging. Over 300 steel H shape soldier piles of 50' in length were placed into the ground surrounding the excavation limits. As excavation progressed, a total of 120,000 square feet of lagging was installed between the piles and over 1000 tiebacks were installed. Tiebacks, also known as steel anchors, were secured into the site soil through the lagging using drilling operations and grout.

Figure 8: Soldier Piles and Lagging

Project Schedule

The schedule at Reston Station and an on-time delivery date is vital because the parking spaces must be available for Reston area commuters prior to the startup of the new Metrorail Silver Line from Washington DC to Dulles Airport. The design and construction schedules were developed for over a year prior to the start of construction in April of 2011. The fully detailed baseline schedule for the project consists of nearly 1200 activities but a more condensed version is available in APPENDIX A of this report. Below Figure 9 shows a summary of the key phases of the schedule.

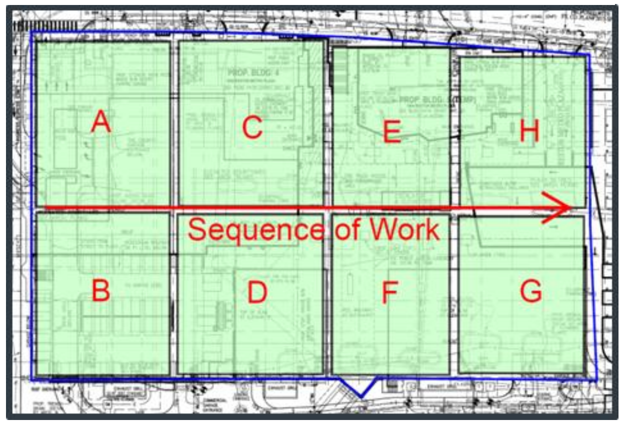
Figure 9: Schedule Highlights

Reston Station Schedule Highlight			
Phase/Task	*Start Date*	*End Date*	*Duration*
Procurment	1/17/2011	5/31/2012	359
Excavation	4/25/2011	1/3/2012	182
Concrete	6/14/2011	7/12/2012	283
MEP & Finishes	2/14/2012	2/18/2013	265
Project Closeout	2/19/2013	7/17/2013	107

Preconstruction services began early in 2010 and several schedules and estimates were produced for early analysis. One of the biggest challenges in this period of time was determining the best strategy to construct such a large project and remove the 600,000 cubic yards of soil required. To increase the benefits of fast-tracking the construction of the garage, design was only completed to a stage required to receive preliminary permits up to the G4 level of the garage before construction began.

The date for the Notice to Proceed on the project was April 18th, 2011. One benefit of the negotiated GMP contract with the contractor is that the procurement for sheeting and shoring could be done prior to the formal notice to proceed so that excavation could be started as soon as possible on site. The excavation of the site was the first major activity that sits on the critical path of the overall project. With a plan area the size of 4 football fields and a depth of over 70 feet, the excavation took an approximate 10 months to complete. Shortly after the first excavations reached subgrade depth the foundations for tower cranes 1 and 2 were constructed because utilizing the tower cranes as early as possible helped reduce traffic and delivery burdens for concrete delivery.

Figure 10: Sequence of Octants



Fortunately, due to the scale of excavation there was adequate room to begin concrete construction of the foundations and lower level slabs in the western half of the garage while soils were still being removed from the east side. The rest of the project schedule follows this same division between east and west halves of the building to maximize crew productivity and space utilization. Critical path analysis shows that most of the critical activities of the project occur within the eastern octants of the project. This makes sense because the last finishes at the conclusion of the project will be in the eastern portions of the building. A diagram of the construction sequence and progression through the building can be seen below in Figure 2.

Concrete placement was scheduled to occur during 30% of the entire duration of the project. Given the scale of the concrete structure and the significance it has on the project schedule a lot of effort was taken to ensure concrete progress keeps up with the rest of the project. The design delays mentioned in the first technical assignment and further analyzed in the constructability issue of this report has put the concrete schedule in serious jeopardy. This is especially true in regards to the buildings east structure; a delay in the G and H octants (the last areas to be poured) could result in a postponed final delivery date if schedule delays cannot be made up elsewhere.

The final inspections and punch list activities are scheduled to take almost 4 months at the end of the construction process. Final cleaning of the garage, commissioning of the MEP systems, punch listing, and project closeout documentation all occur at this time and the final date for substantial completion is July 17th of 2013. Arrival of the Silver Line Metrorail expansion is schedule for early 2014 but Fairfax County is eager to open the garage's bus terminal and collect revenue from parking spaces prior to that date.

Site Plan

Existing Conditions

The Reston Station project site sat directly on top of the parking lot for the previous Metro Bus stop at Wiehle Ave. After closure of this lot, Metro Bus operations were moved one block to the north where street side stops currently occur alongside an annex parking lot. Site logistics on a project the size of Reston Station are incredibly important to the flow of work and efficiency of the project. An existing site layout plan is available in APPENDIX B of this report. The site's closest neighbors are in the Sunset Hills Professional Center, a group of 3, two story office buildings that are also owned by Comstock Partners. While the properties are owned by the same owner, tenant considerations prohibit construction activities to leave the boundaries of construction at Reston Station.

The site is bordered to the East by Wiehle Avenue. This asphalt road is 4 lanes at the entrance to the site with a traffic light and turning lanes accommodating traffic into and out of the site. Once construction vehicles are in the site during preliminary phases it is possible for equipment to proceed to its intended location with little consideration for limitations within the site.

A small adjacent lot at the North East corner of the site provides ample space for construction trailers, waste dumpsters, material laydown area, and equipment storage containers. At the height of construction this space was able to accommodate 8 to 10 trailers plus over 60 personal vehicles.

Existing utility line locations are a vital aspect of the initial stages of construction due to the depth and size of the excavation required. There is a buried electrical line that used to power parking lot street lights running along the south perimeter of the future garage's footprint. Also, an abandoned storm sewer line cuts across the entire building footprint between 4 and 5 feet below grade.

Figure 11: Excavation Ramp

Construction Site Plan

Excavation Phase

The key feature of this plan is the ramp access to the excavation. Most importantly about this ramp is that it must both maintain a safe slope for vehicles and it must be in a location that is most advantageous for work flow. Possibly the largest limitation for the site is their inability to use a one-way traffic flow. This limitation is due to the inability for the site to have 2 ramps as well as the work being done directly to the east of the site on Office Building 1 (OB1). The best solution to this problem is to allow two-way traffic on site except while driving on the ramp.

Another consideration for the layout of the site is that piles must be driven before excavation begins in any given area because of lagging and excavation support concerns. Excavating at one end and slowly moving the ramp and excavation back towards the opposite wall makes clear sense. Considering the duration of excavation lasted 10 months, every gain in productivity can make a difference of days or weeks.

Concrete Structure Phase

The site layout for the structural phase of construction has both incredible assets as well as flaws. The most beneficial aspect of the process of pouring concrete at Reston Station is having two concrete batch plants on site. These plants cut down traffic in and out of the site immensely and the concrete mix contents can be monitored in real time.

Figure 12: Concrete Batch Plant

Even though the batch plants decrease the volume of traffic, the congestion of delivery and trade vehicles is still the biggest flaw in the site logistics. During the structural phase of construction the batch plants narrow the access the road to only 1 lane and there is only one gate for both entry and exit. This means trucks must pull in and back out while other trucks must wait for the delivery in front of them to be completed. This issue can lead to delivery backups at the entrance and in extreme cases trucks must occupy turning lanes outside of the gates until the area is clear for their delivery. Vehicles cannot exit the site at the south east due to the excavation of Office Building 1 (OB-1).

Finishes Phase

The finishes consist largely of painting, curtain walls, and veneers on CMU backing. The most notable consideration in the layout for these trades is the inclusion of scaffolding. At this stage in the project certain demobilization occurs including the tower cranes and some construction trailers.

In this phase of construction most portions of the garage will be open to vehicles. This is useful for the movement of materials and general area accessibility but it also carries certain risks. The floors will at some point be receiving traffic coating as a finish material and after it is applied it becomes the final product. Special care must be taken in this situation to assure that tires do not leave marks on the coating or it will need to be reapplied.

Project Cost

The information provided in this portion of the report was provided by DAVIS Construction and some information has been altered to protect project financial data.

Figure 13: Summary of Construction Cost

Project Financial Data			
Construction Cost	$79,000,000	Total Cost	$91,500,000
Construction Cost/Sq Ft	$ 60.77	Total Cost/Sq Ft	$ 70.38
Construction Cost/Parking Space	$ 25,599.48	Total Cost/Parking Space	$ 29,650.03

Square Foot Cost Estimate

This estimate was produced by the Means Cost Works software and it totaled a construction cost of $50,151,000. This estimate is almost $30 million dollars less in value than the real project cost. The reason for the large difference is most likely the assumptions that the software makes about the structure. The suggested maximum depth from the square foot estimating tool is 2 stories but Reston Station extends 7 stories underground. The software also doesn't account for the immense excavation demands as it underestimates "Basement Excavation" by $6 million. The system that was approximated the closest was concrete and even then, Means was shy by $5million. Actual data regarding the top 6 trades on site can be seen in table 2.

Figure 14: Major Sub Contracts

Major Trade Contracts		
Trade	Value	Value/SF
Concrete	$35,000,000	$26.92
Earthwork	$7,500,000	$5.77
Electrical	$7,000,000	$5.38
Sheeting & Shoring	$5,000,000	$3.85
Mechanical & Plumbing	$4,500,000	$3.46
Waterproofing	$3,000,000	$2.31

System Assembly Estimate

The untraditional nature of a 7 story underground parking garage causes some difficulties in achieving an accurate assembly's estimate using a service like R.S. Means. The most challenging by far was the mechanical system assembly. In the garage, small unitary ductless systems condition the air in certain bathrooms and working areas but there is no central system for the garage. The largest mechanical equipment items are fans that ventilate air at a very high rate, performing a unit cost estimate of these and similar items would likely create a much more accurate estimate. The assembly estimates for several MEP systems can be found in APPENDIX C.

Estimate of General Conditions

The information provided in this portion of the report was provided by DAVIS Construction and some information has been altered to protect project financial data.

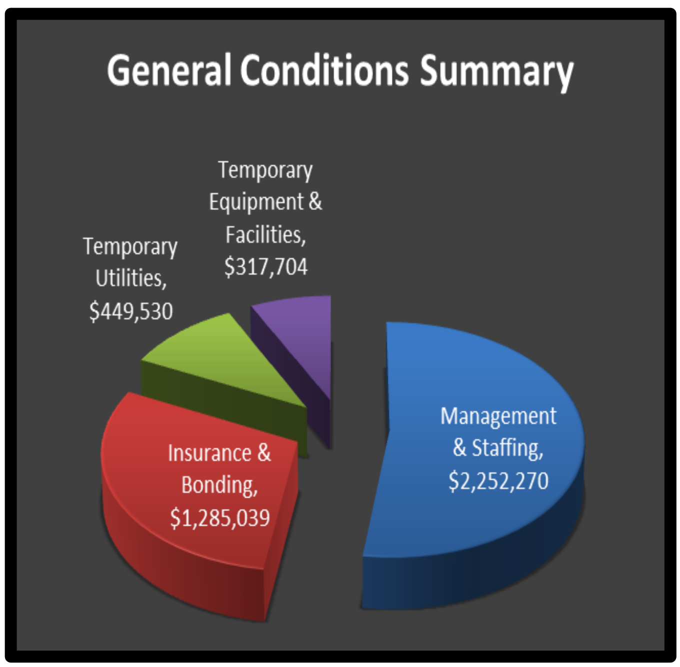
As with every construction project, Reston Station has needs for supporting facilities, utilities, insurance & bonding, and personnel which are all known collectively as general conditions. A full estimate of the general conditions has been produced using data provided by the general contractor and supplemented by RS Means Construction Cost Data 2013. Monthly costs of facilities, utilities, and personnel are based on a project duration of 28 months. The total cost of the general conditions on the project amounts to $4,300,00. A summary of the general conditions costs is provided in figure 15.

Figure 15 - General Conditions Summary

General Conditions Summary			
Category	Estimated Cost	Cost per Month	% of General Condidtions
Management & Staffing	$2,252,270	$81,017	52%
Insurance & Bonding	$1,285,039	$46,224	30%
Temporary Utilities	$449,530	$16,170	10%
Temporary Equipment & Facilities	$317,704	$11,428	7%
Totals	**$4,304,543**	**$154,840**	

The most significant contribution to the cost of the general conditions is the cost of the project staff which accounts for 52% of the total cost. A very skilled and talented staff has been selected by DAVIS Construction to lead this project. In addition to the project managers and superintendents, DAVIS incorporates the services of several other support departments within the company. These support services include a project scheduler, an administrative assistant, a project accountant, and a safety manager. As a result of their investment in the quality of their project team, the general contractor has demonstrated strong leadership amongst the other companies involved in the construction of Reston Station.

Figure 16 - General Conditions Illustration



Insurance and Bonding fees are responsible for 30% of the 4.3 million dollar general conditions cost. These fees are based off a percentage of the total project value and protect both owner and contractor from various risks associated with construction. The major policies that makeup this cost includes a general liability policy, builders risk insurance, and a payment and performance bond.

While temporary equipment, facilities, and utilities only account for a combined 17% of the general contractors general conditions, these two categories of costs are time dependent. In short, an early finish date saves money on these items while a longer project duration will drive the costs of these items up. This is important to realize since project schedule is currently a large concern.

Several items that are typically associated with the general conditions of a construction project have been excluded from the general contractor's estimate due to the capability for sub-contractors to provide those services through their own individual contracts. Some of the most significant costs transferred to the subcontractor contracts include site fences, cranes & material hoists, scaffolding, and temporary heating.

Analysis #1: Implications of Public-Private Partnerships

Problem Identification:

The Reston Station Phase 1 Garage project has a public private partnership (PPP) ownership structure. Comstock Partners is a commercial and high density residential developer in northern Virginia and acts as the private industry partner while Fairfax County is the government owner. PPP's have been prevalent in some forms for a long time but it has only been recently that their use is being seen more and more in construction. While Davis Construction (the contractor) has only one contract with Comstock Partners, Fairfax County owns the land and is contributing a majority of the funding for the public parking structure through County bonds as a funding source. The two owners have their own goals and opinions but have to come to agreement on many issues pertaining to garage design and construction. This is a relatively rare opportunity to see a partnership in building construction so it has many unique characteristics. By understanding more about PPP's, construction professionals can manage the projects that have partnered owners more effectively.

Research Goal:

The goal of this analysis is to understand and present how a PPP works, determine the pros and cons of a PPP, and speculate how a PPP can be beneficial in other areas of the American construction industry. Construction Managers and Owners could both benefit from this research because it could provide a solution to many owner concerns and can help construction professionals understand the relationships between owners. Reston Station Phase 1 Garage will serve as a good case study for this analysis.

Methodology:

In depth investigations of the following areas will allow for a full understanding of the implications of public-private partnerships in the construction industry:

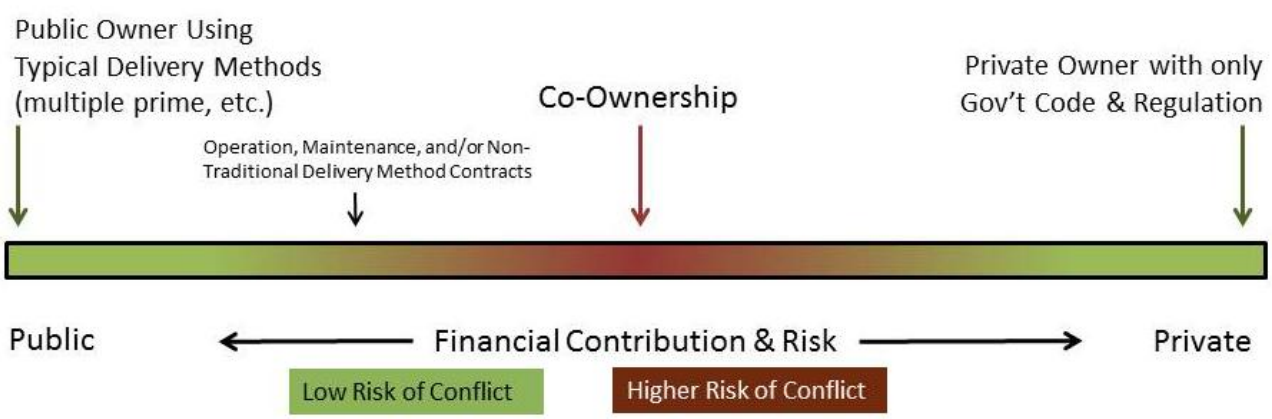
- Review academic articles pertaining to Public-Private Partnerships
- Interview Project team members and partners to fully understand project specific PPP scenario
- Relate findings to the construction industry as a whole
- Develop a system to simplify decision making processes within partnered ownership arrangements
- Develop conclusions and present results

Definition and Background of Partnerships

Public-Private Partnerships (also referred to as PPP's and P3) have been used in the United States in some form for nearly two centuries but are steadily increasing in popularity within the construction industry. A PPP is simply the transfer of the control of a service traditionally controlled by public sector to the private sector. In other words, any time a private company performs a service for or on behalf of a public entity, a partnership has been formed. Partnerships are especially useful in economic recessions because governments seek to use innovative delivery methods to reduce costs on expensive capital projects. These agreements have been historically more popular in infrastructure projects like highways, wastewater management, and other urban development projects but there are increasing opportunities elsewhere for their implementation.[1]

There are many varieties to the structure of partnership agreements with a variety of responsibilities put on each side. The division of responsibility and shared risk between public and private partners can vary greatly from project to project. Similar in the way that construction delivery methods have different structures, public private partnerships also have a variety of typical contract arrangements. These include operations & maintenance, design-build-maintain, build-operate-transfer, enhanced use leasing, and sale/leaseback just to name a few. Most government agencies and entities prefer specific contract organizations depending on the type of project. For example, the General Services Administration (GSA) frequently utilizes a lease/purchase arrangement with developers for the construction of new government office buildings.[2] The scale at which partnerships exist in the construction industry can be seen below in figure 17. The higher risk for conflict exists between public-private partnerships but this is also the general case for all joint-venture owners.

Figure 17: The Scale of Public Private Partnerships in Construction



[1] The National Council for Public-Private Partnerships, *How PPPs Work,* http://www.ncppp.org/howpart/index.shtml#define
[2] United States General Accounting Office, *Public Private Partnerships, Terms Related to Building and Facility Partnerships, http://www.gao.gov/special.pubs/Gg99071.pdf*

Public Advantages

The advantages of public-private partnerships begin with cost savings for public owners but many other benefits stem from this as well. The financial benefit for governments in a public-private partnership is that financial investment by a private sector owner can significantly reduce the upfront public cost of a project. In the example of highway infrastructure, a private owner may provide significant private capital up front and receive a portion of toll revenues in return. In the most extreme scenarios, some states have completely leased the ownership and operation of toll roads to private ownership. In this case, the public entity also experiences increase revenue from lease payments. A public owner can also experience delivery method freedom by allowing a private company to hold construction contracts (as is the case at Reston Station). The final benefit to public owners in a public-private partnership is that there is an increased level of efficiency that is created by combining things such as design, construction, operations, and maintenance on the same contract.

Private Sector Advantages

The most basic advantage and primary motivation for private owners to join in a public private partnership is to gain new business. A secondary goal for a private company may be that they are interested in gaining exposure to the public sector. It seems that many companies are more likely to participate in partnered projects after they have successfully navigated their first. A somewhat intangible benefit to a private company is the new relationship formed between them and a public entity. This can be useful in many ways in construction in terms of communication and overall integrative collaboration. These advantages create a win-win scenario and that is the goal of every public private partnership. Figure 18 outlines the basic advantages for both public and private sector partners in a PPP.

Figure 18: List of PPP Advantages

Advantages of Public Private Partnerships	
Public Owner	*Private Owner*
• Reduced Cost • Delivery Method Freedom • Possible Increase in Revenue • Increased Efficiency	• Operation in New Markets • New Revenue Opportunity • Government Relationship

Disadvantages

The greatest disadvantage of public private partnerships is their lack of previous use. Many organizations have used specifically altered partnerships to deliver services like waste management and space leasing but there are not many examples of civic buildings being constructed under partnerships, especially by state and local governments. Even in the limited examples of these state and local buildings there are many skeptics to the process and much is left to learn. A further discussion of this is provided in the sub section describing implications for the construction industry as a whole.

