WASHINGTON DC AREA

MULTI-USE HIGH RISE

Credit: donohoeconstruction.com

FINAL REPORT

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ARCHITECTURAL ENGINEERING
CONSTRUCTION MANAGEMENT

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DEVELOPED BY:
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- **Name**: Multi-Use High Rise
- **Location**: Washington DC Area
- **Size**: 214,768 SF
- **Stories**: Building A: 10
  Building B: 6
- **Cost**: $44 Million
- **Occupancy**: Mixed-Use High Rise
- **Dates of Construction**: 7/24/2012 – 7/29/2014
- **Delivery Method:** Design-Bid-Build
- **Contract Type:** Guaranteed Maximum Price

Credit: donohoeconstruction.com

PROJECT TEAM

- **Owner**: USAA Real Estate
- **Owner’s Rep**: Patrinely Group
- **Developer**: ZOM Mid Atlantic
- **Architect**: Esocoff & Associates
- **Structural Engineer**: SK&A
- **MEP Engineer**: Summit Engineers
- **Landscape Engineer**: Rhodeside & Harwell
- **General Contractor**: Donohoe Construction
- **Utility Engineer**: Richter & Associates
- **LEED Consultant**: Paladino & Company

MECHANICAL

- Split System Heat Pump Units
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- 3 100% Outside Air Make Up Air Units
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- NEMA PB 1 power and feeder distribution
- Switchboards
  - #1: 2500A, 277/480 V
  - #2: 3000A
  - #3: 1600A
- Panels
  - 3 Phase: 120/208 V
  - 3 Phase: 277/480 V
  - 1 Phase: 120/208 V
- Diesel generator: 277/480 V
  - 300kW/375kVA

FIRE PROTECTION

- Complete and operational dry pipe system
- 1250 GPM Fire Pump
  - 110 PSI boost, 35 PSI Inlet 100 HP, 3 phase, 488 V
- Black Steel & CPVC Piping
- Fire pump, jockey pump, controls switches

RYAN MACNICHOL

CONSTRUCTION MANAGEMENT

EXECUTIVE SUMMARY

This final senior thesis report details four areas of technical analysis that investigates the means and methods of construction utilized for the construction of the Multi-Use High Rise, which is located in the Washington D.C. area. This complex project spans roughly 215,000 square feet, contains two buildings, one reaching ten stories and one reaching six, and a two-story underground parking garage. The buildings will be of multi-use function providing ground floor retail space with the remaining floors being apartments. The four areas of analysis aim to provide a better final product by decreasing cost and schedule duration, increasing sustainability and utilizing technology to save time and increase construction quality.

TECHNICAL ANALYSIS 1: MOBILE TECHNOLOGY INTEGRATION

Mobile technology is an ever-increasing technique in the construction industry, which enables the overall construction management process to be much more efficient. This analysis examines the LATISTA tablet computer program, and how its integration to various projects has been a success, in an effort to apply the appropriate implementation to the Multi-Use High Rise project. Mobile technology will benefit this project due to accessibility to drawings and coordination in the field, email and correspondence, and daily safety evaluations and checklists. Based on case studies, this project will potentially save $2,028/week with a total savings of $210,912. Over the entire project in costs, while increasing quality, efficiency, and customer service.

TECHNICAL ANALYSIS 2: BATHROOM MODULARIZATION

The Multi-Use High Rise project has an extremely tight and congested site, as well as a very tight schedule. Modularization will allow some of the work to be relocated to an offsite facility and allow the bathroom units to be constructed prior to their arrival to the site location. This will clear up some traffic on the project site, as well as time savings. Implementing bathroom modularization allows for more than ten weeks in time savings, as well as a cost increase of $18,349.76.

TECHNICAL ANALYSIS 3: ALTERNATIVE STRUCTURAL SYSTEM

The Multi-Use High Rise project is currently utilizing a traditional, stick-built brick façade system. This analysis will implement a prefabricated panel façade system in exchange for the original façade. This new system will reduce the project duration, clear space on a cluttered jobsite, as well as affect the total cost. Implementing the prefabricated façade will speed up the schedule by 47 weeks, but increase total costs by $830,304.80.

TECHNICAL ANALYSIS 4: GREATER SUSTAINABLE DESIGN

Sustainability is becoming an industry leading criteria for almost any project. The Multi-Use High Rise project is currently on track to receive a LEED certification, due to its sustainable efforts. There are several sustainable strategies that this project is missing out on, that can increase the project's LEED rating. Analysis four will focus implementing greater sustainable design methods to increase the LEED rating. With the recommended additions to the project, the LEED rating will be increased to a LEED Silver certification.

ACKNOWLEDGEMENTS

I WOULD LIKE TO TAKE THE OPPORTUNITY TO THANK THE FOLLOWING INDIVIDUALS IN THEIR ASSISTANCE OVER THE PAST YEAR IN HELPING MAKE THIS THESIS FINAL REPORT POSSIBLE.

DONOHOE CONSTRUCTION COMPANY

RYANE SULLIVAN, *PROJECT ENGINEER*

JOHN BODY, *PROJECT SUPERINTENDENT*

USAA REAL ESTATE

ZOM MID-ATLANTIC

ESOCOFF & ASSOCIATES

SK&A ENGINEERS

SUMMIT ENGINEERS

PALADINO & COMPANY

PENN STATE DEPARTMENT OF ARCHITECTURAL ENGINEERING

PROFESSOR KEVIN PARFITT

ADVISOR RAY SOWERS

FINALLY, I WOULD LIKE TO GIVE A SPECIAL THANKS TO ALL OF MY **FRIENDS AND FAMILY** FOR GIVING ME THE MOTIVATION AND SUPPORT TO SUCCESSFULLY COMPLETE MY FIFTH YEAR AT PENN STATE UNIVERSITY.

Section 1: Project Overview

3.1 Project Description

The Multi-Use High Rise, located in the greater Washington D.C area, is a very unique project with a plethora of distinguishing features and systems. This project, located on a lot containing over 50,000 SF of area, consists of a two-story parking garage, located underneath two large multi-occupancy buildings.

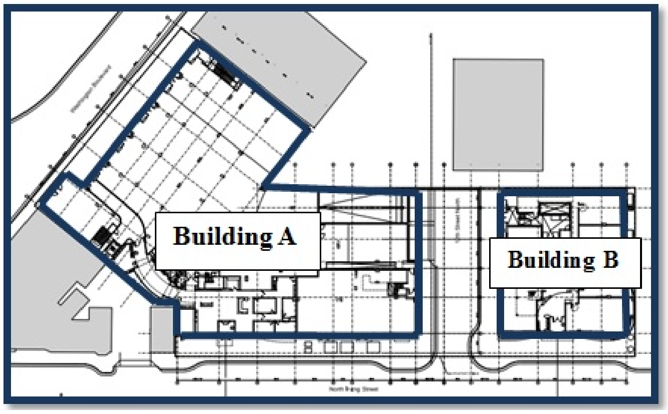


Figure A - Initial Site Plan

The uniqueness in this project begins with it consisting of two separate building, merely connected by an underground parking garage. The underground parking garage is large enough to provide 189 parking spaces for residential occupants, 20 spaces for residential visitors, and 23 spaces for retail uses. Of these spaces, six will be handicapped and 25 will be compact spaces. The two main buildings consist of over 210,000 square feet of total area. Building 1 and Building 2 are seen in *Figure A: Initial Site Plan*, respectively. Building 1 is a ten-story structure, utilizing three areas of retail on the ground floor, with 145 apartment units spanning the remaining nine floors. Building 2 is a six-story apartment complex housing 42 apartment units.

The thoughts of constructing the Multi-Use High Rise project speculated in the spring of 2012, when USAA Real Estate awarded Donohoe Construction Company with the project. The contract didn’t truly start until July 24, 2012. The project delivery method was a design-bid-build project. The project team moved onto the site on August 6, 2012, and excavation efforts began soon after. As the project moves on, the certificate of occupancy will be awarded July 29, 2014.

Structurally, the project consists of cast in place concrete, which was used throughout. Due to the significance of concrete in this project, two vertical and horizontal formwork are utilized. The vertical formwork includes the footings, columns, and foundation walls. The horizontal formwork consisted of floor slabs, slab on grade, and concrete beams.

The majority of this building’s façade is made up of face brick masonry units. A brick and lintel system is found throughout, complimenting a preserved historical façade. While the brick is preserved, new windows, frames, doors and glazing are installed. Other façade include an architectural a glass block curtain wall, structural slate stone, tile, metal panel, and split face CMU. In sustainably, the end result for the Multi-Use High Rise project is a LEED certification.

1.2 CLIENT INFORMATION

Credit: USAA.com

The owner of this project is USAA Real Estate Company. This company thoroughly understands the development process, creating a very dynamic experience in ownership. USAA is known for featuring flexibility and simplicity in each of its investments. This means they provide up to 100% of the project's capitol, funding from a single source during the project's development, and a single set of cash flow documents are initiated. USAA is also responsive and confident, they commit to a project in as little as three weeks. They also have expertise in development and project management, which makes the entire construction process work more efficiently and easily.

USAA Real Estate Company has noticed a vast growth in the greater Washington D.C. area, and decided to act upon building this Multi-Use High Rise. They hope to make the street more visually appealing, while bringing in residents to have the opportunity to live above some of their favorite stores. This project is one of many of its kind for USAA, making this owner experienced and knowledgeable.

1.3 LOCAL CONDITIONS

The site of the Multi-Use High rise will be built on a new site with existing buildings in the Washington D.C area. The previous buildings have been vacant for years and will be demolished. There will be a road to be developed, splitting the site in half, separating Building 1 and Building 2. *Figure B: Site Overview* shows an aerial view of the site.

Credit: Google Maps

Figure B – Site Overview

According to the Geological Map of Virginia, the native soil to the area is Loam and Sandy Loam. This soil has very strong acidity and has a slight erosion hazard. The depth of bedrock is greater than 60 inches and the depth to water table is greater than 72 inches. There is no flooding potential in this area, but a moderate to high frost potential. This soil has is moderately permeable and has a moderate available water capacity.

1.4 PROJECT DELIVERY SYSTEM

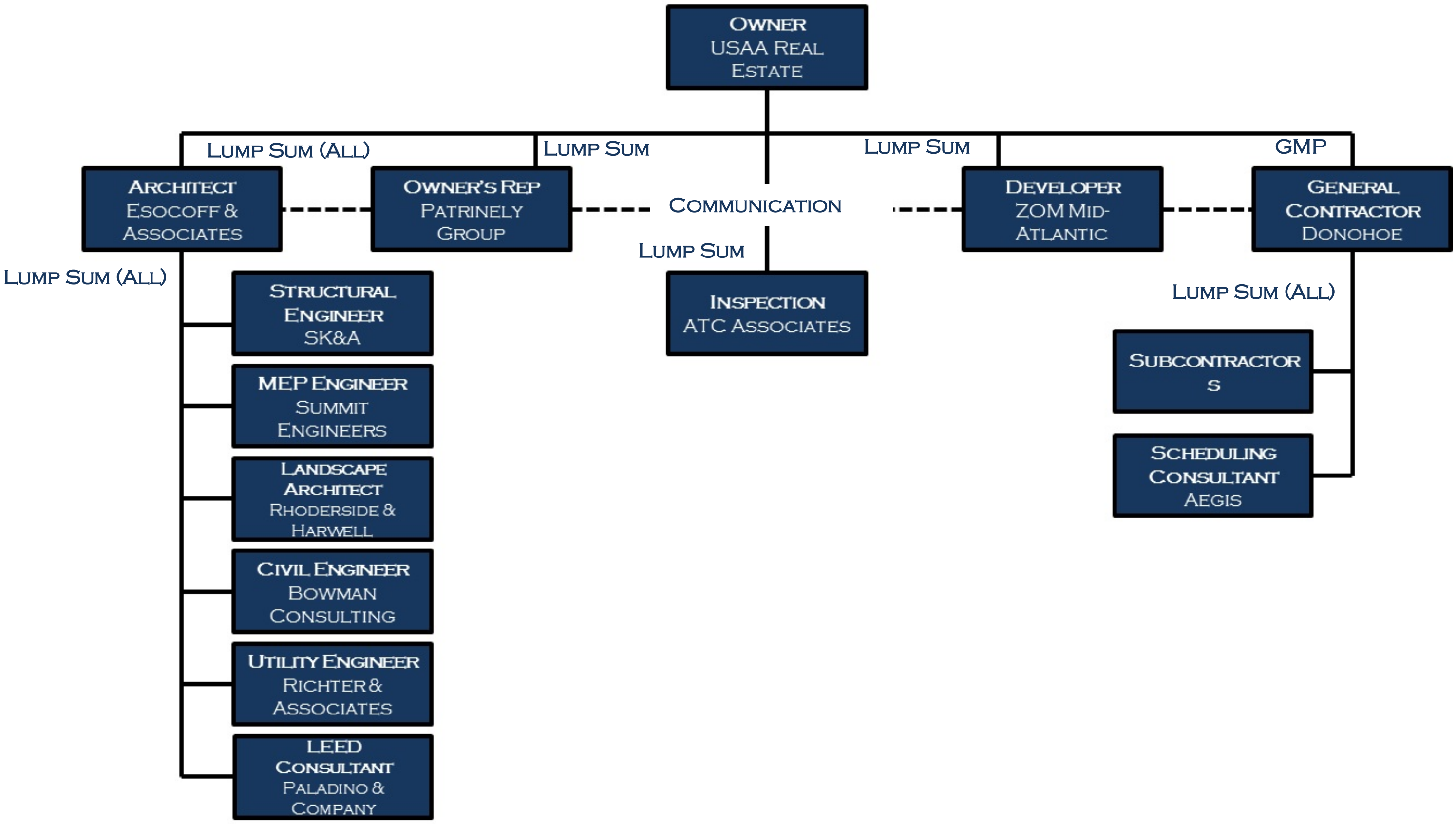


Figure C – Project Delivery Method

The project delivery system for the Multi-Use High Rise project is a traditional design-bid-build method. This can be viewed in the above *Figure C*. The owner, USAA Real Estate, holds a GMP contract with the General Contractor, Donohoe Construction Company. Due to the traditional design-bid-build delivery method, all of the Subcontractor's contracts are held by the General Contractor in a lump sum contract. The architect, owner's representative, developer, and inspectors all hold lump sum contacts with the owner. The structural engineer, MEP engineer, landscape architect, civil engineer, and LEED consultant all hold lump sum contracts through the architect. The advantage of using this method is USAA Real Estate can set a price prior to the beginning of construction, allows the owner to not be actively involved on a day to day basis. This means the General Contractor, Donohoe, is responsible for all work of the subcontractors. On this project, Donohoe holds a builder's risk and liability insurance with the subcontractors, holding liability insurance. There are also performance and serenity bonds being held by Donohoe.

1.5 PROJECT STAFFING PLAN

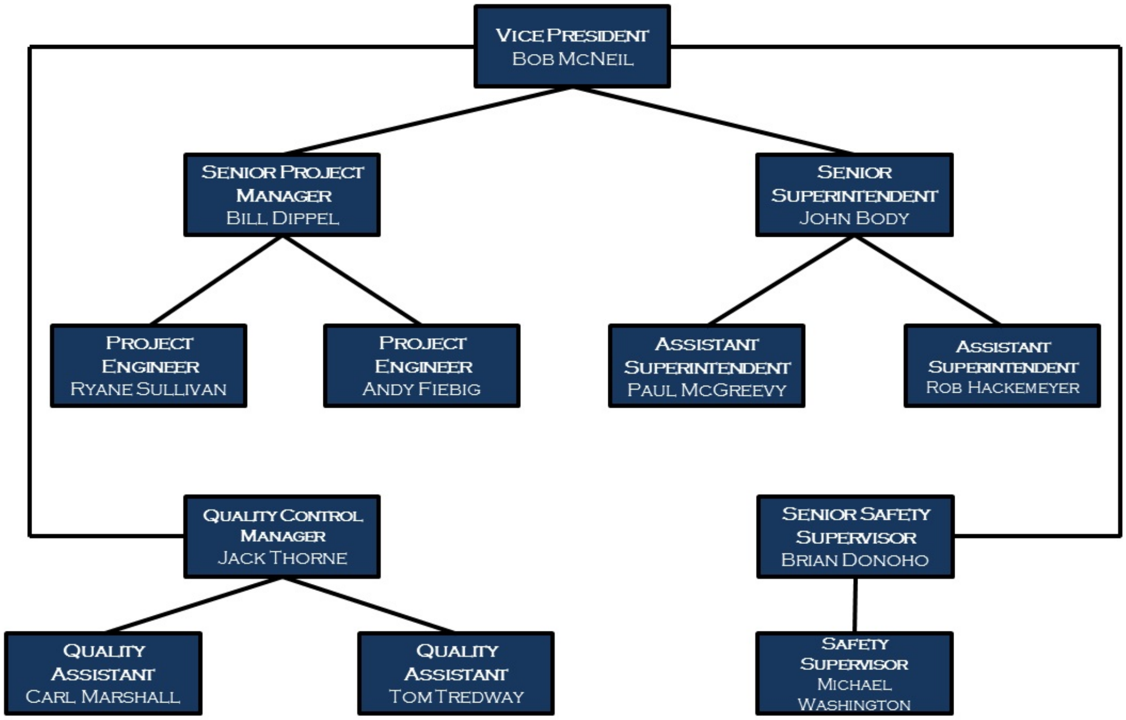


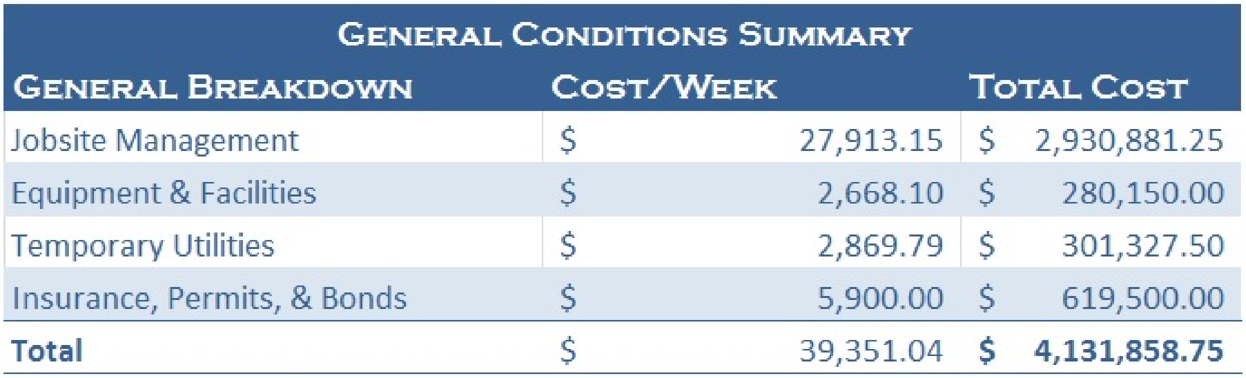
Figure D – Project Staffing Plan

The Donohoe Construction Company staffing plan for the Multi-Use High Rise is viewed in the above *Figure D*. There is a Vice President who is assigned to every project. He overseas the entire project, but only bills part of his time to the project because he is assigned to several projects. The Quality Control Manager reports to the Vice President any issues with the quality of the project. Under the Quality Control Manager are two assistants, one for preconstruction meetinds and one to visit the site every day. These three individuals are assigned to all projects. The Senior Safty Supevisor also reports to the Vice President. He and the Safety Supervisor insure the jobsite remains safe for the duration of construction. The Senior Project Manager and Senior Superintendant also report to the Vice President. There are two Project Engineers assigned in helping the Senior Project Manager, and two Assistant Superintendants assigned to helping the Senior Superintendent. As the project becomes more complex, there are more assistant superintendents assigned under the senior superintendent.

1.6 PROJECT COST EVALUATION

1.6.1 GENERAL CONDITIONS ESTIMATE

A general conditions estimate was performed from the RSMeans CostWorks database. The summary cost of all the categories is $4,131,858.75, as seen in its entirety in ***Appendix A***. *Figure E* shows the summary breakdown of all general conditions costs. The general conditions are broken down into four subgroups: Jobsite Management, Equipment and Facilities, Temporary Utilities, and Insurance, Permits, and Bonds.



GENERAL CONDITIONS SUMMARY		
GENERAL BREAKDOWN	COST/WEEK	TOTAL COST
Jobsite Management	$ 27,913.15	$ 2,930,881.25
Equipment & Facilities	$ 2,668.10	$ 280,150.00
Temporary Utilities	$ 2,869.79	$ 301,327.50
Insurance, Permits, & Bonds	$ 5,900.00	$ 619,500.00
Total	$ 39,351.04	**$ 4,131,858.75**

Figure E – General Conditions Summary

****Refer to Appendix A for the General Conditions Estimate***

Jobsite management totals at $2,930,881.25 total cost, with a weekly cost of $27,913.15. This cost includes all general contractors staffing throughout the duration of the project. In this project, a vice president, project manager, senior superintendent, project engineer, quality control manager, quality assistant, and senior safety supervisor remain staffed for the duration. An additional project engineer is added halfway through the project. An assistant superintendent, a quality assistant, and a safety supervisor remain staffed for 75% of the project duration. Finally, an additional assistant superintendent is added for the final quarter of construction.

Equipment and facilities total at $280,150.00 total cost, and a weekly cost of $2,668.10. This cost includes documentation, overnight delivery, construction signage, field office set-up, field office rental, printers/copiers, office survey/layout equipment, minor tools/equipment, weekly housekeeping, safety equipment, fire extinguishers and other miscellaneous expenses.

Temporary facilities totals at $301,327.5 total cost, and a weekly cost of $2,869.79. This cost includes early, middle and late power, power install, potable water, phone/internet hookup/service, temporary toilets, and dumpsters.

Insurance, permits, and bonds totals at $619,500.00 total cost, and a weekly cost of $5,900.00. This cost includes all permits, the certificate of occupancy, commercial general liability, builder's risk insurance, and payment and performance bonds.

1.6.2 STRUCTURAL ESTIMATE

A quantity takeoff of the detailed structural system was performed in order to reach a final estimate for the project. All estimate costs were taken from RSMeans Cost Data. The entire structure of the Multi-Use High Rise building is cast-in-place concrete. The column footings, columns, beams, and slabs are all cast-in-place-concrete. To complete the estimate, takeoffs were performed for formwork, reinforcing, and concrete. Footings, columns, beams, and slabs all needed formwork, which was taken off to complete the estimate. Reinforcing is broken down into the different sizes used throughout the footings, columns, beams, and slabs. All quantities were taken directly from the structural drawings.

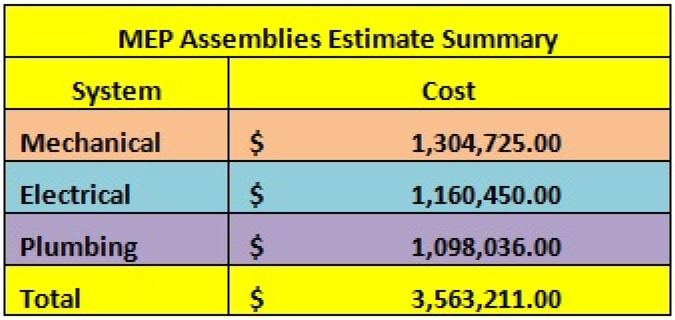
There are several different types of column footers and columns used throughout the project, each differing in size and reinforcing type. Same goes for beams, differing in size and reinforcing from one to another. The slab on grade and slab on deck is 4000 psi normal strength concrete, at 5" in diameter. Various sizes of reinforcing bar is incorporated, differing for each structure it is included in.

After completing the quantity take off and configuring cost data, the structural system of the Multi-Use High Rise will cost roughly $7,666,552.44.

***Refer to Appendix B for the Detailed Structural Estimate**

1.6.3 MEP ASSEMBLIES ESTIMATE

An assemblies MEP estimate was performed on the Multi-Use High Rise project. This estimate gives us an idea of the cost of the mechanical, electrical, and plumbing costs. *Figure F* shows us a breakdown of the individual systems and the total cost of entire MEP system.



MEP Assemblies Estimate Summary	
System	**Cost**
Mechanical	**$ 1,304,725.00**
Electrical	**$ 1,160,450.00**
Plumbing	**$ 1,098,036.00**
Total	**$ 3,563,211.00**

Figure F – MEP Assemblies Estimate Summary

The assemblies estimate is not a detailed estimate, but gives us a reasonable look at what the total cost will become. In the Multi-Use High Rise project the total MEP assemblies cost is set to be $3,563,211.00.

Refer to Appendix C for the MEP Assemblies Detailed Estimate

CONSTRUCTION OVERVIEW

2.1 SITE LAYOUT PLANNING

2.1.1 OVERVIEW

The site layout for the Multi-Use High Rise is broken into three key phases: Excavation, Superstructure, and Finish. These three phases make up the majority of the construction process for this project.

The site layout plan is important because it allows for a safe and organized jobsite. Overhead protection and security fencing is the most important safety measures for all phases of construction. Only certain materials are stored for each phase, depending on the work being performed at the time. The site layout plan is a key factor to completing the project in a smooth, efficient manner.

Refer to Appendix D for the Site Layout

2.1.2 EXCAVATION PHASE

During the excavation phase, the construction entrance is installed, sediment and erosion control is installed, dewatering is set up, and overhead protection is installed. The demolition of existing buildings, hardscape, and concrete is all done during the excavation phase, as well. Soldier beams, bracket piles and caissons are also installed to the site, as well as cutting and lagging. The excavation phase site layout plan, show in Appendix A: Site Layout Plan shows the property line established and security fencing installed. There are two dumpsters placed in strategic locations on either side of the site, and laydown/staging areas and overhead protection is established. General contractor trailers are also put in place at a strategic location, away from the project site itself.

2.1.3 SUPERSTRUCTURE

During the superstructure phase, the foundation and structure is being constructed. Slab on grade, slab on deck, concrete columns, and concrete beams are all being installed to the Underground Parking Garage, Building 1 and Building 2. The superstructure phase site layout plan, shown in Appendix A: Site Layout Plan shows everything from the excavation phase, with some additional equipment placement. The construction entrance has moved. Three placing booms are shown throughout the site, and additional dumpsters are included.

2.1.4 FINISH

During the finish phase, the building enclosure, rough-ins, and interior finishes are being performed for Building 1 and Building 2. The finish phase, shown in Appendix A: Site Layout Plan, it is set up similar to the superstructure phase, with a few exceptions. There are several trash chutes and hoists incorporated to the site for cleanup. The tower cranes are now gone during this phase.

2.2 BUILDING SYSTEMS SUMMARY

2.2.1 STRUCTURAL

The structural system for the Multi-Use High Rise is primarily made up of cast-in-place concrete. The foundation is found on level P2, using concrete footings and slab on grade. The remainder of both buildings, level's P1 to the roof, consists of cast-in-place concrete columns, beams, and slabs. Cast-in-place concrete minimum ultimate compressive strength for footings, slabs-on-grade, and foundation walls are 4000 PSI, while framed slabs and beams are 5000 PSI. Slabs poured on grade will be a minimum of 5 inches thick, poured over a vapor barrier and 6 inches of washed crushed stone.

2.2.2 MECHANICAL SYSTEM

The mechanical system for the Multi-Use High Rise is also a very complex system due to the complexity of the project. A 100% Outside Air Rooftop system is utilized for both Building A and Building B in heating and air conditioning. With this, both buildings use 1.5 ton split system heat pumps with cooling capacities of 18,000 BTU/H and heating capacities of 19,000 BTU/H. Several other mechanical equipment is used to make up the overall system, like fan heaters, including unit and fan wall heaters, air flow regulators, and through-the-wall units. The exhaust fans used in this system include ceiling mounted, direct driven centrifugal and belt driven centrifugal. This project also has specific building envelope requirements for roof R value, exterior above grade walls, floors over outdoor/unconditioned space, slab/below grade walls, and glazing.

2.2.3 ELECTRICAL/LIGHTING SYSTEM

The electrical system for the Multi-Use High Rise is a severely complex system composed of multiple panel boards and switchboards that are required to feed each floor and unit separately, as well as the retail space. The main distribution is made up of three separate distribution panels. Switchboard 1 is a 2,500A 277/480V switchboard, switchboard 2 is a 3000A 120/208V switchboard, and switchboard 3 is a 1600A 120/208V switchboard. Switchboard 1 and 2 distribute to Building A, where switchboard 3 distributes to Building B. Each switchboard is designated to several panel boards throughout each building, giving each unit on each floor control of its own electric. A 300KW/375KVA, 277/480V diesel engine driven emergency generator is used to power a 75 HP fire pump. This generator and fire pump is used for both

Building A and Building B for this project. All power distribution equipment is located on level P1 of the parking garage, in the Electrical Room.

The lighting for the Multi-Use High rise utilizes a total of 78 different lighting fixtures throughout both Building A and Building B. The main types of lighting fixtures throughout the buildings included recessed fluorescent T5, recessed fluorescent T* and LED down lights. There is significant day lighting taken into effect during design of each building. Large windows and open areas make these possible, leaving very few fixtures to be visible. The lighting design also implemented photo sensors around the buildings to reduce energy consumption, whenever there are no occupants or there is enough daylight in the space.

2.2.4 LEED GOALS

A thorough LEED evaluation was performed on the Multi-Use High Rise, giving the project a LEED Certification. 28 of the possible 69 LEED credits were achieved during this project. The LEED certification is broken down into six categories: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, and Innovative & Design Process, which the project scored multiple points in each category to achieve certification.

Sustainable sites credits encourage building project strategies that minimize impact on ecosystems and water resources. In order to qualify for any points in this category, the site must incorporate erosion and sediment control measures. Water efficiency credits promote smarter use of water, inside and out, to reduce potable water consumption. Energy and atmosphere credits promote better building energy performance through innovative strategies. In order to qualify for any points in this category, the site must engage in 3rd party commissioning, develop envelope, HVAC, and lighting systems compliant with ASHRAE 90.1-2004, and all water source HPs must be specified. Materials and resources encourage using sustainable building materials and reducing waste. In order to qualify for points in this category, the site must designate specific space to support building recycling efforts on floors and loading dock. Indoor environmental quality credits promote better indoor air quality and access to daylight and views. In order to qualify for points in this category, the site must design outside air to meet/exceed ASHRAE 62.1-2004 and adopt no smoking policy within 25’ of the building.

2.3 DETAILED PROJECT SCHEDULE

2.3.1 OVERVIEW

The Multi-Use High Rise project began construction efforts on July 24, 2012, when notice to proceed was initiated. Substantial completion of this project is set for July 29, 2014. The total project duration is going to be 735 days, which is slightly over two years of construction. *Figure G* shows an overview of the project schedule, including preconstruction through to project closeout. The project schedule overview shows the major items by phasing. The phases in which this project is completed in is as follows:

- Preconstruction
- Procurement
- Initial Site Work
- Foundation & Structure
- Enclosure
- Rough-In
- Finishes
- Project Closeout

****Refer to Appendix E for the Detailed Project Schedule***

	Duration	Start Date	Finish Date
Notice To Proceed	-	07/24/2012	-
Preconstruction	110 Days	07/24/2012	12/24/2012
Procurement	277 Days	07/24/2012	08/14/2013
MEP Coordination	277 Days	07/24/2012	08/14/2013
Initial Site Work	120 Days	08/06/2012	01/18/2013
Foundation & Structure	152 Days	12/28/2012	07/29/2013
Garage	109 Days	12/28/2012	05/29/2013
Building 1	99 Days	05/14/2013	09/27/2013
Building 2	51 Days	05/20/2013	07/29/2013
Enclosure	250 Days	07/30/2013	07/14/2014
Building 1	250 Days	07/30/2013	07/14/2014
Building 2	93 Days	06/28/2013	11/05/2013
Rough-In	167 Days	07/05/2013	02/24/2014
Garage	167 Days	07/05/2013	02/24/2014
Building 1	151 Days	07/09/2013	02/04/2014
Building 2	122 Days	07/09/2013	12/25/2013
Finishes	244 Days	07/18/2013	06/24/2014
Garage	133 Days	07/18/2013	01/20/2012
Building 1	179 Days	10/17/2013	06/24/2014
Building 2	133 Days	11/29/2013	06/03/2014
Project Closeout	201 Days	10/01/2013	07/08/2014
Substantial Completion	-	-	07/29/2014
Total	**735 Days**	**07/24/2012**	**07/29/2014**

Figure G - Project Schedule Summary

2.3.2 DESIGN AND PRECONSTRUCTION

The preconstruction phase is set to take roughly 110 days, being completed from 07/24/2012 to 12/24/2012. During the preconstruction phase, the detailed schedule shows critical 3rd party structures meetings taking place, as well as sheeting and shoring permits being obtained. Due to project activity requirements, other permitting was not included on this schedule, but was taken in account of the overall project duration. This includes right-of-way, demolition, overhead protection, survey excavation for footing to grade, plat for footing to grade, footing to grade, and building permits were obtained. While the preconstruction phase is being performed, project procurement is also completed. Procurement is set to take 277 days lasting from 07/24/2012 to 08/14/2013. Procurement includes initiating quality control, safety, sediment & erosion control, storm water management, and other plans. It also includes MEP coordination, which will be done for both Building 1 and Building 2 starting with the ground floor working all the way to the 10th floor. Once preconstruction and procurement have been complete, it is time to begin construction.

2.3.3 CONSTRUCTION

Initial site work is the first step in construction for the Multi-Use High Rise. Initial site work will last 120 days from 08/06/2012 to 01/25/2013. Initial site work includes mobilization and demolition of existing buildings as well as site excavation. Mobilization and demolition only take 23 days, while excavation takes roughly three months. Included in excavation is the installation of soldier beams, bracket piles, and caissons, and cutting and lagging to each of the 1st, 2nd, and subgrade tiers. Following the initial site work, it is time for the foundation and structure to be constructed.

The foundations and structure phase includes the foundation for the underground parking garage, as well as structure for the garage, Building 1 and Building 2. This phase is a substantial phase for the project, lasting 150 days from 12/28/2012 to 07/29/2013. The first step in this phase is laying out the foundation for the Underground Parking Garage's Level P2 slab on grade 1. A tower crane is erected in place for the duration of the phase. Level P2 uses slab-on-grade totaling in at seven slabs. The typical procedure for each slab on grade is as follows:

- Form, reinforce, and pour slab walls
- Initial backfill performed
- Underground plumbing and electric rough in
- Stone backfill performed
- Termite and moisture control performed
- The slab is prepped and then poured.

Once Level P2's foundation is poured, the rest of the structure for the underground garage, Building 1 and Building 2 may be complete. The underground garage uses concrete columns and beams, and concrete slab on deck for Level P2 and the Ground Floor. Buildings 1 and 2 also use concrete columns and beams, and a concrete slab on deck for floors 3 through to the roof. Once the buildings foundation and structure is complete, the building enclosure and rough- may begin being constructed.

The building enclosure is the longest phase of the project, lasting 250 days from 07/30/2013 to 07/14/2014. This phase is separated between Building 1 and Building 2, working simultaneously. Building 1 constructs enclosure for 10 floors, including the roof. Building 2 constructs enclosure for 6 floors, including the roof. The typical procedure for constructing each floor’s building enclosure includes removing reshores, installing masonry angles, constructing exterior metal framing, sheathing and Tyvec, setting window receptors, installing scaffolding, installing masonry veneer and exterior glazing. While the building enclosure is being completed, rough-ins is also done. Rough-ins takes about 170 days, lasting from 07/05/2013 to 02/24/2014. A typical floor’s rough in includes interior layout, interior framing, interior wall installation, mechanical, plumbing, sprinkler and electrical riser installation, and overhead MEP work. This is done for Level P2, Level P1, and Ground Floor through Roof for both Building 1 and 2. Following building enclosure and rough-ins, interior finishes are performed.

Interior finishes take approximately 244 days, being done from 07/18/2013 to 06/24/2014. The garage Level P2 and P1 are finished first, following is Building 1 and Building 2 coincided. After interior finishes are complete, Building 1 and Building 2 commissioning and closeout is performed. Project closeout lasts about 200 days from 10/01/2013 to 07/08/2014.

2.3.4 FINAL CLOSEOUT

Once the project is complete, a walkthrough is performed, a final punch list is complete and the final completion brings the building to substantial completion. The project schedule for the Multi-Use High Rise takes lots of coordination from phase to phase by each specific area of work. With great coordination, the project is able to be complete in a reasonably accurate time. If all goes as planned, the project will be complete 07/29/2014.

SECTION 3: MOBILE TECHNOLOGY INTEGRATION

3.1 PROBLEM IDENTIFICATION

Paper construction drawings cost the project management team roughly $30,000 in general conditions costs, not to mention the $500 monthly printer/copier costs. This project's complexity has caused a significant amount of change orders and alterations to the drawings throughout the duration of the project. Implementing mobile technology is becoming an ever-increasing technique in the industry; unfortunately, many owners are not yet convinced by its benefits, which has happened in this project. Mobile technology will only expedite and improve the everyday tasks of a construction management team. This topic will analyze the integration of mobile technology, especially tablet computers, throughout the jobsite, instead of paper copies. This implementation will save time as well as increase quality and efficiency of the project.

3.2 RESEARCH GOAL

The goal of this research is to analyze how integrating mobile technology will reduce the delay of construction efforts, minimize errors throughout the construction process, and save the project team time and money. In order to initiate the research analysis, there has to be background research done on the complexity and cost of paper construction documents. There also has to be research done on how mobile technology allows construction efforts to be performed simpler, reducing the risk of cost and time setbacks. There must also be investigations of case studies, showing the implementation of mobile technology and the overall effect it displayed on the project.

3.3 METHODOLOGY

- Research and ask the construction management team ways these problematic areas have been resolved and how they could have been acted upon better and faster if the construction documents were accessible virtually.
- Interview the project manager and get further details about the changes to the construction document and how they have affected construction
- Discuss with the project manager their personal expertise with mobile technology, if mobile technology could have prevented the problematic areas and why it hasn't been established

- Find industry professionals who have valuable experience using mobile technology and discuss ways to integrate it in the project
- Research LATISTA and various case studies, showing its positive impact.
- Compile all information gathered and show how mobile technology would be the better alternative to paper construction drawings

3.4 PRELIMINARY ANALYSIS

Mobile technology integration is one of the leading topics of discussion within the construction industry in recent years. As technology advances, companies and owners are striving towards a solution that will save both parties money and time. After interviewing with the Project Manager of Donohoe Construction Company, it appears that there are only benefits in the integration. He, as well as other industry professionals who have previously used mobile technology and tablet computers on the job site, make it clear that it provides an easier, more efficient, and better quality overall project. After discussion, it appears the only downside of mobile technology on the jobsite is the lack of knowledge and training to subcontracting staff. Along with industry professionals, ASCE and ENR provide reports and journals, giving added support to presenting the success and fails of implementing mobile technology.

LATISTA is a secure, cloud-based, web and mobile software that delivers a complete field management solution. Their program allows electronic workflow for project quality, commissioning and document management processes in the field and in the office. LATISTA has been proven to reduce rework, delays and eliminates paper.

There are several benefits to LATISTA’s Tablet computer software. The tablet computers, on-site, provide a decrease in site congestion, increase in efficiency, benefits to project preconstruction and procurement, material organization, drawing cost savings, and material delivery traceability. Tablet computers also benefit the commissioning of a project by accelerating the process, providing manageable, organized and communicative PDF documents, and recording issues and keeping performance evaluations for future reference. There are only minor disadvantages in the LATISTA software. These disadvantages include an increase in up-front cost, many trades lack the required knowledge in working with this technology, and the current software may still be working out defects.

LATISTA tablet computers are small and portable and have the ability to run various software including Microsoft Office, QuickBooks, AutoCAD, Primavera and other various schedule programs. With this ability to run any software, mobile technology will soon be taking over the ‘old-school’ paper documentation, and all management tasks on construction sites will be solely technology based.