In practice, the shortcomings of public-private partnerships are most visible when risks and rewards are most closely shared. This is because of the conflicting interests of each party and the desire for each to have decision making power. When opinions do not align and both have a large amount to gain or lose, it is easy to see how tension can arise. Figure 17 illustrates this point further. In an effort to avoid this conflict both Comstock and Fairfax County hired the firm KCM to be a form of mediator between both owners and the contractor. At Reston Station the sharing of decision making authority was a clear challenge in the partnership.

The Public-Private Partnership at Reston Station

In 2008 construction began on the Dulles Corridor Metrorail Project or more commonly known as the "Metro Silver Line". The entire Metrorail expansion project was planned to be completed in two separate phases the first of which was scheduled to be completed in June of 2013. Interestingly, the railway project itself was a public-private partnership between the Virginia Department of Transportation (VDOT) and Bechtel Construction.[3] This allowed for a design-build delivery method instead of the traditional competitive bid scenario as a part of the Virginia Public-Private Partnership Act. VDOT and the Fairfax County Department of Transportation offered funds to the development of facilities adjacent to the rail project in order to take advantage of the new revenue generating opportunity. These funds required certain requirements for their award including a minimum quantity of parking capacity.

Given these minimum requirements for capacity, Fairfax County sought to redevelop a large parking lot to the immediate north of the future Wiehle Avenue stop on the silver line project. Their goal was to construct a 7 level garage that could hold up to 2300 vehicles. Early on in the project development process, Comstock Partners approached Fairfax County with a proposal to construct 5 mixed use buildings on top of the garage in an effort to further develop the area. The partnership between Comstock and Fairfax County is most closely referred to as a "turnkey partnership." Under a turnkey partnership the private partner holds the construction contract in order to secure the project with delivery methods that may not traditionally be acceptable for a purely public owner. There is also an aspect of the "developer finance partnership" arrangement because Comstock is contributing the cost of the construction of the future buildings as well as the leasing fees associated with the 99 year lease on the Fairfax County property.[4]

Fairfax County agreed to partner with Comstock in the construction of the garage with several stipulations. Many of these requirements are outlined in a document known as a proffer agreement. This is not a document of public record but Comstock abides by all of its requirements in order to maintain their development rights. Proffer agreements in building development are requirements that developers and builders agree to that ensure a variety of aspects of a projects design and construction. In the case of Reston Station, some requirements in the proffer included such things as minimum tree canopy area for the plaza level and project progress requirements.[5]

The financial structure of the partnership is that Fairfax County will own and operate the public garage space while Comstock Partners will lease the space of their development from the county. Comstock has agreed to a 99 year lease of the space which includes several private areas of the upper levels of the parking garage. A 99 year lease is commonly accepted as a formality in a

[3] Dulles Corridor Metrorail Project, *Dulles Metrorail Project Overview.* http://www.dullesmetro.com
[4] United States General Accounting Office, Public Private Partnerships, Terms Related to Building and Facility Partnerships, http://www.gao.gov/special.pubs/Gg99071.pdf
[5] Matt Dabrowski, Davis Project Engineer. Jan. 28, 2013

permanent agreement because it is traditionally assumed that the agreement will outlive either participant. The cost of the garage phase of the development project was shared between Fairfax County who contributed 88% and Comstock who contributed 12%. This results in a split of approximately $88 million and $12 million respectfully. It is worth noting that approximately 12% of the parking spaces in the garage are designated to be exclusively used by private sector end-users and this ratio determined cost sharing. Even though a majority of the cost is being contributed by the county, Comstock Partners holds the only construction contract with the construction contractor.

There are many benefits for both sides of this partnership. For Fairfax County, construction risk is mitigated by requiring Comstock to hold the contract with the general contractor. While the county is still contributing a majority of the construction cost, allowing Comstock to hold the contract enables the team to have more flexibility with delivery methods of construction. The final direct benefit for Fairfax County is that the addition of several residential and commercial spaces will likely increase the flow of public traffic in and out of the garage. This in turn results in an increase of revenue for the public owner. More indirectly, new development properties could result in a significant increase of tax revenue for the county.

For Comstock Partners, the benefits to entering this agreement are immense. So long as the market in the region is strong, Comstock can expect to gain very large revenues from the leasing of commercial space. This property was only available to them by entering into this partnering agreement with Fairfax County. In addition to Reston Station, Comstock has already begun planning and construction on a similar project known as Louden Station in Louden County, Virginia. It appears as though Comstock is taking advantage of their exposure to transit oriented development and getting the most out of the opportunities. The final benefit for Comstock is the shared goals between their company and the public government body. While formal procedures for permitting and zoning are still tightly adhered to on the project it never hurts to have the county government as a team mate.

Figure 19: Benefits of the PPP at Reston Station

Benefits of Public Private Partnership at Reston Station	
Public	*Private*
Lower Construction Risk	New Bussiness Sector
99 Year Lease Revenue	Access to Profitable Property
Delivery Method Freedom	Shared Goals with Public Entity

The benefits of a public-private partnership like the one between Comstock Partners and Fairfax County are numerous but there is one significant drawback in the case of Reston Station. This drawback is the complexity of decision making. The types of decisions that are challenging for the team range from things such as paint colors to signage and finish materials. In general, there is no issue with this process in the areas that are solely used by either organization. The real problems occur where spaces are shared between both public and private users. The fear of both sides is that a choice will not be favorable for any reason and the blame will be put back on the decision maker as well as the responsibility to fix it. In short, the result is a finger pointing battle.

Overcoming Decision Making

Descicion making at Reston Station has proved to be the biggest challenge to the public private partnership between Fairfax County and Comtock Partners. It appears that the reason that there is such hesitency in comitting to decisions is because the risks and rewards for both parties are evenly matched. Similarly, in other PPP projects, two owners that are both heavily commited to a project may face these issues with making simple choices. This is not usually an issue when one party has a clear dominance over the other in either project risk or space utlization.

The first question to consider when evaluating decision making power is wheather or not one party has a clear majority of the investment into the project. If either the public or private owner is heavily invested into the project, it is easy to see how they would be entitled to a large portion of the decision making power.

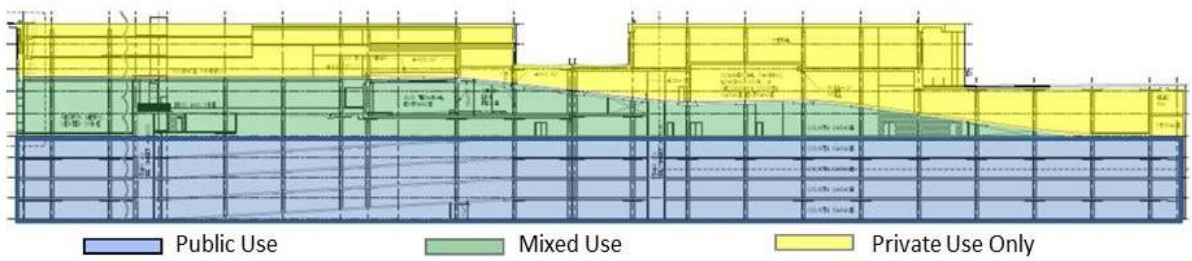
In the Reston Station scenario, Fairfax County is contributing 88% of the funds for the phase 1 construction. This would tend to imply that Fairfax County has clear say in most choices on the project, however this is not as simple as the financial bottom line would seem ot indicate. For one, Comstock Partners holds the contract for the construction services performed by Davis Construction. This means that any cost overruns are held as private risk and Fairfax County isn't accountable for any additional amount of money aside from their $88 million contribution. In addition, Comstock will be building up to $400 million of additional construction over the next 5 to 10 years that Fairfax County has no involvment in other than serving as property "land lord". This gives Comstock a particularly strong interest in the construction quality of the garage considering it will be the foundation and connecting structure for their entire future development.

Since it is clear from the review of these issues that both parties have substaintial investment in the success of the project other methods must be used to establish who has the decision making authority on any given question regarding the garage. The next question to consider is wheather or not any contracts or agreements exist that outline who and what must be decided in certain situations. Aside from project documents and specifications, the Reston Station project has what's known as a proffer agreement. As previously mentioned, this agreement is essentially a list (created by Fairfax County) of mandatory things that Comstock must include in the project to secure development rights of the future buildings. Any decision that falls under a requirement of the proffer agreement must be made according to those requirements.[6]

[6] Matt Dabrowski, Davis Project Engineer. Jan. 28, 2013

The proffer agreement outlines many aspects of the garage but it is not completely inclusive and there are a number of areas of the garage which seem not to be mentioned. In these scenarios the first question to consider is who is the primary user of the space. In the case of Reston Station, leveles G3 and below are entirely occupied by public parking while anything on levels P2 and above are only occupied by private parking and facilities. In these areas both public and private owners make decisions readidly the real challenge is on the shared levels: G2, G1, and P1. A visual of this space use interaction can be seen in Figure 17.

Figure 20: Space Use by Owner



Decifering who is responsible for a descision in the shared areas of a project is the most usful aspect to this process. The key to this mystery is a question of who uses the space. Esspecially in the case of Reston Station, enterances and parking areas are used by one of two catagories of people. The people that utilize the Reston Station garage will have either public or private facility destinations. The most logical solution for descision making ambiguity is to allow the owner whose customers will be looking at an area to make the choices regarding that locations colors, finishes, and et cetera. For example, if a person is going to the train station, they enter the garage under the elephant stand on the west side, drive down to the lower levels of the garage, most likely take an elevator to the plaza level and then walk south on the plaza to the pedestrian bridge. Like-wise, a person going to work, a meeting, or their apartment in one of the future office buildings will use the north private enterance, park in the private garage area adjacent to their respective building and take an elevator to their destination.

This final objective level of determining decision making power will not likely resolve many additional areas that could not be resolved through the previously mentioned methods. The best way to ensure a smooth descion making model is to outline the ambiguous areas of a project prior to the start of construction and determine who will have descion making power or detail specific criteria for the descion making process. Whether by written document or verbal agreement, the best way is to start with a good procedure. Figures 20 and 21 show a flow chart for descion making responsibility for Reston Station and multi-owner projects in general respectively.

Figure 21- Decision Making Flow Chart for Multi-Owner Scenarios

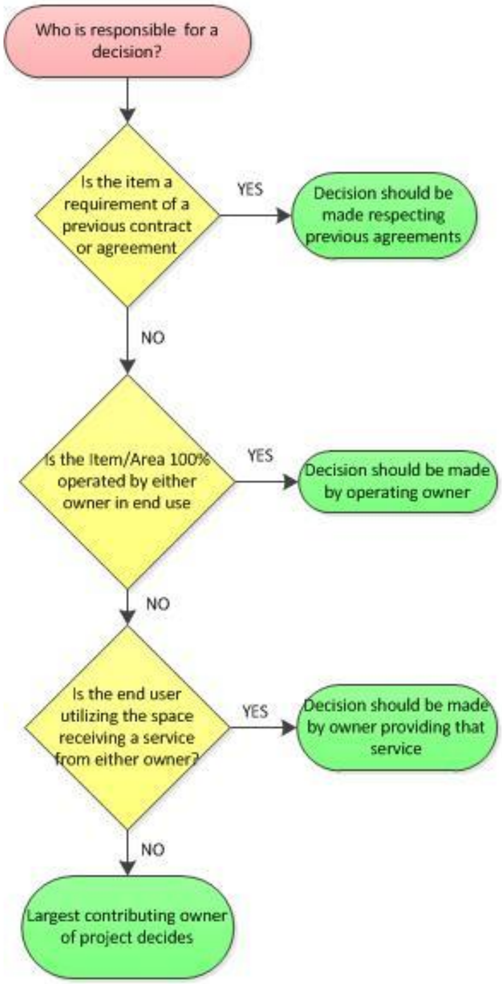
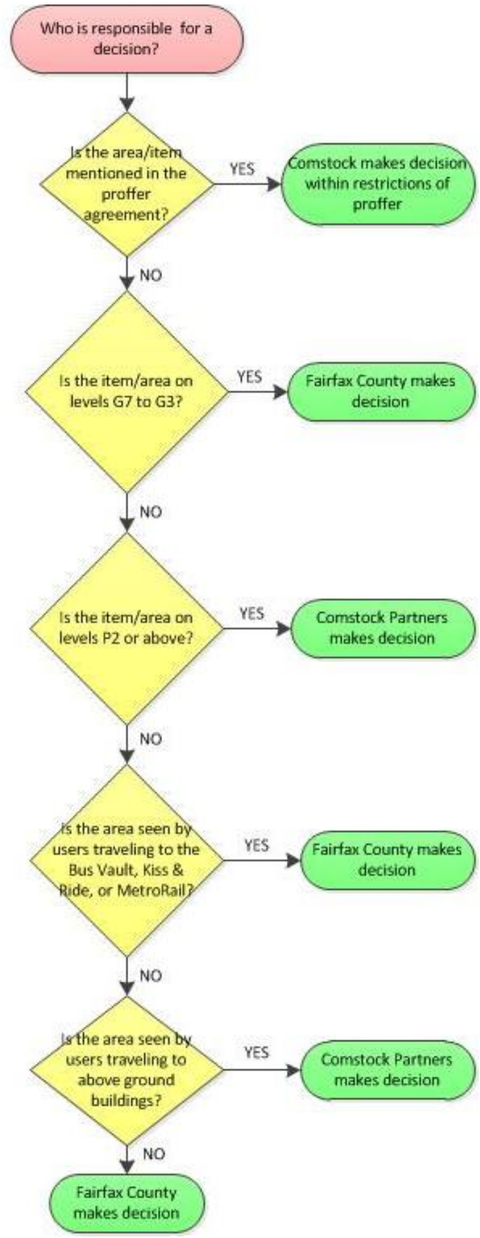


Figure 22 - Reston Station Decision Making Flow Chart



Implications for Construction Industry as a Whole

Public-private partnering is gaining new momentum in the American construction industry. There are many benefits to PPP implementation and their use on projects like Reston Station may be indicative of more prevalent use in building construction in the future. The biggest advantage to using a PPP is the cost savings for the public government. This is particularly advantageous in the current economy and specifically in Pennsylvania where the state is continually looking for ways to increase revenues and balance a large government budget.

Public private partnerships have been used successfully in many areas across the country, especially in creating new roadway revenue. The Chicago Skyway's (an 8 mile portion of I-80) operations, maintenance, and toll revenues were leased to a private company in 2005 for $1.8 billion. This was the first time the operation of a highway transferred from public to private ownership. Since then, the state of Indiana has also leased their entire portion of Interstate 80 to the same company for $3.8 billion. While some attempts at redeeming highway profitability have be successful, past attempts at privatization in Pennsylvania have been met with a lot of challenges and failures. In 2008 there was an attempt to lease the entire Pennsylvania turnpike to a private company in a similar fashion as The City of Chicago and The State of Indiana. This deal would have resulted in increased revenue for the state in the neighborhood of $3 million per day. The plan fell through after the company offering to lease the turnpike backed out after no actions were taken by congress to approve or deny the proposal.[7]

After these set-backs, legislation was passed in the summer of 2012 to enable public-private partnerships in Pennsylvania transportation projects. Chapter 91 of title 74 in Pennsylvania legislation sets up a lot of the framework for entering into partnerships for transportation infrastructure as well as puts certain safeguards in place to resist any type of corruption. One very interesting aspect of the public-private partnership chapter in the transportation legislation is that bidding protocols don't require government entities to award project to lowest bidders. The terminology is such that a project is awarded to "the best qualified responsible offer." The Fairfax County partnership with Comstock Partners is also made possible through the Virginia Public-Private Transportation Act due to its proximity and applications to the new Metro Silver Line project.[8]

[7] Engineering News Record, *Pennsylvania Turnpike Lease Plan Withdrawn as Credit Market Tightens, http://enr.construction.com/news/transportation/archives/081001a.asp*
[8] State of Pennsylvania, Part V Transportation Infrastructure Chapter 91

So what would a PPP look like in a traditional building that's not associated with roads and railways, like a school, or a library, or even a court house? To see how a partnership delivery method could work there are a very limited number of examples that can be examined. Most notably, the Long Beach Courthouse project in California is a recent example of this scenario. In this case, the public-private partnership was formed between The Administrative Office of the Courts of California (public) and Long Beach Judicial Partners (private). The LBJP must design, construct, finance, operate, and maintain the space over the span of a 35 year tenant contract with the Office of the Courts. The government simply pays a service and use fee each month to use the space. Interestingly, if the building is not operating at full performance, the public user isn't obligated to pay the full amount of their fee for that period of time.[9] At the conclusion of the contract's 35 year term the state will continue to hold the title to the building as a sort of lease-to-own arrangement.

This scenario has the benefit of saving up front tax dollars and creating higher quality government buildings. There is also a lot of freedom in the construction procurement methods by using this partnership arrangement. In this specific example, Clark Design/Build was hired to manage the entire design and construction process on behalf of the owner. There are however, some short comings already in this process. 23 pending courthouse projects have been postponed as a result of shifting a large sum of money towards paying the leasing costs of the new $500 million court house. This was caused by an uncertainty in the source of funding for the lease payments on the government's part.[10] While there are many applications for public-private partnerships, there is still a lot to learn about their application in the American construction industry. To best apply PPP's on public building construction, the risks that both sides face need to be critically analyzed so that issues like the one faced in California do not occur.

---

[9] Engineering News Record, *Unusual Delivery Method Highlights New Long Beach Courthouse Project, http://california.construction.com/california_construction_projects/2011/1118-Unusual-Delivery-Method-Highlights-New-Long-Beach-Courthouse-Project.asp*

[10] Press-Telegram, *Long Beach Courthouse Funding May Force State to Cut other Projects*, http://www.presstelegram.com/breakingnews/ci_22124428/long-beach-courthouse-funding-may-force-state-cut

Recommendations

Public-private partnerships are a growing trend in government procurement methodology as a way to cut down on public costs in a struggling economic era. The agreement between the two parties at Reston Station resulted in a 99 year lease for Comstock to develop the Fairfax County property. Fairfax County and Comstock Partners entered into a partnership to build the first phase of the Reston Station property. Fairfax County contributed a majority of the cost to build the structure but required Comstock to hold the contract for construction services. The first phase was primarily public parking garage space for future Metro Silver Line commuters but also included some private parking and upper level facilities for future private buildings. Additionally, some spaces are shared by both public and private owners.

In the areas that are shared by both owners there has been challenges faced in decision making. The problem results from a perception of responsibility and risk of making a bad decision in an area of the garage that affects the other partner. In an attempt to clarify which owners are responsible for making any decision in any given area, a flow chart has been provided in this analysis. To best succeed with clarifying decision making responsibilities it is best to decide who is responsible for what at the outset of the project and decide which entity will decide on matters when there is an even divide in ownership.

Public-private partnerships have traditionally been used in transportation infrastructure and to perform services in government facilities. Recently, more conventional buildings like libraries and court houses are being considered for public-private partnership procurement methods. The Long Beach Courthouse project serves as a great case study of this. A private company financed, designed, built, maintains, and operates the property while the public government pays a leasing fee for their use of the facility. This reduces up front risk and cost for the public and allows for a very flexible delivery method. The public owner however faced payment issues due to an ambiguity in finance sourcing. In conclusion, great care should be taken when entering into public-private partnerships while they are in the early phases of use.

Analysis #2: Using Bonded Warehouses as HUBs for Equipment Staging

Problem Identification:

At Reston Station, the exhaust/intake fans and escalators were delivered to the site and needed to be stored on the concrete slabs in various locations around the building for approximately 1 month longer than what was originally intended. The extra month was due to design delays in the fast-track construction schedule and the need for equipment to be delivered to the site was primarily due to the cash flow concerns of subcontractors. Contracts allow for materials to be billed once they have been delivered and stored on site. In order to remain on the planned cash curve, materials could not be held indefinitely on subcontractor liability. There are several other long lead-time items being delivered in the future that will likely face the same challenges. Storing critical pieces of equipment on site for prolonged periods of time exposes equipment to heightened risks of damage. In addition, the storage of the equipment on the slabs causes a problem in productivity due to the need to work around these items. This is an issue that may occur on other construction sites as well and general contractors may be able to utilize bonded warehouses in a way to alleviate some of these concerns.

Research Goal:

The purpose of this analysis is to develop an alternative solution for the equipment procurement and delivery process and to create a visual model of the garage during the material delivery stages of construction. These tools will be used to compare the current on-site storage solution to the alternative solution of storing materials in an off-site facility nearby. The impacts on both cost, on site productivity, and overall schedule will be evaluated in this analysis of equipment staging.