3.5 INDUSTRY RESEARCH

3.5.1 CASE STUDY 1: ASCE JOURNAL ARTICLE

The ASCE Journal Article *Making the Case for Mobile IT in Construction* details the good, the bad, and the ugly about mobile technology in the construction industry. The main point of this article is to express to industry professionals the effectiveness of mobile technology in the construction industry and the reasons this technology is not being utilized by more companies and owners. This article is used as a valuable resource detailing the various availability of technology that could potentially impact the Multi-Use High Rise.

According to this article, there are clear barriers for the slow adoption of mobile technology and technology within the industry. The main barrier is simple, lack of awareness. Unfortunately, those who are in higher positions in the industry are part of the baby boomer generation. This generation, who are all highly skilled and hardworking, is slow to adapt to the new technology being made available simply because it was unavailable when they were growing more experienced. This generation gap causes the lack of awareness and the hesitance to use the technology. More barriers the ASCE article states include hesitation towards the benefits, the low profit margin most companies operate within, and a lack of success stories within the industry. These barriers are caused by the lack of use in the industry. If companies and owners are too hesitant to upgrade to the age, there will be no success stories to be told and they will all be blinded by the true effectiveness of mobile technology.

Based on the analysis of the several success stories and case studies of this ASCE article shared, the researchers found mobile technology integration is a successful practice for the industry. This implementation allows the construction management team to provide the following applications on site and efficient by using tablet computers:

- Preventive Maintenance

- Job Allocation
- Defect and Fleet Management
- Management of Piling Works
- Site Safety Management
- Timesheets and Payments
- Earthwork Examinations
- Email and PIM
- Field Observations

According to the report, this implementation also provides the following benefits to the construction management team:

- Reports Produced Quicker and Easier
- Better Customer Service
- Identification of Trends
- More Efficient Task Allocation
- Reduced Task Turn Around Time
- Improved Quality of Work
- Increased Staff Accountability
- Avoidance of Rework

In the end, the research team for this ASCE article found that construction efforts do not need to be rendered in any way to see significant benefits with the mobile technology integration. The end result in all cases of integration was a “process improvement” rather than a “process reengineering.” This means there is nothing new going on with the construction efforts, but rather a modification that eliminates unnecessary steps. These findings make it clear that, although introducing this new technology may be unfamiliar for some, it should not be viewed as something that changes the work structure of the project but a tool that can be used to increase efficiency. These findings provide a positive response to the overwhelming hesitation to adopt a new technology.

The ASCE article also dives into the “people issue” that is causing industry professionals to shy away from using mobile technology on their projects. The greatest issues people have with this integration include lack of technology leadership, fear of change, and uncertainty and low technology literacy. In order to prevail past these barriers, some coping strategies were identified. These strategies include appointing a project IT consultant, adopt technology-based applications with short learning curves, and allocate resources to IT training. These coping strategies were explored in all case studies of this article, producing effective results. Creating a project IT consultant was greatly effective in clearing up any concerns regarding the new technology on the jobsite. The training prescribed to those IT-illiterate was minimal, averaging about six hours to be required to make one proficient. Finally, creating user friendly short cuts allowed for great success during all cases.

This article also provided a return of investment for its case studies, showing all studies increased profit margins. The cost of implementing this technology ranged from $7,000 to $135,000, with an average cost of $45,000. These costs include upfront investigation costs, mobile devices, software application, communication infrastructure, data storage system, consultancy, site installation, training, staff time, and ongoing support. According to the report, the time taken to return on investment ranged from four months to twelve months, with an average of nine months. These time benefits include reduced administration time and a reduction in administration staff required. All studies proved to be successfully saving time and money, which is ultimately the goal in any project.

The ASCE journal article *Making the Case for Mobile IT in Construction* provided excellent insight as to how exactly mobile technology integration benefits a project. This insight is an excellent tool when integrating mobile technology in any project. This article and its findings provide a strong influence for the recommendations regarding the Multi-Use High Rise project.

3.5.2 CASE STUDY 2: ELI LILLY & COMPANY

Background

Eli Lilly & Company implemented LATISTA quality management and field-automation software on IE42, a $400-million, 158,000 square foot manufacturing plant in Kinsale, Ireland. Poor construction quality on a previous project left a bad taste in the mouth of Lilly, and they knew they could not afford similar mistakes on the IE42 project. The previous challenge resulted in delays in commissioning and qualification, increased costs associated with facilities opening late, and risk associated with faulty systems.

Integrating LATISTA and Tablet PC's

Learning from their mistakes, Lilly designed an extensive Construction Quality Management (CQM) program to satisfy all quality and documentation goals on their future projects. The number of quality issues would be greatly reduced, assuring the facility was delivered on-time and as-specified. LATISTA was the centerpiece of this program, due to its web-based platform. It allowed inspections and quality monitoring to be routine and efficient on the jobsite. LATISTA allowed users to access all information in the field using one of 15 mobile tablet computers. The five main categories for monitoring quality included:

- Contractor Quality System Auditing
- Inspection/Field Observations
- Testing for Conformance
- Training Records Review
- Documentation Review

All deficiencies could be entered to the LATISTA database following inspections, which would reflect on the tablet computers, standardized checklists, and supporting drawings and specifications. This system would synchronize and automatically created and distributed reports of issues to the defined recipients. This integration allowed for members at all levels of participation to analyze the project, search for areas of improvement, and share responsibility for quality.

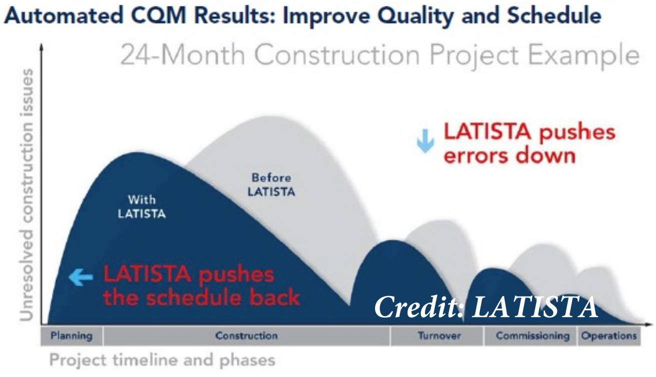
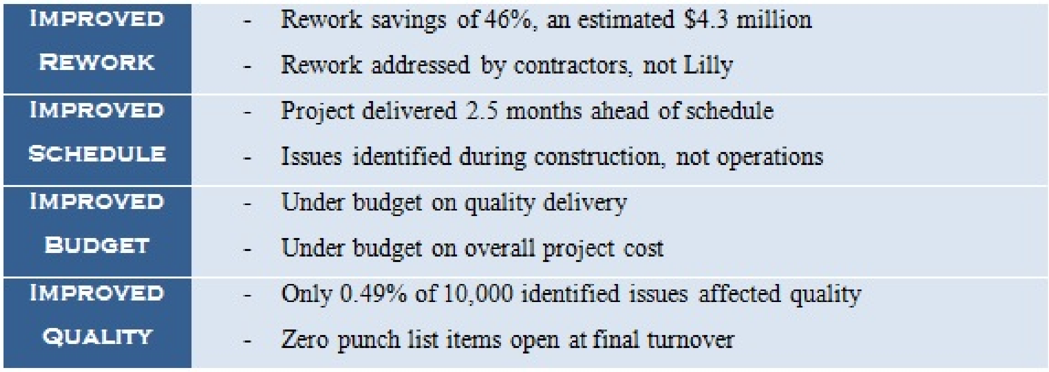


Figure H - LATISTA Impact

Conclusion

As shown in *Figure H* there are significant improvements to the quality and schedule of a project by implementing LATISTA. The effectiveness of Lilly's learning allowed for a majority of quality issues to be defined identified earlier. The project team could identify and correct issues as they occurred, preventing rework and eliminating deficiencies before the quality control process began. The implementation of LATISTA provided the following results:



IMPROVED REWORK	- Rework savings of 46%, an estimated $4.3 million - Rework addressed by contractors, not Lilly
IMPROVED SCHEDULE	- Project delivered 2.5 months ahead of schedule - Issues identified during construction, not operations
IMPROVED BUDGET	- Under budget on quality delivery - Under budget on overall project cost
IMPROVED QUALITY	- Only 0.49% of 10,000 identified issues affected quality - Zero punch list items open at final turnover

Figure I - Summary of LATISTA Impact on IE42 Project

3.6 PROPOSED IMPLEMENTATION

Based on the case studies presented in this analysis, it obvious the integration of tablet computers will provide a successful and efficient tool for various tasks during the entire project. The general use and result of the integration of mobile technology has shown great success, no matter the complexity of the project. The ASCE article *Making the Case for Mobile IT in Construction* shows that tablet computers are tools that must be assigned to the necessary task. This means that tablet computers are capable of various functions, but must have appropriate uses allocated based on individual needs of the project. For the Multi-Use High Rise project, tablet computers are the perfect fit for the following tasks:

- ➢ Accessibility to Drawings in the Field
- ➢ Coordination in the Field
- ➢ Documenting Field Issues
- ➢ Email and Correspondence
- ➢ Safety Evaluations
- ➢ Daily Forms and Checklists

If the construction management team is to implement mobile technology, their day-to-day tasks will become significantly easier. This implementation will allow them to access drawings and specifications in the field and communicate all issues immediately. They will be able to document these issues, perform site safety evaluations, and perform daily checklist tasks, including time sheets and progress reports all while remaining on site. This will decrease the time the team spends walking to and from the trailer to access laptop computers or hard copy drawings, as well as decrease the time spent each day with data entry.

Implementing such a strategy would allow the construction team at the Multi-Use High Rise to see benefits similar to those documented in the case studies cited above. Customer service, efficiency, and quality are all factors that will show improvement. Although there is much success in this implementation, the ‘human factor’ must still be considered. The team must be willing to assign a project IT consultant to focus his or her attention on helping others with technological concerns, they must be willing to make a monetary investment in the technology, and must dedicate time to training users. In order to quantify the cost of implementing tablet computers, a cost estimate including all factors must be considered. The following tables, Table 3a and Table 3b use values and rates from the case studies analyzed earlier in this section, paired with rates specific to the project to determine whether tablet computer integration makes sense, from a financial standpoint.

Table 1 - Direct Costs of Tablet Integration

Direct Costs of Tablet Computer Implementation			
Description	**Quantity**	**Cost/Unit**	**Cost**
Tablet Computers	4	$500/iPad	-($2,000)
Contingency for Software & Add-ons	4	$500/iPad	-($1,200)
Training Project Manager	6 hours	-	-($624)
Training Assistant Project Manager	6 hours	-	-($408)
Training Superintendent	6 hours	-	-($624)
Training Project Engineer #2	6 hours	-	-($408)
Training Project Engineer #2	6 hours	-	-($408)
Total	-	-	**-(5,672)**

Table 2 - Human Resource Costs of Tablet Integration

HUMAN RESOURCE COSTS OF TABLET INTEGRATION (WEEKLY)			
Description	**Quantity**	**Cost/Unit**	**Cost**
Costs			
Project IT Consultant	2 hours	$68/hour	-($136)
Savings			
Project Manager Time	4 hours	-	$416
Assistant Project Manager Time	5 hours	-	$340
Superintendent Time	7 hours	-	$728
Project Engineer #1 Time	5 hours	-	$340
Project Engineer #2 Time	5 hours	-	$340
Total	**-**	**-**	**$2,028/week**

Following the accounting for the costs of initial investment, including the purchase of the tablets, setup and training, the total direct cost resulted in (-$5,672). Based on reported savings from the case studies and extrapolated to the Multi-Use High Rist project, including time spent by the project IT consultant, the total weekly savings cost resulting in $2,028/week. Based on these values, the investment into tablet computers has a payback period of just about three weeks. Considering the 24-month duration of this project, integrating tablet computers at the Multi-Use High Rise project has the opportunity to save $210,912. This overall savings represents the reduction of on-site management time necessary for the Multi-Use High Rise project and allows Donohoe Construction to offer more competitive general conditions fee while providing the same quality of work, at no additional cost to the owner.

3.7 CONCLUSIONS AND RECOMMENDATION

Based on the studies presented in this section, as well as the financial feasibility presented through *Table 1* and *Table 2*, it is recommended to integrate tablet computers to the Multi-Use High Rise project. This integration offers the opportunity for Donohoe Construction to become more advanced and more efficient than its competitors through benefits like decreased on-site management costs of $2,028/week; increased quality, efficiency and customer service; and the adaptability to future practices in the construction industry.

The result of this analysis shows significant success with mobile technology integration. By utilizing tablet computers at the Multi-Use High Rise project, the construction management team will save $210,912 in on-site management costs throughout the entire project.

SECTION 4: BATHROOM MODULARIZATION

4.1 PROBLEM IDENTIFICATION

It takes roughly one month to complete a single bathroom for the apartment units per floor. For every single bathroom in both buildings of the Multi-Use High Rise project, time is taken to rough-in the MEP, trim out the MEP, install individual fixtures and equipment, and the application of finishing features. Being a project consisting of mostly apartment units, the bathrooms in each unit will match from floor to floor, which greatly increases the duration of each floor. If the each bathroom unit is modularized, being constructed to the finished level from an outside source, it can simply be placed into each unit upon its arrival onsite. Building 1 contains 145 bathroom units and Building 2 has 42, all repetitive in nature making them ideal for modularization. This implementation will greatly affect the project duration and space utilization on a complex job site.

4.2 RESEARCH GOAL

The goal of this research is to analyze how modularizing bathroom of apartment units can reduce the duration of the project. Another goal of this research is to analyze how modularizing the bathroom of apartment units can increase space on the jobsite. In order to initiate the research analysis, background research must be performed to explain the principle of modularization and how it can be done regarding individual kitchens and bathrooms. Background research regarding time, space utilization, and ease of transportation of modularized units must also be performed.

4.3 METHODOLOGY

- Research different techniques and the process of modularization
- Research the efficiency, ease of practice, and feasibility of modularizing individual bathroom units
- Contact the project manager and discuss the current bathroom schedule situation and the construction teams thoughts on modularization
- Evaluate the constructability issues, and potential time and cost savings
- Evaluate the current site plan during the interior and finishes phase and how modularized units on the job site can potentially increase useful space

- Compile all information and determine modularization will save the construction team time and space on the jobsite

4.4 Resources and Tools

- Donohoe Construction Company – Project Manager and Project Executive
- Owner Representatives
- Architectural Engineering Department Faculty
- Modularization facilities
- Key industry members with experience using modularization
- Applicable and reputable resources about modularization impacting construction schedule and cost

4.5 Background Information

The Multi-Use High Rise project is a perfect candidate for modular construction due to its repetitive floor plan and makeup. Implementing modular construction to the bathroom units will help decrease the project schedule and budget. *Figure J* represents the module make up of a typical bathroom unit in both a one and two bedroom apartment. Each bathroom unit will be broken into three modules for ease of lifting and installation. The typical bathroom plan is small and basic and is repeated throughout all floors of each building for one and two bedroom apartments. Since there are only a few three bedroom apartments, and the bathroom of these units begin to become complex, these will not be constructed using modularization. Between

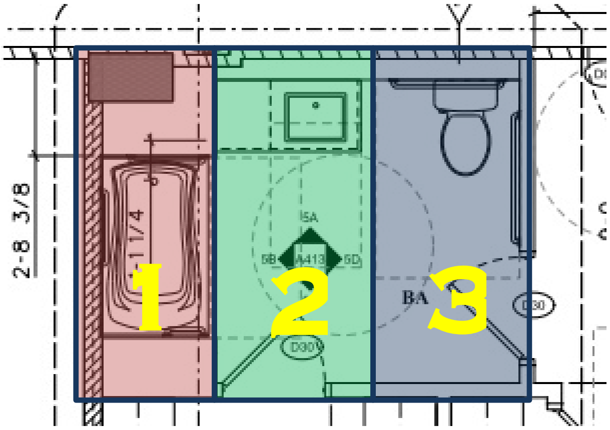


Figure J – Typical Bathroom Modules

Building 1 and Building 2, there are a total of 208 bathroom units throughout. The bathroom unit breakdown can be found below through *Table 3*.

Table 3 - Bathroom Unit Breakdown

BATHROOM UNIT BREAKDOWN	
Building 1	
2nd Floor	28 Bathroom Units
3rd Floor	28 Bathroom Units
4th Floor	28 Bathroom Units
5th Floor	28 Bathroom Units
6th Floor	28 Bathroom Units
7th Floor	28 Bathroom Units
Building 2	
2nd Floor	8 Bathroom Units
3rd Floor	8 Bathroom Units
4th Floor	8 Bathroom Units
5th Floor	8 Bathroom Units
6th Floor	8 Bathroom Units

There are few constraints when using modular construction on the bathroom units of the Multi-Use High Rise project. These modules will need to be able to fit on the material hoist and moved down a stud-framed hallway of each floor. Each module must be small enough to fit on the back of a truck for transportation from the production facility to the site. The framed hallway will be at most 8 feet wide before the modules are installed into each unit. These modules must also be easy and manageable to limit equipment needed for installation. The modules used in this project will meet all size constraints. Module one will be the smallest module with dimensions of 5 feet by 7 feet, and module two and three are each 6 feet by 7 feet.

4.6 SITE LOGISTICS

Creating modules at an offsite facility allows for a much more clear and free site. Once onsite, the site logistics are very simple for each module. There is no onsite storage for the modules due to the location of the material hoist and the extremely constraint site. *Figure K* displays the material hoist location. This location allows access to both Building 1 and Building 2. Upon delivery, the modules will be delivered to the material hoist and moved to the appropriate floor. The modules will then relocate to their approximate location and await connection and installation.

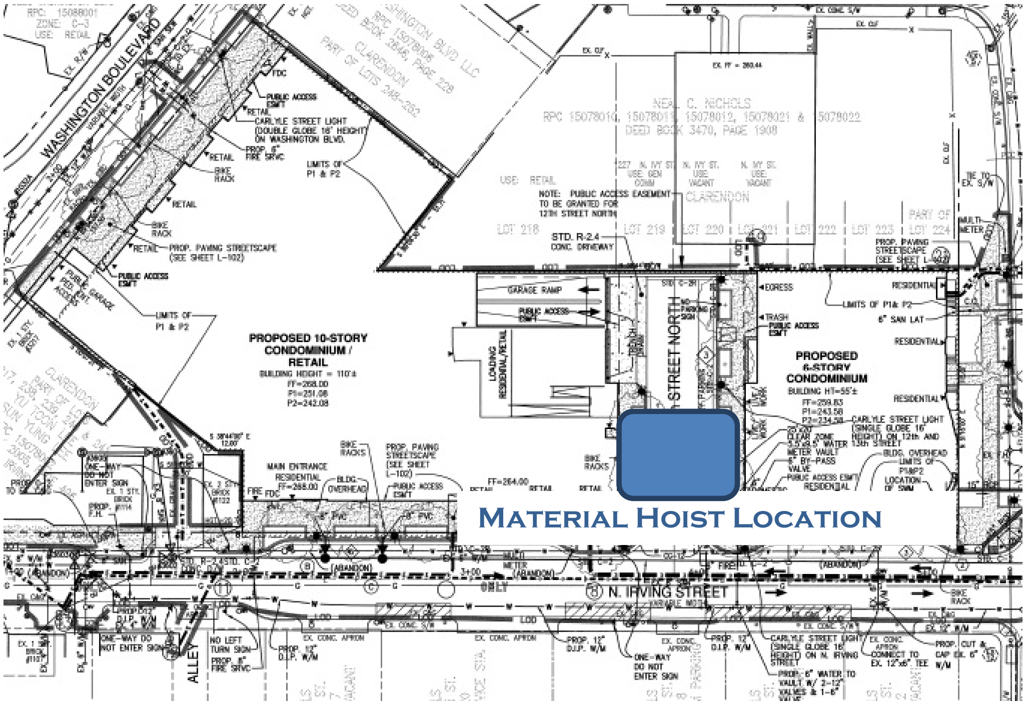


Figure K - Material Hoist Location

4.7 CONSTRUCTABILITY ISSUES

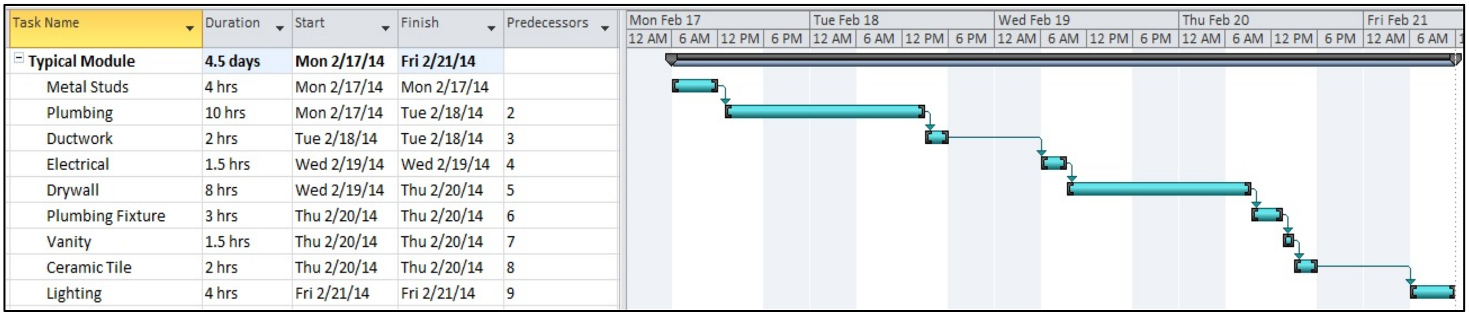
There is significant coordination and constructability concerns involved with implementing modular construction. The order in which each module is installed plays a crucial role in the effectiveness of this style of construction. The modules must be installed in an order of the furthest from the material hoist to the closest. Once the modules are in place, the eight foot wide hallways narrow down to a six foot wide hallway, which will make it impossible to fit any module.

Proper planning and coordination must be taken into consideration in order to properly fit the module into the existing wall. Proper access in and around the modules need to be planned so the installation crew can make any connections and adjustments as needed. These connections and adjustments need to be completed without damaging the work that has already been completed, potentially causing rework and negative effects on duration. Along with this, planning must be coordinated to allow for proper placement of each module and installation of piping through the slab penetrations for vertical risers and floor drains.

4.8 SCHEDULE COMPARISON

Module Construction Schedule

Each module will be constructed concurrently since they are all independent of one another. The schedule is broken down to activities such as, metal stud installation, plumbing, ductwork, electrical, hang/finish drywall, plumbing fixtures, vanity, ceramic tile, and lighting. These schedules are based on an eight hour work day, with crews working only Monday through



Task Name	Duration	Start	Finish	Predecessors
Typical Module	**4.5 days**	**Mon 2/17/14**	**Fri 2/21/14**	
Metal Studs	4 hrs	Mon 2/17/14	Mon 2/17/14	
Plumbing	10 hrs	Mon 2/17/14	Tue 2/18/14	2
Ductwork	2 hrs	Tue 2/18/14	Tue 2/18/14	3
Electrical	1.5 hrs	Wed 2/19/14	Wed 2/19/14	4
Drywall	8 hrs	Wed 2/19/14	Thu 2/20/14	5
Plumbing Fixture	3 hrs	Thu 2/20/14	Thu 2/20/14	6
Vanity	1.5 hrs	Thu 2/20/14	Thu 2/20/14	7
Ceramic Tile	2 hrs	Thu 2/20/14	Thu 2/20/14	8
Lighting	4 hrs	Fri 2/21/14	Fri 2/21/14	9

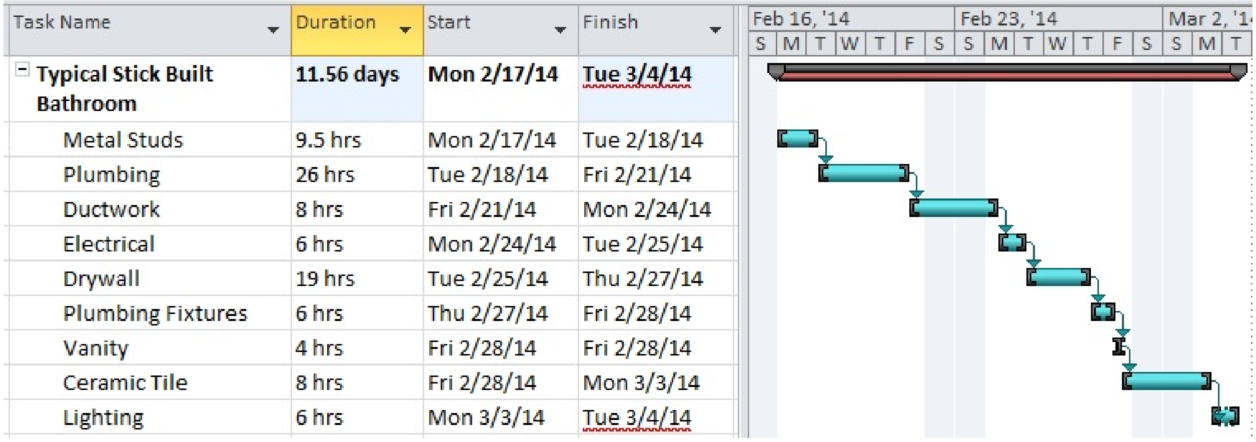
Figure L - Typical Module Schedule

approximately 4.5 days per module. All modules are constructed concurrently, so each module will be ready for shipment to the site after 4.5 days of construction. This will cut significant time from the allotted time for a typical bathroom to be built on site. All schedule data and information was found utilizing RSMeans Online database.

The construction of these modules is being performed at an offsite warehouse facility. Luckily, since the Multi-Use High Rise project is being built in a dense area of the northeast, there are warehouses located within 25 miles of the jobsite, eliminating long shipping durations. All modules required to construct a single bathroom unit will be shipped together, utilizing the same truck, eliminated the possibility of lost and rearranged modules. Upon arrival, each module will be directly lifted to the destined floor to be installed.

Stick Built Construction Schedule

The bathroom units on the Multi-Use High Rise project were built using a traditional stick-built method. *Figure M* represents the schedule for a typical stick-built bathroom. Since a detailed schedule for the bathroom construction was not available, this schedule was created using the RSMeans Online database activity durations. A typical bathroom unit will be constructed in 11.56 days, using the traditional method. The schedule shown above shows the construction of the bathroom concurrently from start to finish. This is generally not the case during the construction process, due to each subcontractor's constraints and coordination, however a continuous cycle is assumed for this analysis.



Task Name	Duration	Start	Finish
Typical Stick Built Bathroom	**11.56 days**	**Mon 2/17/14**	**Tue 3/4/14**
Metal Studs	9.5 hrs	Mon 2/17/14	Tue 2/18/14
Plumbing	26 hrs	Tue 2/18/14	Fri 2/21/14
Ductwork	8 hrs	Fri 2/21/14	Mon 2/24/14
Electrical	6 hrs	Mon 2/24/14	Tue 2/25/14
Drywall	19 hrs	Tue 2/25/14	Thu 2/27/14
Plumbing Fixtures	6 hrs	Thu 2/27/14	Fri 2/28/14
Vanity	4 hrs	Fri 2/28/14	Fri 2/28/14
Ceramic Tile	8 hrs	Fri 2/28/14	Mon 3/3/14
Lighting	6 hrs	Mon 3/3/14	Tue 3/4/14

Figure M - Typical Stick-Built Bathroom Schedule

Conclusion

When comparing the modular construction schedule and the stick-built construction schedule, there are several assumptions that must be accounted for. The following are assumptions based on the schedule of a typical floor using modularized bathroom units:

- Modules will be shipped in groups on six bathroom units (18 modules).
- Three days area allotted for each group of six modules duration for the shipping, setting, connecting and adjusting.

The following are assumptions based on the schedule of a typical floor using stick-built bathroom units:

- Each bathroom construction will begin once the previous bathroom has been under construction for 2 days.

Table 4 - Bathroom Unit Schedule Comparison

	Single Unit		Typical Floor (36 units)	
	Modularized	*Stick Built*	*Modularized*	*Stick Built*
Duration (days)	4.50	11.56	30.00	83.66
Savings (days)	7.06		53.66	

Table 4 outlines the total duration of construction for a single unit, as well as a typical floor. For a single unit, a little over seven days can be saved in construction. When extrapolated for a typical floor, this time savings grows to roughly 53.66 days saved. The schedule comparison does not compare the duration of the entire project because it is assumed multiple floors are being worked on concurrently.

4.9 Cost Comparison

Module Cost

The construction of each module will be taking place at an offsite warehouse. This warehouse will be large enough to be suitable to build six sets of modules at the same time, as well as room for material staging and module storage. The warehouse will cost roughly $6,500 per month of usage. In a typical month, roughly four groups of bathroom units can be constructed (24 units). Since there are 36 bathroom units on a typical floor, it can be assumed that a typical floor will take approximately one and a half months of warehouse usage. This will bring the warehouse cost for a typical floor to be $9,720, or $270 per unit. The assumed cost of shipping three modules comes to $150 per shipment. The total project will require 208 shipments, making the total shipping of a typical floor to cost $5,400. *Table 5* Shows the breakdown of module construction costs.

Table 5 - Module Construction Costs

	Single Unit	Typical Floor (36 Units)	Entire Project (208 Units)
Modularized Bathroom	$ 16,637.44	$ 598,947.84	$3,460,587.52
Shipping	$ 150.00	$ 5,400.00	$ 31,200.00
Warehouse	$ 270.00	$ 6,480.00	$ 56,160.00
Total	**$ 17, 057.44**	**$ 614,827.84**	**$ 3,547,947.52**

****Refer to Appendix F for a more detailed modular bathroom construction estimate***

CONSTRUCTION OVERVIEW

Stick Built Cost

The Multi-Use High Rise project is currently using the stick-built method in construction of each floor, including all bathroom units. This method bypasses any added cost for shipment and warehouse rental that the modularized construction needed. *Table 6* provides a breakdown of the stick-built costs.

Table 6 - Stick-Built Bathroom Cost Breakdown

	MATERIAL COST	LABOR COST	EQUIPMENT COST	TOTAL
Single Unit	$ 9,079.82	$ 7,889.40	$ --	**$ 16,969.22**
Typical Floor	$ 326,873.52	$ 284,018.40	$ --	**$ 610,855.92**
Entire Project	$ 1,888,602.56	$ 1,640,995.20	$ --	**$ 3,529,597.76**

***Refer to *Appendix G* for a more detailed estimate of stick-built bathroom construction**

Conclusion

The difference in cost between modular and stick built construction is negligible, as seen in *Table 7*. It is 0.5% cheaper to construct the bathrooms using stick-built construction. From a cost standpoint, it doesn't make a difference whether stick-built or modular bathroom construction is performed.

Table 7 - Modular vs. Stick-Built Cost

	SINGLE UNIT	TYPICAL FLOOR (36 UNITS)	ENTIRE PROJECT (208 UNITS)
Modular	$ 17,057.44	$ 614,827.84	**$ 3,547,947.52**
Stick-Built	$ 16,969.22	$ 610,855.92	**$ 3,529,597.76**
Difference	$ 88.22	$ 3,159.16	**$ 18,349.76**

4.10 CONCLUSION AND RECOMMENDATION

Based on the analysis performed and results found, it is recommended to implement modular construction on the bathroom units of the Multi-Use High Rise project. Implementing modular construction for the bathroom of the Multi-Use High Rise project will allow construction efforts to be accelerated. Finishing this project on time is a key component to this project that Donohoe Construction Company will strive for. There is a potential to save roughly 55 working days using modular construction on the bathroom units.

The time gained from modular construction can be used to offset delays that are occurring almost on a daily basis during this project. An overwhelming amount of change orders has caused this project to become behind schedule. One significant change order, which had been brought to attention recently, that will be directly solved if switched to modular constructed bathrooms deals with the bathroom shower stall. During stick-built construction, each stall was not accounting for ADA spacing requirements. Since this was not taken for account, each shower needed to be widened. Modular construction would, not only, catch this problem before it was built in place of the building, and save the time and stress to correct the issue. In addition, this winter was an extraordinary winter, causing several more delays.

For the implementation of modular bathroom units, the cost of the bathrooms will increase by 0.5%, or $18, 349.76. This slight cost increase could potentially save the project money in the end by helping to finish the project on time. The sooner this project is complete, the sooner the owner can allow occupants to move in, and the sooner the owner makes money. This slight increase in cost is negligible and should not be the reason modular construction is not performed.

SECTION 5: FAÇADE PREFABRICATION

5.1 PROBLEM IDENTIFICATION

The Multi-Use High Rise project utilizes an enormous amount of face brick for its façade. The amount of face brick to be laid by the mason for a project as large as this will take a great deal of time, roughly 50 weeks. Traditional, stick-built, mason construction will also require a great deal of man power as well as man hours to complete, and potentially affect the overall quality of the project. However, the use of prefabricated masonry panels will save a great deal of time, money and productivity.

5.2 RESEARCH GOAL

The goal of this research is to determine the ability for schedule acceleration by utilizing a prefabricated structural façade. This redesign will also cause an investigation to cost and site congestion impacts.

5.3 METHODOLOGY

- Research prefabricated masonry panels and select an applicable manufacturer.
- Contact manufacturer for design consultant.
- Analyze the impact of the prefabricated brick panels to the existing structure.
- Assess the impact on LEED Certification requirements
- Research specific examples of mixing concrete construction with Infinity structures
- Compare complete stick-built masonry design to the prefabricated system.
- Determine means of transportation, erection, and installation requirements for prefabricated panels.
- Contact industry professionals regarding the use of prefabricated brick façade.
- Evaluate the constructability issues, potential time and cost savings, and feasibility of the new design.
- Compile all information and analyze the cost, schedule, and constructability impact due to prefabricated brick panels.

5.4 RESOURCES AND TOOLS

- Donohoe Construction project team – Project Manager and Project Executive

- Owner representatives
- Prefabricated Brick Panel Manufacturer
- Penn State AE Faculty
- Structural System Software

5.5 EXPECTED OUTCOME

Following substantial analysis of implementing a prefabricated brick façade, the overall construction schedule will be accelerated. It is also expected to cause a slight increase in project cost. The analysis will show no change in structural integrity of either building, nor will any interior units or features be altered. The new facade will provide a more sustainable and greener structural system. Finally, a prefabricated façade will eliminate site congestion, increase safety, and provide a better quality project.

5.6 BACKGROUND INFORMATION

The Multi-Use High Rise project is currently utilizing a traditional stick-built façade design, which dedicates a significant amount of time to the project schedule for its construction. A prefabricated façade panel system would provide schedule relief, while decreasing cost and potentially adding quality and sustainability to the project. Prefabricated façade panels are versatile, with the ability to be made a variety of different sizes and incorporate a number of different building materials. These panels will be manufactured off site and delivered to the project, decreasing the time taken to install. Prefabricated panels can be designed to aesthetically please any design criteria. Another bonus of prefabricated panels is by producing the panels off site, on site labor and site congestion will be reduced. Since constructing prefabricated panels requires skilled labor, it is speculated that the price will be greater than the original façade system. This analysis will aim to design a prefabricated panel with similar aesthetic qualities, while decreasing the time to install and improving project quality as well as sustainability.

5.7 CURRENT FAÇADE

The building's façade is one of the most important and crucial aspects of the construction process. It accounts for an incredible amount of time on the construction schedule, and affects the project critical path. The current façade system for the Multi-Use High Rise project can be seen in *Figure N*. The typical wall section shows the entire detail of the façade system, which is made up of:

- 7 5/8” X 3 5/8” X 3 5/8” Buffstone Wirecut Palmetto Brick
- 1” Void Space
- 1 ½” Rigid Insulation.
- ½” Exterior Sheathing
- Tyvek Commercial Wrap
- 3 5/8” Batt Insulation
- Vapor Retarder
- ½” drywall on 4” Metal Stud Framing

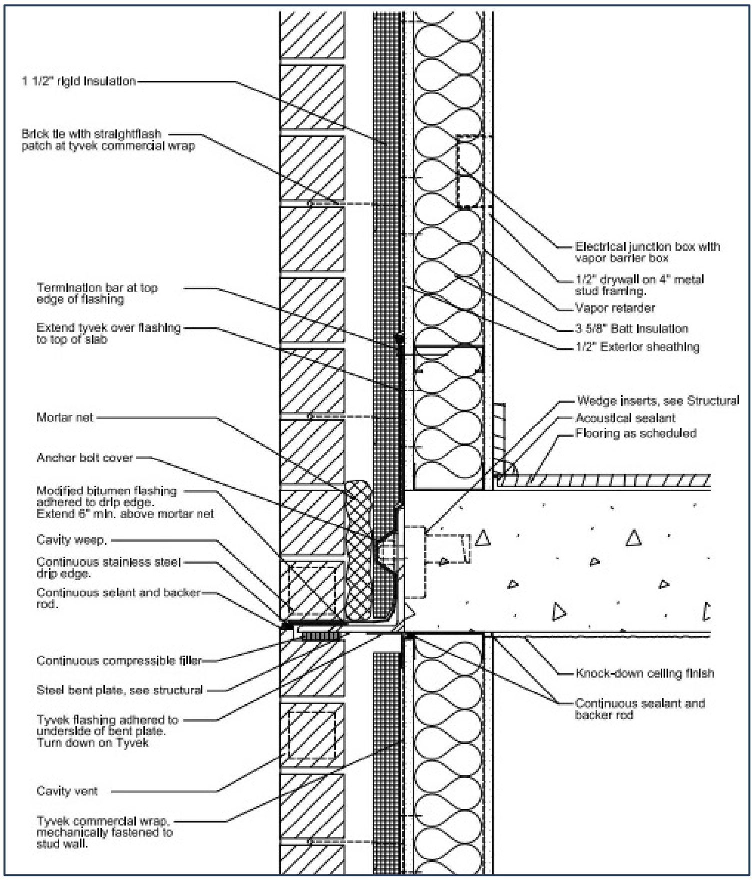
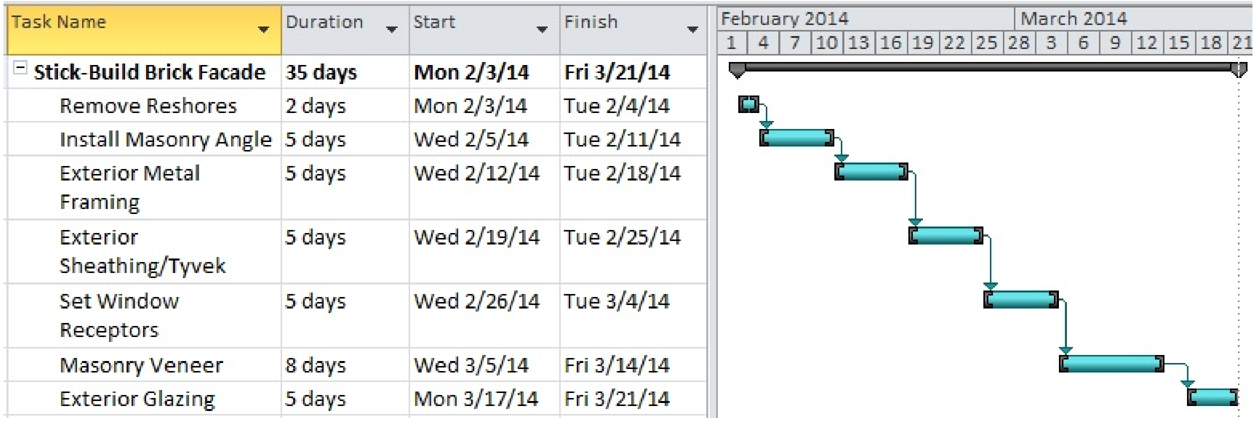


Figure N - Typical Facade Detail

This façade is replicated on both Building 1 and Building 2 and provides suitable structural integrity throughout the multiple floors of each building. The total project has an estimated 75,000 square feet of façade that must be accounted for. Building 1 makes up majority of this, reaching roughly 62,000 square feet of façade, and Building 2 makes up 13,000 square feet of façade.

For this analysis, one typical floor for each Building 1 and Building 2 will be compared, and then extrapolated to represent the entire project. For Building 1, there is a total of roughly 6,165 square feet of brick façade per typical floor, and Building 2 consists of roughly 2,170 square feet of brick façade per floor. Using the Palmetto Brick, this estimates Building 1 to have 41,600 total bricks per floor and Building 2 to have 14,625 total bricks per floor.

There are several steps in construction the original brick façade of the Multi-Use High Rise project. These steps include removing reshores, installing masonry angles, exterior metal framing, exterior sheathing and Tyvek, setting window receptors, installing masonry veneer, and exterior glazing. According to ***Appendix E***, construction efforts for the façade of Building 1 begin July 5, 2013 and are expected to end June 19, 2014. This brings the total duration of façade construction of Building 1 to roughly 50 weeks. Also seen found in *Appendix E*, construction for the façade of Building 2 begins June 28, 2013 and is expected to be complete by November 5, 2013. This brings a total duration of roughly 18 weeks for Building 2. Per floor, Building 1 is expected to take roughly 70 days to construct the façade, and Building 2 is expected about 50 days. These durations include the necessary predecessors and delays involved for each floor and building. *Figure O* shows the typical duration of simply installing the stick-built façade system.



Task Name	Duration	Start	Finish
Stick-Build Brick Facade	**35 days**	**Mon 2/3/14**	**Fri 3/21/14**
Remove Reshores	2 days	Mon 2/3/14	Tue 2/4/14
Install Masonry Angle	5 days	Wed 2/5/14	Tue 2/11/14
Exterior Metal Framing	5 days	Wed 2/12/14	Tue 2/18/14
Exterior Sheathing/Tyvek	5 days	Wed 2/19/14	Tue 2/25/14
Set Window Receptors	5 days	Wed 2/26/14	Tue 3/4/14
Masonry Veneer	8 days	Wed 3/5/14	Fri 3/14/14
Exterior Glazing	5 days	Mon 3/17/14	Fri 3/21/14

Figure O - Typical Stick-Built Facade Schedule

This schedule can be assessed for a typical floor for both building 1 and Building 2. From start to finish, with no delays, it will take 35 days to construct the current, stick-built brick façade.

Table 8 shows the cost breakdown for the traditional, stick-built façade system. The original façade will cost $148,132.78 per floor for Building 1 and $53,302.98 per floor for Building 2. Based on this analysis, it will cost approximately $ 24.12 per square foot to construct the original brick façade system for the Multi-Use High Rise project.

Table 8 - Facade Cost Breakdown

FAÇADE COST BREAKDOWN			
ITEM	FLOORS	COST/FLOOR	TOTAL COST
Building 1 Façade	10	$ 148,132.78	$ 1,481,327.80
Building 2 Façade	6	$ 53,302.98	$ 319,917.40
Total Cost			**$ 1,801,145.20**

****Refer to Appendix H for a more detailed stick-built façade cost estimate***

5.8 PREFABRICATED FAÇADE

Recently, the use of prefabricated façade panels is becoming more and more prevalent in the construction industry. Since the construction of these panels is performed at an off-site warehouse, a significant amount of waste can be minimized, each panel can be produced quicker and each panel can be engineered to exact specifications. Upon research, it became evident that there are a number of prefabricated panel manufacturers in the region in which the project is located. After thorough comparison of all options, I decided to use Nitterhouse Concrete Products. Nitterhouse services the entire northeast, and remains within 500 miles of the Washington DC area, so it became a perfect fit to use.

Upon consulting Mark Taylor of Nitterhouse Concrete, it was determined that a 9" insulated precast panel, with a thin veneer, will be used to meet design criteria. Each panel can be made a maximum of 12' wide and a maximum of 40' tall, and a lead time of five to six months is required. Each panel system will have a total thickness of 9", with a 3" concrete face, 2" of rigid insulation, and a 4" concrete outer face that will be faced with thin brick to achieve a similar architectural finish to the current system. The air panel is not necessary with this precast panel system because the concrete is dense enough to prevent moisture to pass through the assembly.

Utilizing the maximum sized panels, 12’x40’, the installation crew could install about 15 panels per day. Providing direct calculations and a total façade square footage of 74,670 square feet, it will take approximately 11 days to complete the entire project’s worth of prefabricated panel construction. This is a very inaccurate calculation, providing the façade’s design will not allow for 12’ wide uniform panels the entire way across the elevation. Many panels will vary in width, which means the total number of panels will increase, and the total erection time will increase. Each panel will be designed with openings for both windows and doors already formed. For this re-design, there will be a total of ten different panel types, each varying in length and width in order to fit the desired location. Table 9 shows, in detail, the panel sizes and quantity for the entire project.

Table 9 - Panel Information

PANEL INFORMATION		
TYPE	SIZE	QUANTITY
A	10’ x 25’	120
B	8’ x 25’	15
C	4’ x 30’	14
D	10’ x 10’	21
E	8’ x 10’	2
F	14’ x 10’	1
G	14’ x 2’	3
H	6’ x 10’	1
I	4’ x 6’	2
J	14’x 25’	30
Total		**209**

Refer to Appendix I for each panel type location

After this further investigation, there are a total of 209 panels to complete the façade. Assuming that 15 panels will be erected per day, the façade will take a total of 14 working days. Allowing a day for any learning curve or set-backs, the new façade system will take 15 working days, or three weeks’ time to complete.

For this particular panel, the final cost, including fabrication, delivery, and installation, will cost roughly $35 per square foot of panel. With each panel being 480 square feet, for a single 12’x40’ panel, it will cost $16,800. Based on this information, and given a total square footage of 74,670 square feet for the entire project, roughly 155 12'x40' panels will be used costing a total of $2,613,450. Additionally, there is a need for a crane for the installation of the prefabricated façade, which adds costs. Assuming that the crane cost $1,200 per day of rental, $18,000 will be added to the total cost, bringing a final cost of $2,631,450.

5.9 SCHEDULE COMPARISON

According to the detailed project schedule in ***Appendix E***, it will take roughly 50 weeks to construct a stick-built façade to both buildings. This accounts for all delays and predecessors to be complete as well. When analysis was completed on prefabricated brick façade, it was concluded that it will take 15 days, or 3 weeks, to complete all façade construction. Prefabricated façade construction will save the construction management team 47 weeks of time. With such a massive difference, it is evident that implementing the precast panels on this project would be beneficial. See *Table 10* for the schedule breakdown.

Table 10 - Stick-Built vs. Prefabricated Schedule Breakdown

STICK-BUILT VS. PREFABRICATED SCHEDULE	
	DURATION (WEEKS)
Stick-Built Façade	50 Weeks
Prefabricated Facade	3 Weeks
Difference	**47 Weeks**

5.10 COST COMPARISON

After compiling all of the data related to the two types of façade systems, it is evident the implementation of prefabricated façade panels is more expensive than the original façade. The estimated cost to construct the traditional façade is $1,801,145.20. The estimated cost to construct the new prefabricated façade is $2,631,450. The prefabricated façade system is 31% more expensive which comes to $830,304.80. See *Table 11* for the cost breakdown.

Table 11 - Stick-Built vs. Prefabricated Cost Breakdown

STICK-BUILT VS. PREFABRICATED COST ESTIMATE	
	COST
Stick-Built Façade	$ 1,801,145.20
Prefabricated Facade	$ 2,631,450.00
Difference	**$ 830,304.80**

5.11 STRUCTURAL BREADTH

Further research into this new prefabricated design made it clear that there will be a significant increase in load of the façade. This brought about a question whether the current concrete structure is suitable enough to support the increase in load. This breadth will focus on comparing the two façade systems' effect on the original structural system and to determine whether any changes will be needed to be made. Ultimately, this breadth will help determine if the switch to a prefabricated façade is sensible by a structural standpoint.

For this breadth, a typical beam will be analyzed; located on the second floor between column lines 2 and 3 and on column line A, this beam will carry the entire load of the largest

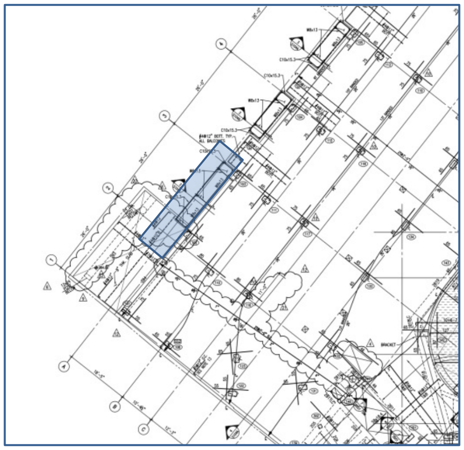


Figure P - Sample Beam Location

panels to be installed on the façade. *Figure P* shows the location of the beam. Being a reinforced concrete structural system, this reinforced concrete beam has a width of 16" and a depth of 30". The allowable limits for this concrete beam are listed below:

Table 12 - Typical Beam Allowable Limits

BEAM SIZE	LENGTH	MAX ALLOWABLE MOMENT (φM_N)	MAX ALLOWABLE DEFLECTION	MAX ALLOWABLE DEFLECTION DUE TO LIVE LOAD
16" x 30"	26'	212.6 k-ft.	1.3"	0.866"

****Refer to Appendix J for all structural breadth calculations***

Calculations to determine the loading from the original façade were performed to set the baseline to compare with the new system. The original façade system is made up of a brick veneer, 1" void, 1-½" rigid insulation, ½" exterior sheathing, Tyvek wrap, 3-5/8" batt insulation, vapor retarder, and ½" drywall supported by 4" metal studding. It is important to note that the façade placed on this beam is a one story tall metal stud wall. Refer to *Figure N* for the original façade's connection to the structure.

Hand calculations were used to determine the loading, moment's deflection, and results of the two façade assemblies, and are available in ***Appendix J***.

Upon checking the results of the original façade against the member's acceptable values, each check showed the member was an acceptable design for the current system. Once it was known the beam is acceptable under the original façade, the prefabricated façade was analyzed. It was expected for the new façade to produce increased loading, moments and deflection, as a result in the increase in weight. Each façade panel, made up of 3" exterior concrete, 2" rigid insulation, and 4" of interior concrete, will weigh approximately 88 pounds per square foot. To connect the façade to the structure, a tube steel system will be put in place connecting to the beam. It is assumed that two panels will be supported by this single beam, with each panel having one support at each corner; with two panels meeting at the center of the beam, a single point load is assumed and will contribute to a significantly increased moment.

Once all calculations were complete, compared to the original design, the prefabricated façade produced a decrease in load and total deflection, but an increase in total moment due to the point load. This increase in moment causes the typical 16" x 30" concrete beam to be insufficient to carry the new façade. Table 13 shows the comparison of these calculations between the original façade and the new prefabricated façade. It is important to note, the prefabricated total load includes the live load, dead load, and converted point load distributed loading.

Table 13 - Facade Load Comparison

	TOTAL LOAD *W* (KLF)	POINT LOAD (KIP)	TOTAL MOMENT M_U (K-FT)	TOTAL DEFLECTION (IN.)	LIVE LOAD DEFLECTION (IN.)
Original Façade	2.27	-	191.82	0.268	0.066
Prefabricated Façade	1.98	28.6	321.95	0.207	.0.066
Increase/Decrease	**13%**	-	**40%**	**23%**	-

Refer to Appendix J for hand calculations

5.12 CONCLUSION AND RECOMMENDATION

Based on analysis and breadth study, it is difficult to decide whether to implement the prefabricated façade panels or stick to the traditional façade. There is an excellent acceleration of the project schedule, providing 47 weeks of duration savings. This is very important for a project with so many time constraints and rising issues throughout the job. Although the time savings is so vast, there is also a significant impact on the total project cost. It will cost the owner over $830,000 to implement the new prefabricated façade system. This is money the owner will not likely want to see being spent.

Based on the structural breadth performed, it is evident the new façade will contribute to a decrease in total load and total deflection, and an increase in total moment for a typical 16” x 30” reinforced concrete beam. This increase in moment causes the beam to be inefficient to withstanding the new façade. With that being said, structurally, the new façade will require a new structural beam design, which will cause the project to become more complex, expensive, and take more time.

In conclusion, implementing a prefabricated brick façade system is not recommended for the Multi-Use High Rise project. Sure, the implementation saves much valuable time, but it is far more expensive than it is worth and the owner would certainly not be appreciated of the decision.

SECTION 6: GREATER SUSTAINABLE DESIGN

6.1 PROBLEM IDENTIFICATION

The Multi-Use High Rise project is on track to barely meet the requirements to achieve a LEED Credible achievement. There are only a few specific sustainability features implemented throughout design, causing the project to be less sustainable than it has the ability to be. Currently, this project is on track to achieve 28 out of the possible 69 total LEED credits, which will give the most basic LEED accreditation. If four more points are obtained, this certification will upgrade to a LEED Silver Certification. This analysis will show how a more sustainable project will simply achieve those four extra points, and potentially far exceed those minimal expectations. This analysis will include a restructured LEED evaluation, a cost and schedule comparison following design implementations, and a mechanical breadth, showing the implementation of a grey-water recapture system.

6.2 RESEARCH GOAL

The goal of this research is to analyze specific sustainable design features that can be implemented to the project that will be effective for the owner. Another goal of this research is to see how the sustainable design implementations will increase the LEED rating of the project, following another LEED evaluation. Additionally, a grey-water recapture system will be implementing, leading to a mechanical breadth, analyzing the influence and usefulness of the system.

6.3 METHODOLOGY

- Research sustainable design techniques, pertinent to the Washington DC area
- Research grey-water recapture,
- Analyze the current sustainable design features and how more techniques can be implemented
- Contact the project manager and discuss the current sustainability and LEED rating of the project
- Evaluate the constructability issues, and potential time and cost savings
- Evaluate the current LEED rating and perform another LEED evaluation following design implementation

- Compile all information and determine a greater implementation of sustainable design will be beneficial to the owner and increase the projects LEED rating

6.4 RESOURCES AND TOOLS

- Donohoe Construction Project Team – Project Manager and Project Executive
- Owner Representatives
- Penn State University AE Faculty
- Sustainable Design Facilities
- Key industry members with experience in sustainability
- LEED Resources
- Applicable and reputable resources pertaining to sustainable design impact on owner cost, construction schedule and project costs

6.5 BACKGROUND INFORMATION

Projects across the world are being exposed to the Leadership in Energy & Environmental Design, prevailing in greed building strategies and practices. In order to receive a LEED certification, a project must satisfy prerequisites and earn points to achieve different levels of certification. There are six areas of prerequisites that LEED covers for a multi-use project, similar to the Multi-Use High Rise project. According to usgbc.com, the following are the credit categories to obtain LEED credits:

- ***Sustainable Sites*** credits encourage strategies that minimize the impact on ecosystems and water resources.
- ***Water Efficiency*** credits promote smarter use of water, inside and out, to reduce potable water consumption.
- ***Energy & Atmosphere*** credits promote better building energy performance through innovative strategies.
- ***Materials & Resources*** credits encourage using sustainable building materials and reducing waste.
- ***Indoor Environmental Quality*** credits promote better indoor air quality and access to daylight and views.

- ***Innovation & Design Process*** credits sustainable building expertise as well as design measures not covered under the five LEED credit categories.

The Multi-Use High Rise project receives credits from all six LEED categories, but still only comes to 28 out of the possible 69 points obtainable. *Table 15* shows, specifically, where these points are obtained:

Table 14 - Current LEED Evaluation Summary

	POINTS EARNED	POSSIBLE POINTS
Sustainable Sites	9	14
Water Efficiency	1	5
Energy & Atmosphere	1	17
Materials & Resources	4	13
Indoor Environmental Quality	8	15
Innovation & Design	5	5
Total	**28**	**69**

Refer to *Appendix K* for the complete current LEED Evaluation

6.6 OBTAINABLE LEED CREDITS

Upon further review, there are several strategies that can be put in place to increase the LEED credibility of this project. *Table 15* reveals an upgraded summary of the New LEED Evaluation.

Table 15 - New LEED Evaluation Summary

	OLD SCORE	NEW SCORE	POSSIBLE POINTS
Sustainable Sites	9	11	14
Water Efficiency	1	3	5
Energy & Atmosphere	1	5	17
Materials & Resources	4	4	13
Indoor Environmental Quality	8	10	15
Innovation & Design	5	5	5
Total	**28**	**39**	**69**

Refer to *Appendix L* for the complete LEED Re-Evaluation

The strategies that help increase the LEED rating are outlined below; there are noticeable changes in the Sustainable Sites, Water Efficiency, Energy & Atmosphere, and Indoor

Environmental Quality categories. A total of 11 points were added to the original LEED Evaluation, bringing the new total to 39 points. With 39 credits, a LEED Gold certification is now achieved.

6.6.1 SUSTAINABLE SITES *(+2 POINTS)*

Currently, nine out of a possible fourteen LEED credits are achieved through sustainable site strategies. There is potential for several more points in this category through Credit 6: Storm Water Design.

Credit 6: Storm Water Design

- Storm Water Collection System- ***2 Points Obtained***

If the Multi-Use High Rise project were to implement a storm water run-off system, there is a potential for a significant amount of rainwater to be harvested. *Table 16* shows the potential rainwater that is harvestable. Note: One inch of rainfall equates to 0.625 gallons of water harvested per square foot of roof area.

Table 16 - Maximum Gallons Harvested

	# gal/sf for 1" rainfall	Avg. Yearly Rainfall	Net Roof Area (SF)	Yearly Gallons Harvested	Monthly Gallons Harvested
Building 1	0.625	42.05	25747	679,996.34	56,666.36
Building 2	0.625	42.05	7884	207,201.36	17,266.78
Total				**860,581.79**	**71,715.15**

It is important to note the total gallons is based on a 97% runoff efficiency factor in order to account for the percent of rain that is likely to bot travel to the collection tanks. Table 16 shows the estimated water usage for the Multi-Use High Rise project. In order to hold the sufficient amount of collected rainwater, three- 25,000 gallon RainMaster Fiberglass Rainwater System tanks should be buried underground to collect the rain water. This will provide over 75,000 gallons of rainwater to be collected, which could easily be done in a month's time, and then pumped to be potentially used for toilet water or irrigation use. Each tank will cost approximately $60,000, take roughly 6 weeks to arrive on site, and will require excavation, bracing and a crane for installation. Along with installation, labor and other necessary parts, the total cost for introducing a storm water collection system is an estimated $ 200,000. If this system were to be put in place, an additional two LEED credits would be achieved.

***Refer to *Appendix M* for the cost breakdown**

6.6.2 WATER EFFICIENCY

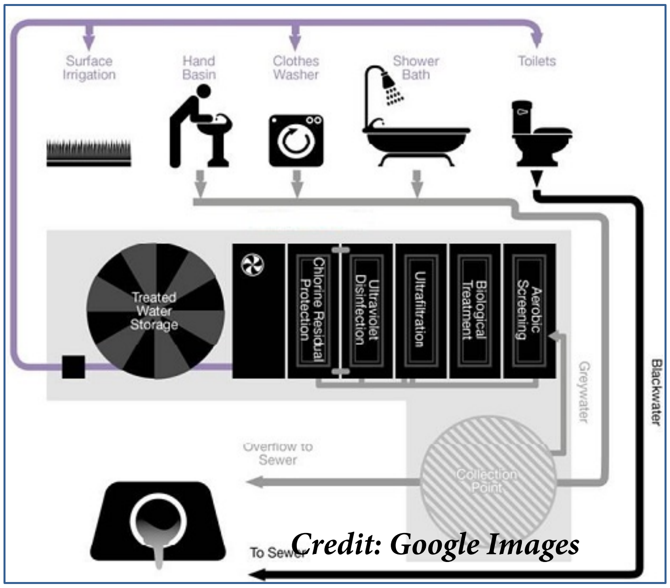
Credit 1: Water Efficient Landscaping

- Storm Water Collection System- ***2 Points Obtained***

The above storm water collection system also gains two LEED credits under this category.

- Grey Water Recapture System- 1 ***Points Obtained***

In order to achieve another LEED credit, a grey-water recapture system may be utilized. Grey water is the waste water that comes from the uses of laundry, dishwashing, sinks, and bathing. Grey water differs from black water because it doesn't take as long for pollutants to decay, making it easier to purify for reuse. In the Multi-Use High Rise project, grey water and black water ware combined at the sewer, and treated under the same system. *Figure Q* shows a clear example of how a grey water system separates grey water from black water.



Credit: Google Images

Figure Q - Grey Water Recapture

In this system, all grey water being produced from each tenant will be collected, treated and purified, and then recycled to be used for irrigation, faucet, laundry, shower, and toilet water. The treatment of this water includes aerobic screening, biological treatment, ultrafiltration, ultraviolet disinfection, and chorine residual protection. Once treated it will be sent to a storage tank where it will then be pumped to its location of use. The black water, which comes from flushing a toilet, will be directed to the sewage system and will not be recycled. This system requires two different pipes, rather than the original single sanitary pipe, to separate the grey water from the black water. If a grey water recapture system is implemented, the project will obtain one additional LEED credit. The cost and constructability breakdown can be found in Section 6.8: Mechanical breadth.

6.6.3 ENERGY & ATMOSPHERE *(+2 POINTS)*

After speaking with the construction management team, it is evident one of the most important parts of achieving the most LEED credits are through Energy & Atmosphere prerequisites. This category has the potential for seventeen points, when this project only utilizes one. There is potential for LEED points through Credit 1: Optimize Energy Performance and Credit 5: Measurement & Verification.

Credit 1: Optimize Energy Performance

Currently, the Multi-Use High Rise project is optimizing 9.6% savings, which is just shy of a LEED credit. If the project uses the following strategies, several points will be obtained:

- Upgrade Core Lighting – ***1 Point Obtained***

The upgrade consists of changing all restroom lighting to LED lights. This resulted in $5,112/yr utility cost savings. A .9% energy cost savings, relative to the baseline, increases the cumulative savings to 10.6%. A10.6% energy savings is large enough to obtain one point in Energy & Atmosphere.

- Reduce Garage Lighting Power Density

This upgrade involved lowering FC levels with the owner’s consent and redesigning fixture layout to be more efficient. This resulted in $14,912/yr utility cost savings. A 2.3% energy cost savings, relative to the new 10.6% energy cost savings, increases total cost savings to 12.9%. This new savings does not allow for a LEED credit, but brings it closer to the next credit of energy performance optimization.

- Add Garage Lighting Occupancy Sensors – ***1 Point Obtained***

This upgrade involved luminaries that remain illuminated for fifteen minutes after being activated. This resulted in a $5,022/yr utility cost savings, which is a 1.2% increase. This increase brings the total cost savings to 14.1%, which is eligible for another LEED credit.

Credit 5: Measurement & Verification

- Tennant Sub-Metering - ***1 Points Obtained***

A main water, electric, and natural gas meter interfaces, as well as retail electric sub-meter will be added, so the owner can monitor each tenant individually. If energy is monitored on a per tenant basis, the tenant is more likely to implement energy efficient measures. This implementation adds one point to the LEED certification.

Credit 6: Green Power

- Dominion Virginia Power – ***1 Point Obtained***

The Multi-Use High Rise project will utilize a local energy efficient power company, Dominion Virginia Power. This company provides distribution and electric supply. The basic customer charge will be $127.60 per month. *Table 17* shows the cost to power this project. Utilizing this power company adds one LEED credit to the project.

Table 17- Dominion Cost Breakdown

	COST
First 5000 kW of Distribution	$ 1.000/kW
Additional kW of Distribution	$ 0.755/kW
rkVA Demand Charge	$ 0.150/rkVA
Primary Service Voltage	$ 11.161/kWh

6.6.4 MATERIALS & RESOURCES

The Multi-Use High Rise project currently has obtained all possible LEED points for the Materials & Resources category. The total points obtained through this category will remain at four points.

6.6.5 INDOOR ENVIRONMENTAL QUALITY *(+2 POINTS)*

The Multi-Use High Rise project has currently obtained 8 of a possible fifteen points under this category. There is a possibility for an additional point through Credit 1: Outdoor Air Delivery Method and Credit 7.2: Thermal Comfort, Verification.

Credit 1: Outdoor Air Delivery Method

- Carbon Monoxide Monitoring – ***1 Point Obtained***

The Multi-Use High Rise project currently does not provide carbon monoxide monitoring. Carbon monoxide is a dangerous, deadly poison that can be found in any apartment complex due to a malfunction in an appliance or exhaust system. If one carbon monoxide detector was installed to each room, it would increase total costs by approximately $10,000. This is a very small increase in price, for a very valuable, life-saving device. Installing these devises add one credit to the LEED certification.

Credit 7.2: Thermal Comfort, Verification

- Thermal Comfort Survey – ***1 Point Obtained***

A survey of the thermal comfort level for the Multi-Use High Rise project was created, which will be delivered to all occupants once the building is turned over to the owner.

****Refer to Appendix N to view the survey***

6.6.6 INNOVATION & DESIGN PROCESS

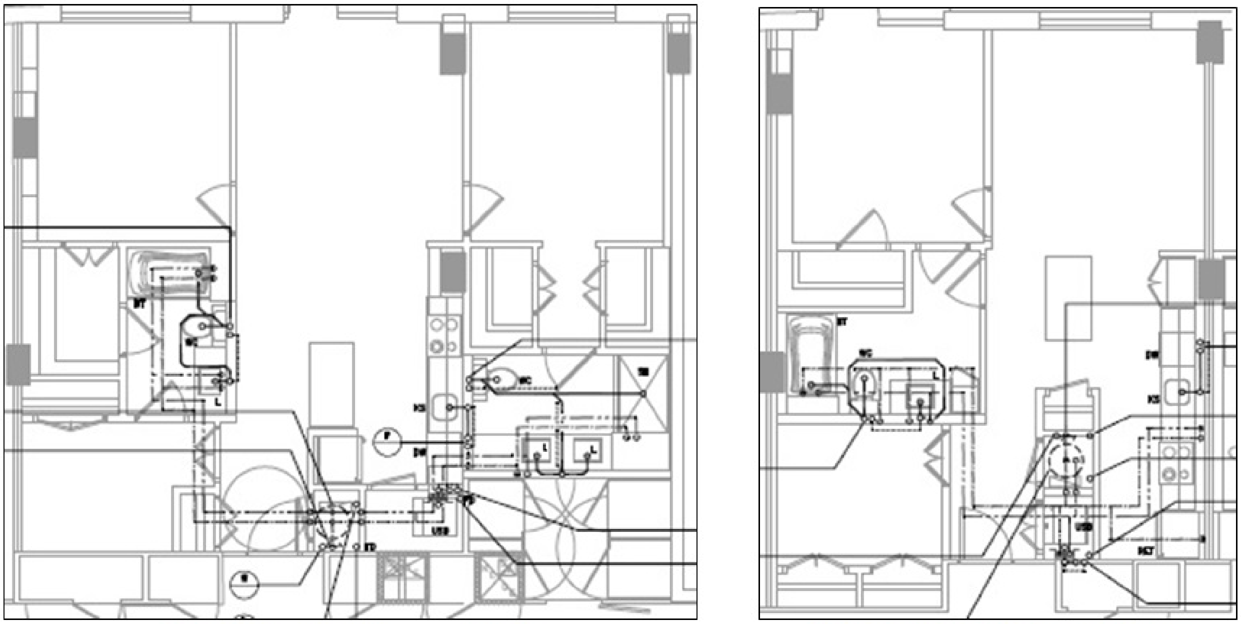
The Multi-Use High Rise project currently has obtained all possible LEED points for the Innovation & Design Process category. The total points obtained through this category will remain at five points.

6.7 MECHANICAL BREADTH

For the mechanical breadth, the focus will be on implementing a grey water recapture system. In order to implement this system, a re-design of the mechanical system will have to take place. For sake of this analysis, the focus of the plumbing redesign will be plumbing for a typical one bathroom unit and a typical two bathroom unit. This analysis will then be extrapolated for the entire project showing a detailed cost breakdown.

6.7.1 CURRENT MECHANICAL SYSTEM

The current mechanical system is a standard mechanical system for an apartment building, with pipe chases and riser directly above each other due to similar bathroom locations on a floor to floor basis. This is true for both the domestic water and sanitary risers. *Figure R*, viewed below shows the pluming design for a typical two bathroom unit and typical one bathroom unit. The two bathroom unit contains a bath tub, a shower stall, two toilets, three lavatories, a hot water heater, dish washer, kitchen sink, and a refrigerator. The one bathroom unit contains a bath tub, one toilet, one lavatory, a hot water heater, dishwasher, kitchen sink, and a refrigerator. Each of these fixtures requires plumbing to connect it to the closest riser. For all domestic water, copper piping is used; for all sanitary water, PVC piping is used. *Table 18* shows the bathroom unit breakdown, revealing 130 1-bathroom units and 30 2-bathroom units. The total cost for the original mechanical system comes to $ 3,625,247.85.



Typical 2 Bathroom Unit

Typical 1 Bathroom Unit

Figure R - Typical Bathroom Unit

******Refer to Appendix O for the detailed cost estimate***

Table 18- Bathroom Unit Breakdown

	BUILDING 1	BUILDING 2	TOTAL
1- Bathroom Units	90	40	130
2- Bathroom Units	30	0	30

Currently, providing 160 total apartment units, this building uses a significant amount of water. *Table 19* shows the approximate amount of water used by the tenants in the building for an entire year, which reaches over 2.5 million gallons. This is one key indicator that a grey-water recapture system may be efficient, when so much water is being wasted in the sanitary pipe, when the potential for water reuse and cost savings is obtainable.

Table 19 - Water Use Breakdown

	GPM	APPROX. MIN/USE	USE/DAY	UNITS	GAL./DAY	GAL./MONTH	GAL./YEAR
Toilet	1.28	.5	2	160	204.8	6,229.33	74,752
Shower	1.8	10	2	160	5,760	175,200	2,102,400
Faucet	1.8	1	5	160	1,440	43,800	525,600
Total					**7,404.8**	**225,229.33**	**2,702,752**

Using this incredible amount of water certainly is not cheap. Not only does it cost money to provide this amount of water to the building, but it also cost to remove the sewage waste from it, once it is drained. For this property, with the amount of water needed to service the toilets, showers and faucets, it will cost $2,840.16 per month, and roughly $34,000 per year. Implementing the grey-water recapture system will ultimately save the building's owner of these utility costs. *Table 20* shows a breakdown of costs savings.

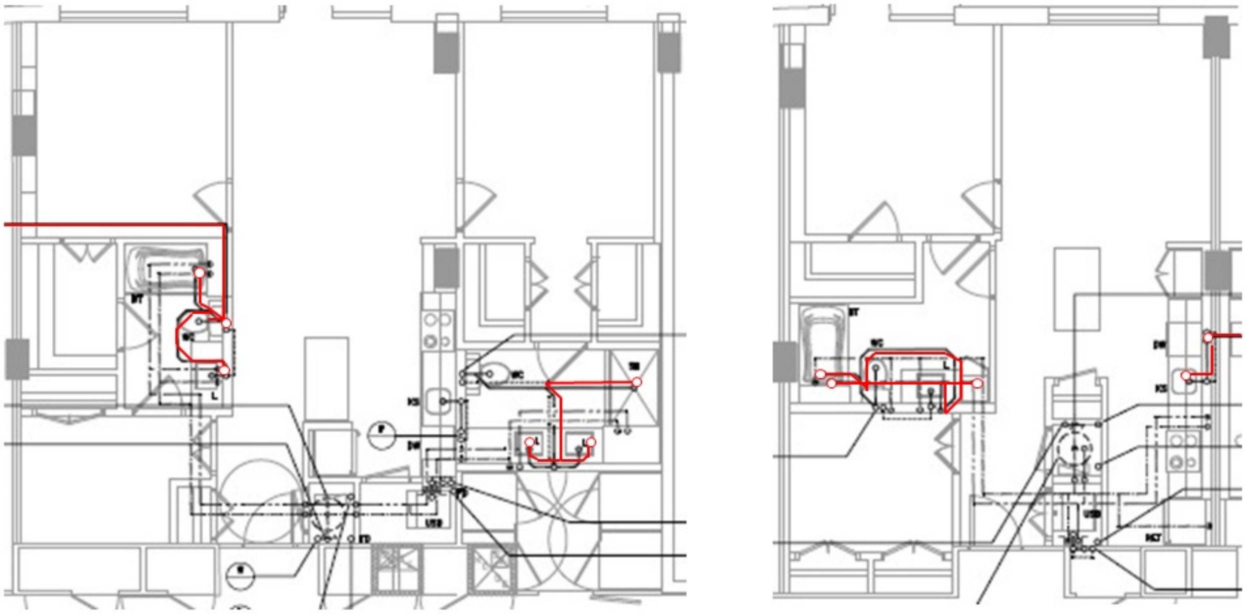
Table 20 - Water Utility Cost Savings

	RATE PER 1,000 GAL.	GAL/MONTH	GAL/YEAR	MONTHLY SAVINGS	YEARLY SAVINGS
Water Supply	$ 3.98	225,229.33	2,702,752	$ 896.41	$ 10,756.95
Sewage	$ 8.63			$ 1,943.75	$ 23,324.75
Total Savings				**$ 2,840.16**	**$ 34,081.70**

Implementing a grey water recapture system will certainly lower these utility costs.

6.7.2 Grey water Recapture System

The grey water recapture system will provide the Multi-Use High Rise building with an ample amount of stored water to use for irrigation and domestic water use. This system will potentially save the owner a significant amount of money, due to the incredibly high amount of water usage the tenants will use throughout the course of a year. The new system design will provide the grey water to be recaptured and delivered to each unit's toilet, shower and faucet. The new mechanical design will be similar to the original plan, but an additional grey-water collection pipe will be incorporated, directly next to the sanitary pipe throughout the entire building. This will also cause additional grey-water risers to be installed. Additional piping will be used to allow the collected grey water travel to the filtration station and the collection tank. View the figures below to see the new grey water recapture implemented to the mechanical system. *Note: The red lines represent the grey water collection piping.*



Typical 2 Bathroom Unit

Typical 1 Bathroom Unit

Figure S - Typical Bathroom Units w/ Grey Water Recapture

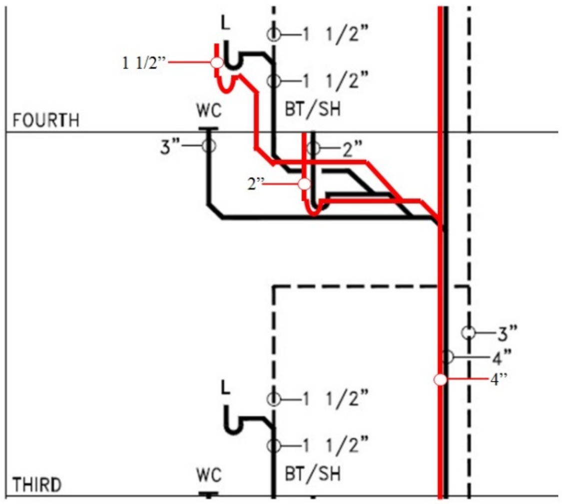


Figure T - Typical Grey Water Riser

Figure S and *Figure T* clearly show the similar piping layout as the original mechanical system, except additional pipe and risers for grey water capture. Once the system is in place, due to the amount of water captured per day, a large tank should be installed to collect the water. A 30,000 gallon capacity tank will be used. The potential location of this tank will be strategically placed between Building A and Building B, and can be seen in *Figure U*. This tank is equipped with an industrial filtration system, purification package, a flow inducer pump station, maintenance and self-cleaning supplies, calming inlet, and an overflow siphon. The tank will be ten feet in diameter and roughly 56 feet in length.

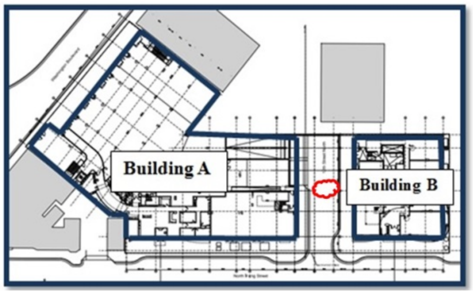


Figure U - Potential Tank Location

After completing a detailed cost estimate of implementing the grey-water recapture system to the mechanical system, it is clearly an increase in total cost. *Table 21* shows the cost breakdown.

Table 21 - Mechanical System Cost Breakdown

	TOTAL COST
Original Mechanical System	$ 3,625,247.85
New Mechanical System	$ 5,122,825.26

Refer to Appendix P for the complete cost estimate of the grey water system.

Although implementing a grey-water recapture system requires a $1,497,577.41 increase in mechanical system costs, it also allows for a $34,081.70. For sake of analysis, there is an estimated $ 1,200 yearly cost for routine maintenance. This allows for a payback period of 44 years. Table 21 shows the payback period breakdown for the first fifty years of service.

Table 22 - Payback Period Breakdown

	COSTS	UTILITY SAVINGS	
Initial Cost	($ 1,497,577.41)		
Year 1		$ 34,081.70	($ 1,464,695.72)
Year 10		$ 34,081.70	($ 1,224,923.81)
Year 20		$ 34,081.70	(815,943.41)
Year 30		$ 34,081.70	($ 475,126.41)
Year 40		$ 34,081.70	($ 202,472.81)
Year 44		$ 34,081.70	$ 2,017.39
Year 50		$ 34,081.70	$ 206,507.59

6.9 CONCLUSIONS AND RECOMMENDATION

The Multi-Use High Rise project utilizes many sustainable features, enough to provide a LEED certification. Following in-depth analysis, it is evident even more strategies can be examined and potentially implemented in order to increase this LEED rating. *Table 23* shows the new sustainable strategies and recommendations. In conclusion, the goal of this analysis was to provide a better LEED score for the project, and this goal was achieved. If all implementations were utilized, a LEED Gold score would be achieved, but following the recommendation to the owner, the project's sustainability rating will become a LEED Silver certification.

Table 23 - Final LEED Recommendations

STRATEGY	POINTS EARNED	RECOMMENDATION
Storm Water Collection	4	*Recommended*
Grey Water Recapture	1	*Not Recommended*
Upgrade Core Lighting	1	*Recommended*
Reduce Garage Lighting Power Distribution	-	*Recommended*
Add Garage Occupancy Sensors	1	*Recommended*
Tennant Sub-Metering	1	*Recommended*
Dominion Virginia Green Power	1	*Recommended*
Carbon Monoxide Monitoring	1	*Recommended*
Thermal Comfort Survey	1	*Recommended*

SECTION 7: FINAL RECOMMENDATIONS AND CONCLUSIONS

Over the course of this final academic year at the Pennsylvania State University, a thorough analysis of the Multi-Use High Rise project had taken place. The first semester consisted of technical research of the entire project and it's all of the systems and components making up the project. This provided a significant background and detail of every single aspect put into the project. During the spring semester, further analysis was taken into areas of proposed change. This analysis was broken into four major areas. The first analysis included implementing mobile technology and PC tablets to the construction site. The second analysis introduced bathroom modularization, rather than traditional stick built bathroom to the project. The third analysis included changing the traditional brick façade to a prefabricated façade; this section also included a structural breadth, measuring the loading of the new façade and its effect on the current concrete structure. Finally, the fourth analysis included implementing greater sustainability strategies in hopes to increase the projects LEED rating; this section also included a mechanical breadth, including a redesign of the mechanical system in order to implement a grey-water recapture system. Once analysis was complete on all topics, recommendations were provided based on each depth of analysis. *Table 24* provides each topic and the final recommendations found through comprehensive analysis.