Methodology:

In depth investigations of the following areas will allow for a full understanding of the implications of the use of bonded warehouses for equipment staging:

- Interview of general contractor team members to understand current situation and problem solving approach
- Consult with logistics industry professionals to determine additional costs and other considerations
- Determine the implications of moving equipment around site on productivity by using productivity data provided by sub-contractor
- Utilize Revit Architecture to show schedule and site congestion impacts with modeling

The Problem with on Site Equipment Storage

On site storage of equipment can be a complicated matter on any project. At Reston Station, large equipment was delivered to the site and stored within the building while construction activities occurred in close proximity. In addition, the schedule of the garage construction was significantly affected by the structural design process in the fast-track construction sequence. This was due to a delayed release of drawings combined with a slow submittal approval process. The concrete production schedule was delayed to a maximum float of -31 days. Items such as escalators and large fans were delivered to the site according to the base line schedule (in late July) since they were long lead time items and cash flow was a concern.

Figure 23: Escalators and Fans Stored on Slabs

The problem was addressed by the project team by storing the 140 fans and 2 escalators on the already poured areas of concrete slab. Originally, the escalators were to be stored on the site after completion of concrete work which would not cause the concerns of heavy construction activity around their storage. The delay resulted in the need to store these items in the way of concrete progress. The storage of the escalators on the slab can be seen in Figure 23. The biggest consequences of this plan were high risks of damage associated with completing work in the proximity of the stored equipment and reduced productivity from moving fans and escalators every time work had to be done in those areas.

According to the projects baseline schedule the escalators were to arrive on site in Late July and begin erection on October 23, 2012 the duration of this task was 45 days. In this scenario the escalators would still be stored on slabs but by this time the areas that they would be stored in would have been completely finished and protected. The escalators still arrived in early August but did not actually begin erection till January 7, 2013 and were stored in areas with active construction for this entire duration. The 140 fans were placed in the parking areas of the G3 and G4 levels.

How Bonded Warehouses Can Help

Bonded warehouses are useful in many material logistics scenarios because the insurance on the space helps mitigate liability for the safe storage of materials while they are being kept off site. In construction, bonded warehouses can be used as off-site storage facilities for a variety of reasons. One example of this is the Pentagon Renovation Project that was led by Hensel Phelps.

Pentagon Renovation Example

In the case of the Pentagon Renovation all deliveries were first checked by security personnel before materials could be taken into the jobsite. Security screenings took place at the Remote Delivery Facility but if both driver and truck were not previously prescreened and registered; shipments were not permitted into the property. On this project, the mechanical and electrical subcontractors were able to register their own drivers and trucks but the other subcontractors did not have their own logistics systems and typically would have used commercial logistics services that would have been impossible to prescreen and register. The solution Hensel Phelps used was to lease a local bonded warehouse and dedicate a full time staff of two drivers and one warehouse manager to its operation.

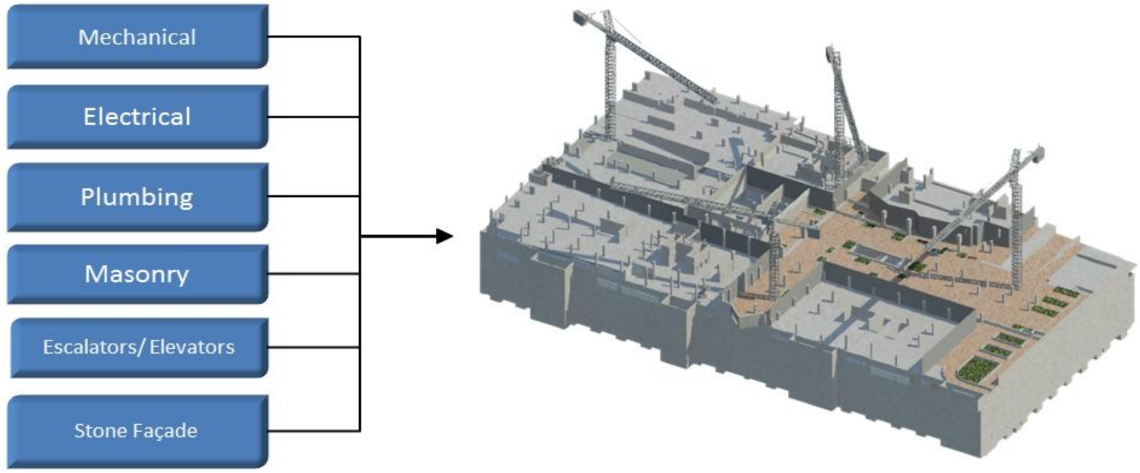
Several Benefits were realized through the use of this warehouse. The greatest benefit for Hensel Phelps was the simplification of security measures and assurance of deliveries not being turned away. In addition to this, Hensel Phelps found that materials could be consolidated into a reduced number of deliveries and they were able to pay subcontractors for material deliveries at the warehouse the same as they would be paid for on site deliveries. As a consequence, they paid an extra expense for the lease on the warehouse space, the bonding of the item storage, and the wage of the 3 staff members dedicated to the warehouse operation.[11]

The 3 Levels of Possible Bonded Warehouse Use

In construction projects, the extent to which bonded warehouses can be useful depends primarily on the location and site constraints of the project. Smaller projects or sites with a lot of usable open space may not need any type of off-site storage facility due to large available space for laydown and storage. This is how almost all general contractors operate projects; by finding space on site to store equipment or to install equipment immediately thanks to just-in-time delivery. A diagram of this logistics scenario with subcontractors delivering materials directly to the site can be seen in Figure 24.

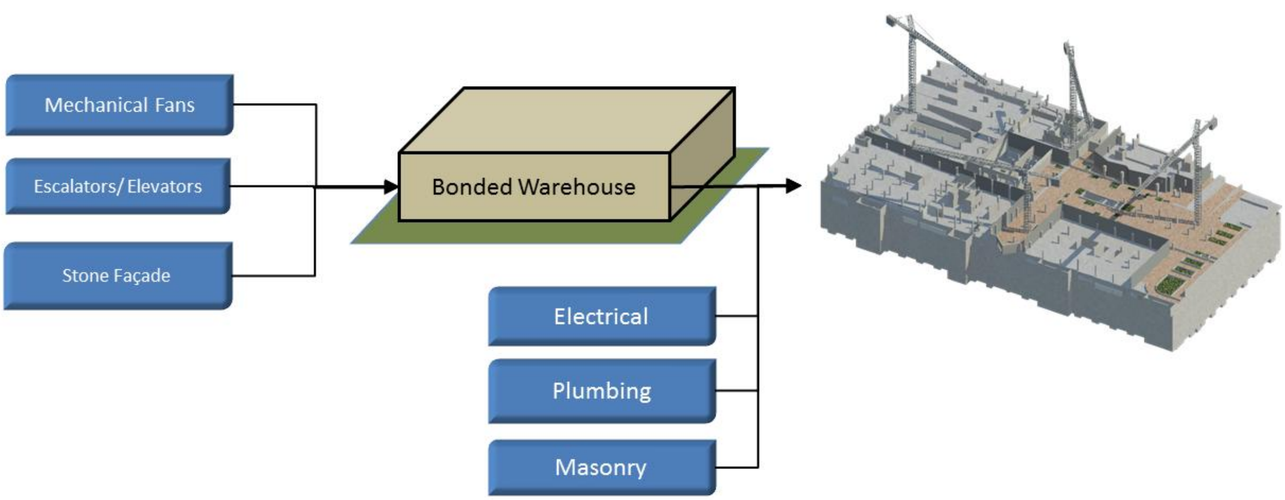
[11] Jeremy Sibert, Phone Interview, March 5th 2013

Figure 24: Bonded Warehouses Unused



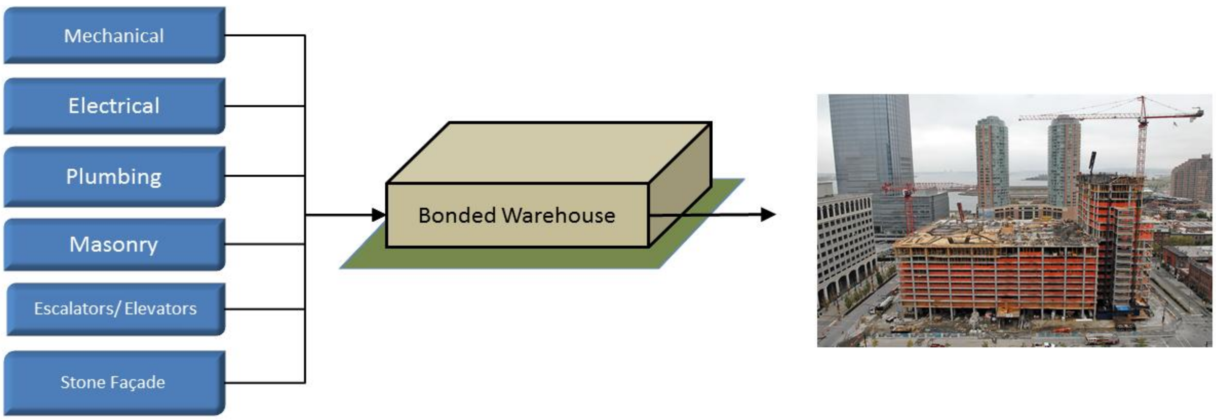
The proposed solution for Reston Station is that large, expensive pieces of material and equipment can be delivered to an offsite bonded warehouse for safe storage before being delivered to the project site. The warehouse space would be rented by the general contractor and the liability for the safe storage of the material is covered by the warehouse bond. A diagram of the logistical flow of materials in this situation can be seen in Figure 25. This is a useful way to ensure the safe storage of materials and influence cash flow to subcontractors when site storage is restricted. For a short term need it is most financially efficient to rent month-to-month storage at a local warehouse than to sign a long term lease on an entire facility. (See Cost Analysis)

Figure 25: Delivery Logistics With Short Term, Limited Bonded Warehouse Use



In a site logistics situation where site storage and laydown areas are extremely limited (like in a downtown environment) or security measures require it (like at the Pentagon) a "one source" method could be established using bonded warehouse space. The biggest advantage to this method is it allows for consolidated delivery of materials to site. For example, 2 half loads can be consolidated to 1 full load. Alternatively, deliveries that would once be made with several small vehicles could be combined and delivered in a vehicle with larger capacity.

Figure 26: Delivery Logistics for Long Term Extensive Bonded Warehouse Use



Cash Flow

One of the benefits of using offsite storage space for general contractors is that it enables subcontractor cash flow without causing unnecessary site congestion. AIA Document A201-1997 (General Conditions of the Contract for Construction) states the following:

"***§9.3.2*** *Unless otherwise provided in the contract document, payments shall be made on account of materials and equipment delivered and suitably store at the site for subsequent incorporation in the work. If approved in advance by the owner, payment may similarly be made for materials and equipment suitably stored off the site at a location agreed upon in writing.*"

This inclusion of off-site storage locations allows for sub-contractors to receive payments for materials after those materials have been transported to the warehouse instead of the site. Some subcontractors utilize their own warehouses or "yards" to store materials so that they are prepared to deliver materials to jobsites ahead of their required time. A common example is mechanical contractors like Southland Industries and JE Richards. In these cases, subs can utilize their own space (similar to the Pentagon Renovation Project) and bill for materials once delivered to site.

A concern is raised if a subcontractor attempts to front load the cash flow of material delivery. Worse yet, there is a possibility that subcontractors could attempt to deliver and invoice materials to the leased warehouse that are not "for subsequent incorporation in the work". These issues are part of the reason why an extra level of management is required for the effective and efficient use of bonded warehouses. Material deliveries can be managed at the warehouse similarly to how they are managed on site. If available space is available, deliveries can be scheduled by management and unscheduled deliveries can simply be turned away. The warehouse is essentially an extension to the project site in terms of management. For subcontractors to receive payment, verification by general contractor staff must be made that materials delivered to the warehouse are in fact purposed for the job that they claim.

Productivity and Schedule Issues

During the period of time that the two escalator trusses were stored on the G2 and G1 slab they had to be moved by tower crane 3 times. Each time this operation was necessary the crane required an hour of rigging and operation. This caused a total delay of 3 hours to the crane operations. Originally, the escalator trusses were to be stored on the completed P1 slab but since construction progress was not advanced enough they were stored on the G2 level. From the G2 level they were moved twice to the south to allow for column and slab concrete construction of the G1 and P1 levels until they were eventually moved to their originally planned location. The difference between the original plan for the storage of the escalators and the modified plan are viewable in figures 28 and 29 respectfully.

In addition to the escalator trusses, the 140 supply and exhaust fans had to be stored in the G3 and G4 levels of the garage. No construction was being performed in those areas during the time of the fan storage but workers and equipment still moved through the space. This puts the fans at heightened risk for damage. In addition, additional time was spent by the mechanical subcontractor to move fans to their intermediate storage location. Since it took a worker 10 minutes to drive each fan to its temporary location on a skid steer, this accumulates to 23.5 hours of extra man hours. This is equivalent to 3 days. Bonded warehouses would allow for the alternative of direct transporting the fans from the truck to the final location of installation.

Each time a shipment of stone arrived on site it was stored in the construction parking area for approximately 2 weeks. Since there were 8 deliveries of stone and approximately 2 deliveries per week, this resulted in a month and a half of restricted parking availability. This limited parking by 6 to 8 spots at its worst and onsite parking was already very limited and valuable to the project team.

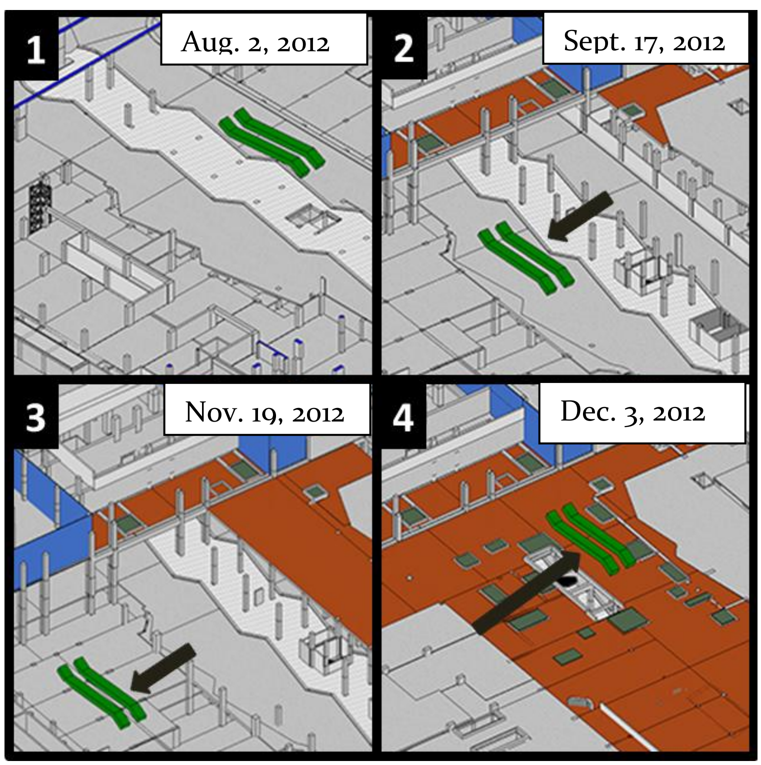
All three of these issues could have been prevented using bonded warehouse staging. These issues in productivity are the issues that do not appear on the "bottom line" that must be considered to find the best value solution. A summary of the productivity issues can be seen in figure 27.

Figure 27: Productivity Loss

Productivity Costs of Onsite Storage	
Escalators	• 3 Hours of Crane Time
Fans	• 23.5 Labor Hours of Moving
Crates of Stone	• 8 Parking Spaces for 6 Weeks

Figure 28: Original Intention of On Site Escalator Truss Storage

Figure 29: Escalator Truss Movement Due to Schedule Delays



Cost Analysis

For the purpose of this analysis, the costs of using warehouse space can be categorized as either short term and limited use or long term and extensive use. These are synonymous with the delivery logistics for limited materials and delivery logistics for all materials on restricted sites respectfully.

Short Term, Limited Use

The storage and transportation of the Reston Station supply fans, exhaust fans, escalators, and stone façade pieces were used for the purpose of examining the costs of short term warehouse use. Cost data was provided by England Logistics and Transwestern.

In the scenario that a general contractor wanted to use a warehouse for the temporary storage of only important items a month to month rental of warehouse space would be best. There are several services that enable logistic operations like this and the leasing out of an entire facility would simply not be necessary. The costs that must be considered are the space rental fees, the transportation fees for shipping materials from the warehouse to the site, and the cost associated with insuring the equipment being stored. The costs of storing, shipping, and bonding the escalators, fans, and stone façade pieces are detailed in APPENDIX D, a brief summary of the costs for the scenario proposed at Reston Station can been seen in figure 30.

Figure 30: Summary of Costs for Temporary Offsite Storage

Total Cost of Off Site Storage of Limited Items	
Storage Cost	$ 20,600.00
Transportation Cost	$ 7,600.00
Bonding (1% Value of Goods)	$ 8,036.00
TOTAL	$ 36,236.00

Long Term, Extensive Use

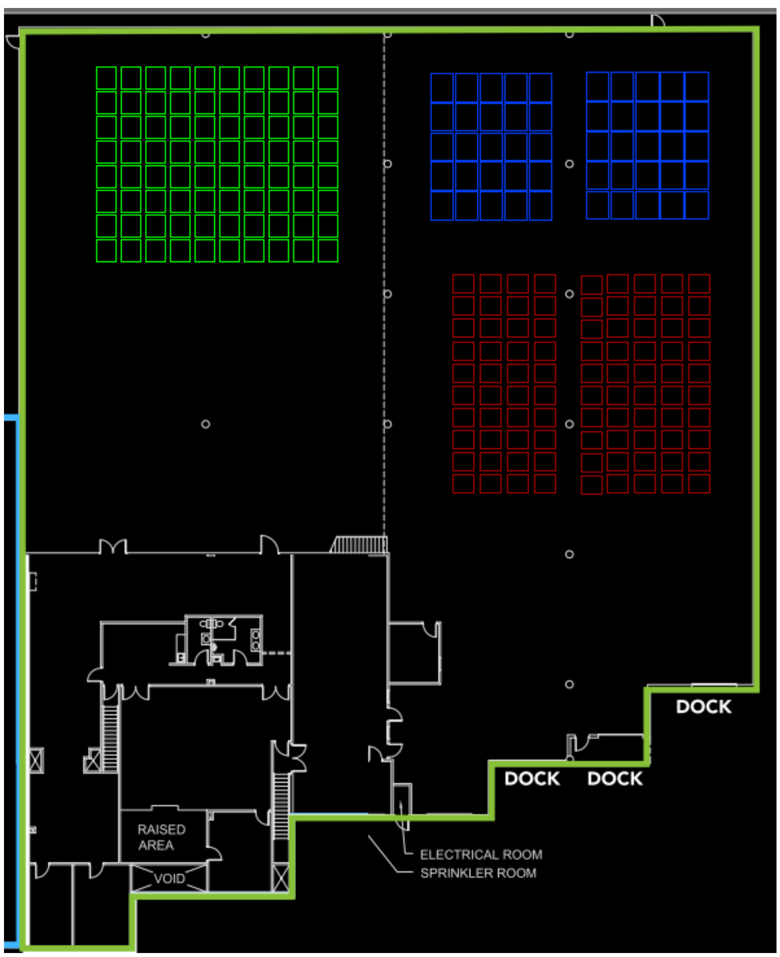
In the situation that a general contractor used bonded warehouses as a permanent equipment staging HUB, they may consider leasing an entire warehouse for an extended period of time. For the purpose of this cost evaluation of the scenario, a warehouse was found in close proximity to the Reston jobsite. The 24,600 square foot facility is located adjacent to the Dulles International Airport and is owned by Transwestern Real Estate. The largest cost met with leasing the facility is the lease itself which at $12/SF/Year amounts to $887,000 over the 3 year lease period. An added cost to the long term HUB facility that was not a part of the short term off-site storage plan is the need for additional management and staff. This adds an additional $660,000 to the cost of this operation. A summary of the costs associated with the HUB facility can be seen in figure 31, a detailed cost analysis is available in APPENDIX D.

Figure 31: Summary of Costs for Permanent HUB Offsite Storage

Total Cost of Off Long Term Off Site Storage	
Storage Cost	$ 896,019.48
Transportation Cost	$ 162,020.00
Staff	$ 660,000.00
TOTAL	$ 1,718,039.48

A CAD drawing has been created that depicts the floor plan of the property with all 90 exhaust fans, 50 supply fans, and 80 crates of granite façade to better understand the scale of 24,600 square feet of storage space. As seen in figure 32, when all the Reston Station materials are stored within the warehouse there is still substantial room for more materials. It is worth noting that all of these materials would not be stored within the space simultaneously and this exercise simply demonstrates the adequate size of the space presented.

Figure 32: Floor Plan of Transwestern Warehouse Property



Recomendations

Bonded warehouses have several advantages in the reduction of site congestion. There are two options for the implementation of bonded warehouses. The first is to utilize temporary storage space provided by a distribution company. This option involves using a third party warehouse that is paid for on a month-to-month basis for space and services used. The second option is to lease a warehouse for an extended period of time and to use it extensively for multiple projects over a period of several years. This would also require extra staffing from the general contractor for the smooth operation of warehouse management and the transportation of materials.

The financial cost of both the short term warehouse use and long term leasing options were analyzed and compared. The leasing option was considerably more expensive but this was expected due to its long term (36 month) use. In order to objectively compare the results each cost was divided by the length of time (in months) that they represented. From this comparison we see that the long term leasing option with extra staff and equipment costs approximately $48,000 per month. The temporary space with transportation costs is only a fraction of this cost at approximately $6,000 per month. A table of the costs per month for each option are shown in figure 33. This result shows that in the event that off site storage at a bonded warehouse is desired for reduction of site congestion it is far more cost effective to use short term renting options. This short term option is the one suggested for the Reston Station project because it would protect $800,000 worth of equipment and save hours of crucial time on site.

The option to lease a warehouse for long term storage and operations is still a useful possibility if security or other restrictions require it. There may even be a situation where the cost, while significantly greater than temporary options, is not restrictive to the general contractors goals for logistics control. The cost of the warehouse lease over the 28 months of the Reston Station project would amount to 1.5% of the base constract value (half of the GC fee)

which makes it clearly cost prohibitive if only used for one project and not explicitly included in the general conditions of the project at the outset of the project.

Figure 33: Cost Comparison per Month

Per Month Comparison of Bonded Warehouse Use			
Scenario	*Time Span (mo.)*	*Cost*	*Cost/Mo*
Long Term Warehouse Leasing	36	$ 1,718,039.48	$ 47,723.32
Short Term Warehouse Space Renting	6	$ 36,236.00	$ 6,039.33

Analysis #3: SIPS Analysis of Finish Sequence

Problem Identification:

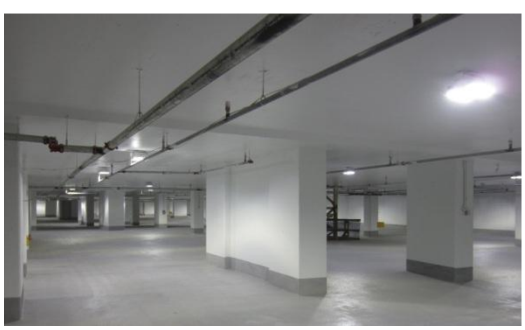
Comstock Partners and Fairfax County, the owners of the Reston Station project, chose to fast track the construction of the garage phase in order to ensure project completion prior to the opening of the Metro Silver Line and maximize revenues through parking fees and bus terminal operation. The design delay of the cast-in-place concrete structure of the garage has caused significant construction schedule consequences. Progress on the project currently faces a 31 day negative float from the baseline schedule. Since the concrete is dependent on structural design drawings, MEP and finish trades must be evaluated for acceleration opportunities. In addition, the reshoring requirements of the garage are prohibitive to the progress of these trades. Since construction loads are greater than the final service loads, reshores are required in the entire

Research Goal:

The purpose of this analysis is to identify the most critical tasks in finishing the underground levels of the garage and develop a sequence of tasks utilizing a short interval production schedule (SIPS). The detailed duration of time for each task (Masonry, Painting, traffic coating, MEP rough-in) on a typical level of the garage will be determined and sequenced accordingly. Each trade will be organized by subcontractor and their tasks (i.e. hang sprinkler pipe hangers, install sprinkler main runs, etc.) This sequence will be presented using a matrix schedule that highlights the presence of work crews in an area and the duration of time spent there. This matrix schedule will also be graphically organized to show the sequence in a section view of the building for better understanding.

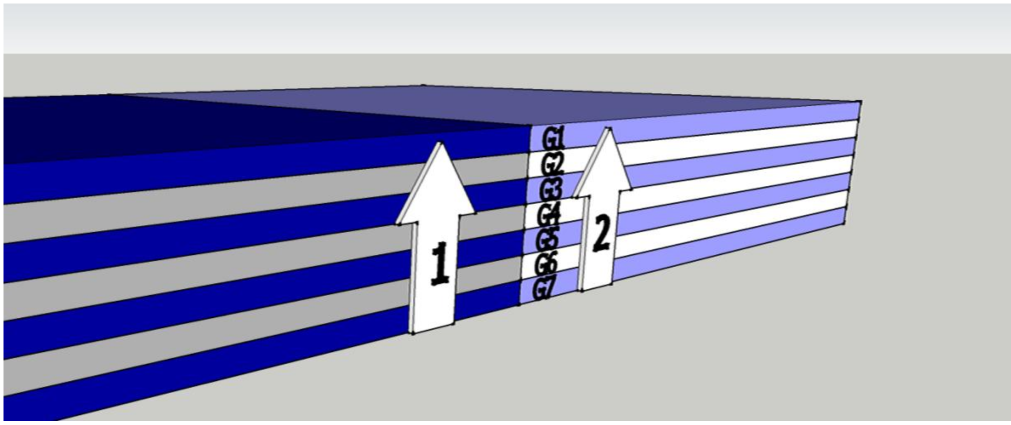
Methodology:

- Utilize project team members and schedule data to determine finish trade productivity rates
- Create a SIPS schedule for a typical bay and determine the most advantageous sequencing
- Extrapolate sequencing to full project schedule using Microsoft Project
- Illustrate results using a matrix schedule
- Redesign slab to require 2 formed levels with 2 shored levels of reshoring under construction loading.



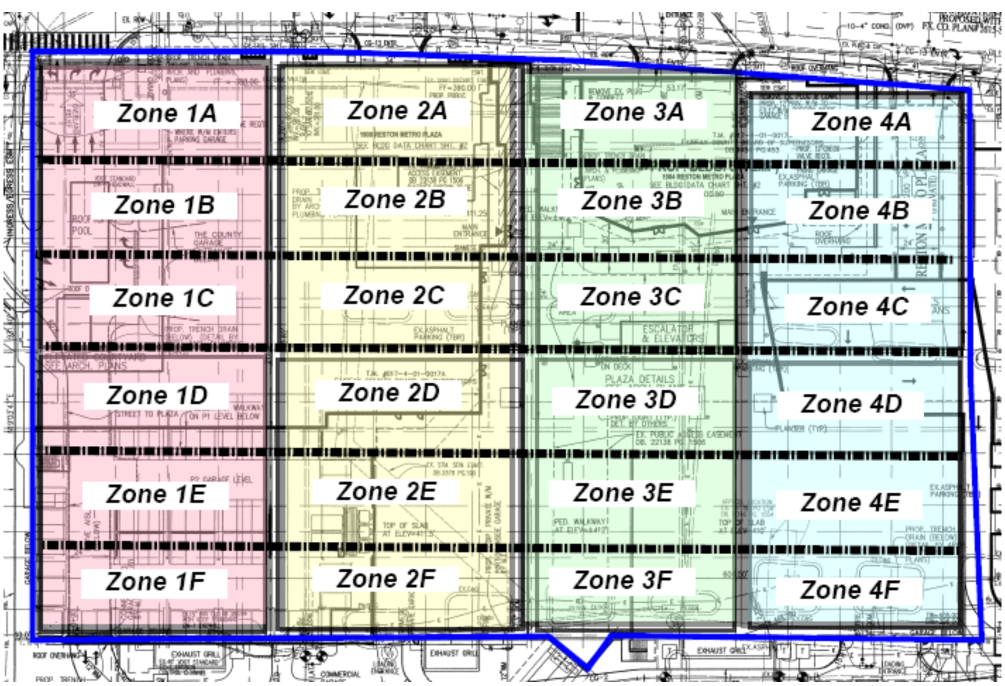
Sequence of Finish Trades

Figure 34: Original Finish Sequence



The original sequence used by the general contractor divided the building into east and west and by floor creating 14 areas of 99,000 square feet each. A visual of this sequence is presented in figure 34. The west side was to be finished entirely prior to beginning finish trades on the east due to the concrete structure sequence. To take better advantage of the concrete progress, the garage finish sequence was reanalyzed with SIPS using the 4 zones that define the concrete structural progress (dictated by the shop drawing submittal approval process). This alternate sequence is depicted for a typical floor in figure 35 each subzone is approximately 8,250 SF.

Figure 35: Alternate Finish Sequence



For the purpose of developing a SIPS schedule the activities associated with finishing an area of the garage were determined as follows:

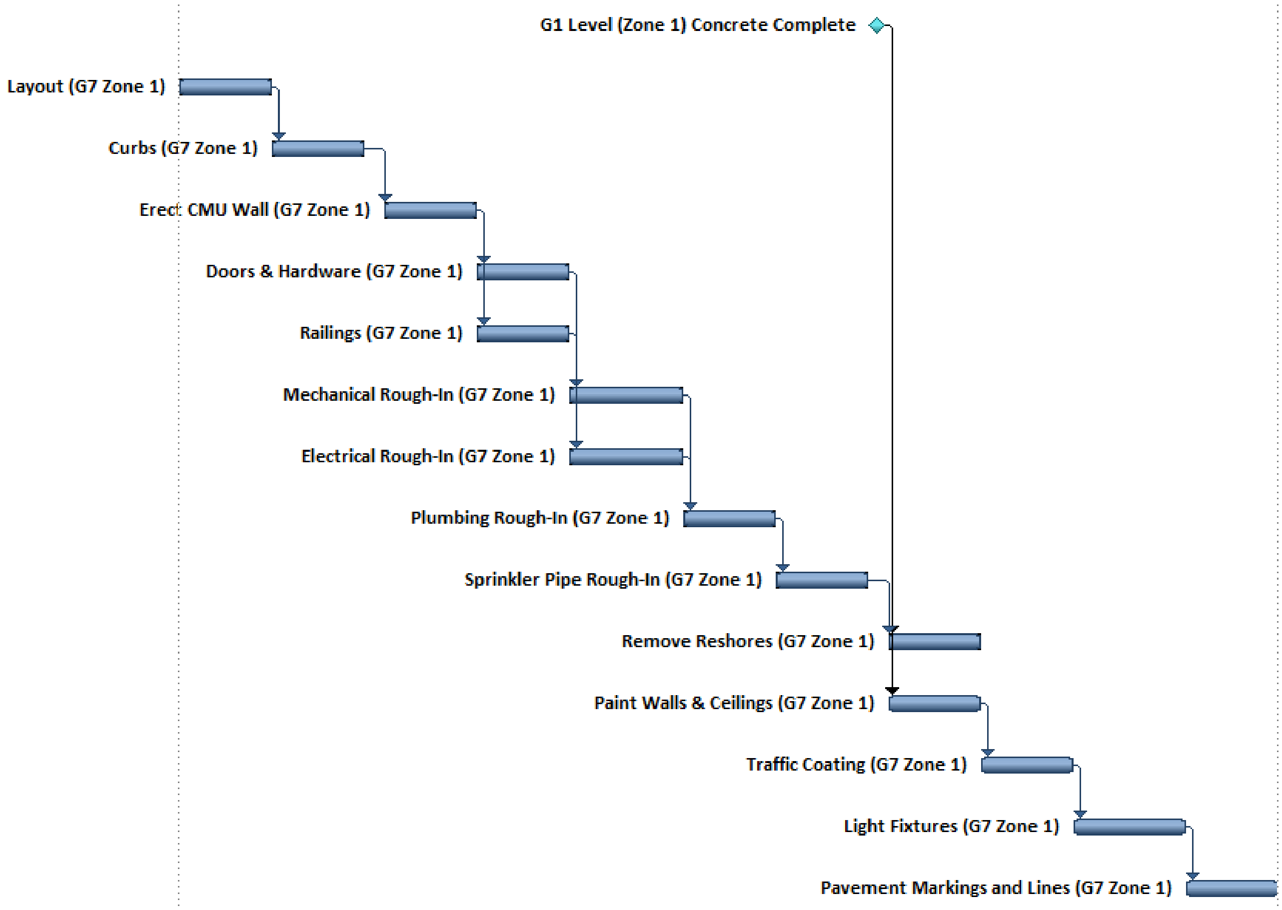
- Layout
- Curbs and Raised Slabs
- Erect CMU Walls
- Install Doors & Hardware
- Install Railings & Misc. Metals
- Mechanical Rough In
- Electrical Rough In
- Plumbing Rough In
- Sprinkler Rough In
- Remove Reshoring
- Paint Walls and Ceiling
- Traffic Coating
- Light Fixtures
- Pavement Markings and Lines

The relation of these trades to eachother can be seen in the gantt chart of Figure 36. This depicts the relative sequence of work in a given subzone. Certain activities have been scheduled as concurrent because it has been determined that these activities can proceed in the same area simultaneously. Doors & Hardware and railings can be installed at the same time because crews are not working in the same immediate area at the same time. This is also the case with mechanical and electrical rough-ins. This would likely not be possible in a typical commercial building but the mechanical equipment in the garage is relitively limited to specific areas around the perimiter.

Reshore removal and painting were also two activities that were found to have co-occupation possibilities in sequencing. This conclusion was arrived at on the basis of reshore removal having an incredibly fast production rate compared to painting. In addition, painting crews will be able to prepare spaces for painting while crews are dissambling shoring posts in relatively close proximity.

A critical issue arises in the sequence of finish activities due to the relationship between concrete completion and reshore removal. If concrete does not progress at a fast pace, the SIPS schedule develops a lag that is dependant on concrete production.

Figure 36: Sequence of Work in a Subzone



Productivity Rates

Due to the repetitive nature of the garage layout, SIPS scheduling can be very useful in determining a highly efficient sequence through the finish activities. Productivity was assessed on the basis of square feet of garage space per day. The original project schedule designated 99,000 square feet of garage space for each finish area. By dividing the area of the finish sequence zone by the original duration of the activity and the number of workers in a crew a simple productivity rate was determined per crew member per day. These findings are presented in Figure 37. A new crew size was determined for certain trades to ensure that productivity rates were equivalent to at least <u>one subzone per day</u>. There is no financial impact from this crew adjustment because there is no added work, just a redistribution of labor over time. The biggest impact this has on project cost is a shift in cost flow for each subcontractor to a steeper, earlier flow in the project.

Figure 37: Productivity Rates of Finish Trades

Garage Activity Productivity Rates							
Schedule Indicator	Activity	Baseline Duration (Days)	Baseline Sequence Zone Area	Productivity (SF/Man/Day)	SIPS Subzone Area (SF)	# of Workers (Baseline)	# of Workers (SIPS)
A	Layout	5	99,000 SF	9900	8250	2	2
B	Curbs	20	99,000 SF	413	8250	12	20
C	CMU Walls	20	99,000 SF	620	8250	8	14
D	Doors & Hardware	5	99,000 SF	9900	8250	2	2
	Railings	10	99,000 SF	3300	8250	3	3
E	Mech Rough In	10	99,000 SF	2475	8250	4	4
	Electrical Rough In	10	99,000 SF	1650	8250	6	6
F	Plumbing Rough In	20	99,000 SF	495	8250	10	17
G	Sprinkler Rough In	30	99,000 SF	825	8250	8	10
H	Remove Reshores	3	99,000 SF	8250	8250	4	4
	Paint Walls and Ceilings	15	99,000 SF	660	8250	10	13
I	Traffic Coating	24	99,000 SF	1094	8250	8	8
J	Light Fixtures	20	99,000 SF	825	8250	6	10
K	Pavement Markings	5	99,000 SF	3300	8250	6	6

Each schedule indicator above represents an activity or group of activities that are currently being performed in a single subzone area. This sequence and pairing is consistent with the previous findings of co-occupation of trades and activities. The results of these findings were compiled into a matrix schedule that can be found in figure 38 which shows a small portion of the sequence, a more complete version can be found in Appendix F.

Figure 38: Excerpt from Matrix Schedule

Level	Subzone	14-Feb	15-Feb	16-Feb	17-Feb	20-Feb	21-Feb	22-Feb	23-Feb	24-Feb	27-Feb	28-Feb	29-Feb	1-Mar	2-Mar	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	12-Mar	13-Mar
G7	1A	A	B	C	D	E	F	G	H	I	J	K										
G7	1B		A	B	C	D	E	F	G	H	I	J	K									
G7	1C			A	B	C	D	E	F	G	H	I	J	K								
G7	1D				A	B	C	D	E	F	G	H	I	J	K							
G7	1E					A	B	C	D	E	F	G	H	I	J	K						
G7	1F						A	B	C	D	E	F	G	H	I	J	K					
G7	2A							A	B	C	D	E	F	G	H	I	J	K				
G7	2B								A	B	C	D	E	F	G	H	I	J	K			
G7	2C									A	B	C	D	E	F	G	H	I	J	K		
G7	2D										A	B	C	D	E	F	G	H	I	J	K	
G7	2E											A	B	C	D	E	F	G	H	I	J	K

Concrete Limitations

While the aforementioned scenario represents an ideal situation the reality of the Reston Station project includes the dependence of finish trades on concrete progress. The biggest risk in the finish sequence in this regard is the dependence that reshore removal has on the slab that is 6 levels above the current finish floor (e.g. The G7 reshores cannot be removed until the G1 slab has been poured). This can create a sufficient lag in the sequence and the baseline schedule dates of concrete completion were added to the SIPS schedule to evaluate this impact. The consequence of this issue is seen in figure 39.

Figure 39: Consequence of Reshoring Requirements

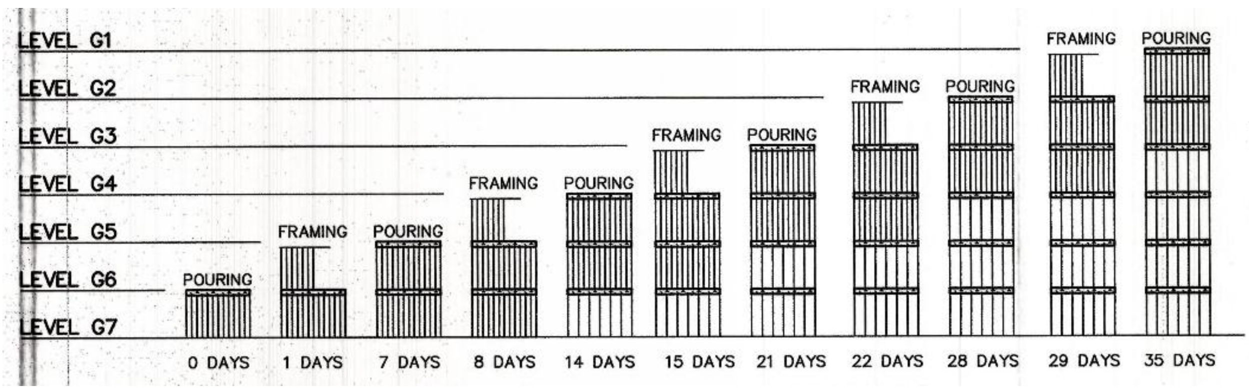
Level	Subzone	14-Feb	15-Feb	16-Feb	17-Feb	20-Feb	21-Feb	22-Feb	23-Feb	24-Feb	27-Feb	28-Feb	29-Feb	1-Mar	2-Mar	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	23-Apr	24-Apr	25-Apr
G7	1A	A	B	C	D	E	F		H	I	J	K																																									
G7	1B		A	B	C	D	E	F	G	H	I	J	K																																								
G7	1C			A	B	C	D	E	F	G	H	I	J	K																																							
G7	1D				A	B	C	D	E	F	G	H	I	J	K																																						
G7	1E					A	B	C	D	E	F	G	H	I	J	K																																					
G7	1F						A	B	C	D	E	F	G	H	I	J	K																																				
G7	2A							A	B	C	D	E	F	G			Concrete Delay									H	I	J	K																								
G7	2B								A	B	C	D	E	F	G												H	I	J	K																							
G7	2C									A	B	C	D	E	F	G												H	I	J	K																						
G7	2D										A	B	C	D	E	F	G												H	I	J	K																					
G7	2E											A	B	C	D	E	F	G												H	I	J	K																				
G7	2F												A	B	C	D	E	F	G												H	I	J	K																			
G6	1A													A	B	C	D	E	F													H	I	J	K																		
G6	1B														A	B	C	D	E	F	G												H	I	J	K																	
G6	1C															A	B	C	D	E	F	G												H	I	J	K																
G6	1D																A	B	C	D	E	F	G												H	I	J	K															
G6	1E																	A	B	C	D	E	F	G												H	I	J	K														
G6	1F																		A	B	C	D	E	F	G												H	I	J	K													
G6	2A																			A	B	C	D	E	F	G														Concrete Delay					H	I	J	K					
G6	2B																				A	B	C	D	E	F	G																			H	I	J	K				
G6	2C																					A	B	C	D	E	F	G																			H	I	J	K			
G6	2D																						A	B	C	D	E	F	G																			H	I	J	K		
G6	2E																							A	B	C	D	E	F	G																			H	I	J	K	
G6	2F																								A	B	C	D	E	F	G																			H	I	J	K

The strongest prospect for accelerating the finish sequence is the alteration of the reshoring requirements from the prescribed 2 framed with 4 shored levels to a more typical requirement of 2 framed and 2 shored levels.