Table 24 - Final Recommendations

TECHNICAL ANALYSIS	RECOMMENDATION
Mobile Technology Integration	***Recommended***
Bathroom Modularization	***Recommended***
Façade Prefabrication	***Not Recommended***
Greater Sustainable Design	***Recommended***
Storm Water Collection	*Recommended*
Grey Water Recapture	*Not Recommended*
Upgrade Core Lighting	*Recommended*
Reduce Garage Lighting Power Distribution	*Recommended*
Add Garage Occupancy Sensors	*Recommended*
Tennant Sub-Metering	*Recommended*
Dominion Virginia Green Power	*Recommended*
Carbon Monoxide Monitoring	*Recommended*
Thermal Comfort Survey	*Recommended*

TECHNICAL ANALYSIS 1: MOBILE TECHNOLOGY INTEGRATION

Based on the studies presented in section 3, as well as the financial feasibility presented through *Table 1* and *Table 2*, it is recommended to integrate tablet computers to the Multi-Use High Rise project. This integration offers the opportunity for Donohoe Construction to become more advanced and more efficient than its competitors through benefits like decreased on-site management costs of $2,028/week; increased quality, efficiency and customer service; and the adaptability to future practices in the construction industry. The result of this analysis shows significant success with mobile technology integration. By utilizing tablet computers at the Multi-Use High Rise project, the construction management team will save $210,912 in on-site management costs throughout the entire project.

TECHNICAL ANALYSIS 2: BATHROOM MODULARIZATION

Based on the analysis performed in section 4, it is recommended to implement modular construction on the bathroom units of the Multi-Use High Rise project. Implementing modular construction for the bathroom of the Multi-Use High Rise project will allow construction efforts to be accelerated. Finishing this project on time is a key component to this project that Donohoe Construction Company will strive for. There is a potential to save roughly 55 working days using modular construction on the bathroom units. For the implementation of modular bathroom units, the cost of the bathrooms will increase by 0.5%, or $18, 349.76. This slight cost increase could potentially save the project money in the end by helping to finish the project on time. The sooner this project is complete, the sooner the owner can allow occupants to move in, and the sooner the owner makes money. This slight increase in cost is negligible and should not be the reason modular construction is not performed.

TECHNICAL ANALYSIS 3: ALTERNATIVE STRUCTURAL SYSTEM

Based on analysis and breadth study, it is difficult to decide whether to implement the prefabricated façade panels or stick to the traditional façade. There is an excellent acceleration of the project schedule, providing 47 weeks of duration savings. This is very important for a project with so many time constraints and rising issues throughout the job. Although the time savings is so vast, there is also a significant impact on the total project cost. It will cost the owner over $830,000 to implement the new prefabricated façade system. This is money the owner will not likely want to see being spent. Following a structural breadth, it is evident the new façade will contribute to a decrease in total load and total deflection, and an increase in total moment for a typical 16” x 30” reinforced concrete beam. This increase in moment causes the beam to be inefficient to withstanding the new façade. With that being said, structurally, the new façade will require a new structural beam design, which will cause the project to become more complex, expensive, and take more time. In conclusion, implementing a prefabricated brick façade system is not recommended for the Multi-Use High Rise project. Sure, the implementation saves much valuable time, but it is far more expensive than it is worth and the owner would certainly not be appreciated of the decision.

TECHNICAL ANALYSIS 4: GREATER SUSTAINABLE DESIGN

The Multi-Use High Rise project utilizes many sustainable features, enough to provide a LEED certification. Following in-depth analysis, it is evident even more strategies can be examined and potentially implemented in order to increase this LEED rating. *Table 22* shows the new sustainable strategies and that all but the grey-water recapture system is recommended for use. In conclusion, the goal of this analysis was to provide a better LEED score for the project, and this goal was achieved. If all implementations were utilized, a LEED Gold score would be achieved, but following the recommendation to the owner, the project’s sustainability rating will become a LEED Silver certification.

APPENDIX

APPENDIX A: GENERAL CONDITIONS ESTIMATE

Jobsite Management

Title	Weeks	Cost/Week	Total Cost
Vice President	105	$ 3,930.00	$ 412,650.00
Senior Project Manager	105	$ 3,275.00	$ 343,875.00
Senior Superintendent	105	$ 3,275.00	$ 343,875.00
Project Engineer	105	$ 1,875.00	$ 196,875.00
Project Engineer	52.5	$ 1,875.00	$ 98,437.50
Assistant Superintendent	78.5	$ 3,025.00	$ 237,462.50
Assistant Superintendent	26.25	$ 3,025.00	$ 79,406.25
Quality Control Manager	105	$ 3,275.00	$ 343,875.00
Quality Assistant	105	$ 2,025.00	$ 212,625.00
Quality Assistant	78.5	$ 2,025.00	$ 158,962.50
Senior Safety Supervisor	105	$ 3,275.00	$ 343,875.00
Safety Supervisor	78.5	$ 2,025.00	$ 158,962.50
Total			**$ 2,930,881.25**

Equipment & Facilities

Item	Quantity	Unit	Cost/Unit	Total Cost
Documentation	1	Ls	$ 30,000.00	$ 30,000.00
Overnight Delivery	24.5	Mo	$ 700.00	$ 17,150.00
Construction Signage	1	Ls	$ 6,500.00	$ 6,500.00
Field Office Set-Up	1	Mo	$ 2,500.00	$ 2,500.00
Field Office Rental	24.5	Mo	$ 1,000.00	$ 24,500.00
Printer/Copier	24.5	Mo	$ 500.00	$ 12,250.00
Office Survey/Layout Equipment	24.5	Mo	$ 700.00	$ 17,150.00
Minor Tools & Equipment	24.5	Mo	$ 1,600.00	$ 39,200.00
Housekeeping	105	Wk	$ 780.00	$ 81,900.00
Safety Equipment	24.5	Mo	$ 200.00	$ 4,900.00
Fire Extinguishers	24.5	Mo	$ 250.00	$ 6,125.00
Miscellaneous Expenses	24.5	Mo	$ 1,550.00	$ 37,975.00
Total				**$ 280,150.00**

Temporary Utilities

Item	Quantity	Unit	Cost/Unit	Total Cost
Early Power	8.085	Mo	$ 2,000.00	$ 16,170.00
Middle Power	8.085	Mo	$ 9,500.00	$ 76,807.50
Late Power	8.085	Mo	$ 15,000.00	$ 121,275.00
Power Install	1	Ls	$ 50,000.00	$ 50,000.00
Potable Water	24.5	Mo	$ 200.00	$ 4,900.00
Phone/Internet Hookup	1	Ls	$ 2,500.00	$ 2,500.00
Phone/Internet Service	24.5	Mo	$ 150.00	$ 3,675.00
Temporary Toilets	24.5	Mo	$ 1,000.00	$ 24,500.00
Dumpsters	3	Ld	$ 500.00	$ 1,500.00
Total				**$ 301,327.50**

Insurance, Permits, & Bonding

Item	Value	Total
Permits		$ 2,500.00
Certificate of Occupancy		$ 1,000.00
Comercial General Liability	.4% Total Contract	$ 176,000.00
Builder’s Risk Insurance	.25% Total Contract	$ 110,000.00
Payment & Performance Bond	.75% Total Contract	$ 330,000.00
Total		**$ 619,500.00**

APPENDIX B: STRUCTURAL SYSTEMS DETAILED ESTIMATE

DETAILED STRUCTURAL ESTIMATE

Item	QTY	Unit	Mat'l $/Unit	Mat'l Total	Labor $/Unit	Labor Total	Equip't $/Unit	Equip't Total	Total Cost
FORMWORK									
Footings	1265.7	SFCA	$ 2.97	$ 3,759.13	$ 9.30	$ 11,771.01	$ -	$ -	$ 15,530.14
Columns	14647	SFCA	$ 2.97	$ 43,501.59	$ 9.30	$ 136,217.10	$ -	$ -	$ 179,718.69
Beams	8913.17	SFCA	$ 2.97	$ 26,472.11	$ 9.30	$ 82,892.48	$ -	$ -	$ 109,364.60
Slabs	3185.35	SFCA	$ 2.97	$ 29,623.76	$ 9.30	$ 29,623.76	$ -	-	$ 59,247.51
REINFORCING									
#3	38.04	TON	$ 1,000.00	$ 38,040.00	$ 550.00	$ 20,922.00	$ -	$ -	$ 58,962.00
#5	34.79	TON	$ 1,000.00	$ 34,790.00	$ 550.00	$ 19,134.50	$ -	$ -	$ 53,924.50
#7	0.291	TON	$ 1,000.00	$ 291.00	$ 550.00	$ 160.05	$ -	$ -	$ 451.05
#8	44.64	TON	$ 1,000.00	$ 44,640.00	$ 445.00	$ 19,864.80	$ -	$ -	$ 64,504.80
#9	222.39	TON	$ 1,000.00	$ 222,390.00	$ 445.00	$ 98,963.55	$ -	$ -	$ 321,353.55
#10	53.78	TON	$ 1,000.00	$ 53,780.00	$ 445.00	$ 23,932.10	$ -	$ -	$ 77,712.10
#12	1.07	TON	$ 1,000.00	$ 1,070.00	$ 445.00	$ 476.15	$ -	$ -	$ 1,546.15
CONCRETE									
Column Footings	2554.43	CY	$ 112.00	$ 286,096.16	$ 73.00	$ 186,473.39	$ -	$ -	$ 472,569.55
Columns	9915.29	CY	$ 112.00	$ 1,110,512.48	$ 73.00	$ 723,816.17	$ -	$ -	$ 1,834,328.65
Reinforced Bean	2356.77	CY	$ 112.00	$ 263,958.24	$ 73.00	$ 172,044.21	$ -	$ -	$ 436,002.45
Slab on Grade	3125.33	CY	$ 104.00	$ 325,034.32	$ 14.40	$ 45,004.75	$ -	$ -	$ 370,039.07
Slab on Deck	2583.93	CY	$ 104.00	$ 268,728.72	$ 26.00	$ 67,182.18	$ -	$ -	$ 335,910.90
TOTAL COST				**$ 2,723,063.75**		**$ 1,608,854.44**		**$ -**	**$ 4,391,165.71**

APPENDIX C: MEP ASSEMBLIES DETAILED ESTIMATE

MEP Systems Estimate

	QTY	Units	Size	Material $/Unit	Material Total	Installation $/Unit	Installation Total	Total
Mechanical Distribution System								
Garage Fans	3	Ea	13,800 CFM	$ 11,600.00	$ 34,800.00	$ 47,900.00	$ 143,700.00	$ 178,500.00
Stair Air Pressure Fans	2	Ea	8500 CFM	$ 10,800.00	$ 21,600.00	$ 41,700.00	$ 83,400.00	$ 105,000.00
Ceiling Mounted Exhaust Fans	3	Ea	500 CFM	$ 2,650.00	$ 7,950.00	$ 2,850.00	$ 8,550.00	$ 16,500.00
Exhaust Fan	4	Ea	200 CFM	$ 2,900.00	$ 11,600.00	$ 1,800.00	$ 7,200.00	$ 18,800.00
Exhaust Fan	5	Ea	400 CFM	$ 3,225.00	$ 16,125.00	$ 2,475.00	$ 12,375.00	$ 28,500.00
Exhaust Fan	4	Ea	600 CFM	$ 3,625.00	$ 14,500.00	$ 3,375.00	$ 13,500.00	$ 28,000.00
Exhaust Fan	2	Ea	800 CFM	$ 3,825.00	$ 7,650.00	$ 3,875.00	$ 7,750.00	$ 15,400.00
Exhaust Fan	4	Ea	1000 CFM	$ 4,125.00	$ 16,500.00	$ 4,350.00	$ 17,400.00	$ 33,900.00
Exhaust Fan	4	Ea	1250 CFM	$ 4,700.00	$ 18,800.00	$ 5,450.00	$ 21,800.00	$ 40,600.00
Exhaust Fan	1	Ea	10000 CFM	$ 130,000.00	$ 130,000.00	$ 41,700.00	$ 41,700.00	$ 171,700.00
Air Flow Regulator	5	Ea	25 CFM	$ 2,000.00	$ 10,000.00	$ 500.00	$ 2,500.00	$ 12,500.00
AC Units	3	Ea	2 Ton	$ 2,050.00	$ 6,150.00	$ 525.00	$ 1,575.00	$ 7,725.00
100% OA Unit	1	Ea	21000 CFM	$ 220,000.00	$ 220,000.00	$ 41,500.00	$ 41,500.00	$ 261,500.00
Heat Pump	1	Ea	1.5 ton	$ 2,600.00	$ 2,600.00	$ 1,525.00	$ 1,525.00	$ 4,125.00
Heat Pump	4	Ea	2 ton	$ 3,525.00	$ 14,100.00	$ 1,825.00	$ 7,300.00	$ 21,400.00
Heat Pump	3	Ea	3 ton	$ 3,725.00	$ 11,175.00	$ 1,950.00	$ 5,850.00	$ 17,025.00
Heat Pump	2	Ea	3.5 ton	$ 4,025.00	$ 8,050.00	$ 2,000.00	$ 4,000.00	$ 12,050.00
100% OA Roof Unit	2	Ea	15,000 CFM	$ 100,000.00	$ 200,000.00	$ 25,000.00	$ 50,000.00	$ 250,000.00
100% OA Roof Unit	1	Ea	10,000 CFM	$ 69,500.00	$ 69,500.00	$ 12,000.00	$ 12,000.00	$ 81,500.00
MECHANICAL SYSTEM TOTAL					**$ 821,100.00**		**$ 483,625.00**	**$ 1,304,725.00**
Electrical Distribution System								
High Voltage Cable	7500	LF	25 kV	$ 40.50	$ 303,750.00	$ 32.50	$ 243,750.00	$ 547,500.00
3P/4W 600 A	3	Ea	600 A	$ 11,900.00	$ 35,700.00	$ 8,550.00	$ 25,650.00	$ 61,350.00
Switchboards	4	Ea	2500 A	$ 42,500.00	$ 170,000.00	$ 8,300.00	$ 33,200.00	$ 203,200.00
Panel	8	Ea	100 A	$ 3,475.00	$ 27,800.00	$ 3,825.00	$ 30,600.00	$ 58,400.00
Panel	4	Ea	400 A	$ 17,800.00	$ 71,200.00	$ 13,000.00	$ 52,000.00	$ 123,200.00
Panel	3	Ea	800 A	$ 36,200.00	$ 108,600.00	$ 19,400.00	$ 58,200.00	$ 166,800.00
ELECTRICAL TOTAL					**$ 717,050.00**		**$ 443,400.00**	**$ 1,160,450.00**
Plumbing Distribution System								
Water Heater Units	3	Ea	960 gph	$ 60,000.00	$ 180,000.00	$ 3,050.00	$ 9,150.00	$ 189,150.00
Domestic Water Heat Pump	2	Ea	Ton	$ 19,200.00	$ 38,400.00	$ 6,799.00	$ 13,598.00	$ 51,998.00
Sump Pump	4	Ea	2500 GPM	$ 41,000.00	$ 164,000.00	$ 14,972.00	$ 59,888.00	$ 223,888.00
Dry Sprinkler System	150000	SF	Steel Pipe	$ 2.28	$ 342,000.00	$ 1.94	$ 291,000.00	$ 633,000.00
PLUMBING SYSTEM TOTAL					**$ 724,400.00**		**$ 373,636.00**	**$ 1,098,036.00**
GRAND TOTAL					**$ 2,262,550.00**		**$ 1,300,661.00**	**$ 3,563,211.00**

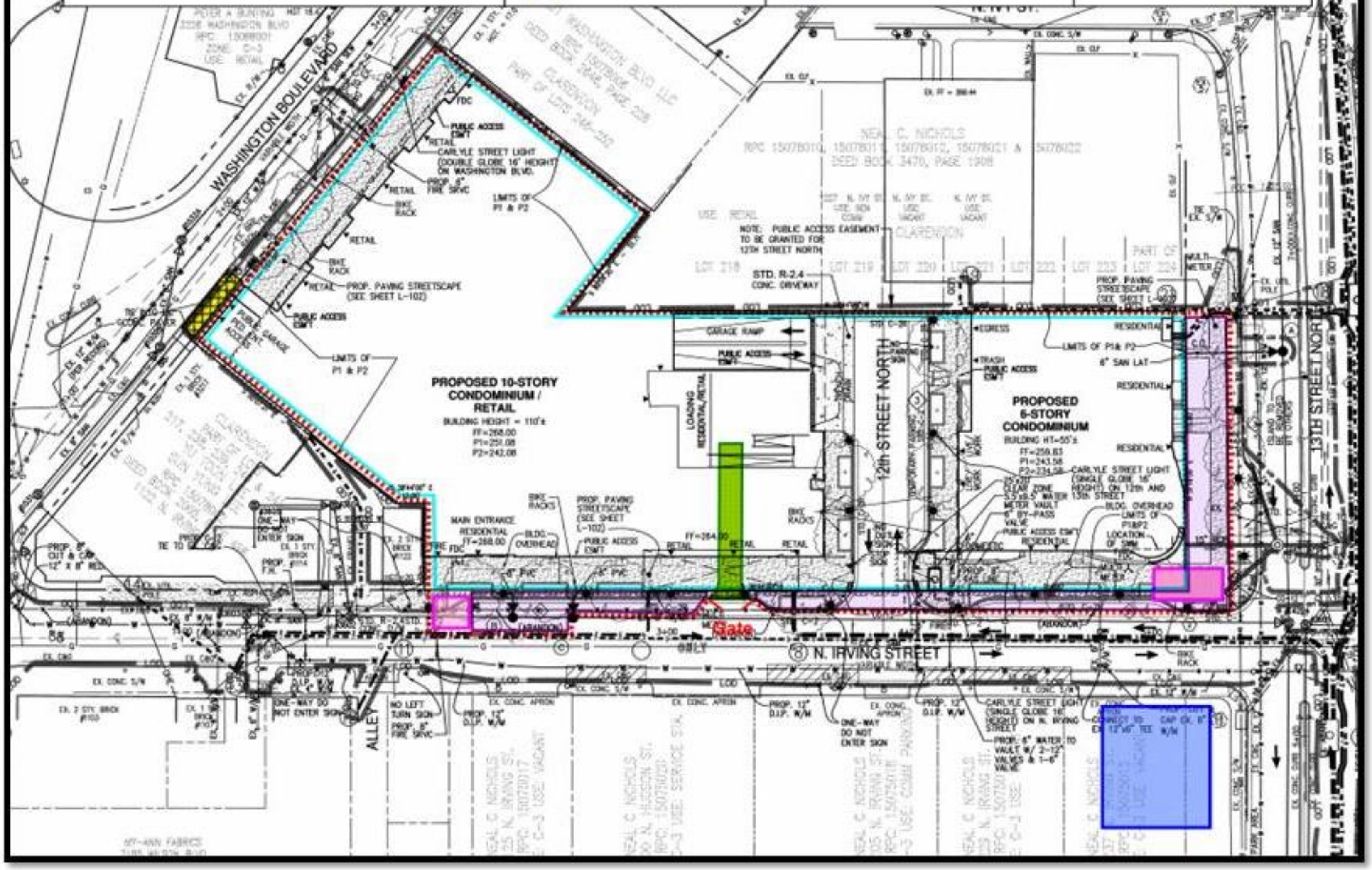
APPENDIX D: SITE LAYOUT

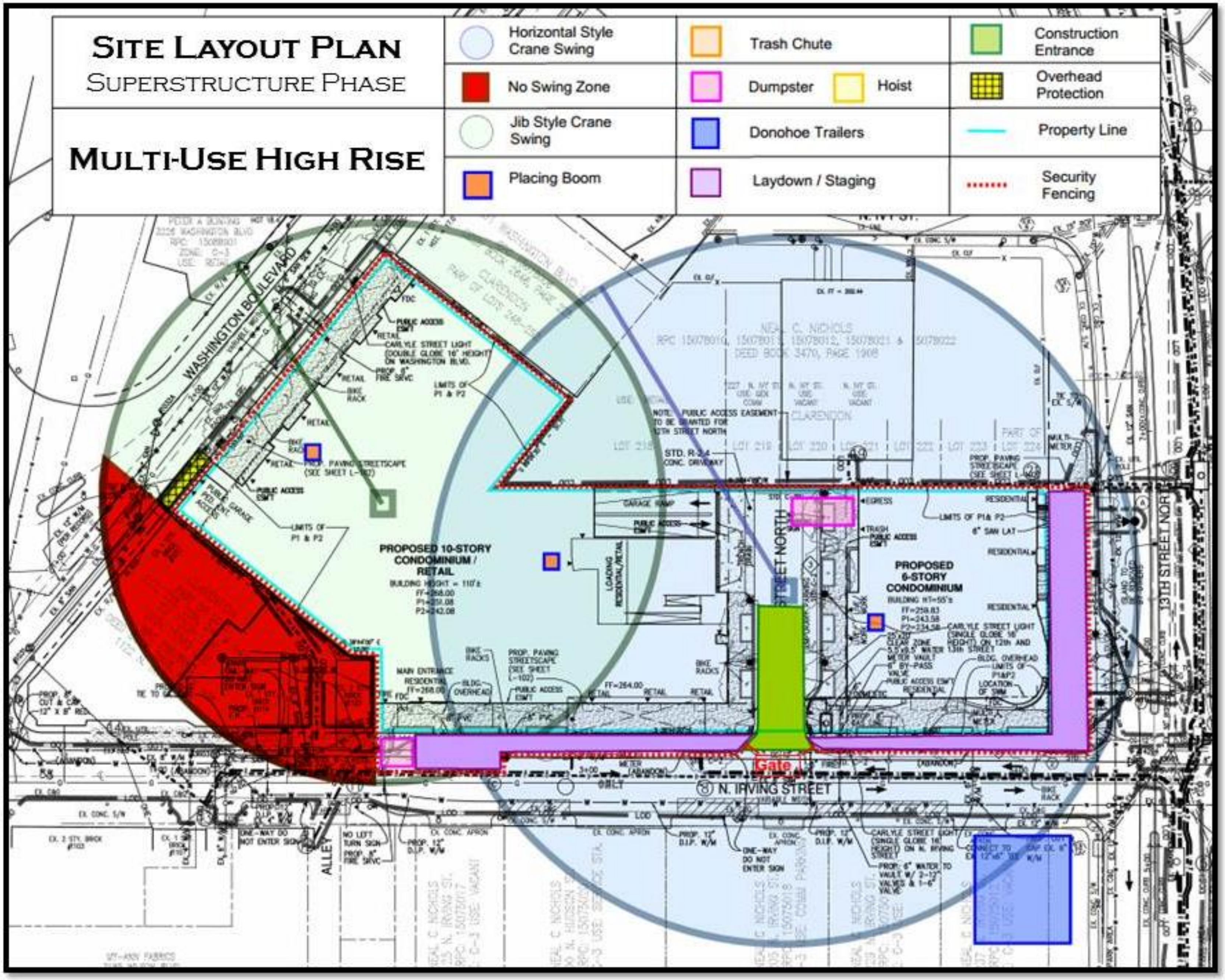
SITE LAYOUT PLAN

EXCAVATION PHASE

MULTI-USE HIGH RISE

○	Horizontal Style Crane Swing	🟧	Trash Chute	🟩	Construction Entrance
🟥	No Swing Zone	🟪	Dumpster 🟨 Hoist	▦	Overhead Protection
○	Jib Style Crane Swing	🟦	Donohoe Trailers	—	Property Line
🟧	Placing Boom	🟪	Laydown / Staging	……	Security Fencing





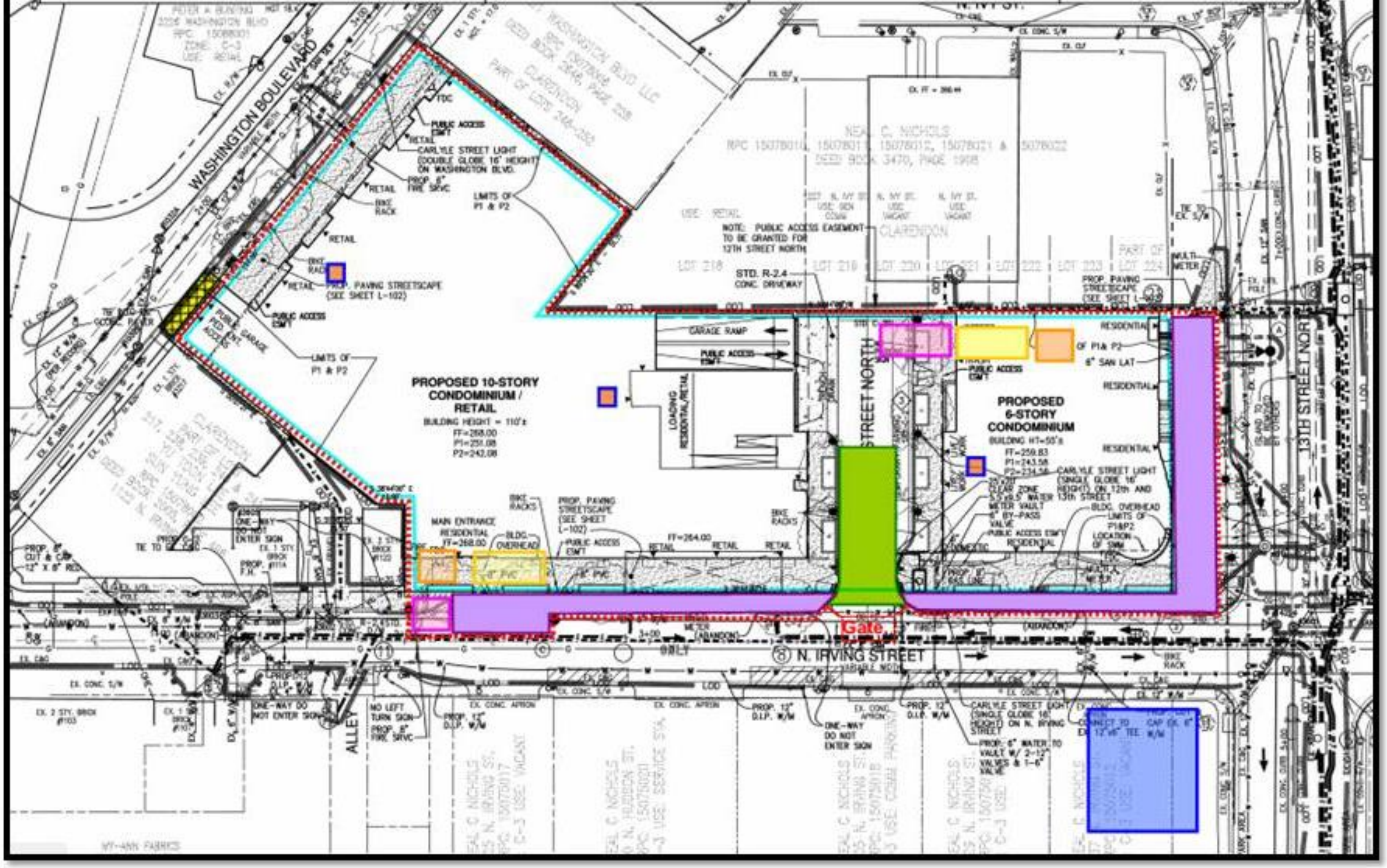
SITE LAYOUT PLAN
SUPERSTRUCTURE PHASE

MULTI-USE HIGH RISE

SITE LAYOUT PLAN
FINISH PHASE

MULTI-USE HIGH RISE

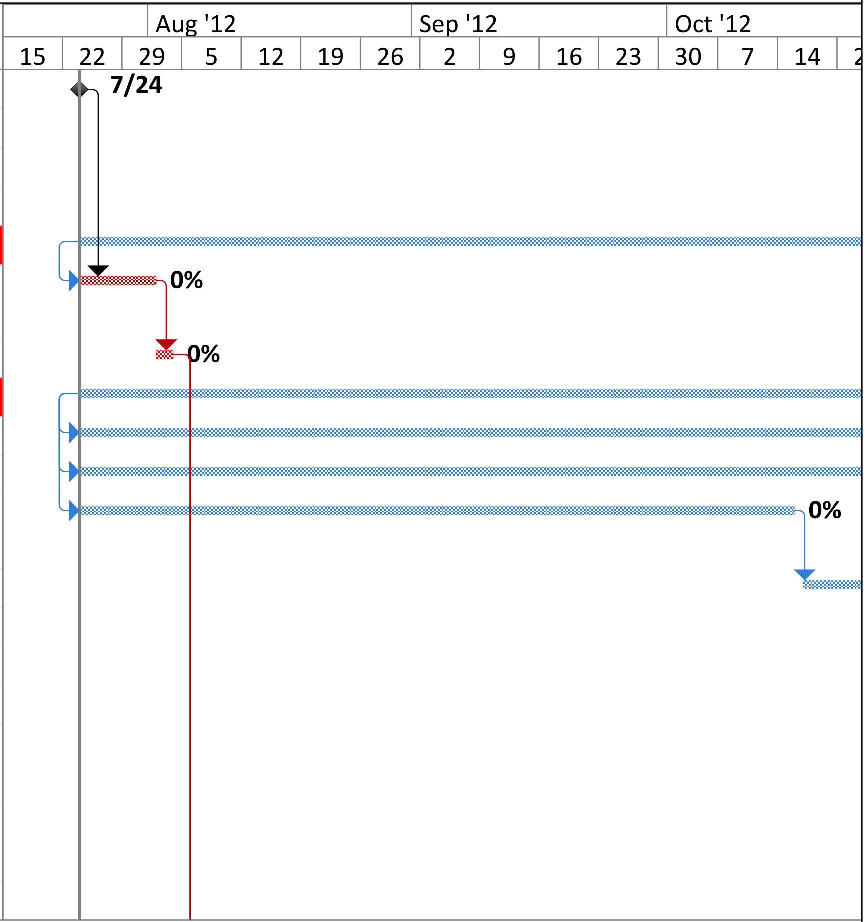
○	Horizontal Style Crane Swing	🟧	Trash Chute	🟩	Construction Entrance
🟥	No Swing Zone	🟪	Dumpster 🟨 Hoist	▦	Overhead Protection
○	Jib Style Crane Swing	🟦	Donohoe Trailers	—	Property Line
🟧	Placing Boom	🟪	Laydown / Staging	······	Security Fencing



APPENDIX E: DETAILED PROJECT SCHEDULE

Detailed Schedule.mpp

ID		Task Name	Duration	Start
1		**Notice To Proceed**	**0 days**	**Tue 7/24/12**
2		**Substantial Completion**	**0 days**	**Tue 7/29/14**
3		**Final Punchlist**	25 days	Wed 6/25/14
4		**Final Completion**	0 days	Tue 7/29/14
5		**PRECONSTRUCTION**	**110 days**	**Tue 7/24/12**
6		**3rd Party Critical Structures Meeting**	7 days	Tue 7/24/12
7		**Sheeting/Shoring Permit**	2 days	Thu 8/2/12
8		**Procurement**	**277 days**	**Tue 7/24/12**
9		**Procurement**	175 days	Tue 7/24/12
10		**MEP Coordination**	277 days	Tue 7/24/12
11		*Award MEP Contracts/Begin Coordination*	60 days	Tue 7/24/12
12		*MEP Coord: Ground FL*	20 days	Wed 10/17/12
13		*F/D Materials: Ground FL*	10 days	Wed 11/14/12
14		*MEP Coord: 2nd FL*	20 days	Wed 11/14/12
15		*F/D Materials: 2nd FL*	10 days	Fri 12/14/12
16		*MEP Coord: 3rd FL*	20 days	Fri 12/14/12
17		*F/D Materials:3rd FL*	10 days	Tue 1/15/13
18		*MEP Coord: 4th FL*	20 days	Tue 1/15/13
19		*F/D Materials:4th FL*	10 days	Tue 2/12/13
20		*MEP Coord: 5th FL*	20 days	Tue 2/12/13



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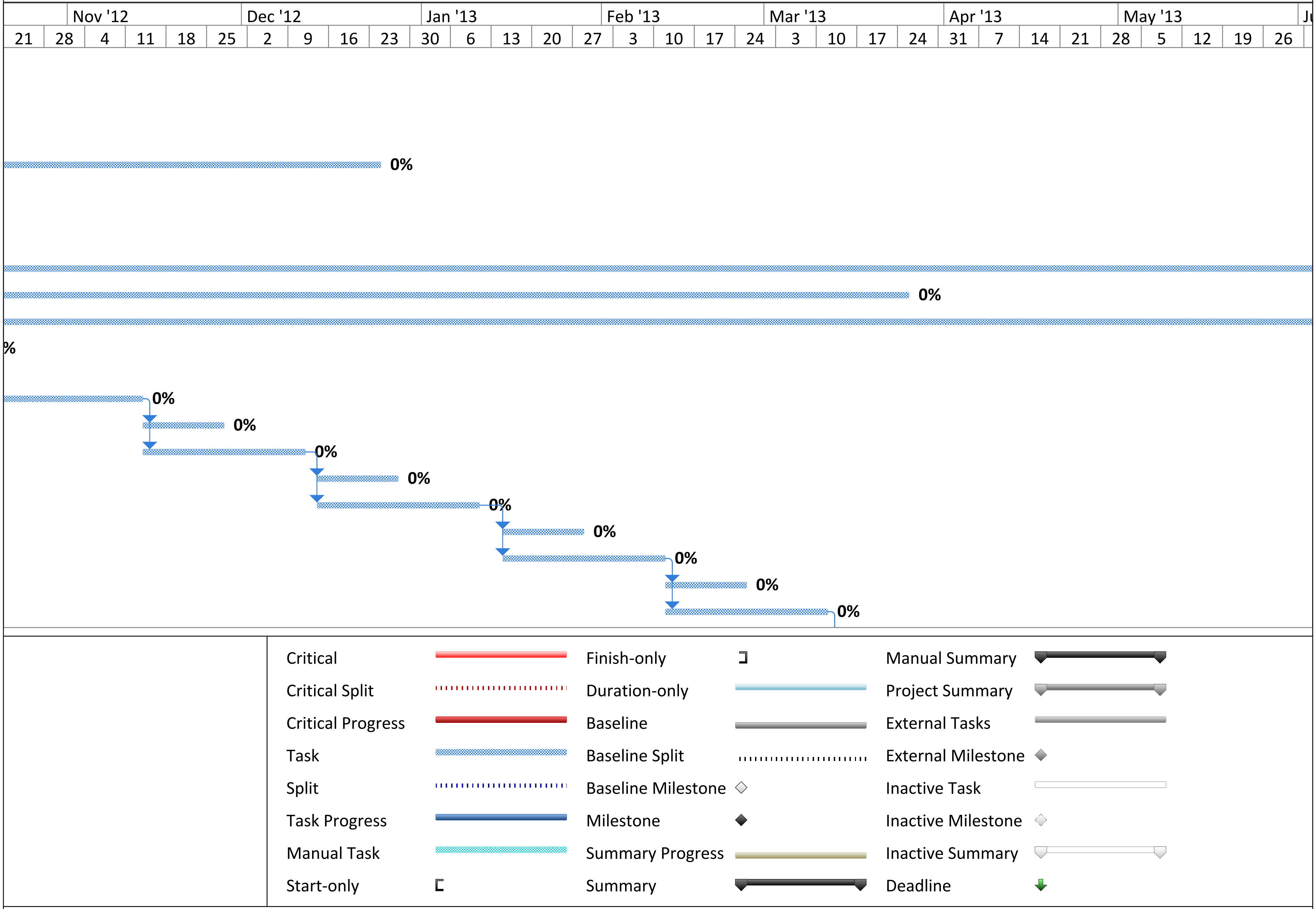
Critical Split	⋯	Duration-only	▬	Project Summary	▬
Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▬	Baseline Split	⋯	External Milestone	◆
Split	⋯	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▬	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	↓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External Milestone
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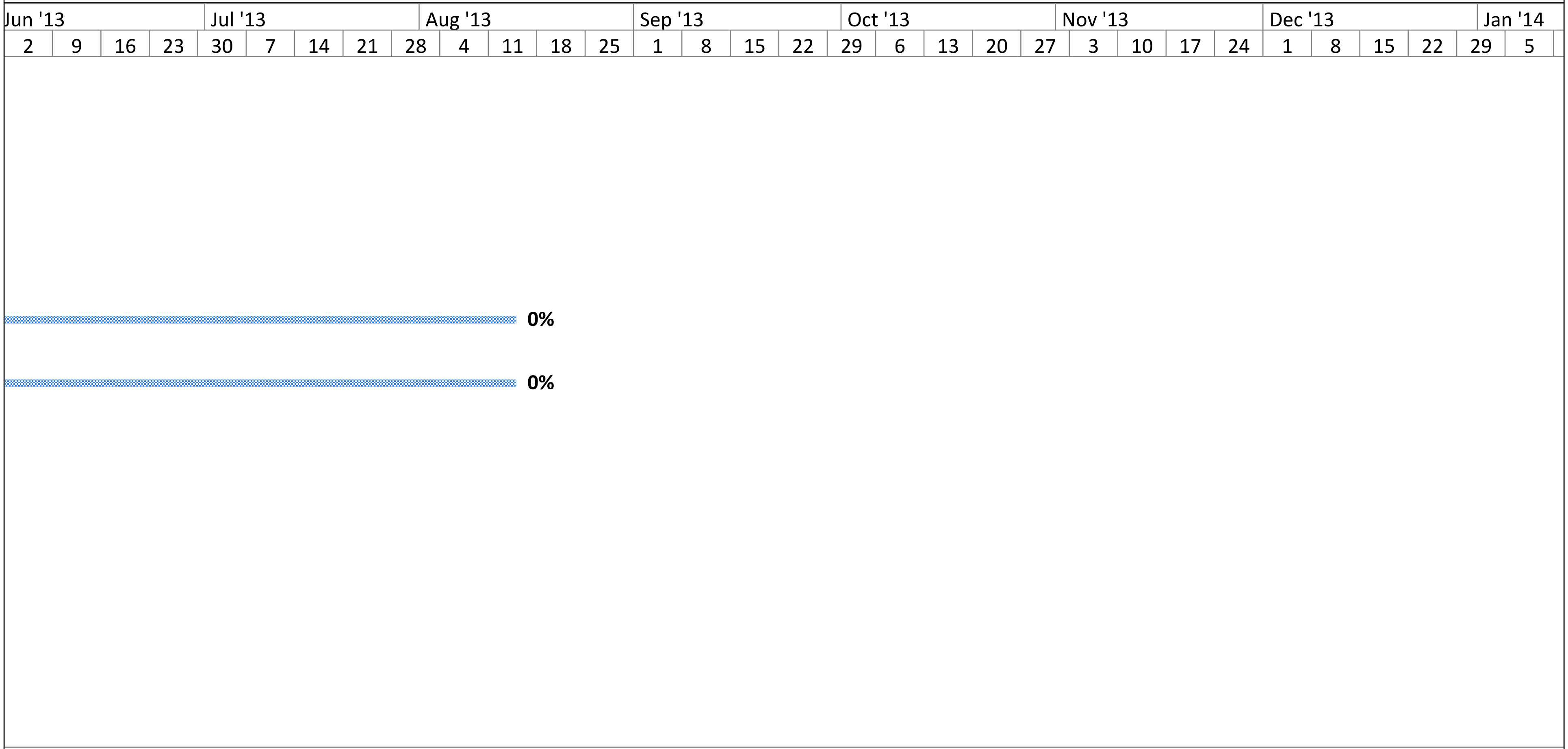
Inactive Summary
Deadline