Structural Breadth: Slab Redesign

It was found during this analysis that one of the most critical activities driving the progress of the finish trades was the removal of reshores. Reshores are put in place to support slabs during the curing process until they have reached full strength. The original reshore requirements for the slab at Reston Station were 2 framed floors with 4 additional shored floors. For example if the G1 slab was currently being poured the G2 framing would have to remain until G1 was completely poured. In addition, shoring would be in place on levels G4, G5, G6, and G7 (see figure 40). Reshores prevent the painting, traffic coating, and light fixture installation activities due to the lack of access to ceiling and floor space.

Figure 40: Reshoring Requirements



According to table 4-1 of ASCE 7-05 the minimum uniformly distributed live load in a garage structure is 40 psf. Alternatively, in table 2 of ASCE 37 the required construction live load on a project of this nature is 50 psf. The fact that the slabs were designed to hold a lighter load than the construction load is the reason that the structural engineer prescribed such an aggressive reshoring plan. In order to reduce the reshoring requirements the slab was redesigned to accommodate the construction loads instead of the loads associated with the end use of the building.

The way that engineers evaluate reshoring systems assumes that the framing and reshores transfer the excess loads from above floors down to the older slabs beneath. Therefore when a slab system's combined capacity is greater than the combined loading on those floors it is considered an adequate shoring plan. For this analysis a 5.5" drop panel redesign was found to satisfy the requirements of supporting both construction loads and design loads. The Process of this structural analysis is explained below and full hand calculations can be found in Appendix G.

Slab Design Process

1. Determining Design Loads

ASCE 37 defines the construction live loads for buildings in Table 2. For this analysis the most conservative value of 75 PSF was used to ensure stability and account for equipment storage issues mentioned previously in this report.

<u>Construction Loads</u>

- *Slab Dead Load (10" slab)* = 125 PSF
- *Formwork* = 10 PSF
- *Reshores* = 5 PSF
- *Construction Live Load* = 75 PSF

2. Check Deflection

The first requirement for determining slab thickness is checking deflection requirements. ACI 318-11 was used for this and according to table 9.5 a 2-way slab with drop panels and a 28 foot column to column span the minimum slab thickness is 9.33" which means the current selection of 10" is adequate.

3. Punching Shear Analysis of Worst Case Column

In the case of 2-way slabs, punching shear almost always controls so the ACI procedure for checking punching shear was applied to the new slab drop panel design. The P5 column on the G5 level was used due to its long spans and relatively small dimensions (24" square). The concrete used for the slabs was a design strength f'c of 5000 psi. A 5.5" drop panel was analyzed for punching shear at the recommendation of a structural engineering professional. A 5.5" drop panel allows for the use of dimensional lumber in forming. This is a key component to productivity on site because it reduces the need for cutting material on site.

<u>Punching Shear</u>

$V_u < \Phi V_c$

$V_u = q_u \times A_t$

$V_u = (298 \text{ PSF})(675 \text{ SF}) = 201{,}150$ Lbs

$V_{c1} = 4 \times \lambda \times \sqrt{f'c} \times b_{01} d_1$

$V_{c1} = 643{,}890$ lbs

$V_u < \Phi V_c$

$201{,}150 < 482{,}900$

OK

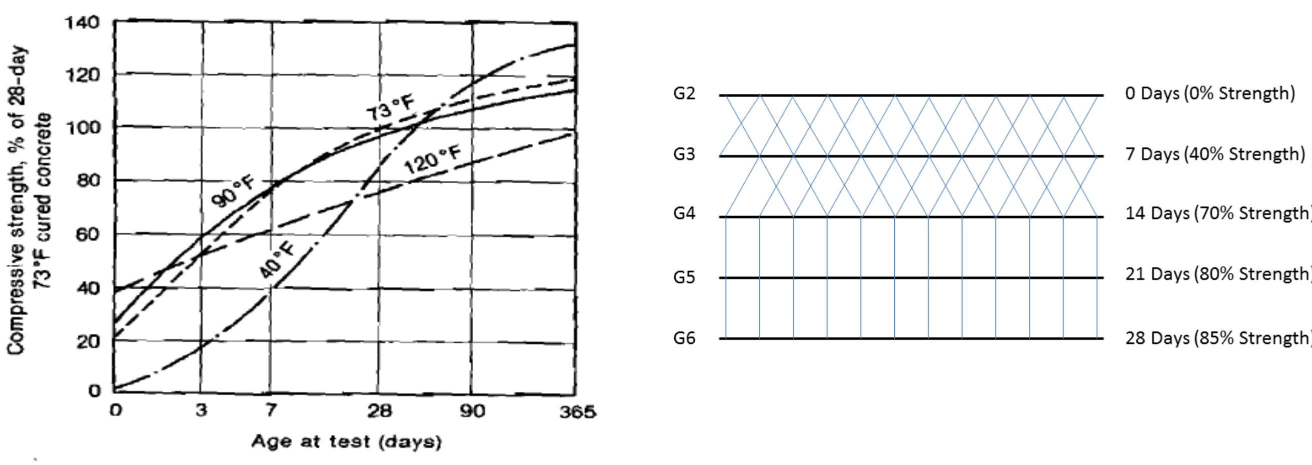
4. Analysis of Reshore 2+2 Scenario and Slab Strength Over Time

To determine their strength at the specific time represented in the reshoring calculation a curing temperature of 40 degrees Fahrenheit was assumed to be conservative. The strength over time curve used for this analysis can be seen in figure 41, taken from the text "Reinforced Concrete".

Using a conservative estimate of 7 days of curing for each floor (the same assumption in the original calculation) the system had the capacity of 2353 PSF and an ultimate load of 1400PSF which means the reshoring system using a 10" slab with 5 ½" drop panel is suitable for construction with a 2 framed and 2 reshored scenario. The full set of hand calculations is available in APPENDIX G of this report.

An extra inch of thickness to all drop panels of the garage results in an extra 1,850 cubic yards of concrete on the entire project. Using the RS Means value of $108/CY of concrete this results in a cost increase of approximately $200,000. This price only includes concrete material as labor will not change significantly. This result will now allow for G7 finish work to begin after the G3 slab is poured.

Figure 41: Strength of Concrete over Time



Recomendations

The short interval production scheduling for the garage space has both great advantages and high costs. The earliest finish date was achieved by using both SIPS scheduling and a slab redesign to include 5.5" drop panels. The cost of extra concrete in the structural redesign equals $200,000. This cost is equivalent to $2,500 per saved day. While this seems like a large sum of money, it is important to note that the liquidated damages associated with the construction contract total $10,000 per day past the date of substantial completion. This makes the SIPS sequence and the structural redesign a viable option in retrospect.

Figure 42: Comparison of Schedule Scenarios

SIPS Schedule Results				
Finish Scenario	*Start*	*Finish*	*Duration*	*Cost Increase*
Baseline Schedule	14-Feb-12	5-Feb-13	256	$ -
Uninterupted SIPS	14-Feb-12	18-Oct-12	178	$ -
SIPS w/ 4+2 Shoring	14-Feb-12	13-Nov-12	196	$ -
SIPS w/ 2+2 Shoring	2-Jan-12	10-Oct-12	203	$ 200,000.00

The recommendation to the project team is to re-evaluate the reasons for the current slab design and to consider designing the slab to meet the design loads for construction activities instead of garage service loads. This change to the slab design had the biggest impact on the end date of the finish sequence. Accelerating trade progress through reevaluation of crew sizes and SIPS sequence organization also has a significant effect on the duration of finish construction in the garage areas. It has been noted by structural consultants that the reasons for the aggressive reshoring requirements of the garage may be due to other considerations like protection against early deflections in the slab.

Analysis #4: Results of Adding Mechanical Chases between Garage and Future Building Areas

Problem Identification:

The underground garage and the above ground buildings at Reston Station are being designed concurrently due to the fast-track construction schedule of the 1st phase. Significant construction delays have been encountered due to the complications with structural and mechanical system design where the garage meets the 5 other buildings on the P1 level. Further complicating this issue is that Luis Fernandez and Associates is the structural engineer for the garage but Structura is the structural engineer for the apartment building and hotel. There are also 3 separate architects and 3 separate MEP engineers involved throughout the entire project. In order to reduce the impact that the future building designs have on the underground garage, the benefits and costs will be evaluated of including 5 mechanical chases in the garage design.

Research Goal:

The purpose of this analysis is to determine the impact that mechanical chases will have on the cost, schedule and work management process of the garage. Since the original design of the garage did not account for future buildings to be built above, including mechanical chases will eliminate the need to coordinate garage pipe and duct penetrations with a variety of designers of the future buildings. In this analysis, the maximum size of sanitary pipe and storm water drain pipe will be determined as a breadth analysis.

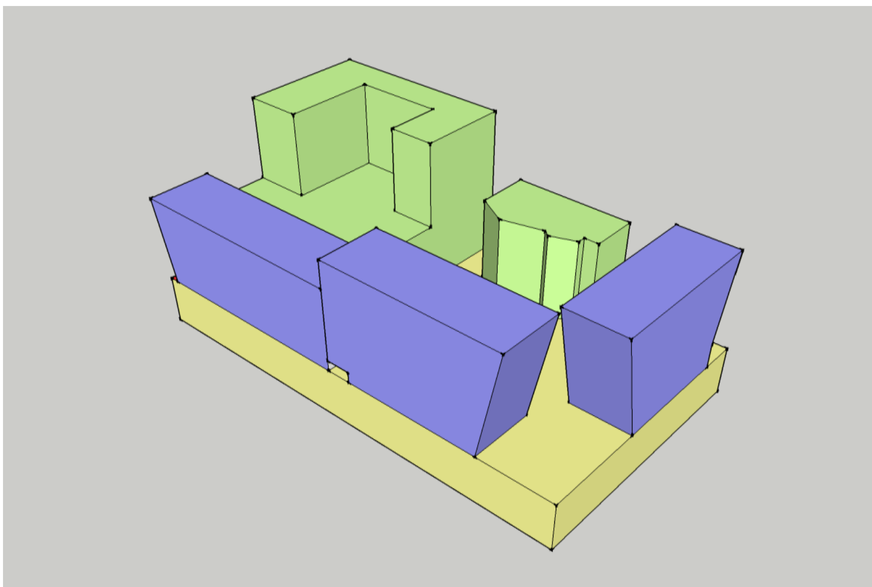
Methodology:

- Review design coordination scenario and current project experiences with pipe penetration coordination.
- Determine the pipe sizing for building storm and sanitary drains of the future buildings on site using International Plumbing Code compliance.
- With the size of these pipes decide on the location and size of mechanical chases within the original garage space to eliminate slab penetration ambiguity
- Determine the added and/or saved costs associated with this solution

Design Coordination

Comstock is the owner of the above ground buildings at the Reston Station development. For reasons of cost and quality Comstock chose to change design teams for these above ground buildings from the garage designers. All three office buildings are being designed by the team of Murphy Jahn, Thorton Thomasetti, and GHT Chartered. The apartment and hotel are designed by Hickok Cole, Structura, and Hoffman Borowski. As stated, the garage design team is made up of Davis Carter Scott, Luis Fernandez, and Jordan & Skala. This mixture of design teams leads to complications in coordination where the 6 structures meet at the plaza level. An illustration of the different design team responsibilities is available in Figure 43.

Figure 43: Responsibilities of the Multiple Design Teams



Architect - Hickok Cole Structural - Structura MEP - Hoffman Borowski	Architect – Davis, Carter, Scott Structural – Luis Fernandez MEP – Jordan & Skala	Architect – Murphy/Jahn Structural – Thorton Thomasetti MEP – GHT Chartered

One impact that this design separation has on the fast-track construction of the garage is the difficult coordination of slab penetrations in the garage for the above ground buildings. The original plan for the construction of the garage requires tight coordination with the future structures for the placement of pipe penetrations. If chases are included in the garage design, future construction will need to align accordingly with the opening of the 1st phase. The first step in this process was to determine the size of the pipes for the roof drain system and the sanitary drain system to determine a relative size for the chase. Since the future buildings were still in schematic design phase in early 2013 the sizes of the pipes were determined through the design methods presented in the mechanical breadth portion of this report.

Mechanical Breadth: Sizing Penetrations for Future Building Roof Drains and Sanitary Drains

The size of roof drains and pipes are based on maximum rainfall rates, roof slope, and horizontal projected roof areas. In Reston, Virginia the maximum 100-year rainfall rate is 3 inches/hour.[12] It was assumed that the slope of the flat roof on all buildings does not exceed ¼" per linear foot. In addition, a takeoff of the schematic designs revealed the horizontal projected area of each of the structures' roofs. The manner that the sizing was performed assumes that all the roof drains on a building consolidate to a single drain pipe before entering the garage area. The results of the takeoff and sizing can be seen in Figure 44.

Figure 44: Takeoff and Sizing of Roof Drain Piping

Building	Total Roof Area (SF)	Largest Roof Drain Pipe Size
Office Building 1	30000	10"
Office Building 2	40000	12"
Office Building 3	35400	10"
Apartment 4	58125	12"
Hotel 5	14400	8"

Size of Pipe in.	Flow at ¼ in./ft Slope gpm	Maximum Allowable Horizontal Projected Roof Areas Square Feet at Various Rainfall Rates				
		1 in./h	2 in./h	3 in./h	4 in./h	5 in./h
3	48	4640	2320	1546	1160	928
4	110	10,600	5300	3533	2650	2120
5	196	18,880	9440	6293	4720	3776
6	314	30,200	15,100	10,066	7550	6040
8	677	65,200	32,600	21,733	16,300	13,040
10	1214	116,800	58,400	38,950	29,200	23,350
12	1953	188,000	94,000	62,600	47,000	37,600
15	3491	336,000	168,000	112,000	84,000	67,250

The sizing of sanitary waste drain piping required that plumbing building loads be determined. The process began by finding the occupancy type and area of each occupied floor of each building. The occupant density requirements of ASHRAE standard 62 were used as a base value to determine the number of occupants per floor. Once the number of occupants on each floor was found, the number of plumbing fixtures could be determined using table 403.1 of the International Plumbing Code "Minimum Number of Required Plumbing Fixtures". The portion of the table that was utilized for this analysis can be seen in figure 45. The number of fixtures in the hotel and apartment buildings were found on the basis of the number of living units on each level. The results were determined and compiled through spreadsheets which can be found in Appendix H of this report.

[12] International Plumbing Code. International Code Council, Inc., Falls Church,VA.

Figure 45: IPC Fixture Requirements by Occupancy Type

TABLE 403.1 —continued
MINIMUM NUMBER OF REQUIRED PLUMBING FIXTURES[a]
(See Sections 403.2 and 403.3)

OCCUPANCY	DESCRIPTION	WATER CLOSETS (URINALS SEE SECTION 419.2) MALE	WATER CLOSETS FEMALE	LAVATORIES MALE	LAVATORIES FEMALE	BATHTUBS/ SHOWERS	DRINKING FOUNTAIN[e,f] (SEE SECTION 410.1)	OTHER
A-4	Coliseums, arenas, skating rinks, pools and tennis courts for indoor sporting events and activities	1 per 75 for the first 1,500 and 1 per 120 for the remainder exceeding 1,500	1 per 40 for the first 1,520 and 1 per 60 for the remainder exceeding 1,520	1 per 200	1 per 150	—	1 per 1,000	1 service sink
B	Buildings for the transaction of business, professional services, other services involving merchandise, office buildings, banks, light industrial and similar uses	1 per 25 for the first 50 and 1 per 50 for the remainder exceeding 50		1 per 40 for the first 80 and 1 per 80 for the remainder exceeding 80		—	1 per 100	1 service sink[g]
M	Retail stores, service stations, shops, salesrooms, markets and shopping centers	1 per 500		1 per 750		—	1 per 1,000	1 service sink[g]
R-1	Hotels, motels, boarding houses (transient)	1 per sleeping unit		1 per sleeping unit		1 per sleeping unit	—	1 service sink

The way that sanitary drainage loads are quantified is in Drainage Fixture Units. This allows for a standard measure of the amount of waste water that is drained from various, and otherwise dissimilar, fixtures and appliances. A table of the fixtures and appliances used in the above ground buildings of Reston Station and their related DFU's can be seen in figure 46. With the quantity of DFU's per building determined, a simple table dictates the necessary pipe diameter to adequately drain the waste water load. This result can be seen in figure 47. This analysis assumes that sanitary drain pipes run at no less than a slope of 1/8" every foot of linear space and that all sanitary waste drain pipes consolidate into a single pipe before exiting into the garage space. The exception to this assumption is the division of the apartment building's sanitary drains into two risers because the vertical drop to anyone location exceeds 3 feet. This would require an excessive ceiling plenum height.

Figure 46: DFU's of Related Fixtures

Table of Drainage Fixture Unit Values	
Automatic Clothes Washer	2
Shower	2
Dishwashing Machine	2
Lavatory	1
Kitchen Sink	2
Service Sink	2
No-Flush Urinal	0.5
Water Closet (Private)	3
Water Closet (Public)	4

Figure 47: DFU Results and Size Determination of Sanitary Waste Pipe

Building	DFU's	Building Sainitary Drain Size
Office Building 1	468.5	6"
Office Building 2	244	5"
Office Building 3	202	5"
Apartment 4	3116	12"
Hotel 5	1478	8"

TABLE 22.5 Building Drains and Sewers

Diameter of Pipe		*Maximum Number of dfu Connected to Any Portion of the Building Drain or Building Sewer, Including Branches of the Building Drain*[a] *Fall, in. per ft (% slope)*			
in.	mm[b]	1/16 (0.5%)	1/8 (1.04%)	1/4 (2.1%)	1/2 (4.2%)
2	51			21	26
2½	64			24	31
3	76		36	42	50
4	102		180	216	250
5	127		390	480	575
6	152		700	840	1000
8	203	1400	1600	1920	2300
10	254	2500	2900	3500	4200
12	305	3900	4600	5600	6700
15	381	7000	8300	10,000	12,000

Mechanical Chases in Garage

After the pipes were sized, the size and location of the chases must be determined so that they can be included in construction of the garage. There were three critical considerations for determining the location of these chases within the garage. Chases are generally close to other shafts in buildings like elevators and stairs. They should also be in a central location in a building to minimize the vertical drop in a drainage run. Finally, in the case of Reston Station, the interference with parking areas should be minimized as much as possible.

Fortunately, sanitary drain pipes and storm drainage pipes from the roofs do not need to extend down to the G7 level. The invert elevations of local utility systems for storm and sanitary from the garage is approximately 381'. This elevation is 6 feet above the G3 slab so the drain pipes from buildings to garage must only extend to this level. There is however, a system for garage floor drains that pumps the drained water from a drainage pit back up to the G3 level where it is released to the utility connection. This means that a single chase will need to extend to the G7 level in the vicinity of this pump.

To address all of these issues the addition of 6 mechanical chases was evaluated. Based on the maximum diameter of the roof drain and sanitary drain pipe a 6' x 8' chase was used to accommodate these plus any need for conduit, fire sprinkler piping, or domestic water supply. Metal grating supported by steel angle imbeds will allow for safe access to the chase from any garage level for maintenance but still provide flexibility for the pipe layout without core drilling or sacrificing structural stability. Typical 8" CMU block was assumed for walls and a door was added for access. An illustration of the typical chase can be seen in figure 48 and the chosen locations for these shafts can be seen in figure 49.