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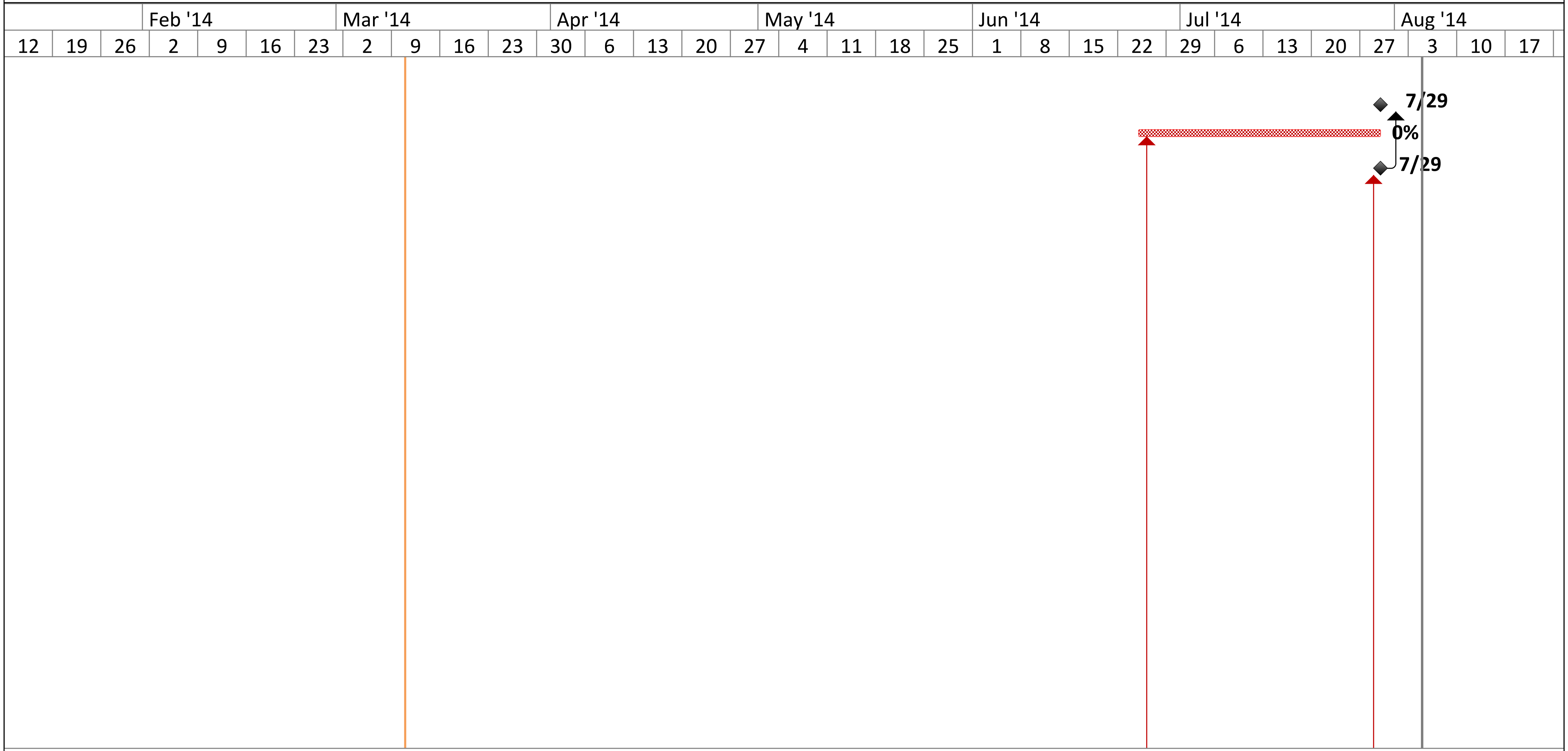
Task	▨	Baseline Split	┄	External Milestone	◆
Split	┄	Baseline Milestone	◇	Inactive Task	☐
Task Progress	━	Milestone	◆	Inactive Milestone	◇
Manual Task	▨	Summary Progress	━	Inactive Summary	☐
Start-only	[	Summary	━	Deadline	↓



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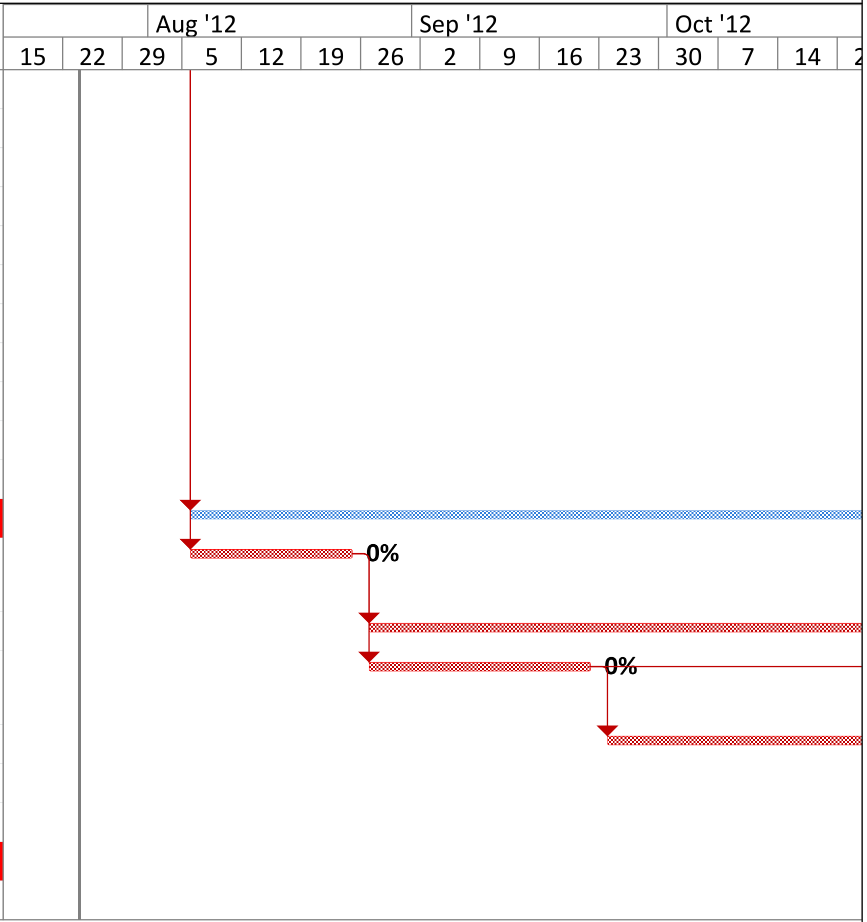
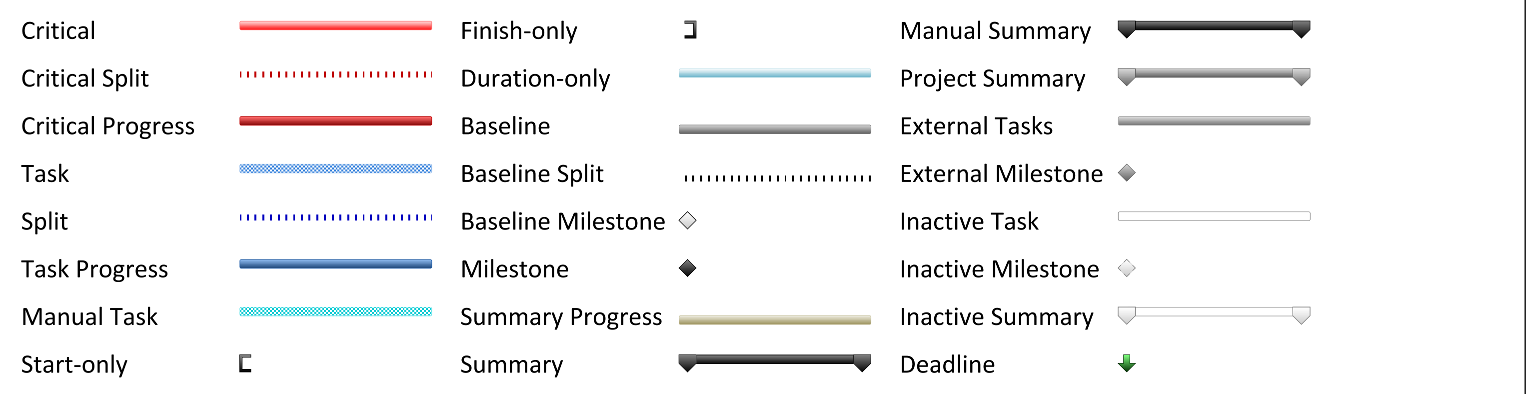
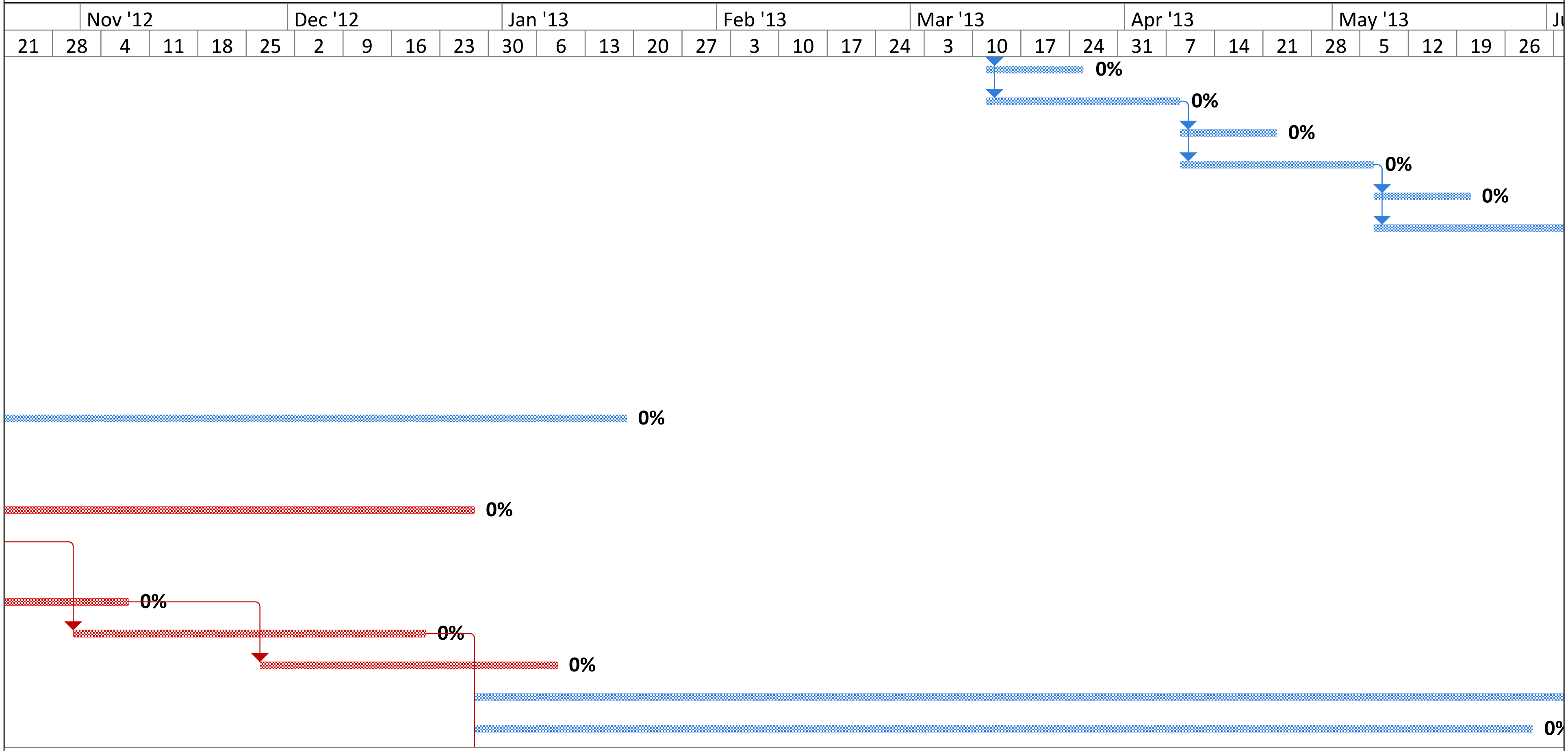
Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▨	Baseline Split	┅	External Milestone	◆
Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▨	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	⬇

ID	ℹ	Task Name	Duration	Start
21	▦	*F/D Materials: 5th FL*	10 days	Tue 3/12/13
22	▦	*MEP Coord: 6th FL*	20 days	Tue 3/12/13
23	▦	*F/D Materials: 6th FL*	10 days	Tue 4/9/13
24	▦	*MEP Coord: 7th FL*	20 days	Tue 4/9/13
25	▦	*F/D Materials: 7th FL*	10 days	Tue 5/7/13
26	▦	*MEP Coord: 8th FL*	20 days	Tue 5/7/13
27	▦	*F/D Materials: 8th FL*	10 days	Wed 6/5/13
28	▦	*MEP Coord: 9th FL*	20 days	Wed 6/5/13
29	▦	*F/D Materials: 9th FL*	10 days	Wed 7/3/13
30	▦	*MEP Coord: 10th FL*	20 days	Wed 7/3/13
31	▦	*F/D Materials: 10th FL*	10 days	Thu 8/1/13
32	▦	**INITIAL SITEWORK**	**120 days**	**Mon 8/6/12**
33	▦	**Site Mobilization/Demolition**	15 days	Mon 8/6/12
34	▦	**Excavation**	89 days	Mon 8/27/12
35	▦	*Soldier Beams/Brackets/Piles/Caissons*	20 days	Mon 8/27/12
36	▦	*Cut/Lag to 1st Tier*	33 days	Mon 9/24/12
37	▦	*Cut/Lag to 2nd Tier*	37 days	Wed 10/31/12
38	▦	*Cut/Lag to Subgrade*	31 days	Tue 11/27/12
39	▦	**FOUNDATION & STRUCTURE**	**152 days**	**Fri 12/28/12**
40	▦	**GARAGE**	**109 days**	**Fri 12/28/12**







Critical	▬	Finish-only	]	Manual Summary	▬
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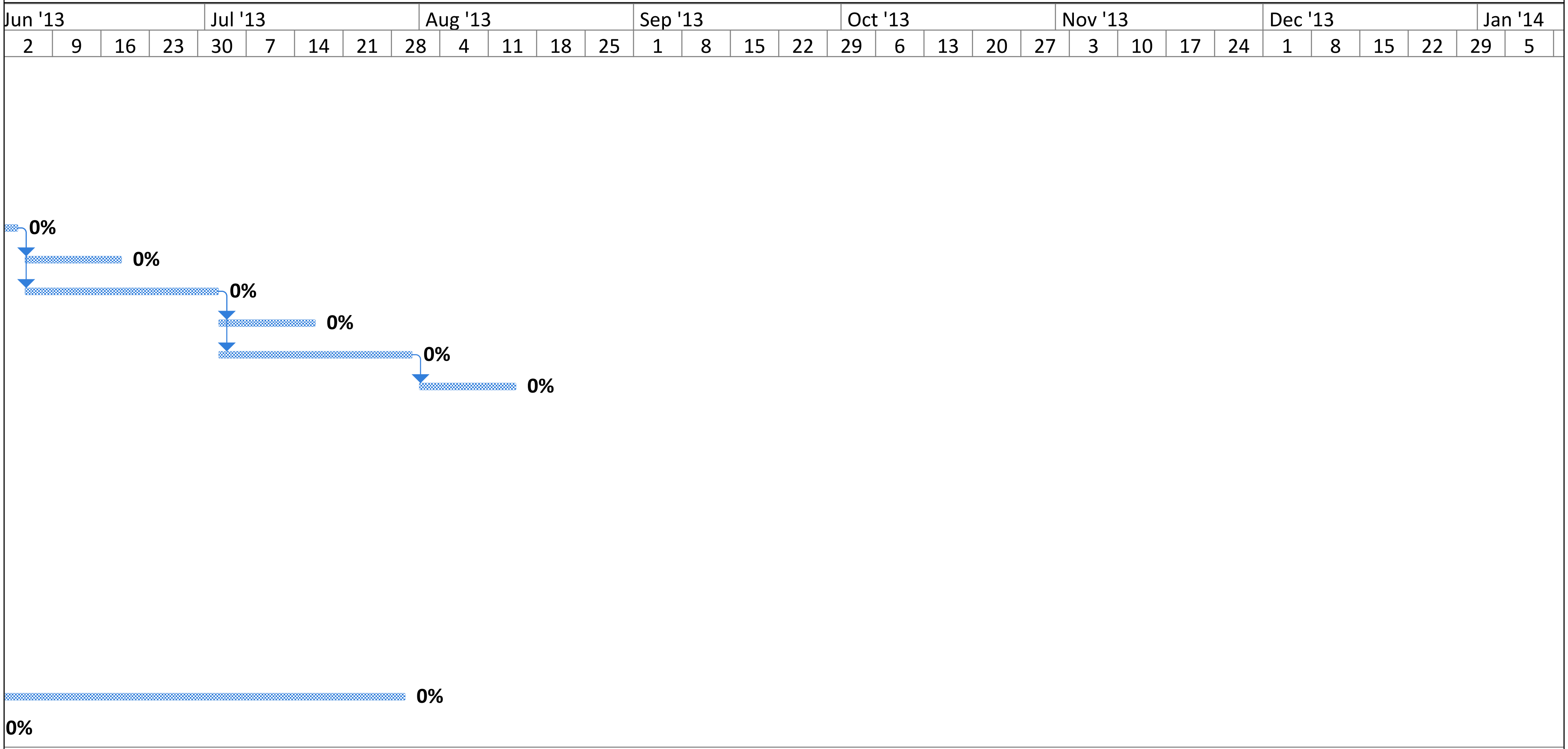
Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▨	Baseline Split	┄	External Milestone	◆
Split	┄	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▨	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	⇩

Detailed Schedule.mpp



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Critical Progress	━	Baseline	━	External Tasks	━
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Split	┈	Baseline Milestone	◇	Inactive Task	▭
Task Progress	━	Milestone	◆	Inactive Milestone	◇
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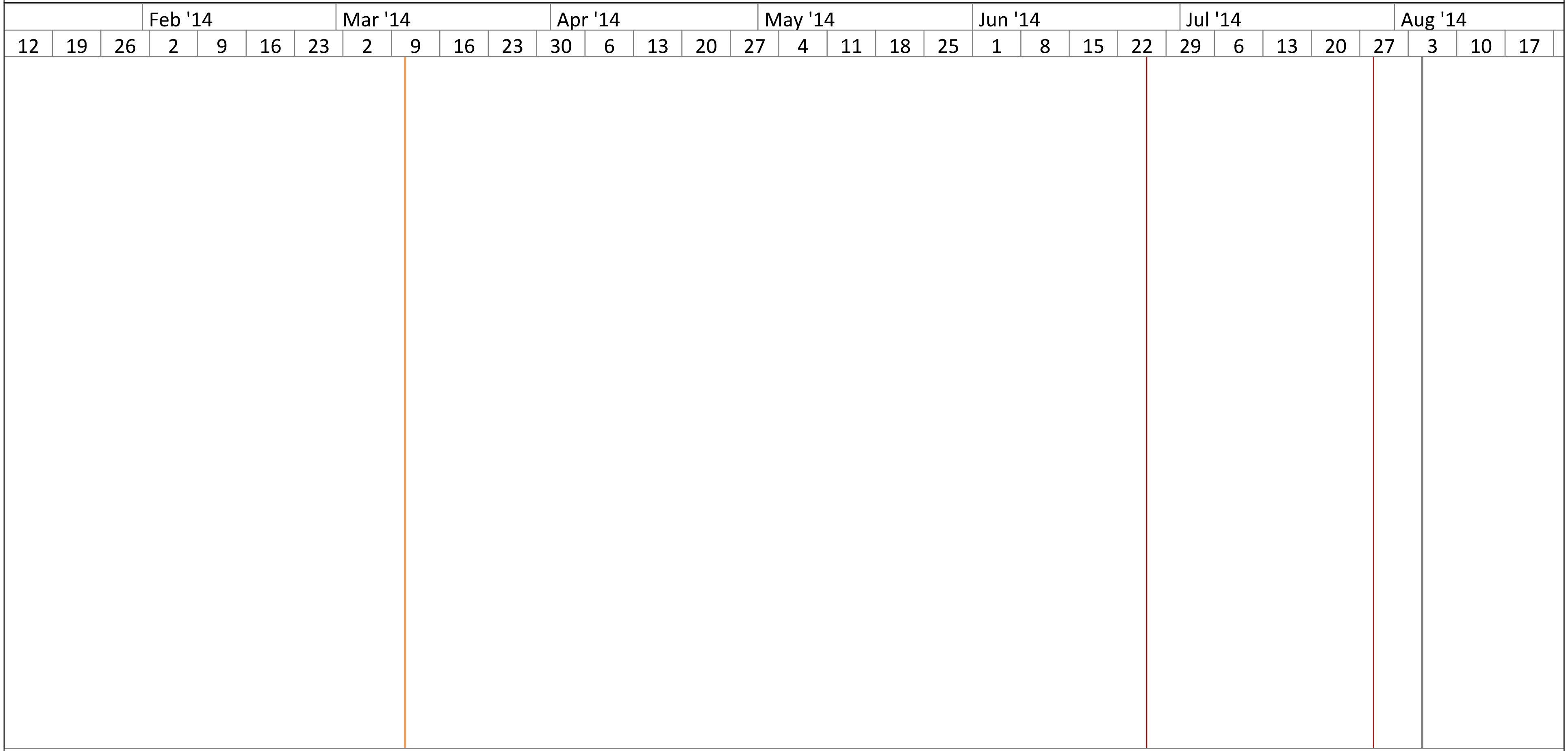

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Critical Split	┈	Duration-only	▬	Project Summary	▬
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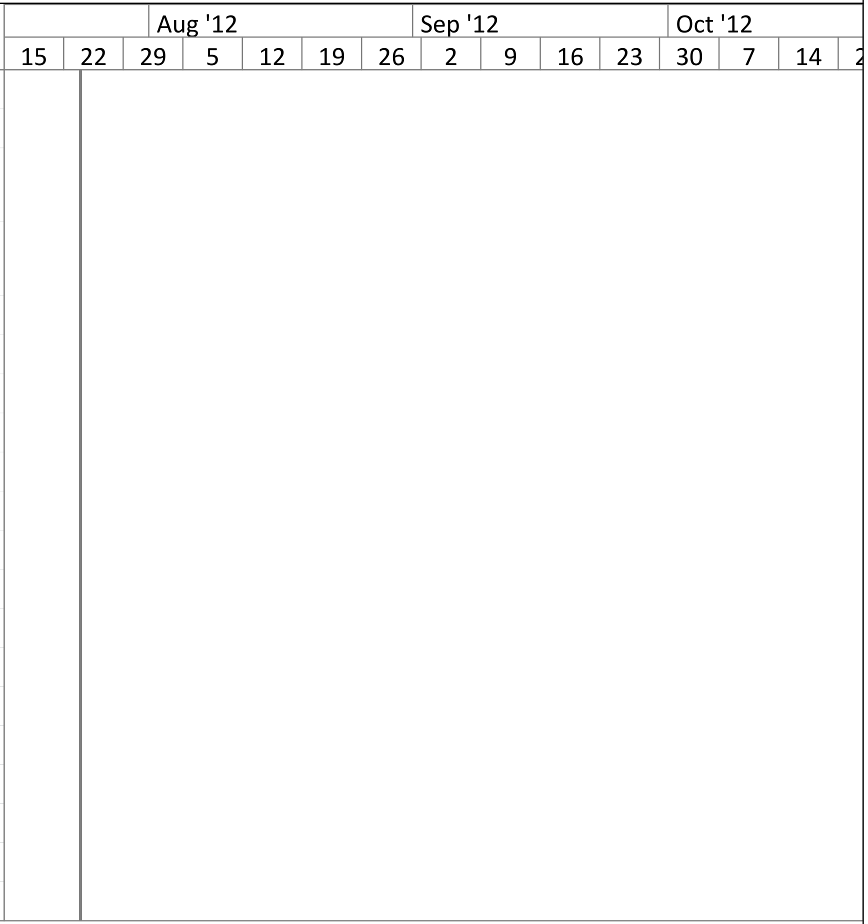
Task	▨	Baseline Split	┈	External Milestone	◆
Split	┈	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▨	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	⇩

ID	ℹ	Task Name	Duration	Start
41	▦	**Level P2 SOG 1**	30 days	Fri 12/28/12
42	▦	*Layout Founadtion*	2 days	Fri 12/28/12
43	▦	*FRP Tower Crane 1 Foundation*	5 days	Fri 12/28/12
44	▦	*Cure Tower Crane Foundation*	7 days	Mon 1/7/13
45	▦	*Erect Tower Crane 1*	5 days	Wed 1/16/13
46	▦	*FRP Walls*	10 days	Wed 1/23/13
47	▦	**Level P2 SOG 2**	3 days	Fri 2/8/13
48	▦	**Level P2 SOG 3**	5 days	Thu 2/14/13
49	▦	**Level P2 SOG 4**	5 days	Fri 2/22/13
50	▦	**Level P2 SOG 5**	3 days	Fri 3/1/13
51	▦	**Level P2 SOG 6**	7 days	Thu 3/7/13
52	▦	**Level P2 SOG 7**	18 days	Thu 3/21/13
53	▦	*FRP Walls*	5 days	Thu 3/21/13
54	▦	*Initial Backfill*	2 days	Thu 3/28/13
55	▦	*U/G Plumbing R/I*	4 days	Mon 4/1/13
56	▦	*U/G Electric R/I*	4 days	Mon 4/1/13
57	▦	*Stone Backfill*	2 days	Mon 4/8/13
58	▦	*Termite/Moisture Control*	1 day	Thu 4/11/13
59	▦	*Prep Slab*	3 days	Fri 4/12/13
60	▦	*Pour Slab*	1 day	Thu 4/18/13



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Critical Progress	━	Baseline	━	External Tasks	━
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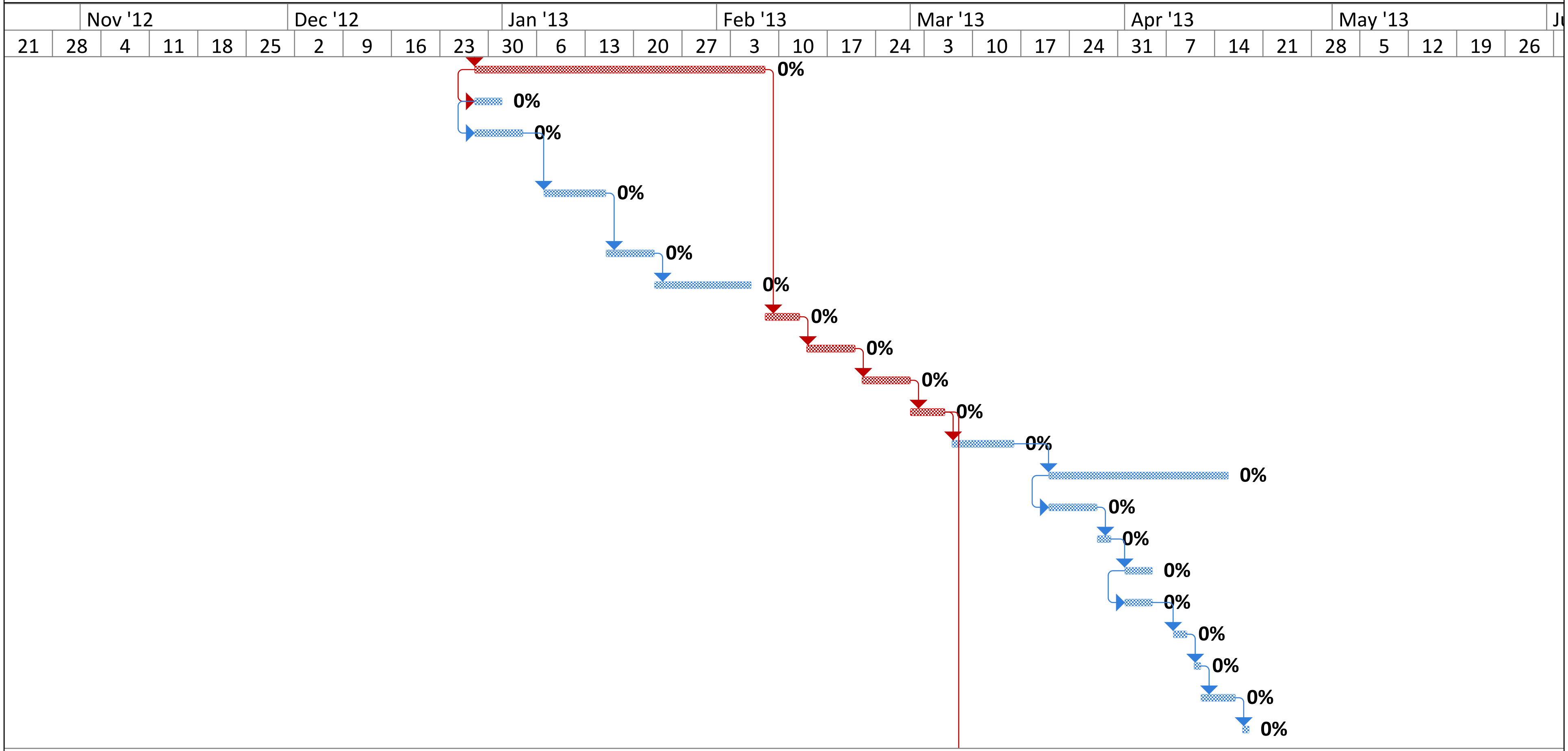
Start-only	[	Summary	━	Deadline	⇩

Detailed Schedule.mpp



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Split	┈	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
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Start-only	⊏	Summary	▬	Deadline	⇩

Detailed Schedule.mpp

Jun '13				Jul '13					Aug '13				Sep '13				Oct '13					Nov '13				Dec '13			Jan '14	
2	9	16	23	30	7	14	21	28	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5

Critical	━	Finish-only	]	Manual Summary	▼━▼
Critical Split	┈	Duration-only	━	Project Summary	▼━▼
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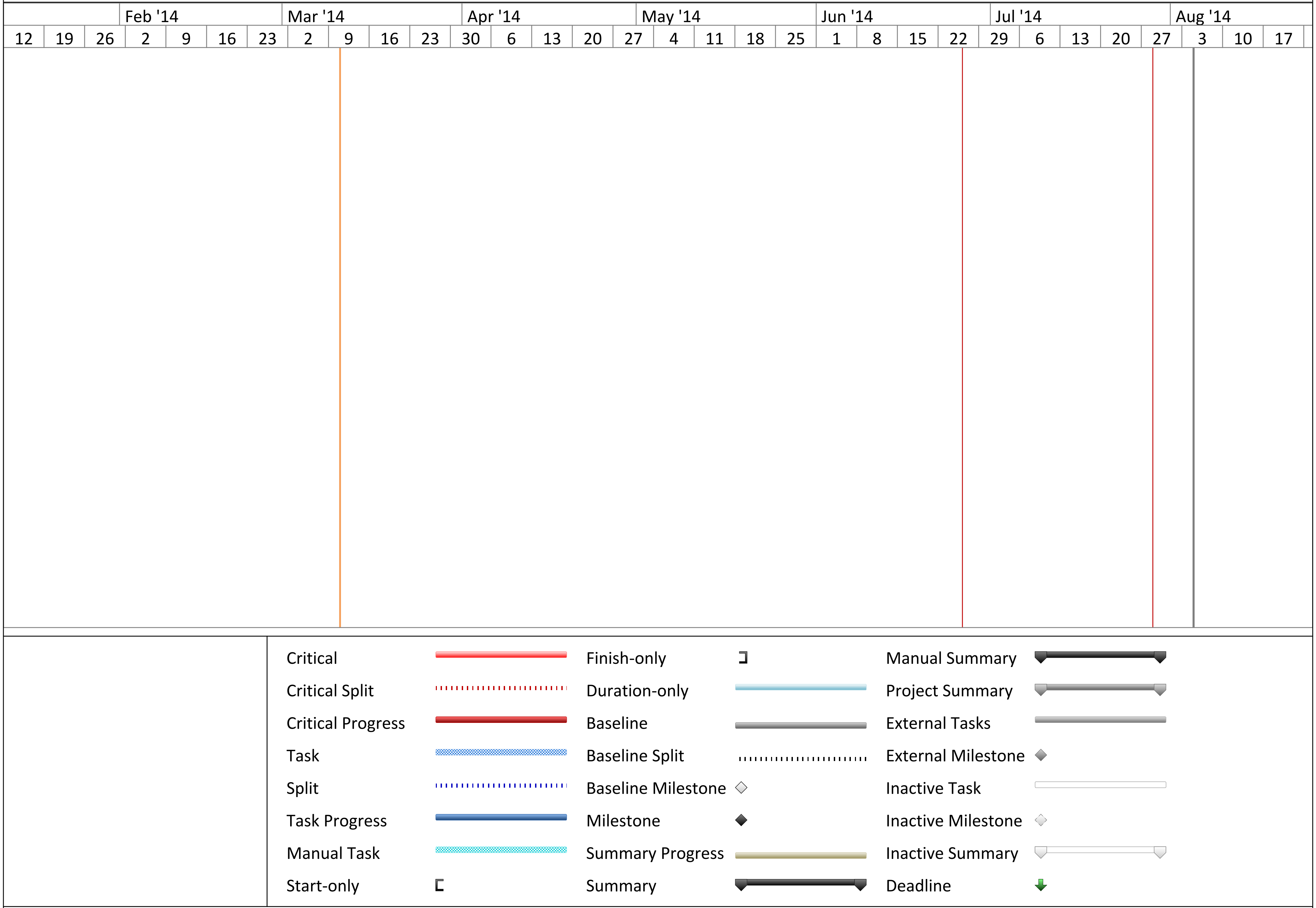
Start-only	[	Summary	▼━▼	Deadline	⬇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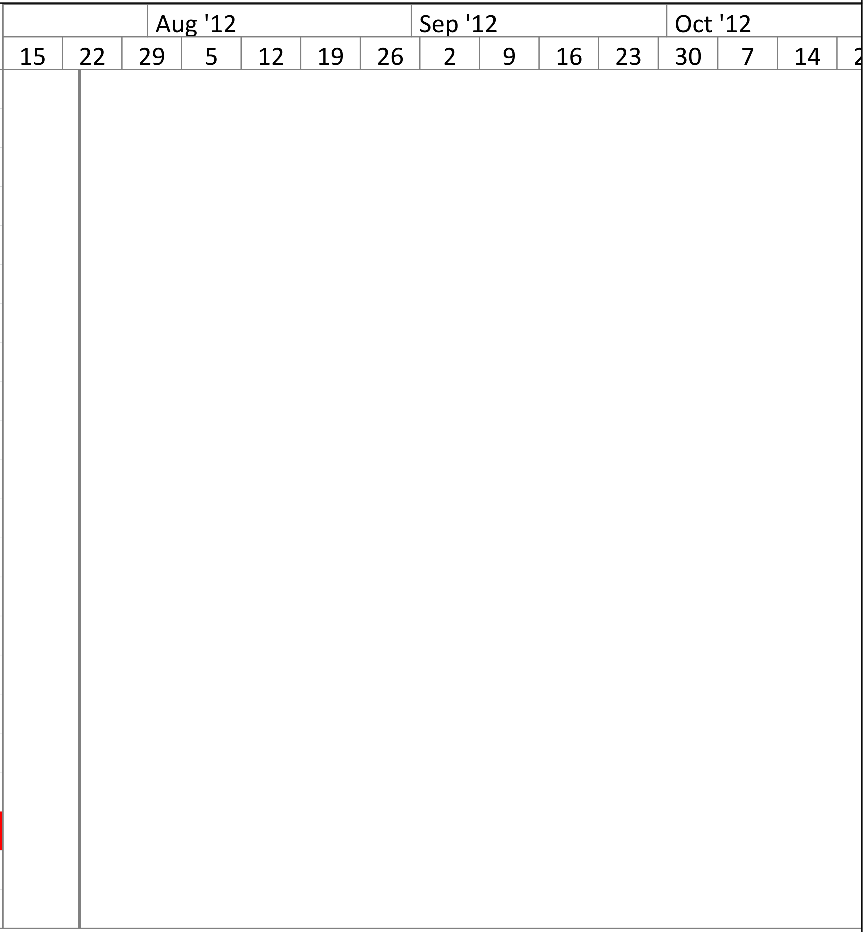
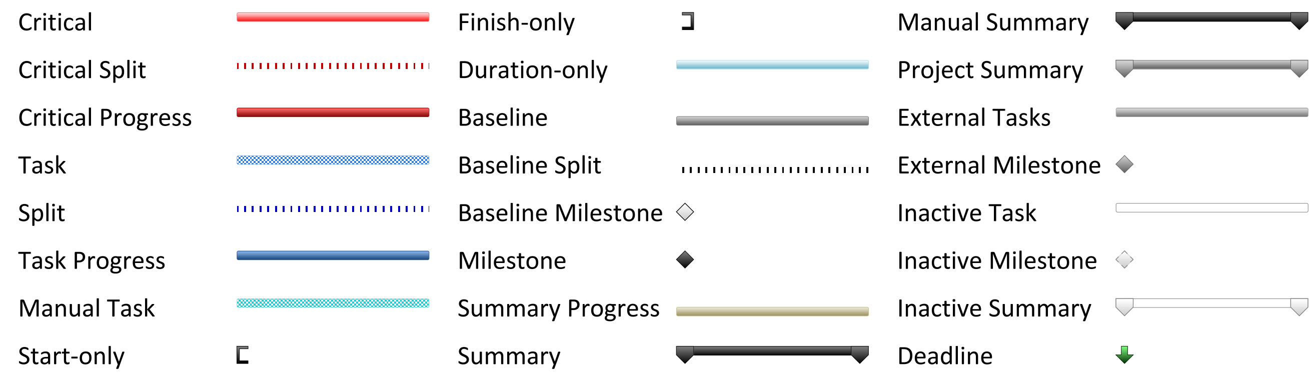
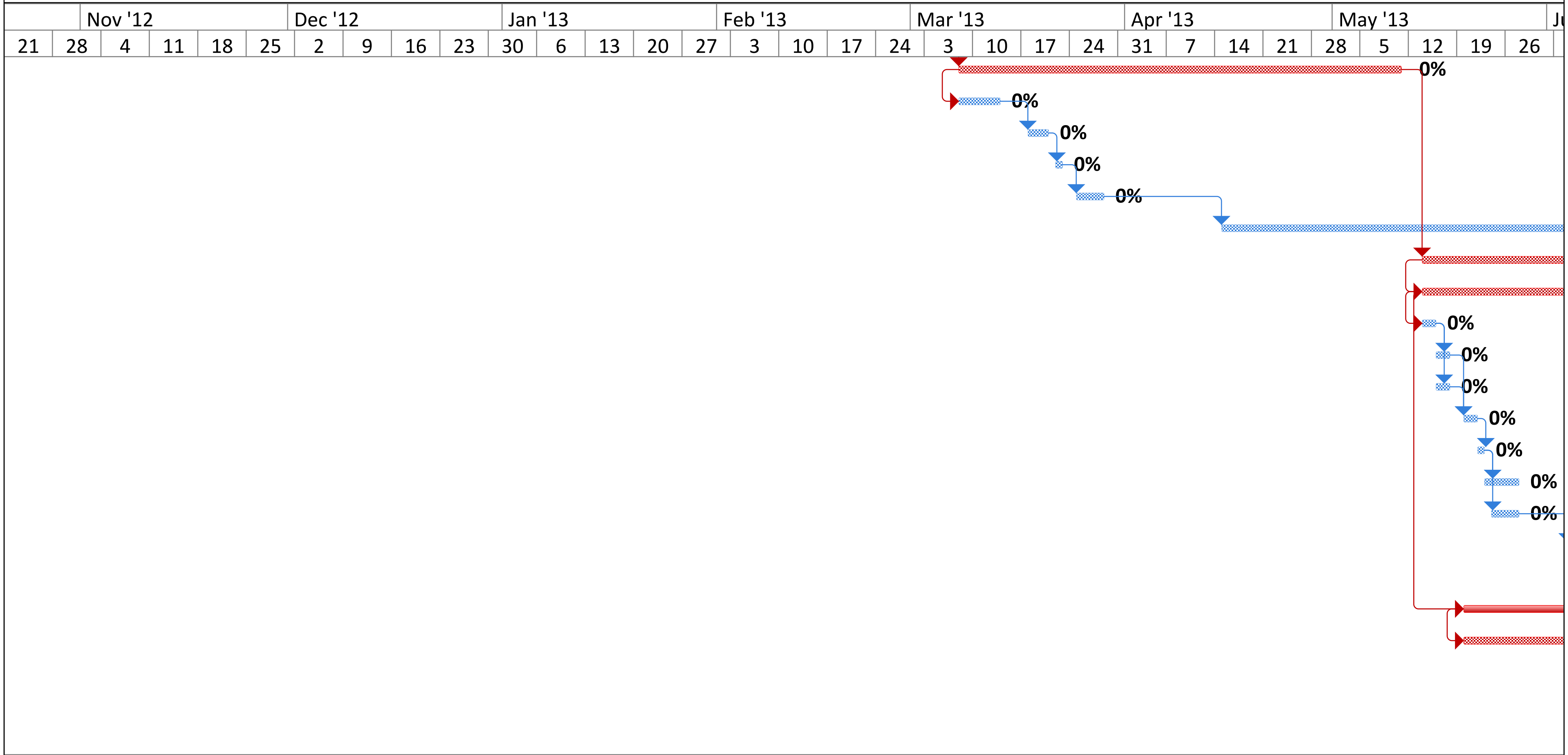
Inactive Milestone
Inactive Summary
Deadline