Figure 48: Garage Pipe Chase

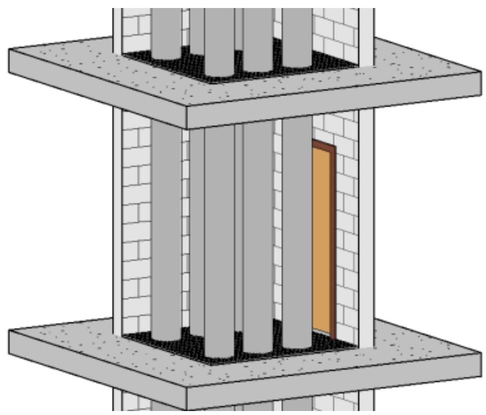
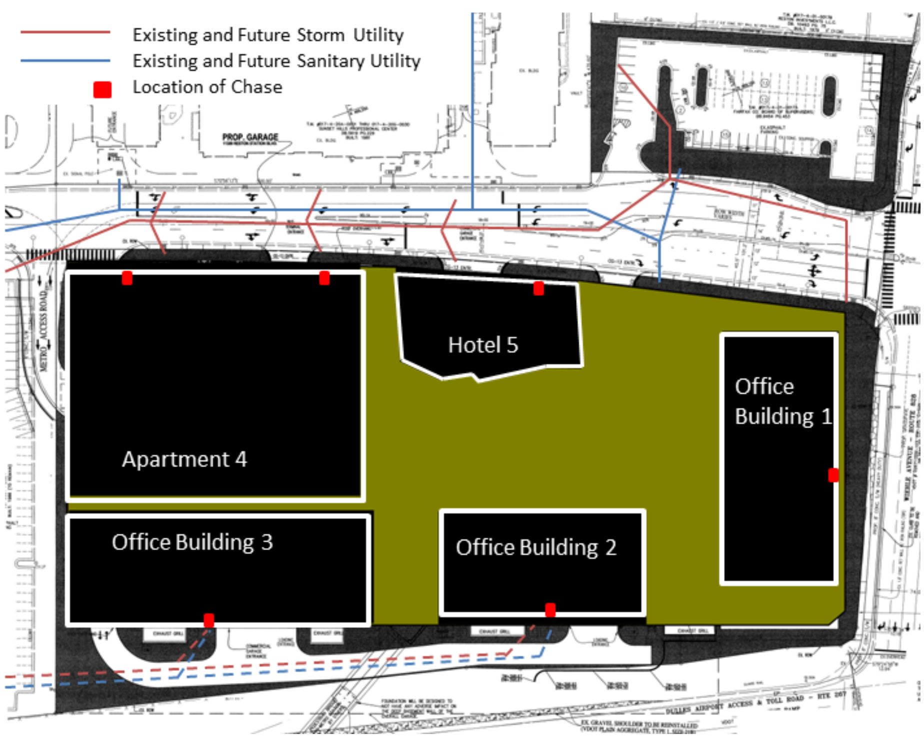


Figure 49: Garage Chase Locations



These locations best meet the criteria for the location of mechanical chases. They are in relatively central locations of the buildings. The longest run from a fixture to a shaft is less than 192 feet which allows for a vertical drop of less than 2 feet between fixture and riser connection. The locations are in suitable areas for stairwells and take up about the area of 1 parking space. Even though the possibility of redesigning the parking layout is not a part of this analysis, ten public spaces could be eliminated without redistribution efforts. This result may still be acceptable to Fairfax County because the minimum number of public spaces is 2300 and the final design included 2318. The opportunity cost of losing these 10 spaces can most likely be offset by an agreement between the owners or the construction cost advantages may outweigh the lost revenue from those spaces.

Cost Impact

The major cost impacts on the garage of the addition of mechanical chases are the added costs of the shaft walls and metal grating. The total cost increase for the addition of the chases is $99, 285. The detailed cost estimate for the added material labor and equipment as well as the assumptions used for the estimate is available in figure 50. This is a relatively large increase in cost but in order to see the actual value of the chases the cost of not including the chases must also be considered. This cost is best determined by calculating the cost of core drilling the slabs for penetrations as a future step in MEP riser construction.

Figure 50: Cost of Mechanical Chases

Cost of Chases								
Item	Unit	Quantity	Labor (Unit Cost)	Material (Unit Cost)	Equipment	Total Labor	Total Material	Total Equipment
Steel Grating	SF	1008	$ 14.85	$ 4.50	$ 2.49	$ 14,968.80	$ 4,536.00	$ 2,509.92
Steel Angles	Ea	56	$ 56.00	$ 29.50	$ -	$ 3,136.00	$ 1,652.00	$ -
HM Doors	Ea	28	$ 560.00	$ 39.00	$ -	$ 15,680.00	$ 1,092.00	$ -
HM Frames	Ea	28	$ 199.00	$ 44.00	$ -	$ 5,572.00	$ 1,232.00	$ -
CMU Block	SF	6688	$ 2.40	$ 4.34	$ -	$ 16,051.20	$ 29,025.92	$ -
Concrete Expansion Anchors	Ea	280	$ 2.38	$ 3.07	$ -	$ 666.40	$ 859.60	$ -
					Total	$ 56,074.40	$ 38,397.52	$ 2,509.92
					Tax		$ 2,303.85	
					Total	**$ 99,285.69**		

Assumptions
● CMU: regular block, not reinforced, 8"x16"x8" thick
● 3/4" Wedge Anchors for Concrete
● Steel Angle: 4"x3-1/2"x1/4" 9'0" long
● Grating: Cross bars @ 2" o.c. 1-1/4"x3/16"

The cost of core drilling the slab was determined by using RS Means. Since each chase was designed to house a maximum of 6, 12" pipes this assumption was made for the number and size of the penetrations. This results in 132 12" cores through 10" slab. Using the cost data found in figure 51 a resulting price of $11,000. This cost is significantly less than the expense of building chases in the orgional construction of the phase 1 garage.

Figure 51: Cost of Core Drilling

03 82 Concrete Boring

03 82 13 – Concrete Core Drilling

03 82 13.10 Core Drilling

0010	CORE DRILLING									
0020	Reinf. conc slab, up to 6" thick, incl. bit, layout & set up									
0100	1" diameter core	B-89A	17	.941	Ea.	.18	38	6.50	44.68	66
0150	Each added inch thick in same hole, add		1440	.011		.03	.45	.08	.56	.80
0200	2" diameter core		16.50	.970		.29	39	6.70	45.99	67.50
0250	Each added inch thick in same hole, add		1080	.015		.05	.60	.10	.75	1.08
0300	3" diameter core		16	1		.41	40.50	6.90	47.81	70
0350	Each added inch thick in same hole, add		720	.022		.07	.89	.15	1.11	1.62
0500	4" diameter core		15	1.067		.49	43	7.35	50.84	74.50
0550	Each added inch thick in same hole, add		480	.033		.49	1.34	.23	2.06	2.86
0700	6" diameter core		14	1.143		.81	46	7.85	54.66	80.50
0750	Each added inch thick in same hole, add		360	.044		.13	1.79	.31	2.23	3.25
0900	8" diameter core		13	1.231		1.03	49.50	8.50	59.03	87
0950	Each added inch thick in same hole, add		288	.056		.17	2.24	.38	2.79	4.06
1100	10" diameter core		12	1.333		1.50	53.50	9.20	64.20	95
1150	Each added inch thick in same hole, add		240	.067		.25	2.68	.46	3.39	4.92
1300	12" diameter core		11	1.455		1.65	58.50	10	70.15	103
1350	Each added inch thick in same hole, add		206	.078		.27	3.13	.54	3.94	5.70
1500	14" diameter core		10	1.600		2.07	64.50	11	77.57	114
1550	Each added inch thick in same hole, add		180	.089		.34	3.58	.61	4.53	6.55

12" Core Drills					
unit	Quantity	Material	Labor	Equipment	Total Cost
Ea	132	$ 2.75	$ 71.02	$ 12.16	$ 11,001.54

Recomendations

Three separate design teams are responsible for various segments of the Reston Station property. This causes several coordination issues throughout the garage, including the difficulty of determining exact locations for slab penetrations for various utility connections, especially those that must run downward into the garage. The schematic design data was used from each future building to size the maximum size of pipe that must be used as a main building riser. This allowed for the sizing of mechanical chases.

It was discovered that six 6' by 8' chases could handle the number and size of utility pipes and conduits that may be installed between the garage and future buildings. The construction of the chases would consist of CMU partition wall and a steel grating access floor at every level supported by steel angles. The cost of this design feature totaled a hefty price tag of approximately $99,000. This is in contrast to the price for core drilling the 12" diameter penetrations after the slab cures which costs in total approximately $11,000.

As a recommendation, I do not believe incorporating mechanical chases is a cost effective way of addressing the issue with design coordination. While the chase allows for an easier coordination effort between design teams, the difference in cost between chases and core drilling indicate that core drilling is still a better choice.

Final Recommendations and Conclusion

Analysis 1

Public-private partnerships are not currently used heavily in the commercial building construction industry but over time their use will likely grow as public entities search for new innovative ways to fund projects and save money. At Reston Station the biggest obstacle in the operation of the dual owner structure was the conflicts with decision making. The flow chart provided in the analysis is a good underlying structure for determining who has decision making power but the best way to reduce conflicts is to construct a system early in the project planning process to mitigate complication later in construction. The Long Beach Courthouse project is one example of how the construction of public facilities may look in the future. This project severely affected the operating budget for the courts system due to funding ambiguity and it is an example of the sort of pitfalls that must be avoided when entering into a new ownership arrangement.

Analysis 2

The use of bonded warehouses for off-site storage of equipment shows significant promise. The ability to protect expensive long lead items is extremely valuable in mitigating risk on site. Bonded warehouses can also be used when security measures necessitate their use like in the example of The Pentagon renovation. In the case of Reston Station a month-to-month logistics service would be the most economical option for the safe storage of valuable equipment. The option to lease and entire warehouse property is extremely cost prohibitive when considering the storage of only a limited number of items from one project. The extensive use of off-site storage through leasing could still be a viable option however where sites are extremely restricted or a number of projects have a long term need for safe storage of valuable equipment.

Analysis 3

Short interval project scheduling (SIPS) is a valuable tool for maximizing the efficiency of construction progress in a repetitive building. In the example of Reston Station, using SIPS sequencing and redesigning the slab drop panels was able to complete the finish sequence of the garage 85 days earlier with a cost of $200,000 for the structural redesign. This makes the cost of this schedule reduction $2350/saved day. This is a lower cost than the cost of liquidated damages which are $10,000/day past the date of substantial completion.

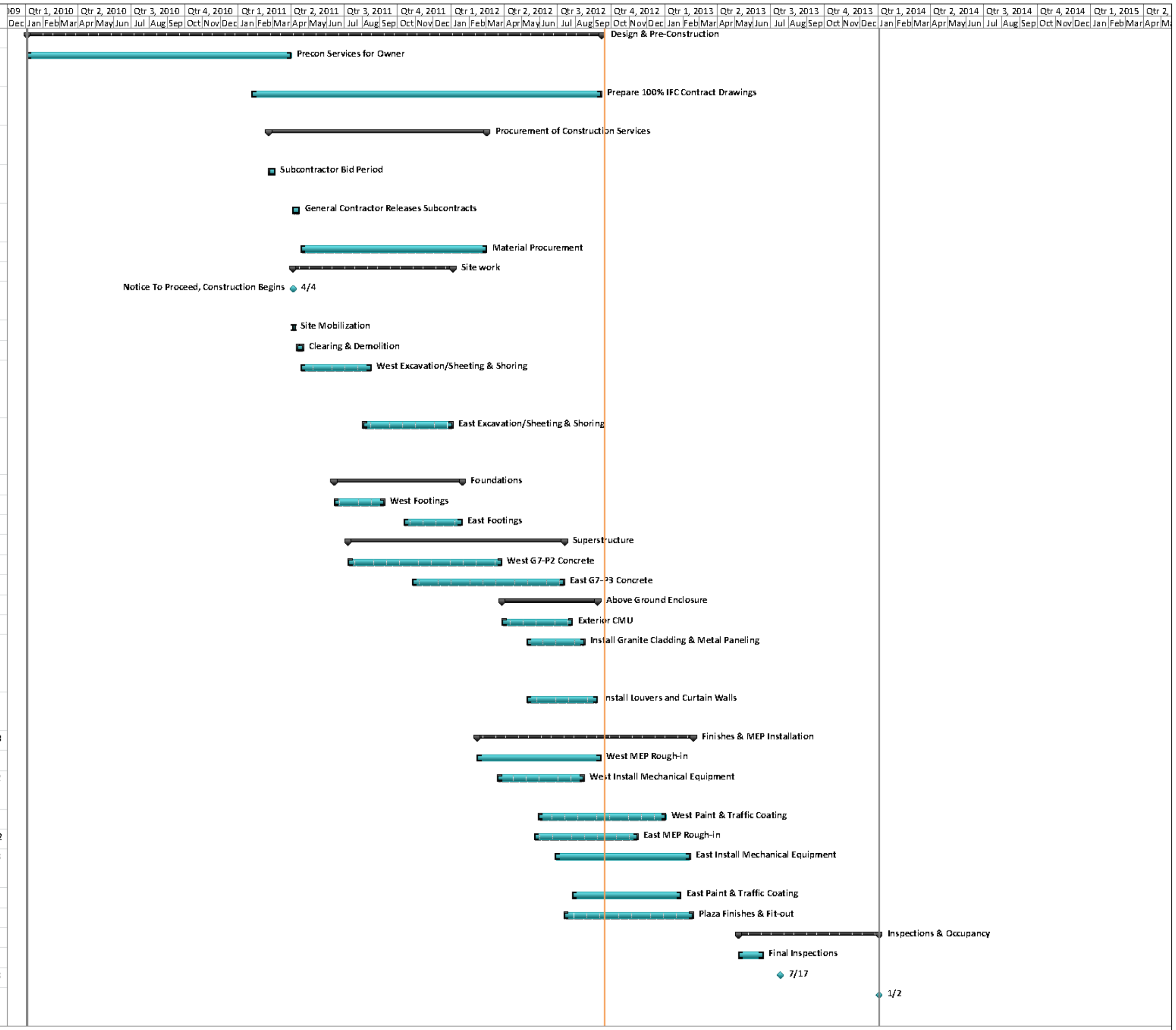
Analysis 4

The addition of mechanical chases to the original garage design alleviates the complications associated with the design coordination between the 3 different design teams on the various Reston Station projects. Unfortunately the cost of building mechanical chases into the garage for pipes and conduit that pass between the garage and future buildings is 9 times more expensive than the cost of core drilling the slab in the future when designs are finalized for their locations. The mechanical breadth associated with this analysis successfully determined the appropriate size of pipe for building sanitary and storm drains.

APPENDIX A

Project Summary Schedule

ID	Task Name	Duration	Start	Finish
1	**Design & Pre-Construction**	**705 days**	**Mon 1/4/10**	**Fri 9/14/12**
2	Precon Services for Owner	325 days	Mon 1/4/10	Fri 4/1/11
3	Prepare 100% IFC Contract Drawings	430 days	Mon 1/24/11	Fri 9/14/12
4	**Procurement of Construction Services**	**268 days**	**Tue 2/22/11**	**Thu 3/1/12**
5	Subcontractor Bid Period	9 days	Tue 2/22/11	Fri 3/4/11
6	General Contractor Releases Subcontracts	10 days	Mon 4/4/11	Fri 4/15/11
7	Material Procurement	229 days	Mon 4/18/11	Thu 3/1/12
8	**Site work**	**197 days**	**Mon 4/4/11**	**Tue 1/3/12**
9	Notice To Proceed, Construction Begins	1 day	Mon 4/4/11	Mon 4/4/11
10	Site Mobilization	5 days	Mon 4/4/11	Fri 4/8/11
11	Clearing & Demolition	10 days	Mon 4/11/11	Fri 4/22/11
12	West Excavation/Sheeting & Shoring	87 days	Mon 4/18/11	Tue 8/16/11
13	East Excavation/Sheeting & Shoring	111 days	Tue 8/2/11	Tue 1/3/12
14	**Foundations**	**158 days**	**Tue 6/14/11**	**Thu 1/19/12**
15	West Footings	63 days	Tue 6/14/11	Thu 9/8/11
16	East Footings	72 days	Wed 10/12/11	Thu 1/19/12
17	**Superstructure**	**265 days**	**Fri 7/8/11**	**Thu 7/12/12**
18	West G7-P2 Concrete	188 days	Fri 7/8/11	Tue 3/27/12
19	East G7-P3 Concrete	187 days	Wed 10/26/11	Thu 7/12/12
20	**Above Ground Enclosure**	**118 days**	**Wed 3/28/12**	**Fri 9/7/12**
21	Exterior CMU	87 days	Wed 3/28/12	Thu 7/26/12
22	Install Granite Cladding & Metal Paneling	72 days	Wed 5/9/12	Thu 8/16/12
23	Install Louvers and Curtain Walls	88 days	Wed 5/9/12	Fri 9/7/12
24	**Finishes & MEP Installation**	**265 days**	**Tue 2/14/12**	**Mon 2/18/13**
25	West MEP Rough-in	153 days	Tue 2/14/12	Thu 9/13/12
26	West Install Mechanical Equipment	107 days	Tue 3/20/12	Wed 8/15/12
27	West Paint & Traffic Coatin	157 days	Tue 5/29/12	Wed 1/2/13
28	East MEP Rough-in	128 days	Tue 5/22/12	Thu 11/15/12
29	East Install Mechanical Equipment	166 days	Wed 6/27/12	Wed 2/13/13
30	East Paint & Traffic Coating	133 days	Thu 7/26/12	Mon 1/28/13
31	Plaza Finishes & Fit-out	158 days	Thu 7/12/12	Mon 2/18/13
32	**Inspections & Occupancy**	**173 days**	**Tue 5/7/13**	**Thu 1/2/14**
33	Final Inspections	31 days	Tue 5/7/13	Tue 6/18/13
34	Substantial Completion	1 day	Wed 7/17/13	Wed 7/17/13
35	Metro Silver Line Goes Live	1 day	Thu 1/2/14	Thu 1/2/14



Project: Summary Schedule
Date: Thu 9/20/12

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Progress

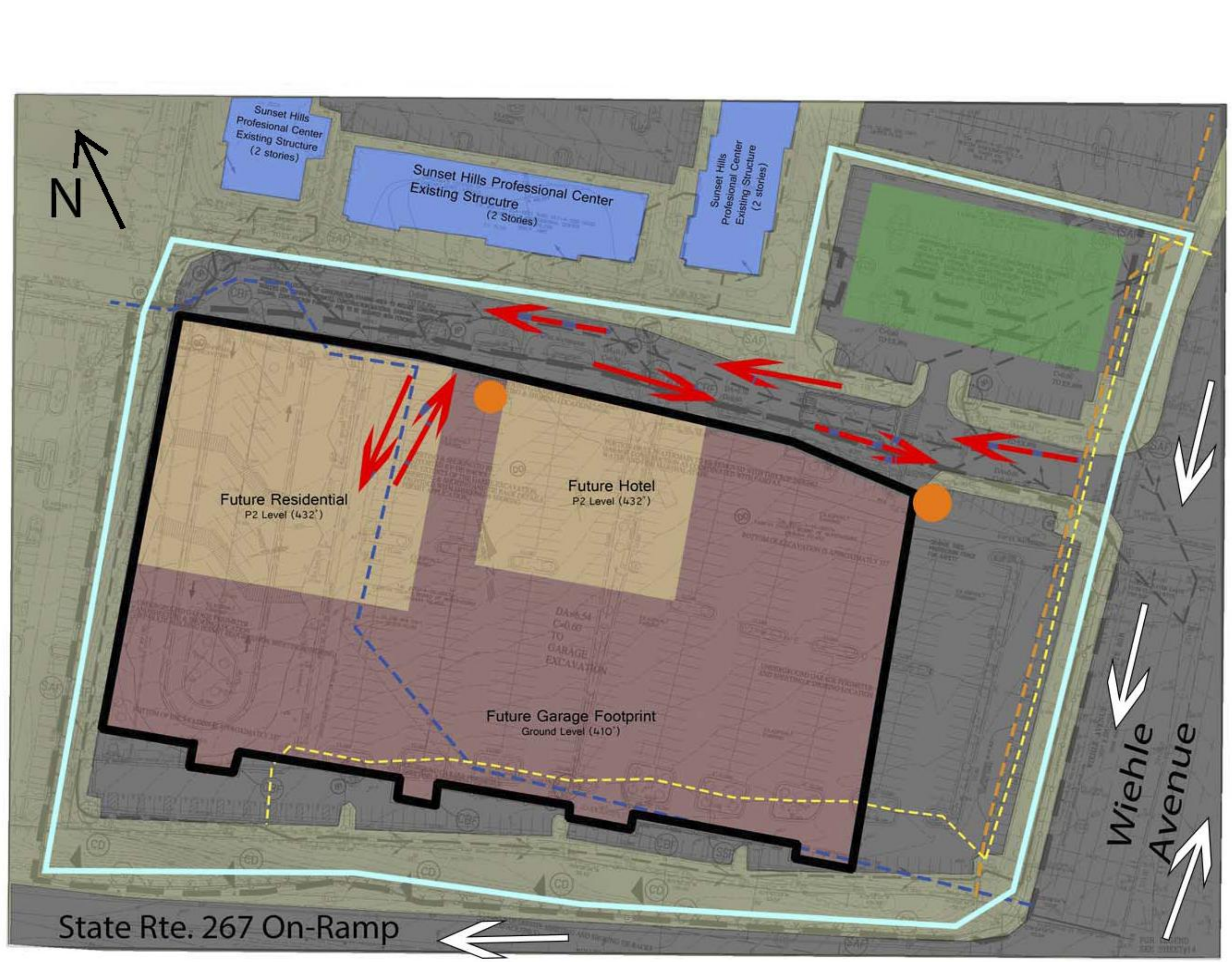
Jon Fisher
Building Summary Schedule
Date: 9/17/2012