ID	ℹ	Task Name	Duration	Start
61	▦	**Level P1 SOD A-Ramp**	46 days	Fri 3/8/13
62	▦	*Frame Deck*	4 days	Fri 3/8/13
63	▦	*Reinforce Deck*	3 days	Mon 3/18/13
64	▦	*Pour Deck*	1 day	Fri 3/22/13
65	▦	*FRP Columns/Walls*	4 days	Mon 3/25/13
66	▦	**Ground FL SOD A-I**	36 days	Mon 4/15/13
67	▦	**BUILDING 1**	**99 days**	**Tue 5/14/13**
68	▦	**2nd FL SOD A-C**	20 days	Tue 5/14/13
69	▦	*Frame Deck*	2 days	Tue 5/14/13
70	▦	*Inslab Electric R/I*	2 days	Thu 5/16/13
71	▦	*Inslab Plumbing R/I*	2 days	Thu 5/16/13
72	▦	*Reinforce Deck*	2 days	Mon 5/20/13
73	▦	*Pour Deck*	1 day	Wed 5/22/13
74	▦	*Cure Deck*	3 days	Thu 5/23/13
75	▦	*FRP Columns*	2 days	Fri 5/24/13
76	▦	**3rd-Roof SOD A**	74 days	Tue 6/4/13
77	▦	**3rd FL-Roof SOD B**	79 days	Tue 6/11/13
78	▦	**BUILDING 2**	**51 days**	**Mon 5/20/13**
79	▦	**2nd FL-Roof SOD**	51 days	Mon 5/20/13
80	▦	**Enclosure**	**88 days**	**Tue 7/30/13**
81	▦	**BUILDING 1**	250 days	Tue 7/30/13
82	▦	**Ground FL**	147 days	Tue 7/30/13







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Split	┈	Baseline Milestone	◇	Inactive Task	▭
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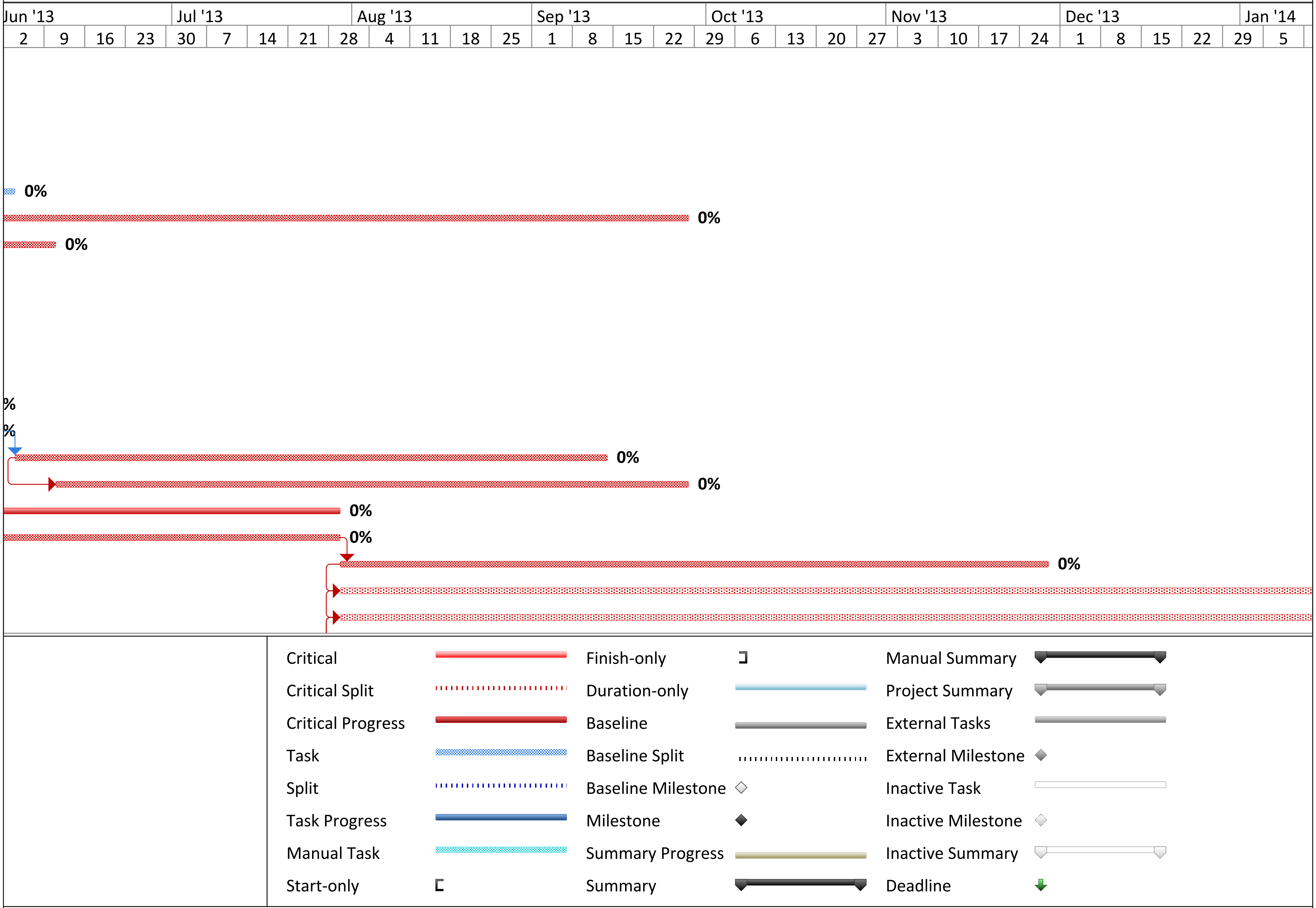
Start-only	[	Summary	▬	Deadline	⇩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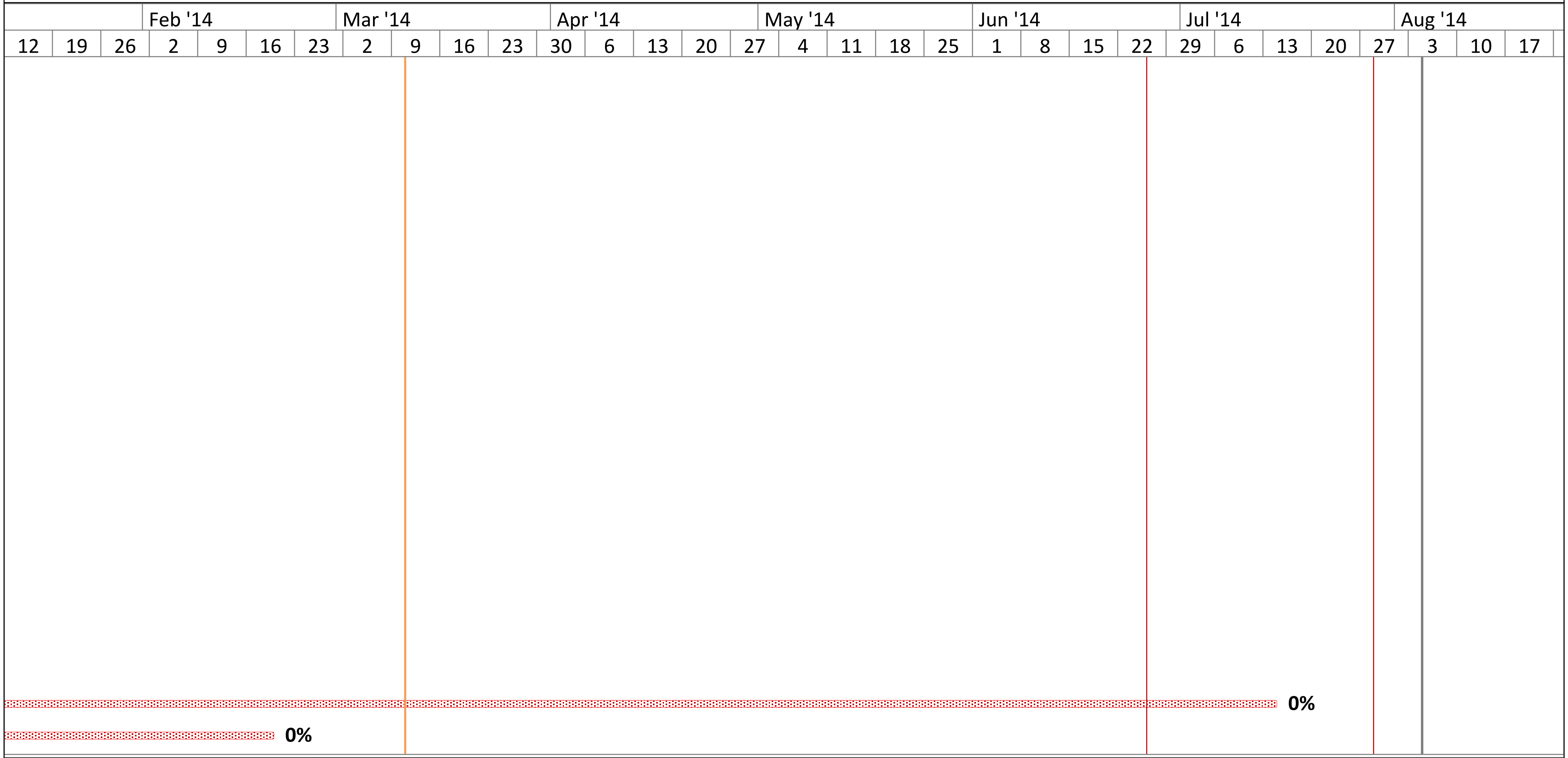

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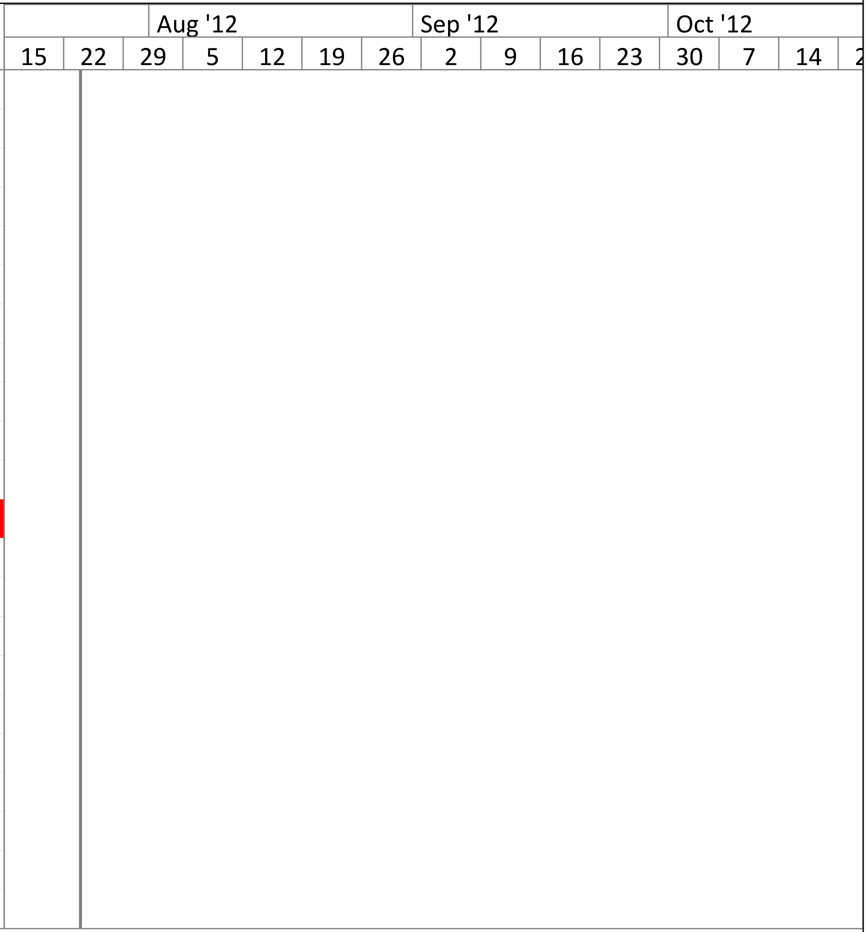
Critical Split	┈	Duration-only	▬	Project Summary	▬
Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▨	Baseline Split	┈	External Milestone	◆
Split	┈	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▨	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	⬇

ID	ℹ	Task Name	Duration	Start
83	▦	*Remove Reshores*	2 days	Tue 7/30/13
84	▦	*Install Masonry Angle*	5 days	Thu 8/1/13
85	▦	*Exterior Metal Framing*	5 days	Thu 8/8/13
86	▦	*Exterior Sheathing/Tyvec*	5 days	Thu 8/15/13
87	▦	*Set Window Receptors*	5 days	Thu 8/22/13
88	▦	*Install Scaffolding*	5 days	Thu 8/29/13
89	▦	*Masonry Veneer*	8 days	Thu 9/5/13
90	▦	*Exterior Glazing*	5 days	Tue 9/17/13
91	▦	**2nd FL-Roof**	265 days	Tue 7/30/13
92	▦	**BUILDING 2**	**93 days**	**Fri 6/28/13**
93	▦	**Ground-Roof**	93 days	Fri 6/28/13
94	▦	**ROUGH-IN**	**167 days**	**Fri 7/5/13**
95	▦	**GARAGE**	**167 days**	**Fri 7/5/13**
96	▦	**Level P2**	167 days	Fri 7/5/13
97	▦	**Level P1**	117 days	Tue 7/16/13
98	▦	**BUILDING 1**	**151 days**	**Tue 7/9/13**
99	▦	**Ground FL**	71 days	Tue 7/9/13
100	▦	*Layout Interior*	2 days	Thu 7/11/13
101	▦	*Frame Interior*	5 days	Thu 7/18/13
102	▦	*HTF Interior Priority Walls*	5 days	Thu 7/25/13
103	▦	*Mechanical Risers*	5 days	Thu 7/25/13
104	▦	*Pluming Risers*	5 days	Thu 7/25/13



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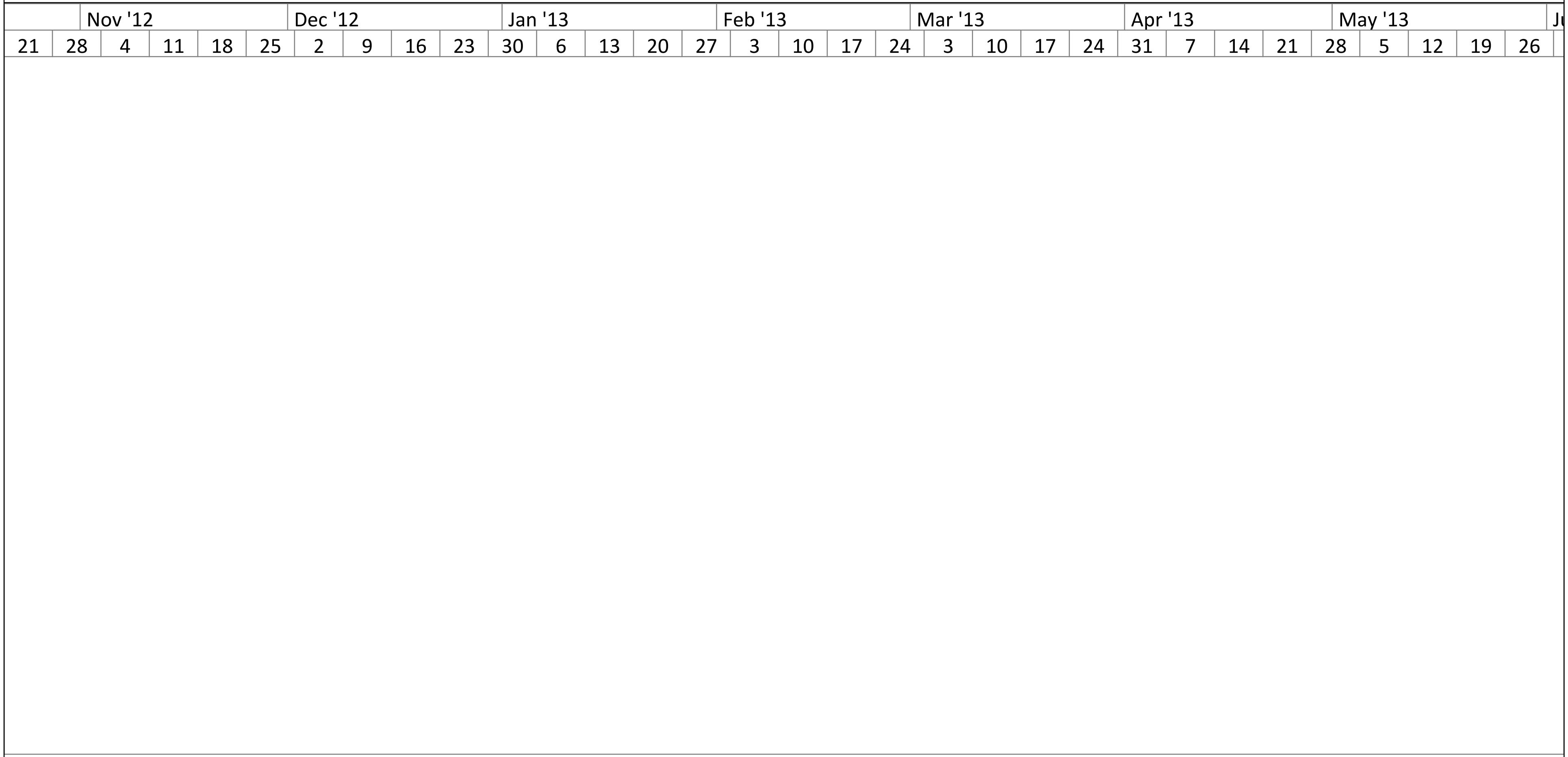
Start-only	[	Summary	▬	Deadline	⬇



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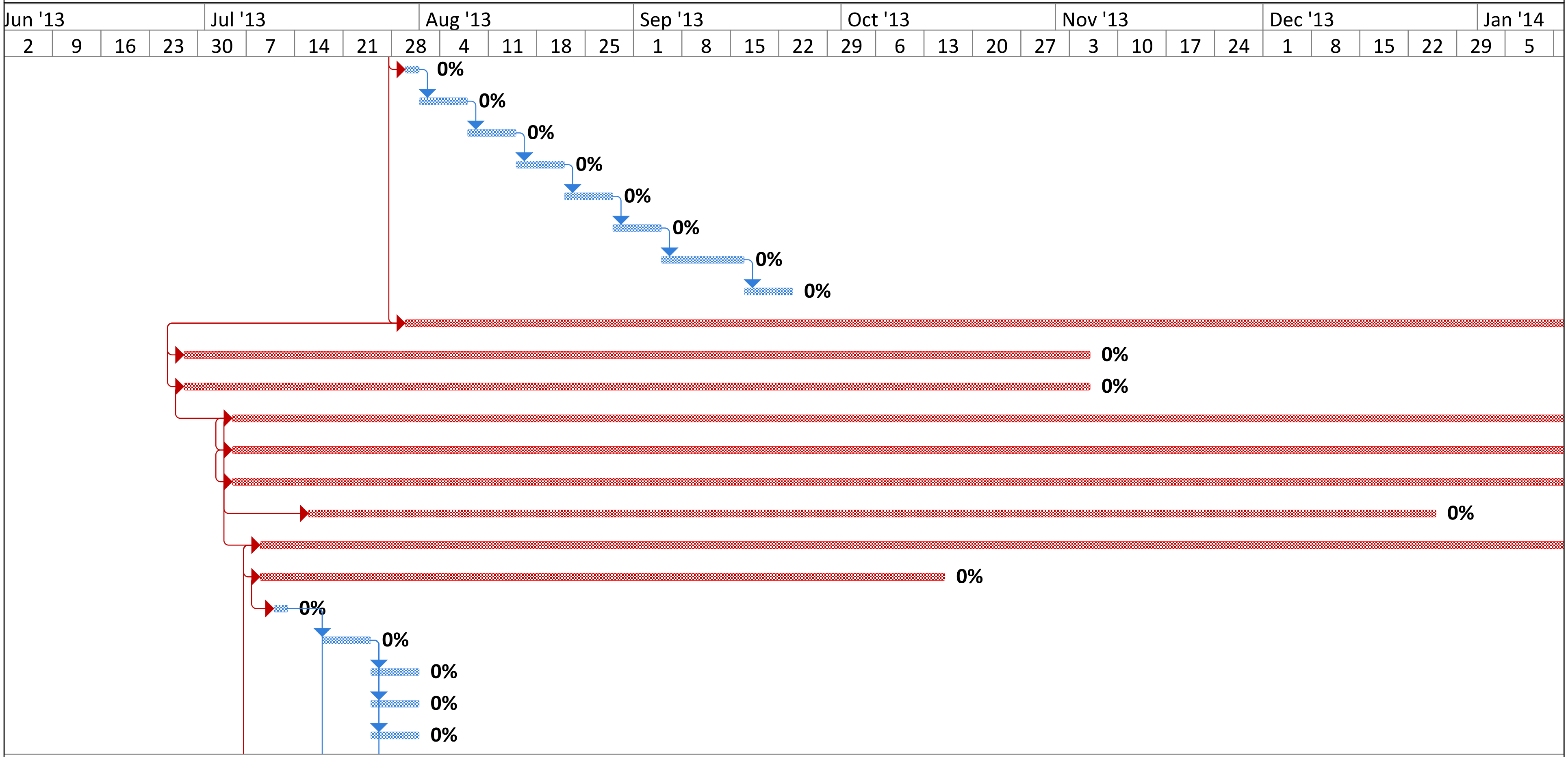
Critical Progress	━	Baseline	━	External Tasks	━
Task	▨	Baseline Split	┅	External Milestone	◆
Split	┅	Baseline Milestone	◇	Inactive Task	☐
Task Progress	━	Milestone	◆	Inactive Milestone	◇
Manual Task	▨	Summary Progress	━	Inactive Summary	━
Start-only	[	Summary	━	Deadline	⬇

Detailed Schedule.mpp



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Critical Progress	▬	Baseline	▬	External Tasks	▬
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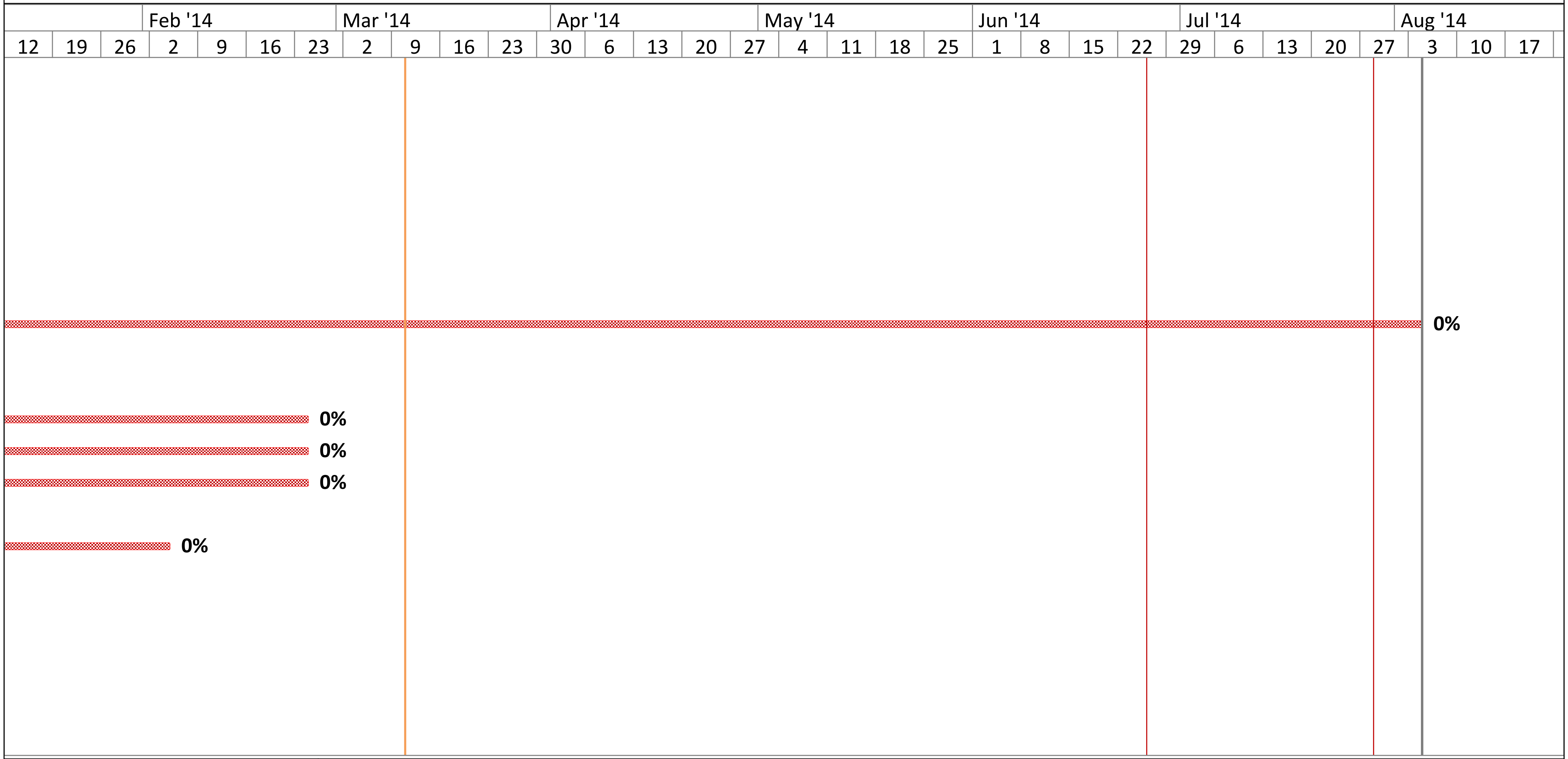
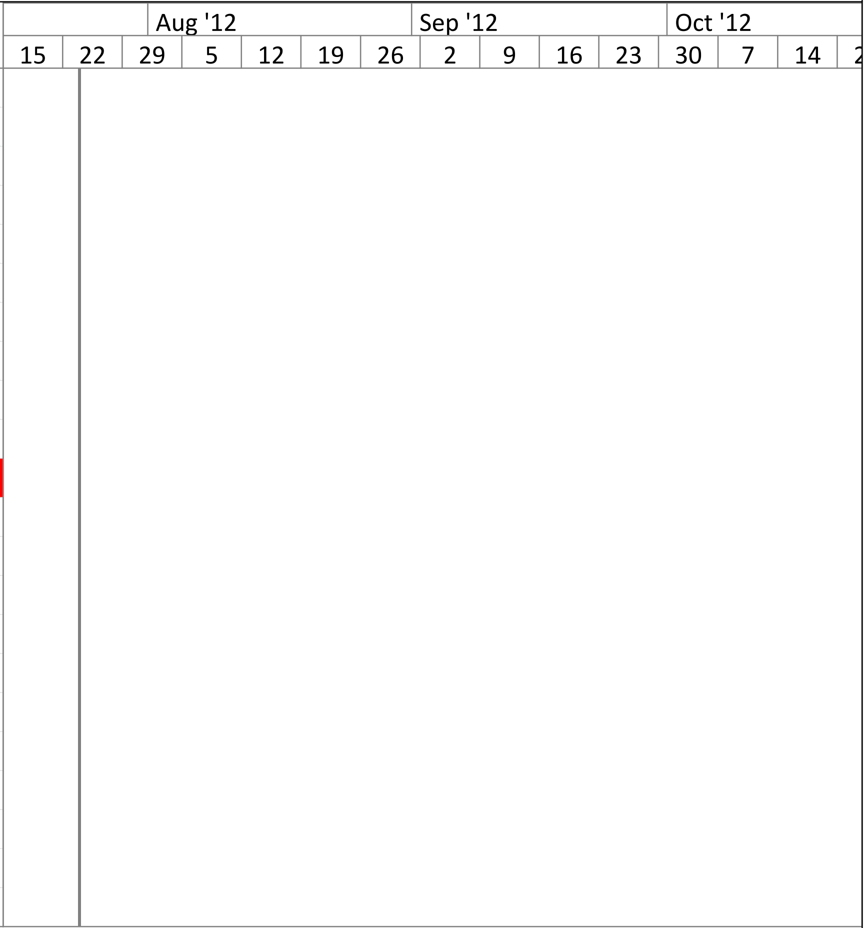
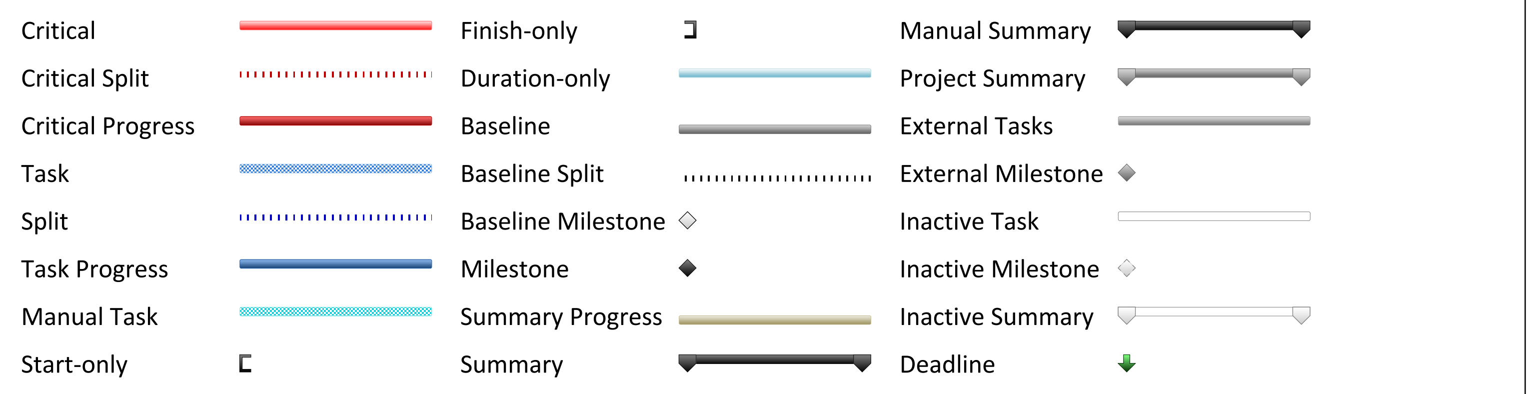
Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▨	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	⬇



Critical	▬	Finish-only	]	Manual Summary	▬
Critical Split	┈	Duration-only	▬	Project Summary	▬
Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▬	Baseline Split	┈	External Milestone	◆
Split	┈	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▬	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	⬇

ID	ℹ	Task Name	Duration	Start
105	▦	*Sprinkler Risers*	5 days	Thu 7/25/13
106	▦	*Electrical Risers*	5 days	Thu 8/1/13
107	▦	*OH Mechanical R/I*	10 days	Thu 8/15/13
108	▦	*OH Plumbing R/I*	8 days	Thu 8/29/13
109	▦	*OH Sprinkler R/I*	8 days	Thu 8/29/13
110	▦	*OH Fire Alarm R/I*	8 days	Thu 8/29/13
111	▦	*OH Electrical R/I*	11 days	Thu 8/29/13
112	▦	**2nd FL-10th FL**	144 days	Thu 7/18/13
113	▦	**BUILDING 2**	**122 days**	**Tue 7/9/13**
114	▦	**Ground-Roof**	122 days	Tue 7/9/13
115	▦	**FINISHES**	**244 days**	**Thu 7/18/13**
116	▦	GARAGE	**133 days**	**Thu 7/18/13**
117	▦	**Level P2**	128 days	Thu 7/18/13
118	▦	*Install Doors & Hardware*	2 days	Thu 7/18/13
119	▦	*Prime & point Up*	4 days	Mon 7/22/13
120	▦	*Instal GRD's*	2 days	Fri 7/26/13
121	▦	*1st Finish Paint*	5 days	Thu 7/25/13
122	▦	*Install MEP Trim*	89 days	Mon 8/5/13
123	▦	*Stripping*	2 days	Fri 12/6/13
124	▦	*2nd Finish Paint*	3 days	Tue 12/24/13
125	▦	*Install Misc Accessories*	4 days	Fri 12/27/13
126	▦	*Signage*	3 days	Fri 1/3/14





	Nov '12				Dec '12					Jan '13				Feb '13				Mar '13					Apr '13				May '13				Ju
21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	3	10	17	24	3	10	17	24	31	7	14	21	28	5	12	19	26

Critical	▬	Finish-only	]	Manual Summary	▬
Critical Split	┄	Duration-only	▬	Project Summary	▬
Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▬	Baseline Split	┄	External Milestone	◆
Split	┄	Baseline Milestone	◇	Inactive Task	▭
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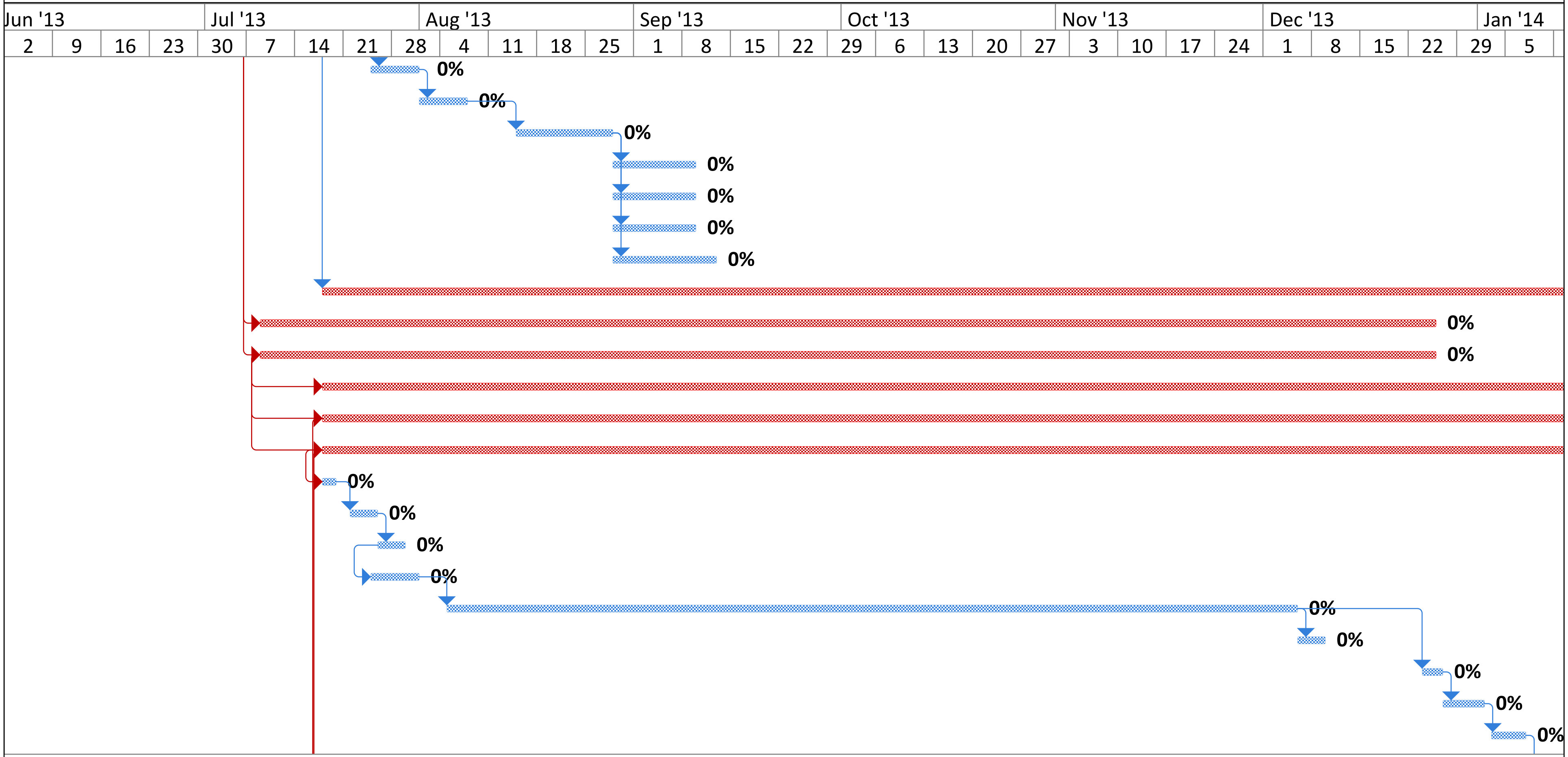
Start-only	[	Summary	▬	Deadline	⇩



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Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
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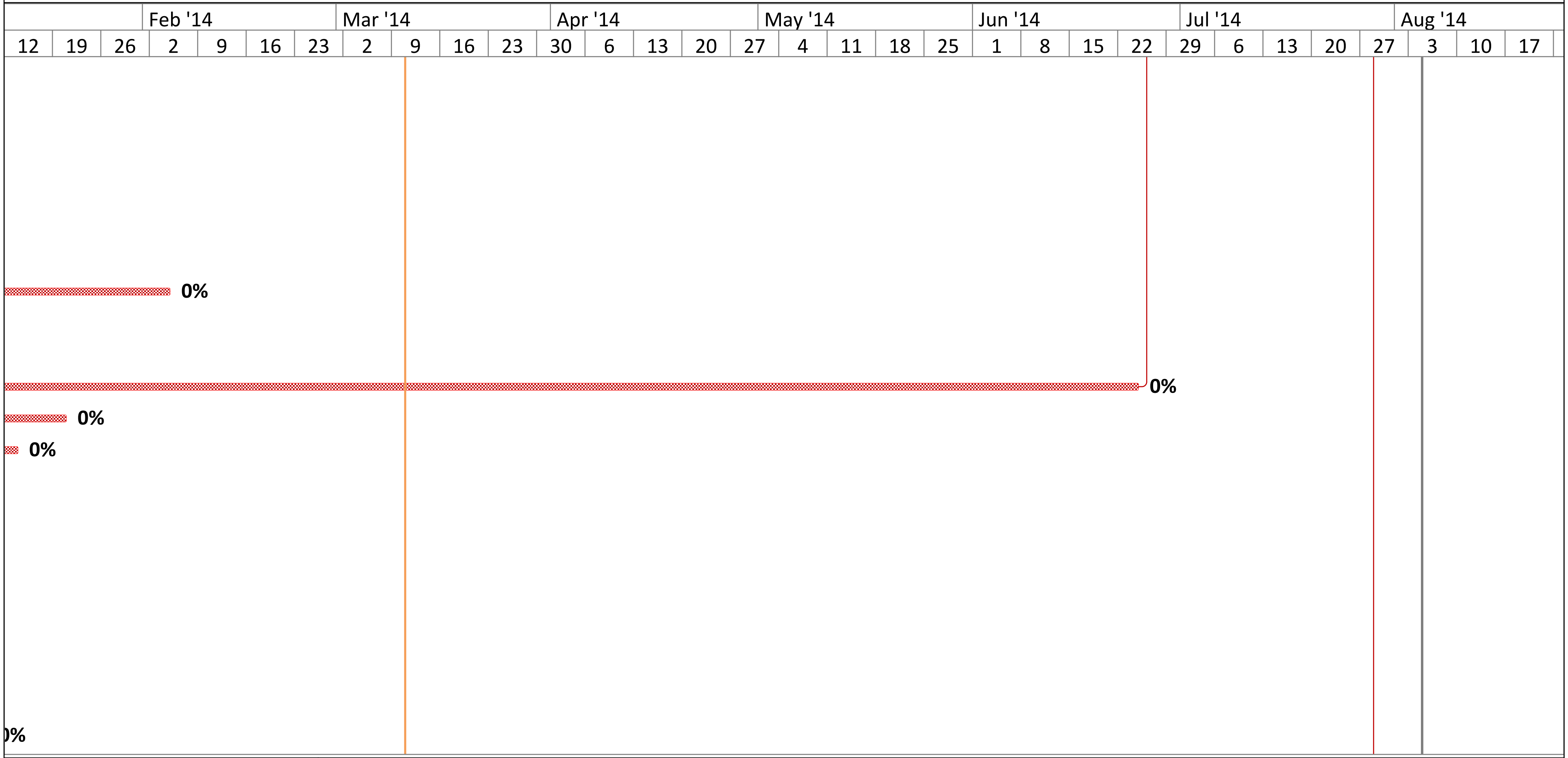
Start-only	[	Summary	▬	Deadline	⬇