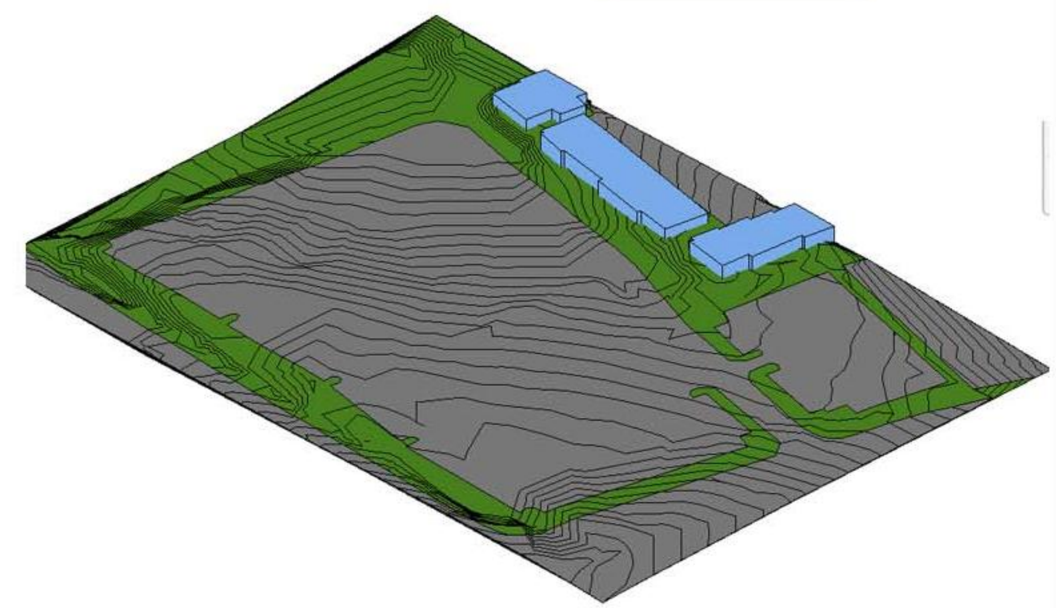
Reston Station Phase 1 Garage
Reston, VA

Advisor: Dr. Leicht

APPENDIX B

Existing Site Conditions





1 Site
1" = 100'-0"

PENNSTATE Department of Architectural Engineering	Reston Station Phase 1 Garage Jon Fisher

No.	Description	Date

Existing Conditions Plan

Project number	TA1	001
Date	9/21/2012	
Drawn by	Jon Fisher	
Checked by		Scale 1" = 100'-0"

9/16/2012 8:03:11 PM

APPENDIX C

Assembly and Structural Cost Estimate Data

MEP Assemblies Cost Estimate

Assembly Number	Description	Quantity	Unit	Materials	Labor	Total	Total Cost of Assembly
Mechanical Systems							
D3050 185 0580	CRAC, 3TON, Air cooled, Includes Remote Condenser	19	Ea	$19,600.00	$2,425.00	$22,025.00	$418,475.00
Total Mechanical							**$418,475.00**
Electrical Systems							
D5010 240 0400	2000A Switchgear	2	Ea	$ 35,800.00	$ 20,600.00	$ 56,400.00	$ 112,800.00
D5020 218 0400	Flourescent lighting, 1 Watt/SF	1,500,000	SF	$ 1.58	$ 2.06	$ 3.64	$ 5,460,000.00
D5020 135 0440	Misc Power to 2 Watts	1,500,000	SF	$ 0.13	$ 0.40	$ 0.53	$ 795,000.00
Total Electrical							**$ 6,367,800.00**
Fire Protection System							
D4010 310 0640	Dry Pipe Sprinkler System, Light Haz 50,000SF (1st floor)	200,000	SF	$ 1.80	$ 1.72	$ 3.52	$ 704,000.00
D4010 310 0760	Dry Pipe Sprinkler System, Light Haz 50,000SF(additional floors)	1,300,000	SF	$ 1.37	$ 1.53	$ 2.90	$ 3,770,000.00
Total Fire Protection							**$ 4,474,000.00**
Plumbing							
D2010 310 1560	Lavatory w/ trim	3	Ea	$ 800.00	$ 700.00	$ 1,500.00	$ 4,500.00
D2010 110 2080	Wall Hung Water Closet	3	Ea	$ 1,800.00	$ 795.00	$ 2,595.00	$ 7,785.00
D2020 240 2020	Electric Water Heater	2	Ea	$ 29,900.00	$ 1,825.00	$ 31,725.00	$ 63,450.00
Total Plumbing							**$ 75,735.00**

Detailed Structural Estimate Between Column Lines 4 and 5

Code	Item	Unit	Quantity	Waste Factor	Material	Labor	Equipment	Total	Total Cost in Selected Bay
Division 03 11 13 Structural Cast-in-Place Concrete Forming									
03 11 13.20 2500	Form in place interior beam, 24" wide, 1 use	SFCA	1833	1.1	$2.55	$6.55		$9.10	$18,343.33
03 11 13.25 6500	Forms in place columns, Job-built Plywood 24"x24"	SFCA	12470	1.1	$2.97	$7.15		$10.12	$138,816.04
03 11 13.25 7000	Forms in place columns, Job-built Plywood 36"x36"	SFCA	12028	1.1	$2.47	$6.80		$9.27	$122,644.42
03 11 13.35 2000	Forms in place Elevated flat slab with drop panels	SF	64745	1.1	$4.06	$4.67		$8.73	$621,746.24
03 11 13.45 5000	Forms in place Spread footings, 1 use	SFCA	4984	1.1	$2.00	$4.46		$6.46	$35,418.67
03 11 13.65 3000	Forms in place Slab on Grade, wood edge forms up to 6"	LF	660	1.1	$0.31	$2.27		$2.58	$1,873.08
03 11 13.85 2400	Forms in place Walls, 8'-16' high, job-built, 1 use	SFCA	7709	1.1	$2.82	$7.50		$10.32	$87,508.71
03 11 13.85 4200	Forms in place Walls, Below grade, job-built, 1 use	SFCA	7268	1.1	$2.33	$9.30		$11.63	$92,980.04
Division 03 21 10 Uncoated Reinforcing Steel									
03 21 10.60 0150	Beams and Girders #8-#18	Ton	5.8	1.1	$1,000.00	$590.00		$1,590.00	$10,084.21
03 21 10.60 0250	Columns #8-#18	Ton	119.4	1.1	$1,000.00	$695.00		$1,695.00	$222,560.09
03 21 10.60 0400	Elevated Slabs #4-#7	Ton	57.1	1.1	$1,000.00	$550.00		$1,550.00	$97,298.62
03 21 10.60 0550	Footings #8-#18	Ton	25.7	1.1	$1,000.00	$445.00		$1,445.00	$40,917.32
03 21 10.60 0700	Walls #3-#7	Ton	16.4	1.1	$1,000.00	$530.00		$1,530.00	$27,663.50
03 21 10.60 0750	Walls #8-#18	Ton	7.5	1.1	$1,000.00	$400.00		$1,400.00	$11,533.60
Division 03 21 16 Epoxy Coated Reinforcing Steel Bars									
03 21 13.10 0100	Elevated Slab #4-#7 Epoxy Coated Rebar	Ton	54.4	1.1	$1,465.00	$550.00		$2,015.00	$120,613.04
Division 03 22 05 Uncoated Welded Wire Fabric									
03 22 05.50 0200	6x6 W2.1xW2.1 (8x8)	CSF	90	1.1	$17.35	$25.50		$42.85	$4,242.15
Division 03 31 05 Normal Weight Structural Concrete									
03 31 05.35 0300/1410	4000 psi + mid range water reducer	CY	209	1.1	$105.79			$105.79	$24,375.00
03 31 05.35 0400/1410	5000 psi + mid range water reducer	CY	2304	1.1	$111.79			$111.79	$283,359.48
03 31 05.35 0411/1410	6000 psi + mid range water reducer	CY	866	1.1	$126.79			$126.79	$120,840.20
03 31 05.35 0412/1410	8000 psi + mid range water reducer	CY	105	1.1	$204.79			$204.79	$23,594.84
03 31 05.35 0413/1410	10000 psi + mid range water reducer	CY	324	1.1	$288.79			$288.79	$102,880.64
03 31 05.70 2650	Placing footings, spread, over 5CY, pumped	CY	809	1.1		$16.30	$5.20	$21.50	$19,144.35
03 31 05.70 4350	Placing Slab on grade up to 6", Pumped	CY	139	1.1		$18.80	$6.00	$24.80	$3,788.89
03 31 05.70 0850	Placing columns 24" thick, w/ crane&bucket	CY	244	1.1		$39.50	$17.20	$56.70	$15,213.66
03 31 05.70 1050	Placing columns 36" thick, w/ crane&bucket	CY	312	1.1		$28.00	$12.05	$40.05	$13,753.73
03 31 05.70 1650	Elevated Slabs 10" and thicker, w/ crane&bucket	CY	2262	1.1		$21.50	$9.25	$30.75	$76,508.03
03 31 05.70 5400	placing walls 15" thick, w/ crane&bucket	CY	277	1.1		$29.50	$12.70	$42.20	$12,848.54
03 31 05.70 0100	placing beams w/ crane & bucket	CY	42	1.1		$62.00	$27.00	$89.00	$4,154.71
	Raw Totals				$1,320,954.50	$991,308.68	$42,441.91		$2,354,705.09
	Tax				$660,477.25				
	Cost with Tax								$3,015,182.34
	Location adjustment (Fairfax, VA)								0.92
	Final Cost								$2,773,967.75

APPENDIX D

Cost Analysis of Bonded Warehouses

Cost of Renting Bonded Warehouse Space (Short Term Limited Use)

Storage Costs

Item	*Cost*	*Quantity*	*Unit*	*Duration (mo)*	*Total*	*Notes*
Oversize Pallets For Fans	$ 20.00	220	/pallet/m	2	$ 8,800.00	Transwestern Estimate
Drop Trailer Rental	$ 150.00	4	/mo	6	$ 3,600.00	England Logistics Quote
Drop Trailer Drop off/ Pick up	$ 125.00	8	Ea		$ 1,000.00	England Logistics Quote
40 foot drop trailer storage	$ 300.00	4	/drop trail	6	$ 7,200.00	Transwestern Estimate
				TOTAL	$ 20,600.00	

Transportation Costs

Item	*Cost*	*Quantity*	*Unit*		*Total*	*Notes*
"Live Load" delivery of fans and stone	$ 400.00	14	/ Load		$ 5,600.00	England Logistics Quote
"Live Load" delivery of escalator drop trailers	$ 500.00	4	/Load		$ 2,000.00	England Logistics Quote
				TOTAL	$ 7,600.00	

Value of Goods Being Stored and Transported

Item	*Cost*	*Quantity*	*Unit*		*Total*	*Notes*
Granite Stone Façade	$ 18.00	10200	SF		$ 183,600.00	
Garage Supply Air Fans	$ 3,140.00	50	Ea		$ 157,000.00	
Garage Exhaust Air Fans	$ 2,700.00	90	Ea		$ 243,000.00	
Escalator Trusses	$ 110,000.00	2	Ea		$ 220,000.00	
				TOTAL	$ 803,600.00	

Total Cost of Off Site Storage of Limited Items

Storage Cost	$ 20,600.00
Transportation Cost	$ 7,600.00
Bonding (1% Value of Goods)	$ 8,036.00
TOTAL	$ 36,236.00

Cost of Renting Bonded Warehouse Space (Long Term Extensive Use)

Storage Costs

Item	Cost	Quantity	Unit	Duration (Yr)	Total	Notes
Lease on Warehouse Space	$ 12.00	24,643	/SF/Year	3	$ 887,148.00	Minimum 3-year Lease, Transwestern
Bonding	$ 8,871.48				$ 8,871.48	1% of Lease Value
				TOTAL	$ 896,019.48	

Staffing Costs

Team Member	Cost	Quantity	Unit	Duration	Total	Notes
Warehouse Manager	$ 80,000.00	1	/Year	3	$ 240,000.00	Includes Phone + Computer + Benefits
Drivers	$ 70,000.00	2	/Year	3	$ 420,000.00	Includes Phone + Benefits
				TOTAL	$ 660,000.00	

Transportation Costs

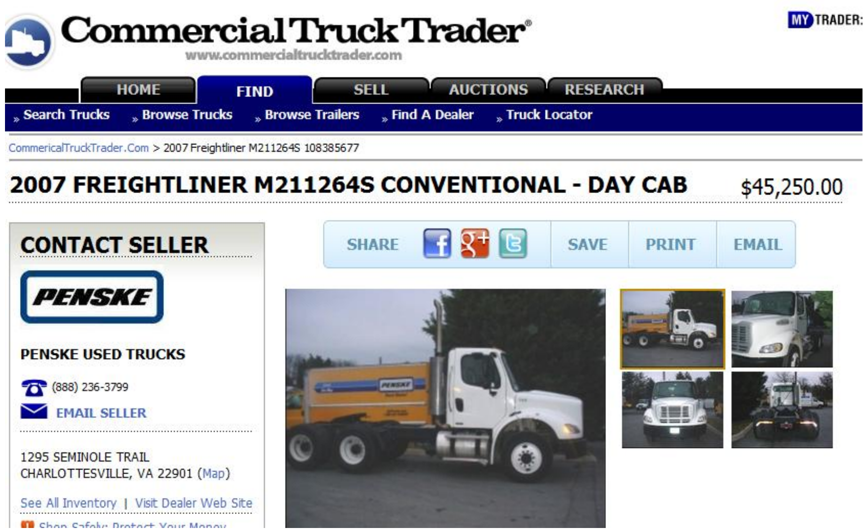
Item	Cost	Quantity	Unit	Duration	Total	Notes
Truck (Class 8)	$ 45,000.00	2	Ea		$ 90,000.00	
Flatbed Trailer	$ 15,000.00	1	Ea		$ 15,000.00	
Dry Van Trailer	$ 5,000.00	1	Ea		$ 5,000.00	
Diesel Gas	$ 4.25	16	Gal/Day	765	$ 52,020.00	Duration = Workdays in 3 Years
				TOTAL	$ 162,020.00	

Total Cost of Off Long Term Off Site Storage

Storage Cost	$ 896,019.48
Transportation Cost	$ 162,020.00
Staff	$ 660,000.00
TOTAL	$ 1,718,039.48

APPENDIX E

Assumptions and Calculations for Cost of Bonded Warehouses

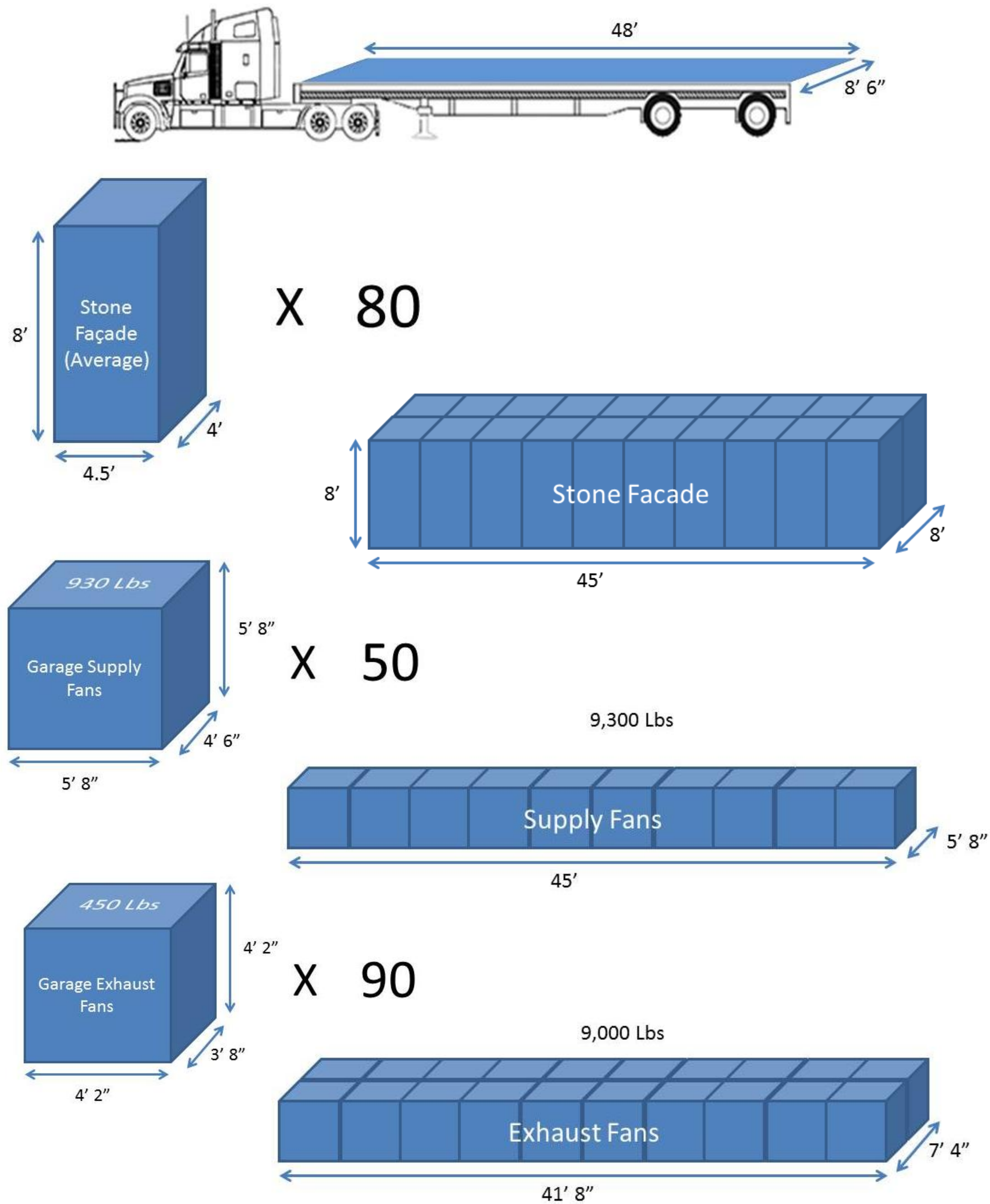


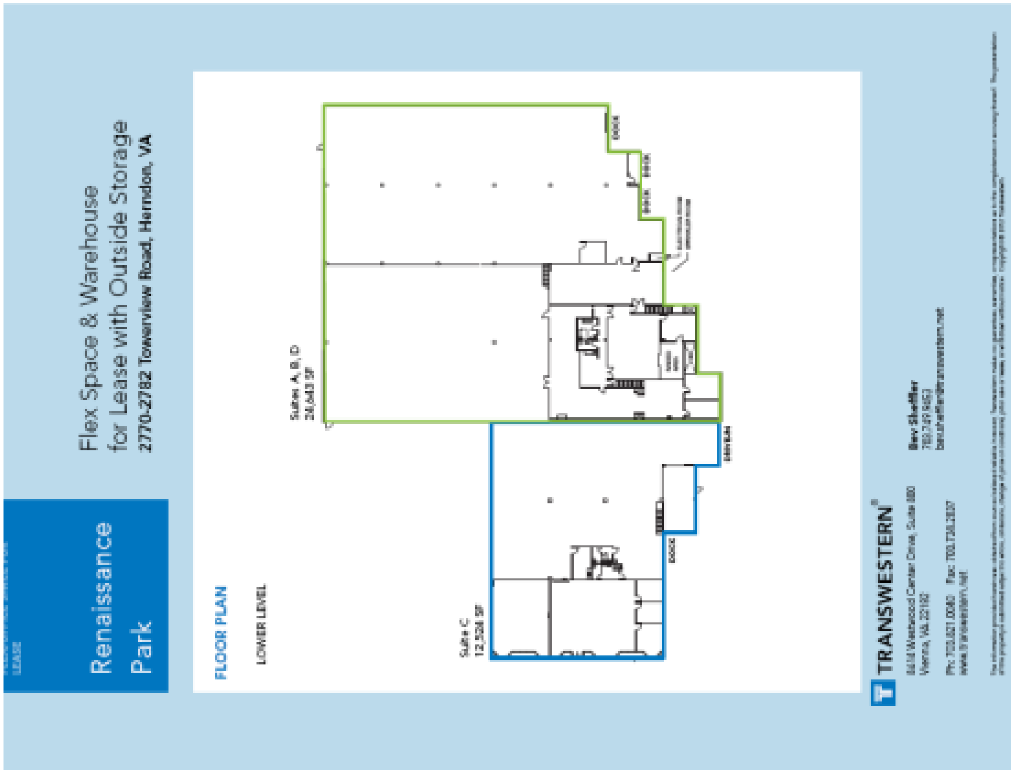
Fuel Consumption:

2770 Towerview Road, Herndon, VA (Warehouse) to 1860 Wiehle Ave, Reston, VA (Jobsite) = 8 Mi

Assume 6 Deliveries per day from warehouse = 8miles * 12 trips = 96 Miles/day

Department of Energy estimates Class 8 trucks = 6 mpg


48'
8' 6"
8'
Stone
Façade
(Average)
4'
4.5'
X 80
8'
Stone Facade
8'
45'
930 Lbs
Garage Supply
Fans
5' 8"
4' 6"
5' 8"
X 50
9,300 Lbs
Supply Fans
5' 8"
45'
450 Lbs
Garage Exhaust
Fans
4' 2"
3' 8"
4' 2"
X 90
9,000 Lbs
Exhaust Fans
7' 4"
41' 8"


Renaissance Park
Flex Space & Warehouse for Lease with Outside Storage
2770-2782 Towerview Road, Herndon, VA
FLOOR PLAN
LOWER LEVEL
Suites A, B, D
24,643 SF
Suite C
12,524 SF
TRANSWESTERN
Bev Sheffler


Renaissance Park
Flex Space & Warehouse for Lease with Outside Storage
2770-2782 Towerview Road, Herndon, VA
12,524 SF Flex
3,000 SF of office
100% conditioned warehouse
1 dock and 1 drive-in
$10.00 PSF, NNN
24,643 SF Industrial
4,000 SF of office
Secured outside storage
3 docks
$8.50 PSF, NNN
2012 operating expenses (estimated) $2.15 PSF
AMENITIES
Building has capacity for 8MVA of power
Deli on-site
Minutes from Dulles Airport
Nearby amenities include hotels, restaurants, health club and more
TRANSWESTERN
Bev Sheffler

APPENDIX F

Matrix Schedule

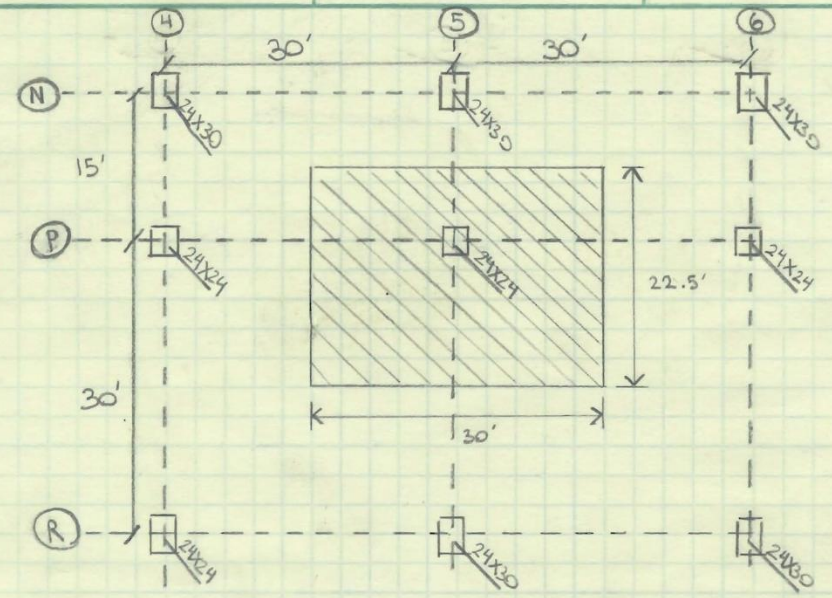
Level	Subzone	14-Feb	15-Feb	16-Feb	17-Feb	20-Feb	21-Feb	22-Feb	23-Feb	24-Feb	27-Feb	28-Feb	29-Feb	1-Mar	2-Mar	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	26-Mar	27-Mar	28-Mar	29-Mar
G7	1A	A	B	C	D	E	F	G	H	I	J	K																						
G7	1B		A	B	C	D	E	F	G	H	I	J	K																					
G7	1C			A	B	C	D	E	F	G	H	I	J	K																				
G7	1D				A	B	C	D	E	F	G	H	I	J	K																			
G7	1E					A	B	C	D	E	F	G	H	I	J	K																		
G7	1F						A	B	C	D	E	F	G	H	I	J	K																	
G7	2A							A	B	C	D	E	F	G	H	I	J	K																
G7	2B								A	B	C	D	E	F	G	H	I	J	K															
G7	2C									A	B	C	D	E	F	G	H	I	J	K														
G7	2D										A	B	C	D	E	F	G	H	I	J	K													
G7	2E											A	B	C	D	E	F	G	H	I	J	K												
G7	2F												A	B	C	D	E	F	G	H	I	J	K											
G6	1A													A	B	C	D	E	F	G	H	I	J	K										
G6	1B														A	B	C	D	E	F	G	H	I	J	K									
G6	1C															A	B	C	D	E	F	G	H	I	J	K								
G6	1D																A	B	C	D	E	F	G	H	I	J	K							
G6	1E																	A	B	C	D	E	F	G	H	I	J	K						
G6	1F																		A	B	C	D	E	F	G	H	I	J	K					
G6	2A																			A	B	C	D	E	F	G	H	I	J	K				
G6	2B																				A	B	C	D	E	F	G	H	I	J	K			
G6	2C																					A	B	C	D	E	F	G	H	I	J	K		
G6	2D																						A	B	C	D	E	F	G	H	I	J	K	
G6	2E																							A	B	C	D	E	F	G	H	I	J	K

3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	10-Sep	11-Sep	12-Sep	13-Sep	14-Sep	17-Sep	18-Sep	19-Sep	20-Sep	21-Sep	24-Sep	25-Sep	26-Sep	27-Sep	28-Sep	1-Oct	2-Oct	3-Oct	4-Oct	5-Oct	8-Oct	9-Oct	10-Oct	11-Oct	12-Oct	15-Oct	16-Oct	17-Oct	18-Oct	Level	Subzone
A	B	C	D	E	F	G	H	I	J	K																								G2	3A
	A	B	C	D	E	F	G	H	I	J	K																							G2	3B
		A	B	C	D	E	F	G	H	I	J	K																						G2	3C
			A	B	C	D	E	F	G	H	I	J	K																					G2	3D
				A	B	C	D	E	F	G	H	I	J	K																				G2	3E
					A	B	C	D	E	F	G	H	I	J	K																			G2	3F
						A	B	C	D	E	F	G	H	I	J	K																		G2	4A
							A	B	C	D	E	F	G	H	I	J	K																	G2	4B
								A	B	C	D	E	F	G	H	I	J	K																G2	4C
									A	B	C	D	E	F	G	H	I	J	K															G2	4D
										A	B	C	D	E	F	G	H	I	J	K														G2	4E
											A	B	C	D	E	F	G	H	I	J	K													G2	4F
												A	B	C	D	E	F	G	H	I	J	K												G1	3A
													A	B	C	D	E	F	G	H	I	J	K											G1	3B
														A	B	C	D	E	F	G	H	I	J	K										G1	3C
															A	B	C	D	E	F	G	H	I	J	K									G1	3D
																A	B	C	D	E	F	G	H	I	J	K								G1	3E
																	A	B	C	D	E	F	G	H	I	J	K							G1	3F
																		A	B	C	D	E	F	G	H	I	J	K						G1	4A
																			A	B	C	D	E	F	G	H	I	J	K					G1	4B
																				A	B	C	D	E	F	G	H	I	J	K				G1	4C
																					A	B	C	D	E	F	G	H	I	J	K			G1	4D
																						A	B	C	D	E	F	G	H	I	J	K		G1	4E
																							A	B	C	D	E	F	G	H	I	J	K	G1	4F

APPENDIX G

Structural Hand Calculations

Structural Breadth | Slab Redesign | 5.5" drop panel



Evaluation of slab @ Column P5 on G5 Level (5.5" drop panel) redesign

Loads

Slab Dead Load = 141 PSF

Formwork (DL) = 10 PSF

Construction Live Load = 75 PSF (ASCE 37 Table 2, heavy Equipment)

$q_u = 1.2D + 1.6L$

$q_u = 1.2(151\ PSF) + 1.6(75\ PSF) = 301\ PSF$

Deflection ACI 318-11

2 way slab w/ drop panels (table 9.5)

$h > l_n/36$

$10 > 28(12)/36$

$10 > 9.33$

$\therefore$ OK

Structural Breadth	Slab Redesign	5.5" drop panel

Punching shear

$V_u < \Phi V_c$

$V_u = q_u A_T$

$V_u = (301 \text{ PSF})(675 \text{ PSF})$

$V_u = 203,175 \text{ lbs}$

$V_{c_1} = 4\lambda\sqrt{f'c}\, b_{o_1} d$

$V_{c_1} = 4\sqrt{5000}\,(157)(14.75")$

$V_{c_1} = 643,890 \text{ lbs}$

$V_u < \Phi V_c$

$201,150 < (.75)(643,890)$

$201,150 < 482,900$

$\therefore$ OK

$V_{c_2} = 4\lambda\sqrt{f'c}\, b_{o_2} d$

$V_{c_2} = 4\sqrt{5000}\,(524)(9.25)$

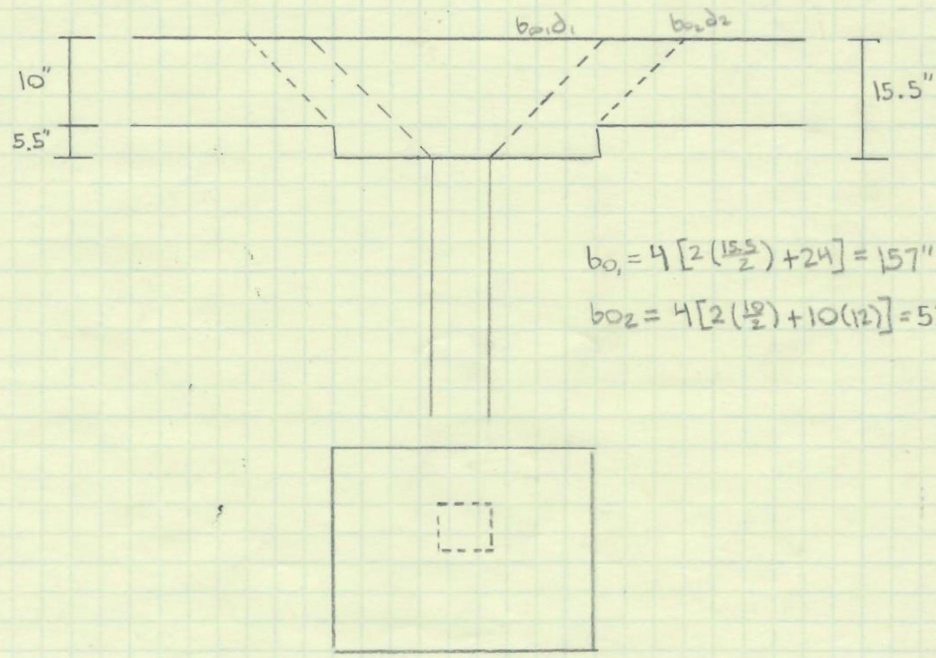
$V_{c_2} = 1,646,710 \text{ lbs}$

$V_u < \Phi V_c$

$201,150 < (.75)(1,646,710)$

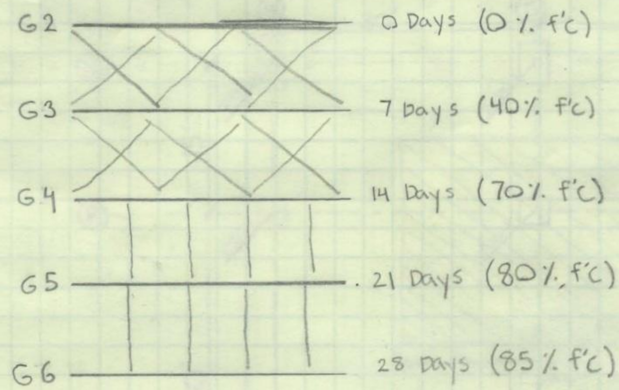
$201,150 < 1,235,032$

$\therefore$ OK



$b_{o_1} = 4\left[2\left(\frac{15.5}{2}\right) + 24\right] = 157"$

$b_{o_2} = 4\left[2\left(\frac{10}{2}\right) + 10(12)\right] = 524"$



* Assume 40° F cure temperature

Level	capacity	ultimate Load
G2	0	298 psf
G3	452 psf	298 psf
G4	600 psf	298 psf
G5	640 psf	293 psf
G6	660 psf	293 psf
	2352 psf >	1480 psf OK

G3: $\frac{\Phi V_{c_1}}{A_T} = \frac{4\lambda\sqrt{.4 \times f'c}\, b_{o,}d_1}{A_T} = \frac{(.75)(407230)}{675 \text{ sf}} = 452$ psf

G4: $\frac{\Phi V_{c_1}}{A_T} = \frac{4\lambda\sqrt{.7 \times f'c}\, b_{o,}d_1}{A_T} = \frac{(.75)(538700)}{675 \text{ sf}} = 500$ psf

G5: $\frac{\Phi V_{c_1}}{A_T} = \frac{4\lambda\sqrt{.8 \times f'c}\, b_{o,}d_1}{A_T} = \frac{(.75)(575914)}{675 \text{ sf}} = 640$ psf

G6: $\frac{\Phi V_{c_1}}{A_T} = \frac{4\lambda\sqrt{.85 \times f'c}\, b_{o,}d_1}{A_T} = \frac{(.75)(593600)}{675 \text{ sf}} = 660$ psf

* Note: these calculations are considered conservative and do not implicate that construction will progress at a rate of 1 floor per 7 days. This is only to show that a 2+2 reshore system is adequate when construction progresses no faster than 1 floor per 7 days.

APPENDIX H

Building Sanitary Drainage Load Calculation

Office Building 1								
Floor	*Area*	*Classification*	*Area/Occupant (SF)*	*# of Occupants*	*Public Water Closets*	*Urinals*	*Lavatories*	*Service Sink*
L1	7700	Mercantile	66	117	2	2	2	1
L2	12900	Bussiness	150	86	4	3	4	1
L3	16600	Bussiness	150	111	6	4	4	1
L4	17150	Bussiness	150	114	6	4	4	1
L5	17690	Bussiness	150	118	6	4	4	1
L6	23470	Bussiness	150	156	6	4	4	1
L7	24000	Bussiness	150	160	6	4	4	1
L8	24600	Bussiness	150	164	6	4	6	1
L9	25000	Bussiness	150	167	6	4	6	1
L10	25600	Bussiness	150	171	6	4	6	1
L11	26100	Bussiness	150	174	6	4	6	1
L12	26600	Bussiness	150	177	6	4	6	1
L13	27200	Bussiness	150	181	6	4	6	1
L14	27700	Bussiness	150	185	6	4	6	1
L15	28400	Bussiness	150	189	6	4	6	1
				Total Fixtures	84	57	74	15
				dfu's	336	28.5	74	30
				Building dfu's	468.5			

Office Building 2								
Floor	*Area*	*Classification*	*Area/Occupant (SF)*	*# of Occupants*	*Public Water Closets*	*Urinals*	*Lavatories*	*Service Sink*
L1	14000	Mercantile	66	212	2	2	2	1
L10	25720	Bussiness	150	171	6	4	6	1
L11	26150	Bussiness	150	174	6	4	6	1
L12	26535	Bussiness	150	177	6	4	6	1
L13	38070	Bussiness	150	254	8	6	6	1
L14	38500	Bussiness	150	257	8	6	6	1
L15	38900	Bussiness	150	259	8	6	6	1
				Total Fixtures	44	32	38	7
				dfu's	176	16	38	14
				Building dfu's	244			

Office Building 3								
Floor	*Area*	*Classification*	*Area/Occupant (SF)*	*# of Occupants*	*# Water Closets*	*Urinals*	*# Lavatories*	*Service Sink*
L1	7000	Mercantile	66	106	2	2	2	1
L10	25600	Assembly (A-4)	25	1024	20	12	7	1
L11	26100	Assembly (A-4)	25	1044	20	12	7	1
				Total Fixtures	42	26	16	3
				dfu's	167	13	16	6
				Building dfu's	202			

Apartment 4														
Floor	*Area*	*Classification*	*Area/Occupant (SF)*	*Studios*	*1 BR*	*2 BR*	*3BR*	*Water Closets*	*Lavatories*	*Showers*	*Sinks*	*Dishwashers*	*Clotheswashers*	*Service Sink*
P1	2700	Assembly	10					8	6					1
	7600	Residential	200	2	3	2		9	9	9	7	7	7	1
	1600	Bussiness	150					2	2					1
P2	10600	Residential	200	2	3	2		9	9	9	7	7	7	1
P3	18150	Residential	200	5	9	3		20	20	20	17	17	17	1
P4	18100	Residential	200	5	9	3		20	20	20	17	17	17	1
P5	17850	Residential	200	5	9	3		20	20	20	17	17	17	1
P6	17850	Residential	200	5	9	3		20	20	20	17	17	17	1
P7	17800	Residential	200	6	8	3		20	20	20	17	17	17	1
P8	17800	Residential	200	6	8	3		20	20	20	17	17	17	1
R9	17800	Residential	200	8	14	8		38	38	38	30	30	30	1
R10	29000	Residential	200	8	14	7		36	36	36	29	29	29	1
R11	29000	Residential	200	5	14	9		37	37	37	28	28	28	1
R12	29000	Residential	200	7	14	9		39	39	39	30	30	30	1
R13	29000	Residential	200	7	14	9		39	39	39	30	30	30	1
R14	29000	Residential	200	7	14	9		39	39	39	30	30	30	1
R15	29000	Residential	200	7	14	9		39	39	39	30	30	30	1
R16	29000	Residential	200	7	14	9		39	39	39	30	30	30	1
R17	28000	Residential	200	7	14	9		39	39	39	30	30	30	1
R18	28000	Residential	200	7	14	9		39	39	39	30	30	30	1
R19	25000	Residential	200		2	7	5	31	41	26	14	14	14	1
R19	25000	Residential	200		2	7	5	31	41	26	14	14	14	1
							Total Fixtures	594	612	574	441	441	441	22
							dfu's	1782	612	1148	882	882	882	44
							Building dfu's	6232						

Hotel 5								
Floor	*Area*	*Classification*	*Area/Occupant (SF)*	*Hotel Rooms*	*Water Closets*	*Lavatories*	*Showers*	*Service Sink*
P1	15000	Assembly	25		12	8	0	1
P2	15000	Residential	200	20	20	20	20	1
P3	15000	Residential	200	20	20	20	20	1
P4	15000	Residential	200	20	20	20	20	1
P5	15000	Residential	200	20	20	20	20	1
P6	15000	Residential	200	20	20	20	20	1
P7	15000	Residential	200	20	20	20	20	1
P8	15000	Residential	200	20	20	20	20	1
P9	15000	Residential	200	20	20	20	20	1
P10	15000	Residential	200	20	20	20	20	1
P11	15000	Residential	200	20	20	20	20	1
				Total Fixtures	212	208	200	11
				dfu's	848	208	400	22
				Building dfu's	1478			