Detailed Schedule.mpp



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Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▨	Baseline Split	┅	External Milestone	◆
Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▨	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	⬇

ID	ℹ	Task Name	Duration	Start
127	▦	*Touch Up Paint*	4 days	Wed 1/8/14
128	▦	*Final Clean*	5 days	Tue 1/14/14
129	▦	**Level P1**	124 days	Thu 7/25/13
130	▦	**BUILDING 1**	**179 days**	**Thu 10/17/13**
131	▦	**Ground FL (Lobby/Fitness)**	104 days	Thu 10/17/13
132	▦	*Insulation*	5 days	Thu 10/17/13
133	▦	*Insulation Inspection*	2 days	Thu 10/24/13
134	▦	*Hang Drywall*	5 days	Mon 10/28/13
135	▦	*Finish Drywall*	5 days	Mon 11/4/13
136	▦	*Sand/PointUp Drywall*	3 days	Mon 11/11/13
137	▦	*Kniock Down Ceiling Finish*	3 days	Thu 11/14/13
138	▦	*Prime & 1st Coat Paint*	3 days	Tue 11/19/13
139	▦	*Interior Doors/Trim*	7 days	Fri 11/22/13
140	▦	*Set/Connect HVAC*	7 days	Fri 11/22/13
141	▦	*Interior Store Front*	9 days	Fri 11/22/13
142	▦	*Plumbing Fixtures/Small Appliances*	5 days	Thu 12/5/13
143	▦	*MEP Trimout*	13 days	Thu 12/5/13
144	▦	*2nd Coat Paint*	6 days	Tue 12/24/13
145	▦	*FirePlace*	6 days	Wed 1/1/14
146	▦	*Water Feature*	6 days	Wed 1/1/14
147	▦	*Stone Walls*	16 days	Wed 1/1/14

	Aug '12					Sep '12				Oct '12		
15	22	29	5	12	19	26	2	9	16	23	30	7	14

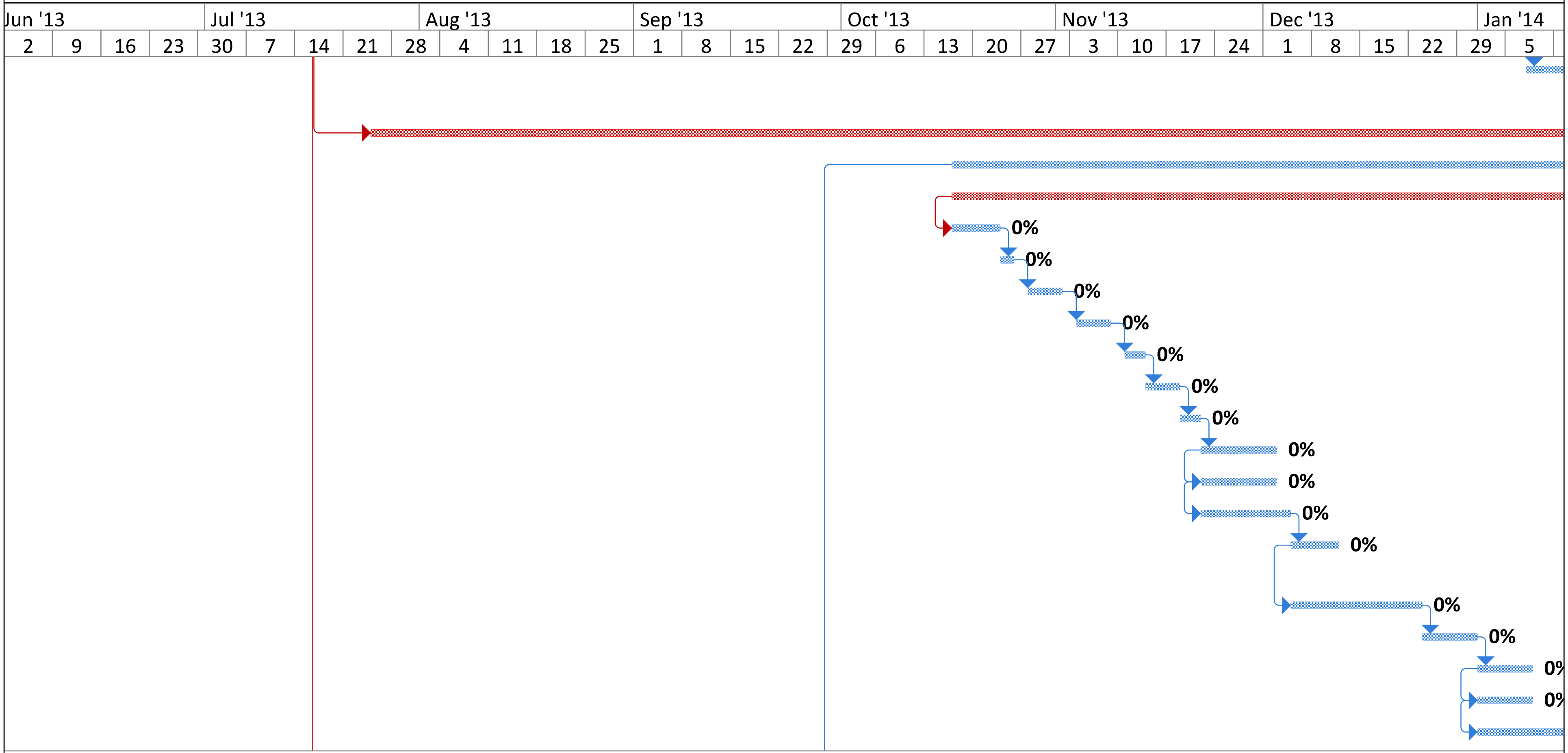
Critical	━	Finish-only	]	Manual Summary	━
Critical Split	┈	Duration-only	━	Project Summary	━
Critical Progress	━	Baseline	━	External Tasks	━
Task	━	Baseline Split	┈	External Milestone	◆
Split	┈	Baseline Milestone	◇	Inactive Task	▭
Task Progress	━	Milestone	◆	Inactive Milestone	◇
Manual Task	━	Summary Progress	━	Inactive Summary	▭
Start-only	[	Summary	━	Deadline	⬇

Nov '12 Dec '12 Jan '13 Feb '13 Mar '13 Apr '13 May '13 Ju

21 28 4 11 18 25 2 9 16 23 30 6 13 20 27 3 10 17 24 3 10 17 24 31 7 14 21 28 5 12 19 26

Critical	▬	Finish-only	]	Manual Summary	▬
Critical Split	┅	Duration-only	▬	Project Summary	▬
Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▬	Baseline Split	┅	External Milestone	◆
Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▬	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	⇩

Detailed Schedule.mpp



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Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▨	Baseline Split	┅	External Milestone	◆
Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
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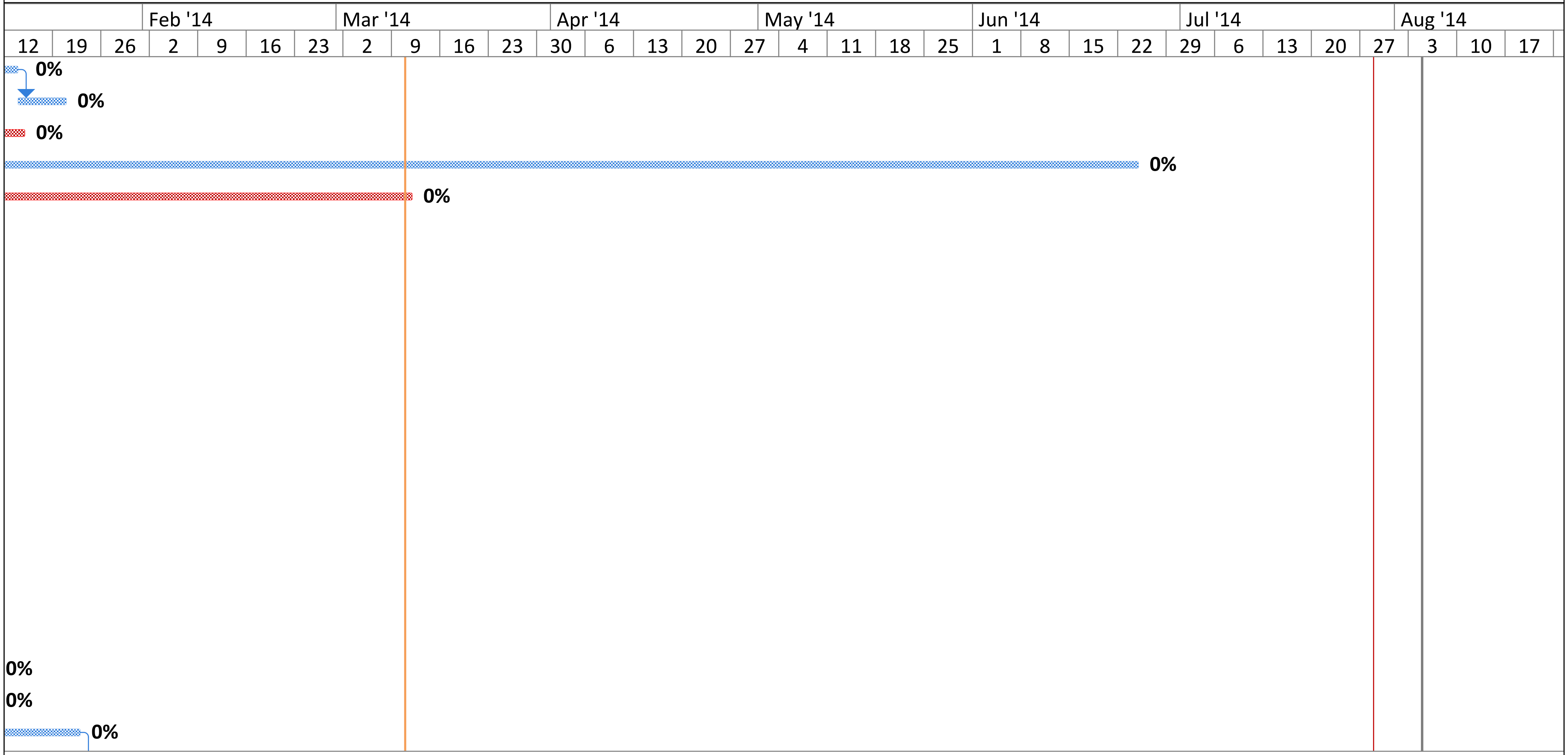
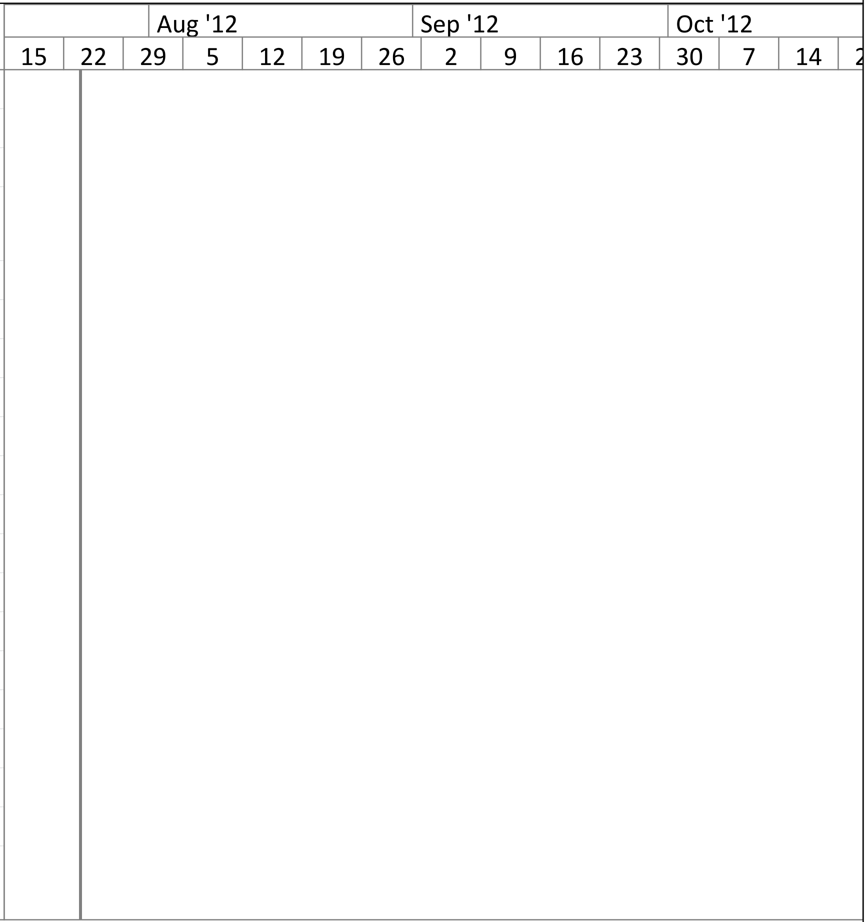
Start-only	[	Summary	▬	Deadline	⬇



Critical	━	Finish-only	⊐	Manual Summary	━
Critical Split	┅	Duration-only	━	Project Summary	━
Critical Progress	━	Baseline	━	External Tasks	━
Task	▬	Baseline Split	┅	External Milestone	◆
Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	━	Milestone	◆	Inactive Milestone	◇
Manual Task	▬	Summary Progress	━	Inactive Summary	▭
Start-only	⊏	Summary	━	Deadline	⬇

Detailed Schedule.mpp

ID	ℹ	Task Name	Duration	Start
148	▦	*Rough Clean*	3 days	Thu 1/23/14
149	▦	*Athletic Flooring*	5 days	Tue 1/28/14
150	▦	*Carpet Flooring*	3 days	Tue 2/4/14
151	▦	*DCC QC Inspection / Punchout*	7 days	Fri 2/7/14
152	▦	*Final Clean - Turnover*	18 days	Tue 2/18/14
153	▦	**2nd FL**	101 days	Fri 11/22/13
154	▦	*Insulation*	3 days	Fri 11/22/13
155	▦	*Insulation Inspection*	4 days	Wed 11/27/13
156	▦	*Hang Drywall*	5 days	Tue 12/3/13
157	▦	*Finish Drywall*	5 days	Tue 12/10/13
158	▦	*Sand/PointUp Drywall*	3 days	Tue 12/17/13
159	▦	*Knock Down Ceiling Finish*	3 days	Fri 12/20/13
160	▦	*Prime & 1st Coat Paint*	3 days	Thu 12/26/13
161	▦	*Ceramic Tile*	6 days	Tue 12/31/13
162	▦	*Interior Doors/Trim*	6 days	Tue 12/31/13
163	▦	*Set/Connect HVAC*	6 days	Tue 12/31/13
164	▦	*Set Vanities*	5 days	Wed 1/8/14
165	▦	*Kitchen Cabinets*	5 days	Wed 1/15/14
166	▦	*Countertops*	5 days	Wed 1/22/14
167	▦	*Plumbing Fixtures/Small Appliances*	5 days	Wed 1/29/14



Critical	▬	Finish-only	]	Manual Summary	▬
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Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▬	Baseline Split	┅	External Milestone	◆
Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▬	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	⬇

	Nov '12				Dec '12					Jan '13				Feb '13				Mar '13					Apr '13				May '13				Ju
21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	3	10	17	24	3	10	17	24	31	7	14	21	28	5	12	19	26

Critical	▬	Finish-only	]	Manual Summary	▬
Critical Split	┈	Duration-only	▬	Project Summary	▬
Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▬	Baseline Split	┈	External Milestone	◆
Split	┈	Baseline Milestone	◇	Inactive Task	▭
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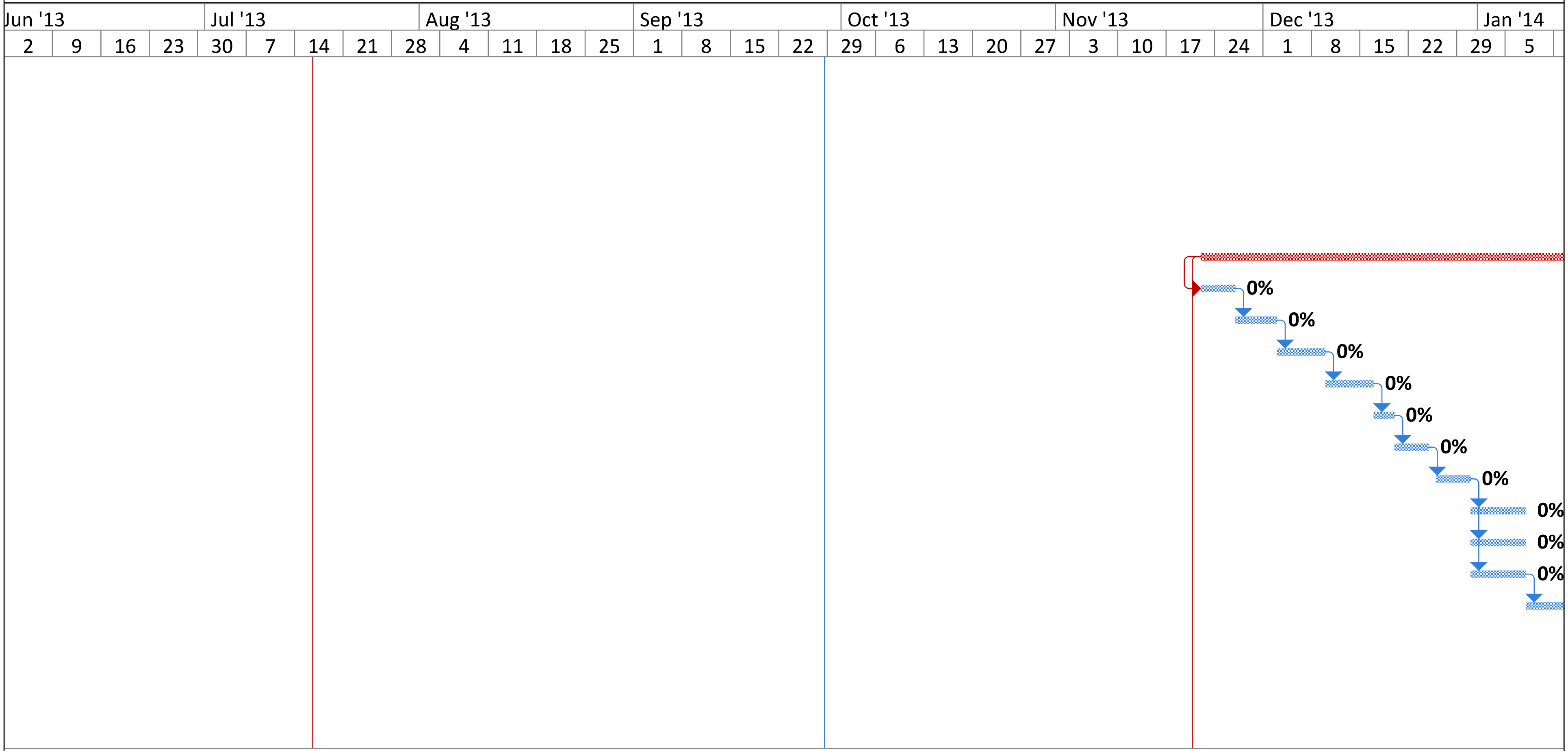
Start-only	[	Summary	▬	Deadline	⬇



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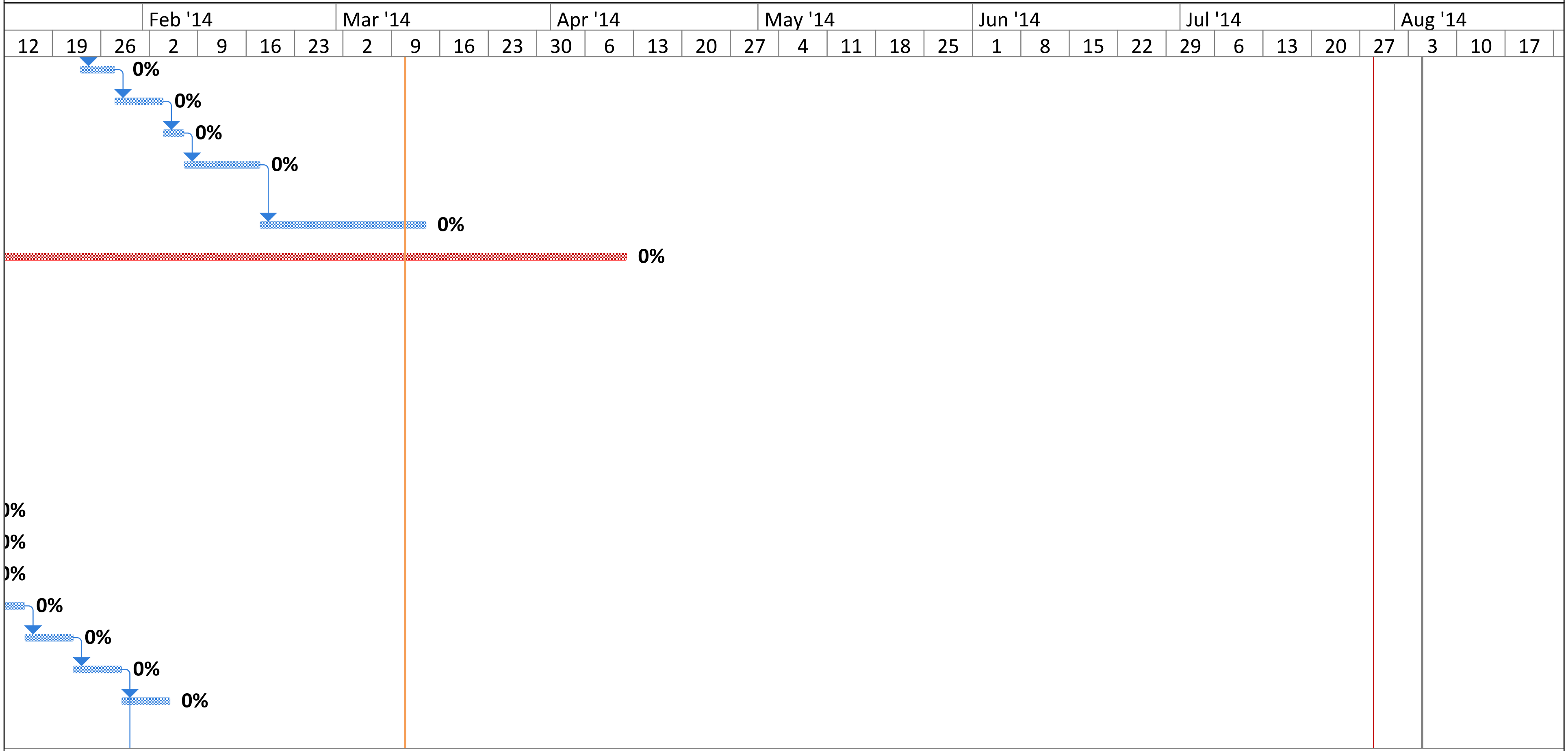
Critical Progress	▬	Baseline	▬	External Tasks	▬
Task	▬	Baseline Split	┈	External Milestone	◆
Split	┈	Baseline Milestone	◇	Inactive Task	▭
Task Progress	▬	Milestone	◆	Inactive Milestone	◇
Manual Task	▬	Summary Progress	▬	Inactive Summary	▭
Start-only	[	Summary	▬	Deadline	⇩

Detailed Schedule.mpp



Critical	━	Finish-only	⊐	Manual Summary	━
Critical Split	┅	Duration-only	━	Project Summary	━
Critical Progress	━	Baseline	━	External Tasks	━
Task	━	Baseline Split	┅	External Milestone	◆
Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	━	Milestone	◆	Inactive Milestone	◇
Manual Task	━	Summary Progress	━	Inactive Summary	▭
Start-only	⊏	Summary	━	Deadline	⇩

ID	ℹ	Task Name	Duration	Start
168	▦	*MEP Trimout*	12 days	Wed 1/29/14
169	▦	*Rough Clean*	3 days	Fri 2/14/14
170	▦	*2nd Coat Paint*	5 days	Wed 2/19/14
171	▦	*Vinyl Flooring*	5 days	Wed 2/26/14
172	▦	*Carpet Flooring*	3 days	Wed 3/5/14
173	▦	*DCC QC Inspection / Punchout*	7 days	Mon 3/10/14
174	▦	*Final Clean / Punchlist*	13 days	Wed 3/19/14
175	▦	**3rd FL - 10th FL**	150 days	Fri 11/29/13
176	▦	**Retail**	25 days	Fri 7/19/13
177	▦	*Interior Metal Framing*	7 days	Thu 7/25/13
178	▦	*Install Storefront*	15 days	Thu 7/25/13
179	▦	*Mechanical Fitout*	5 days	Thu 8/15/13
180	▦	*Electrical R/I*	7 days	Thu 8/22/13
181	▦	*Electrical Trim*	5 days	Mon 9/2/13
182	▦	*Owner Walk*	2 days	Mon 9/9/13
183	▦	**BUILDING 2**	**133 days**	**Fri 11/29/13**
184	▦	**Ground FL - Roof**	133 days	Fri 11/29/13
185	▦	**COMMISSIONING/CLOSEOUT**	**201 days**	**Tue 10/1/13**
186	▦	Building 1	156 days	Tue 12/3/13
187	▦	Building 2	153 days	Tue 10/1/13

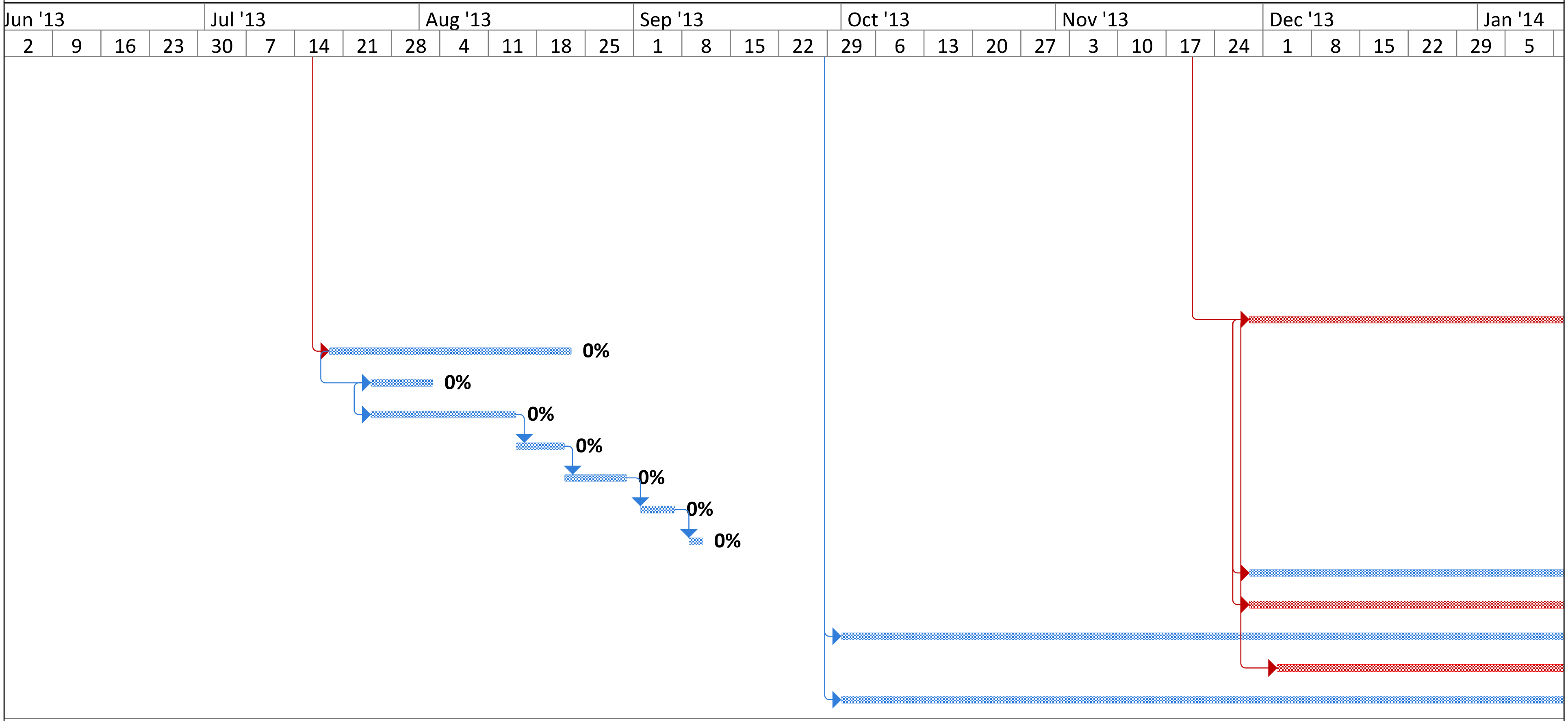
Aug '12 | Sep '12 | Oct '12

15 | 22 | 29 | 5 | 12 | 19 | 26 | 2 | 9 | 16 | 23 | 30 | 7 | 14

Critical	━	Finish-only	]	Manual Summary	━
Critical Split	┅	Duration-only	━	Project Summary	━
Critical Progress	━	Baseline	━	External Tasks	━
Task	━	Baseline Split	┅	External Milestone	◆
Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	━	Milestone	◆	Inactive Milestone	◇
Manual Task	━	Summary Progress	━	Inactive Summary	▭
Start-only	[	Summary	━	Deadline	⇩

	Nov '12					Dec '12				Jan '13					Feb '13				Mar '13					Apr '13				May '13		
21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	3	10	17	24	3	10	17	24	31	7	14	21	28	5	12	19	26

Critical	━	Finish-only	]	Manual Summary	━
Critical Split	┅	Duration-only	━	Project Summary	━
Critical Progress	━	Baseline	━	External Tasks	━
Task	━	Baseline Split	┅	External Milestone	◆
Split	┅	Baseline Milestone	◇	Inactive Task	▭
Task Progress	━	Milestone	◆	Inactive Milestone	◇
Manual Task	━	Summary Progress	━	Inactive Summary	▭
Start-only	[	Summary	━	Deadline	⬇



Critical	━	Finish-only	]	Manual Summary	━
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Task Progress	━	Milestone	◆	Inactive Milestone	◇
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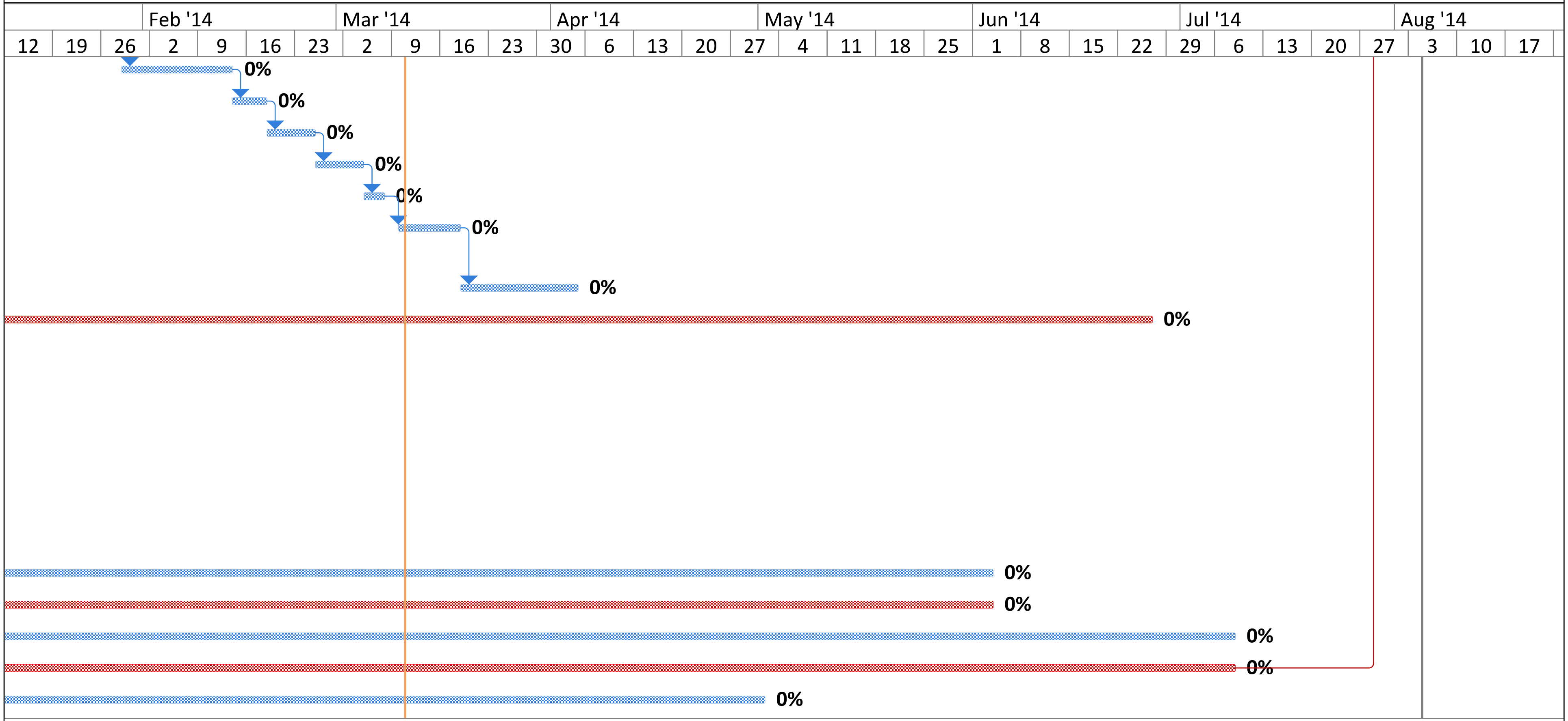
Start-only	[	Summary	━	Deadline	⬇

Detailed Schedule.mpp



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Split	┈	Baseline Milestone	◇	Inactive Task	▭
Task Progress	━	Milestone	◆	Inactive Milestone	◇
Manual Task	▨	Summary Progress	━	Inactive Summary	▭
Start-only	[	Summary	━	Deadline	⬇

APPENDIX F: MODULAR BATHROOM DETAIL ESTIMATE

Typical Modularized Bathroom Unit Cost

Item	QTY	Unit	Mat'l $/Unit	Mat'l Total	Labor $/Unit	Labor Total	Equip $/Unit	Equip Total	Total Cost
Piping - Copper - 1/2" dia.	26	L.F.	$ 4.47	$ 116.22	$ 5.90	$ 153.40	$ -	$ -	$ 269.62
Piping - Copper - 3/4"	4	L.F.	$ 4.62	$ 18.48	$ 4.50	$ 18.00	$ -	$ -	$ 36.48
Piping - Copper - 1" dia.	6	L.F.	$ 10.60	$ 63.60	$ 7.00	$ 42.00	$ -	$ -	$ 105.60
Piping - Copper - 1-1/2" dia.	38	L.F.	$ 17.15	$ 651.70	$ 9.20	$ 349.60	$ -	$ -	$ 1,001.30
Piping - Cast Iron - 1-1/2"	31	L.F.	$ 9.15	$ 283.65	$ 11.65	$ 361.15	$ -	$ -	$ 644.80
Piping - Cast Iron - 4"	47	L.F.	$ 16.95	$ 796.65	$ 14.30	$ 672.10	$ -	$ -	$ 1,468.75
Receptical - Duplex - 20 amp	4	Ea.	$ 39.50	$ 158.00	$ 15.80	$ 63.20	$ -	$ -	$ 221.20
Switches - Single Pole	5	Ea.	$ 23.50	$ 117.50	$ 30.00	$ 150.00	$ -	$ -	$ 267.50
Fixture - Flourescent -T8	4	Ea.	$ 67.00	$ 268.00	$ 53.50	$ 214.00	$ -	$ -	$ 482.00
Fixture - Recessed	4	Ea.	$ 47.50	$ 190.00	$ 75.00	$ 300.00	$ -	$ -	$ 490.00
Duct - Metal	29	Lb.	$ 3.66	$ 106.14	$ 16.35	$ 474.15	$ -	$ -	$ 580.29
Framing - Metal Stud	53	C.L.F	$ 48.00	$ 2,544.00	$ 52.50	$ 2,782.50	$ -	$ -	$ 5,326.50
Framing - 7'-0" x 3'-0" Steel	2	Ea.	$ 150.00	$ 300.00	$ 46.00	$ 92.00	$ -	$ -	$ 392.00
Partition Wall - 1/2" Gypsum	790	S.F	$ 1.06	$ 837.40	$ 2.10	$ 1,659.00	$ -	$ -	$ 2,496.40
Vanity Top - Center Bowl - 22" x 37"	2	Ea.	$ 460.00	$ 920.00	$ 36.50	$ 73.00	$ -	$ -	$ 993.00
Shower - Stall - 36" x 36" Square	1	Ea.	$ 505.00	$ 505.00	$ 151.00	$ 151.00	$ -	$ -	$ 656.00
Water Closet	1	Ea.	$ 1,050.00	$ 1,050.00	$ 156.00	$ 156.00	$ -	$ -	$ 1,206.00

Total Cost				**$ 8,926.34**		**$ 7,711.10**		**$ -**	**$ 16,637.44**

APPENDIX G: STICK-BUILT BATHROOM DETAILED ESTIMATE

Typical Stick-Built Bathroom Unit Cost

Item	QTY	Unit	Mat'l $/Unit	Mat'l Total	Labor $/Unit	Labor Total	Equip $/Unit	Equip Total	Total Cost
Piping - Copper - 1/2" dia.	26	L.F.	$ 4.47	$ 116.22	$ 5.90	$ 153.40	$ -	$ -	$ 269.62
Piping - Copper - 3/4"	14	L.F.	$ 4.62	$ 64.68	$ 4.50	$ 63.00	$ -	$ -	$ 127.68
Piping - Copper - 1" dia.	6	L.F.	$ 10.60	$ 63.60	$ 7.00	$ 42.00	$ -	$ -	$ 105.60
Piping - Copper - 1-1/2" dia.	38	L.F.	$ 17.15	$ 651.70	$ 9.20	$ 349.60	$ -	$ -	$ 1,001.30
Piping - Cast Iron - 1-1/2"	31	L.F.	$ 9.15	$ 283.65	$ 11.65	$ 361.15	$ -	$ -	$ 644.80
Piping - Cast Iron - 4"	47	L.F.	$ 16.95	$ 796.65	$ 14.30	$ 672.10	$ -	$ -	$ 1,468.75
Receptical - Duplex - 20 amp	4	Ea.	$ 39.50	$ 158.00	$ 15.80	$ 63.20	$ -	$ -	$ 221.20
Switches - Single Pole	5	Ea.	$ 23.50	$ 117.50	$ 30.00	$ 150.00	$ -	$ -	$ 267.50
Fixture - Flourescent -T8	5	Ea.	$ 67.00	$ 335.00	$ 53.50	$ 267.50	$ -	$ -	$ 602.50
Fixture - Recessed	4	Ea.	$ 47.50	$ 190.00	$ 75.00	$ 300.00	$ -	$ -	$ 490.00
Duct - Metal	29	Lb.	$ 3.66	$ 106.14	$ 16.35	$ 474.15	$ -	$ -	$ 580.29
Framing - Metal Stud	53	C.L.F	$ 48.00	$ 2,544.00	$ 52.50	$ 2,782.50	$ -	$ -	$ 5,326.50
Framing - 7'-0" x 3'-0" Steel	2	Ea.	$ 150.00	$ 300.00	$ 46.00	$ 92.00	$ -	$ -	$ 392.00
Partition Wall - 1/2" Gypsum	828	S.F	$ 1.06	$ 877.68	$ 2.10	$ 1,738.80	$ -	$ -	$ 2,616.48
Vanity Top - Center Bowl - 22" x 37"	2	Ea.	$ 460.00	$ 920.00	$ 36.50	$ 73.00	$ -	$ -	$ 993.00
Shower - Stall - 36" x 36" Square	1	Ea.	$ 505.00	$ 505.00	$ 151.00	$ 151.00	$ -	$ -	$ 656.00
Water Closet	1	Ea.	$ 1,050.00	$ 1,050.00	$ 156.00	$ 156.00	$ -	$ -	$ 1,206.00
Total Cost				**$ 9,079.82**		**$ 7,889.40**		**$ -**	**$ 16,969.22**

APPENDIX H: STICK0BUILT FAÇADE DETAILED ESTIMATE

Typical Floor Façade Cost - Building 1

Item	QTY	Unit	Mat'l $/Unit	Mat'l Total	Labor $/Unit	Labor Total	Equip $/Unit	Equip Total	Total Cost
Brick Masonry - Building 1	41.61	M	$ 595.00	$ 24,757.95	$ 1,125.00	$ 46,811.25	$ -	$ -	$ 71,569.20
Rigid Insulation - Building 1	6165	S.F	$ 0.41	$ 2,527.65	$ 0.33	$ 2,034.45	$ -	$ -	$ 4,562.10
Sheathing - Building 1	6165	S.F	$ 1.70	$ 10,480.50	$ 2.53	$ 15,597.45	$ -	$ -	$ 26,077.95
Tyvek - Building 1	6166	S.F	$ 0.14	$ 863.24	$ 0.09	$ 554.94	$ -	$ -	$ 1,418.18
Batt Insulation - Building 1	6165	SF	$ 0.60	$ 3,699.00	$ 0.23	$ 1,417.95	$ -	$ -	$ 5,116.95
1/2" Drywall - Building 1	6165	S.F	$ 1.06	$ 6,534.90	$ 2.10	$ 12,946.50	$ -	$ -	$ 19,481.40
4" Metal Stud Framing - Building 1	340	Ea.	$ 17.55	$ 5,967.00	$ 41.00	$ 13,940.00	$ -	$ -	$ 19,907.00

Total Cost				**$ 54,830.24**		**$ 93,302.54**		**$ -**	**$ 148,132.78**

Typical Floor Façade Cost - Building 2

Item	QTY	Unit	Mat'l $/Unit	Mat'l Total	Labor $/Unit	Labor Total	Equip $/Unit	Equip Total	Total Cost
Brick Masonry - Building 2	14.63	M	$ 595.00	$ 8,704.85	$ 1,125.00	$ 16,458.75	$ -	$ -	$ 25,163.60
Rigid Insulation - Building 2	2170	S.F	$ 0.41	$ 889.70	$ 0.33	$ 716.10	$ -	$ -	$ 1,605.80
Sheathing - Building 2	2170	S.F	$ 1.70	$ 3,689.00	$ 2.53	$ 5,490.10	$ -	$ -	$ 9,179.10
Tyvek - Building 2	2170	S.F	$ 0.14	$ 303.80	$ 0.09	$ 195.30	$ -	$ -	$ 499.10
Batt Insulation - Building 2	2170	SF	$ 0.60	$ 1,302.00	$ 0.23	$ 499.10	$ -	$ -	$ 1,801.10
1/2" Drywall - Building 2	2170	S.F	$ 1.06	$ 2,300.20	$ 2.10	$ 4,557.00	$ -	$ -	$ 6,857.20
4" Metal Stud Framing - Building 2	140	Ea.	$ 17.55	$ 2,457.00	$ 41.00	$ 5,740.00	$ -	$ -	$ 8,197.00

Total Cost				**$ 19,646.55**		**$ 33,656.35**		**$ -**	**$ 53,302.90**

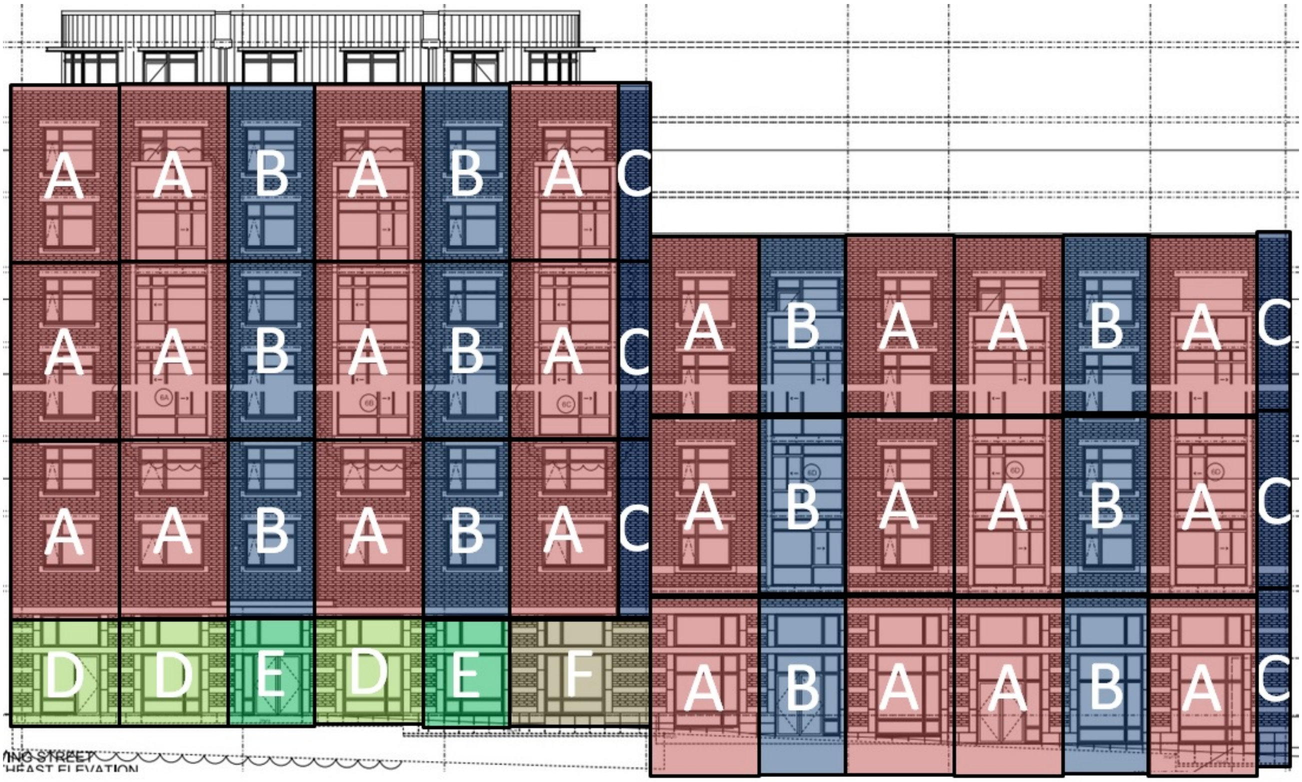
Stick Built Façade Cost

Item	Floors	Cost/Floor		Total Cost
Building 1	10	$148,132.78		**$ 1,481,327.80**
Building 2	6	$53,302.90		**$ 319,816.40**

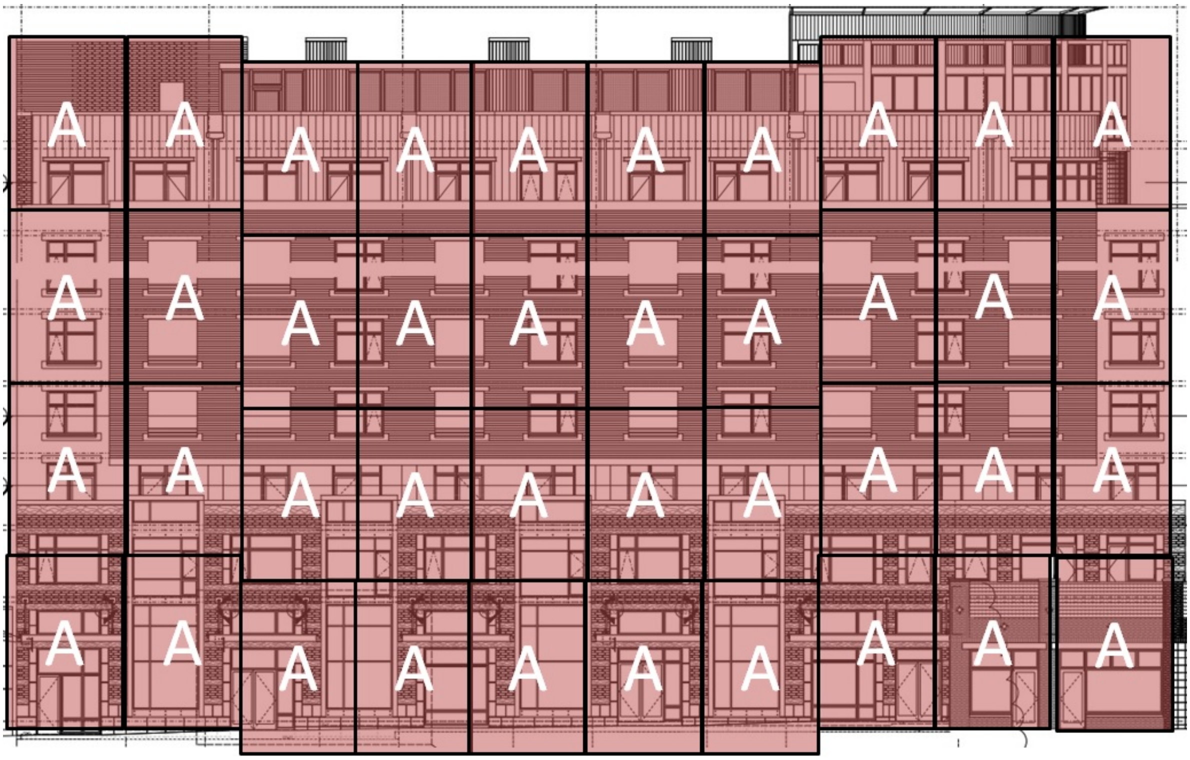
Total Cost	**$ 1,801,144.20**

APPENDIX I: PANEL TYPE LOCATION

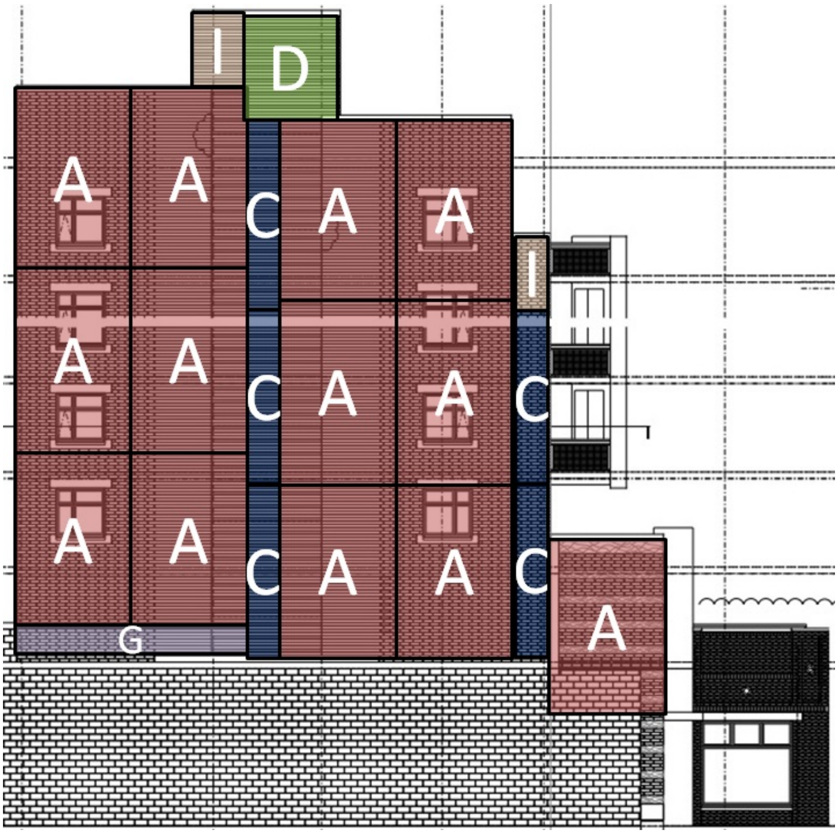
BUILDING 1 – NE ELEVATION



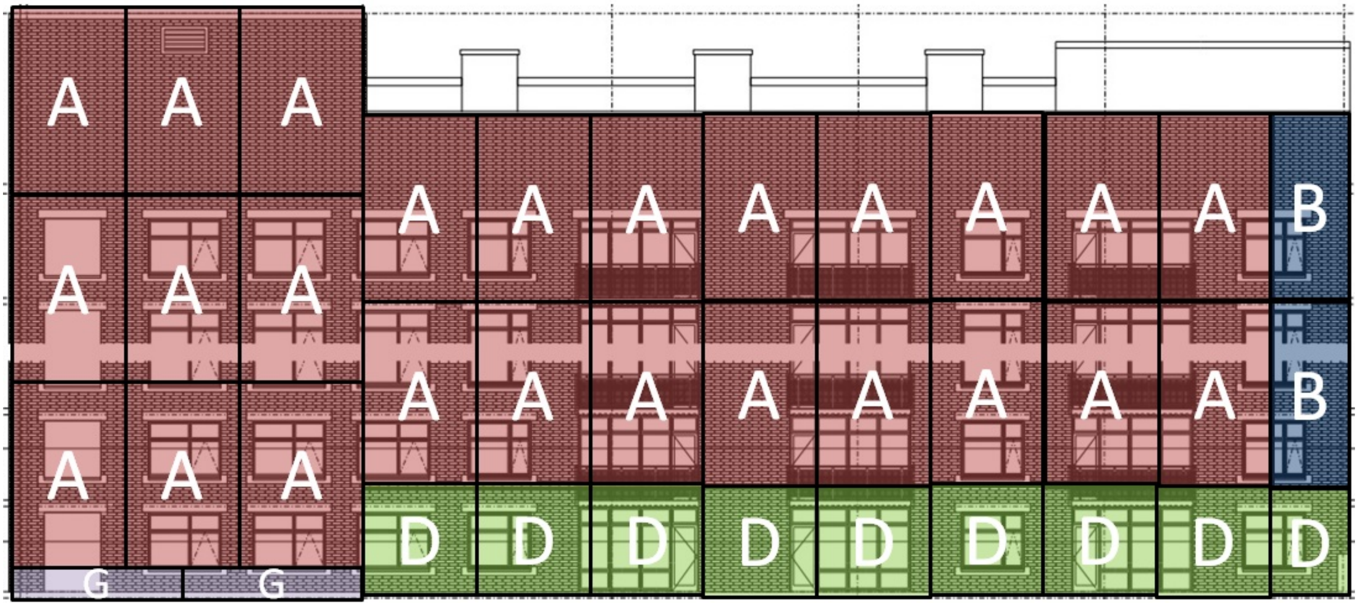
BUILDING 1 – SOUTH ELEVATION



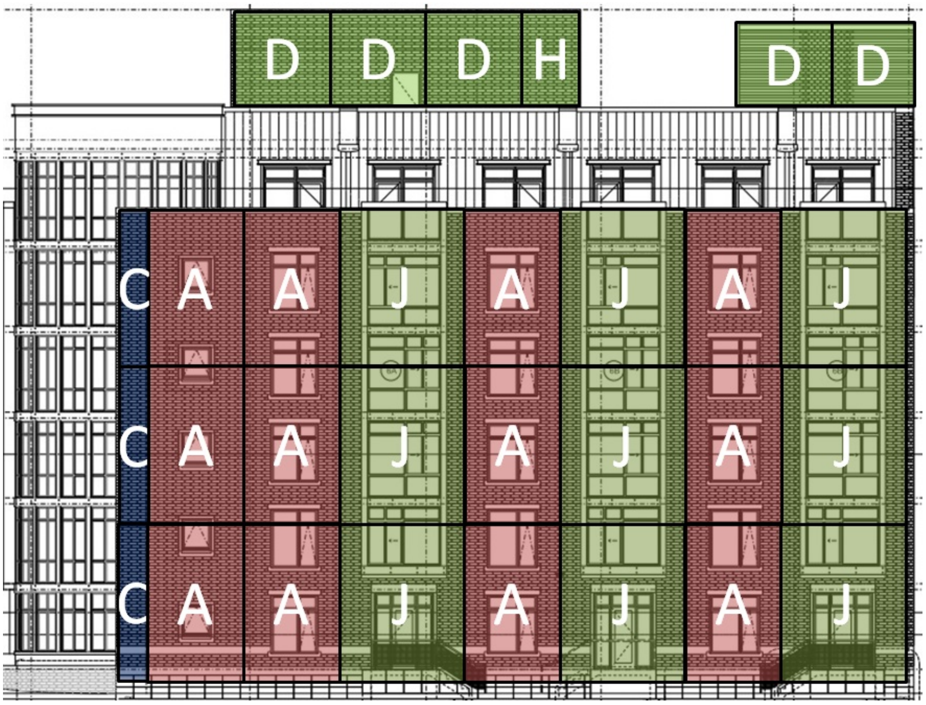
BUILDING 1 – SW ELEVATION



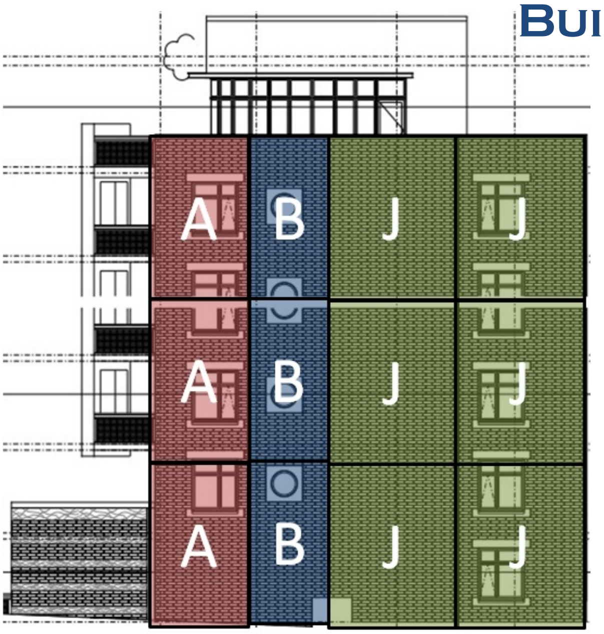
BUILDING 1 – WEST ELEVATION



BUILDING 2 – NORTH ELEVATION



BUILDING 2 – SOUTH ELEVATION

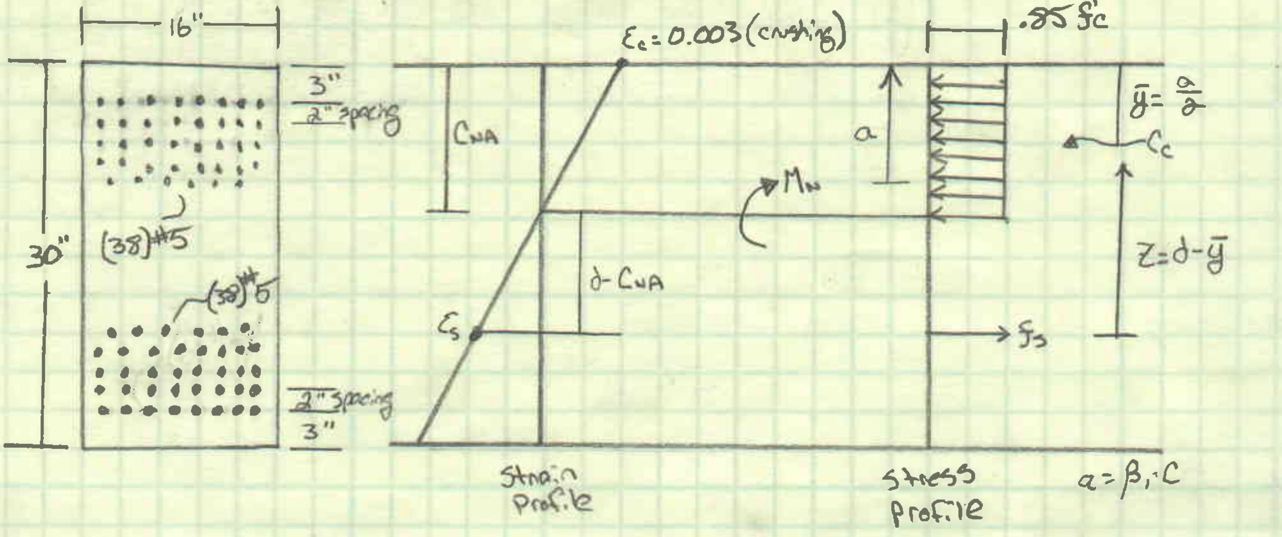


BUILDING 2 – WEST ELEVATION

APPENDIX J: STRUCTURAL BREADTH CALCULATIONS

Design Moment

Beam: Typical 16" x 30" reinforced concrete - 26' Span, Grade 60 steel



(i) Calculate C_{NA}

$A_s = 38(.31 in^2) + 38(.31 in^2) = 23.56$

$\overrightarrow{\uparrow}\Sigma F = 0 \qquad T_s = C_s$

$f_y A_s = 0.85 f'_c (A_c)$

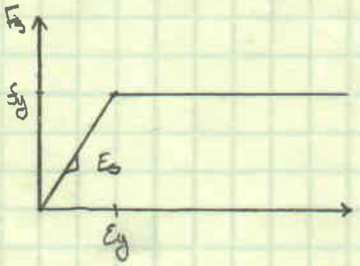
$f_y A_s = 0.85 f'_c (b \cdot a)$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{23.56 in^2 (60 ksi)}{0.85(4 ksi)(16")} = 25.99"$$

$a = \beta_1 C_{NA}$

$$C_{NA} = \frac{a}{\beta_1} = \frac{25.99}{.85} = 30.57"$$

(ii) Verify Steel Yield



$$\varepsilon_y = \frac{f_y}{E_s} = \frac{60 ksi}{29000 ksi} = 0.0021 < \varepsilon_s = 0.007 \quad \checkmark ok$$

↳ use $\phi = 0.9$

$$d = \frac{8(3") + 8(5") + 8(7") + 6(9") + 6(19") + 8(21) + 8(23') + 8(25') + 8(27")}{76} = 15"$$

(iii) Calculate Nominal Moment

$\curvearrowleft + \Sigma M = 0 \qquad M_n = f_y A_s \left(d - \frac{a}{2}\right) = (60 ksi)(23.56")\left(15 - \frac{25.99}{2}\right) = 2834.27$ Kp·in

$= 236.189$ Kp-ft

(iv) Calculate Design Moment

$\phi M_n = (0.9)(236.189 \text{ kip-ft}) = 212.6$ Kip-ft

$$\boxed{\phi M_n = 212.6 \text{ Kip-ft}}$$

Original Façade

(i) Load Calculations

Dead loads : 15 psf - Superimposed
45 psf - slab self wt.
5 psf - self wt. allowance
55 psf - brick wt.
120 psf - Dead load

Tributary width : 9.25"
(col. line A & B)

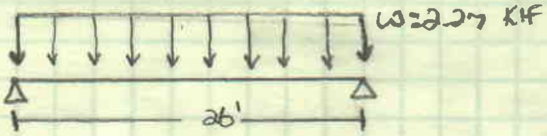
Wall Ht: 10'

Live loads : 40 psf - residential area
20 psf - partitions
60 psf - live load

*Assume NO live load reduction

$$\omega_{DL+LL} = 1.2\left[(15+45+5)(9.25")\right] + 1.6\left[(40+20)(9.25")\right] = 1.61 \text{ klf}$$

$$\omega_{cmu} = (55)(10')(12") = 0.66 \text{ klf}$$

$$\omega = \omega_{DL+LL} + \omega_{cmu} = 2.27 \text{ klf}$$

(ii) Moment Calculation

$$M_u = \frac{wL^2}{8} = \frac{(227 \text{ klf})(26^2 \text{ in})}{8} = 191.82 \text{ k·ft}$$

$$\boxed{M_u = 191.82 \text{ k-ft}}$$

$$\boxed{M_u \leq \phi M_n \quad \checkmark \text{OK}}$$

(iii) Deflection Calculation

$$\Delta = \frac{5wL^4}{384EI}$$

$$I = \frac{bh^3}{12} = \frac{(16")(30"^3)}{12} = 36{,}000 \text{ in}^4$$

Total load: $$\Delta_T = \frac{5(2.27 \text{ klf})(312"^4)}{384(29000)(36000 \text{ in}^4)} = 0.268 \text{ in}$$

$$\frac{L}{240} = \frac{(26')(12")}{240} = 1.3"$$

$$\boxed{\Delta_T = 0.268" < 1.3" \quad \checkmark \text{OK}}$$

Live load: $$\Delta_{LL} = \frac{5(.555)(312"^4)}{384(29000)(36000 \text{ in}^4)} = 0.066 \text{ in}$$

$$\frac{L}{360} = \frac{(26')(12")}{360} = 0.866"$$

$$\boxed{\Delta_{LL} = 0.066" < 0.866" \quad \checkmark \text{OK}}$$

New Façade

(i) Load Calculations

Dead Load: 15 psf - Superimposed
45 psf - Slab self wt
5 psf - self wt allowance
88 psf - panel self wt
153 psf - Dead Load

Tributary Width = 9.25'
(col. line A & B)

Live Load: 40 psf - residential area
20 psf - partitions
60 psf - Live load

*Assume No Live load reduction

$$w = 1.2\left[(15+45+5)(9.25')\right] + 1.6\left[(20+40)(9.25')\right] = 1.61 \text{ klf}$$

$$P = (88 \text{ psf})(25')\left(\frac{26'}{2}\right) = 28.6 \text{ kip}$$

*Note: 25' is typical facade panel Ht.

(ii) Moment Calculations

$$M_{dist} = \frac{1.61(26')}{8} = 136.05 \text{ K-ft}$$

$$M_{pt.} = \frac{28.6(26')}{4} = 185.9 \text{ K-ft}$$

$$M_u = M_{dist} + M_{pt} = 321.95 \text{ K-ft}$$

$$\boxed{M_u = 321.95 \text{ K-ft} \cancel{\leq} \phi M_n \quad {}^{\times}\text{Not OK}}$$

(iii) Deflection Calculations

$$\text{Total load: } \Delta_T = \frac{5wL^4}{385EI} + \frac{PL^3}{48EI} = \frac{5(1.61)(312^4)}{384(29000)(36{,}000)} + \frac{(28.6)(312^3)}{48(29000)(36000)} = 0.207 \text{in}$$

$$\boxed{\begin{array}{l} \Delta_T = 0.207 \text{in} \leq 1.3 \text{ in} \ \checkmark\text{ok} \\ \Delta_{LL} \rightarrow \text{same as original} \ \checkmark\text{OK} \end{array}}$$

APPENDIX K: CURRENT LEED EVALUATION

LEED-NC Version 2.2 Registered Project Checklist

Multi-Use High Rise

Yes	?	No			
9		5	**Sustainable Sites**		**14** Points
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
1			Credit 1	**Site Selection**	1
1			Credit 2	**Development Density & Community Connectivity**	1
		1	Credit 3	**Brownfield Redevelopment**	1
1			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
1			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
1			Credit 4.3	**Alternative Transportation**, Low-Emitting and Fuel-Efficient Vehicles	1
1			Credit 4.4	**Alternative Transportation**, Parking Capacity	1
		1	Credit 5.1	**Site Development,** Protect of Restore Habitat	1
1			Credit 5.2	**Site Development,** Maximize Open Space	1
		1	Credit 6.1	**Stormwater Design,** Quantity Control	1
		1	Credit 6.2	**Stormwater Design,** Quality Control	1
1			Credit 7.1	**Heat Island Effect,** Non-Roof	1
1			Credit 7.2	**Heat Island Effect,** Roof	1
		1	Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
1	1	3	**Water Efficiency**		**5** Points
	1		Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
		1	Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
		1	Credit 2	**Innovative Wastewater Technologies**	1
1			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
		1	Credit 3.2	**Water Use Reduction**, 30% Reduction	1

Yes	?	No			
1	1	13	**Energy & Atmosphere**		**17** Points
Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required
		10	Credit 1	**Optimize Energy Performance**	1 to 10
		1	Credit 2	**On-Site Renewable Energy**	1 to 3
1			Credit 3	**Enhanced Commissioning**	1
		1	Credit 4	**Enhanced Refrigerant Management**	1
		1	Credit 5	**Measurement & Verification**	1
	1		Credit 6	**Green Power**	1

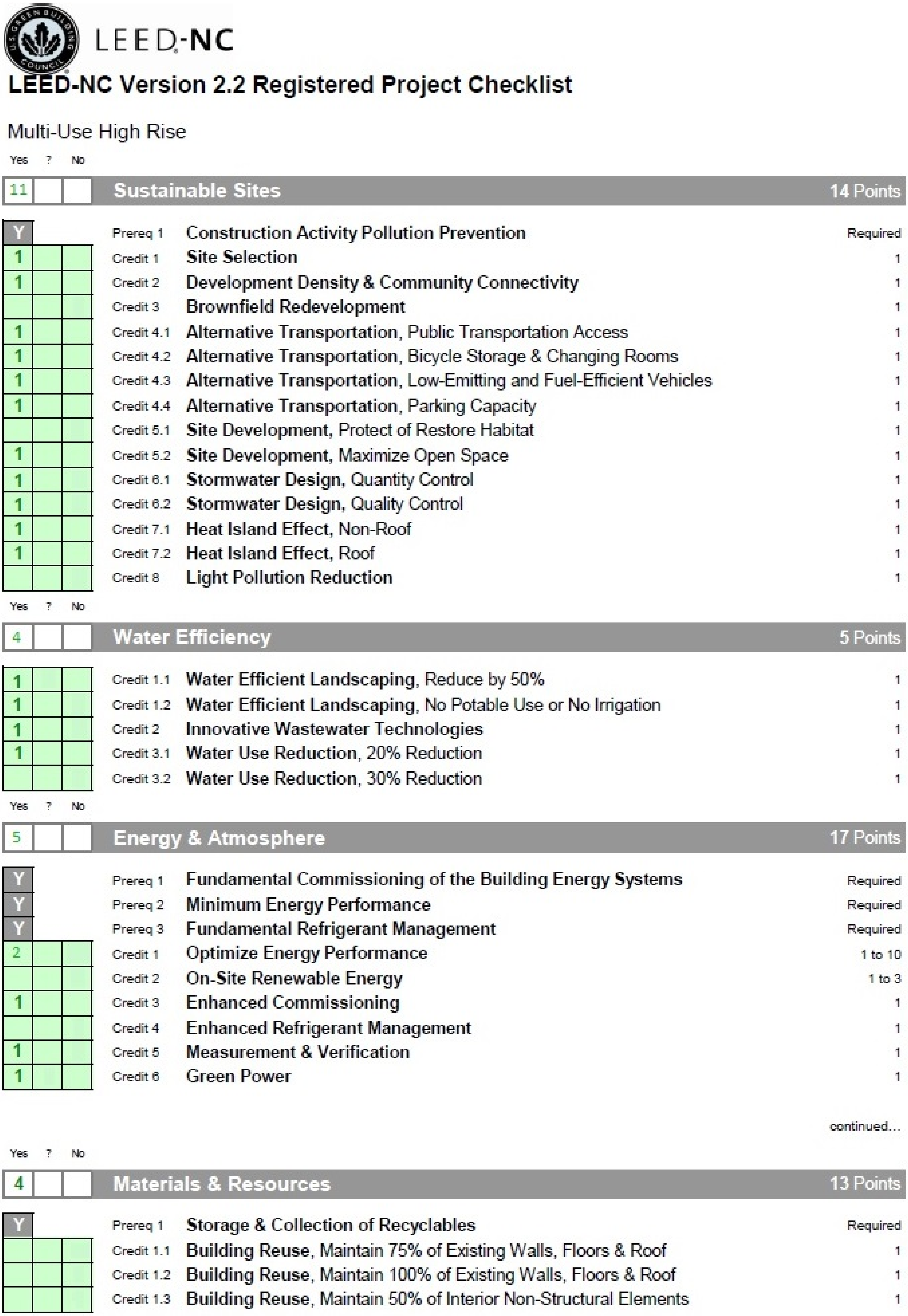
continued…

Yes	?	No			
4	2	7	**Materials & Resources**		**13** Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
		1	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
		1	Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roof	1
		1	Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1

1			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
1			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
		1	Credit 3.1	**Materials Reuse**, 5%	1
		1	Credit 3.2	**Materials Reuse**,10%	1
1			Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
	1		Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
1			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regionally	1
	1		Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regionally	1
		1	Credit 6	**Rapidly Renewable Materials**	1
		1	Credit 7	**Certified Wood**	1
Yes	?	No			
8	1	6	**Indoor Environmental Quality**		**15** Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
		1	Credit 1	**Outdoor Air Delivery Monitoring**	1
		1	Credit 2	**Increased Ventilation**	1
1			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
		1	Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
1			Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
1			Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
		1	Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
		1	Credit 5	**Indoor Chemical & Pollutant Source Control**	1
1			Credit 6.1	**Controllability of Systems**, Lighting	1
1			Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
1			Credit 7.1	**Thermal Comfort**, Design	1
	1		Credit 7.2	**Thermal Comfort**, Verification	1
		1	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
1			Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1
Yes	?	No			
5			**Innovation & Design Process**		**5** Points
1			Credit 1.1	**Innovation in Design**: Education Program	1
1			Credit 1.2	**Innovation in Design**: Energy Star Appliances	1
1			Credit 1.3	**Innovation in Design**: Low Mercury Lamps	1
1			Credit 1.4	**Innovation in Design**: Heat Island Effect, Non-Roof: 100% Underground Parking	1
1			Credit 2	**LEED® Accredited Professional**	1
Yes	?	No			
28	5	34	**Project Totals** **(pre-certification estimates)**		**69** Points

Certified 26-32 points **Silver** 33-38 points **Gold** 39-51 points **Platinum** 52-69 points

APPENDIX L: LEED RE-EVALUATION



LEED-NC

LEED-NC Version 2.2 Registered Project Checklist

Multi-Use High Rise

Yes	?	No			
11			**Sustainable Sites**		14 Points
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
1			Credit 1	**Site Selection**	1
1			Credit 2	**Development Density & Community Connectivity**	1
			Credit 3	**Brownfield Redevelopment**	1
1			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
1			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
1			Credit 4.3	**Alternative Transportation**, Low-Emitting and Fuel-Efficient Vehicles	1
1			Credit 4.4	**Alternative Transportation**, Parking Capacity	1
			Credit 5.1	**Site Development,** Protect of Restore Habitat	1
1			Credit 5.2	**Site Development,** Maximize Open Space	1
1			Credit 6.1	**Stormwater Design,** Quantity Control	1
1			Credit 6.2	**Stormwater Design,** Quality Control	1
1			Credit 7.1	**Heat Island Effect,** Non-Roof	1
1			Credit 7.2	**Heat Island Effect,** Roof	1
			Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
4			**Water Efficiency**		5 Points
1			Credit 1.1	**Water Efficient Landscaping,** Reduce by 50%	1
1			Credit 1.2	**Water Efficient Landscaping,** No Potable Use or No Irrigation	1
1			Credit 2	**Innovative Wastewater Technologies**	1
1			Credit 3.1	**Water Use Reduction,** 20% Reduction	1
			Credit 3.2	**Water Use Reduction,** 30% Reduction	1

Yes	?	No			
5			**Energy & Atmosphere**		17 Points
Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required
2			Credit 1	**Optimize Energy Performance**	1 to 10
			Credit 2	**On-Site Renewable Energy**	1 to 3
1			Credit 3	**Enhanced Commissioning**	1
			Credit 4	**Enhanced Refrigerant Management**	1
1			Credit 5	**Measurement & Verification**	1
1			Credit 6	**Green Power**	1

continued...

Yes	?	No			
4			**Materials & Resources**		13 Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse,** Maintain 75% of Existing Walls, Floors & Roof	1
			Credit 1.2	**Building Reuse,** Maintain 100% of Existing Walls, Floors & Roof	1
			Credit 1.3	**Building Reuse,** Maintain 50% of Interior Non-Structural Elements	1

1			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
1			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
			Credit 3.1	**Materials Reuse**, 5%	1
			Credit 3.2	**Materials Reuse**,10%	1
1			Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
			Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
1			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regionally	1
			Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regionally	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1
Yes	?	No			
10				**Indoor Environmental Quality**	15 Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	Required
1			Credit 1	**Outdoor Air Delivery Monitoring**	1
			Credit 2	**Increased Ventilation**	1
1			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
1			Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
1			Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
1			Credit 6.1	**Controllability of Systems**, Lighting	1
1			Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
1			Credit 7.1	**Thermal Comfort**, Design	1
1			Credit 7.2	**Thermal Comfort**, Verification	1
			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
1			Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1
Yes	?	No			
5				**Innovation & Design Process**	5 Points
1			Credit 1.1	**Innovation in Design**: Education Program	1
1			Credit 1.2	**Innovation in Design**: Energy Star Appliances	1
1			Credit 1.3	**Innovation in Design**: Low Mercury Lamps	1
1			Credit 1.4	**Innovation in Design**: Heat Island Effect, Non-Roof: 100% Underground Parking	1
1			Credit 2	**LEED® Accredited Professional**	1
Yes	?	No			
39				**Project Totals** (pre-certification estimates)	69 Points

Certified 26-32 points **Silver** 33-38 point **Gold** 39-51 points **Platinum** 52-69 points

APPENDIX M: STORM WATER COST BREAKDOWN

Storm Water Cost Breakdown									
Item	**QTY**	**Unit**	**Mat'l $/Unit**	**Mat'l Total**	**Labor $/Unit**	**Labor Total**	**Equip $/Unit**	**Equip Total**	**Total Cost**
Rainmaster Fiberglass Tank	3	Ea.	$ 59,974.95	$ 179,924.85	$ 950.00	$ 2,850.00	$ -	$ -	$ 182,774.85
4" PVC Piping	450	L.F	$ 0.58	$ 261.00	$ 2.82	$ 1,269.00	$ -	$ -	$ 1,530.00
Crane Rental	4	hrs	$ -	$ -	$ -	$ -	$ 1,500.00	$ 6,000.00	$ 6,000.00
Rainmaster Pump Station	3	Ea.	$ 3,499.95	$ 10,499.85	$ -	$ -	$ -	$ -	$ 10,499.85
Filter	3	Ea.	$ 423.33	$ 1,269.99	$ -	$ -	$ -	$ -	$ 1,269.99
Rainwater Guage	3	Ea.	$ 59.99	$ 179.97	$ -	$ -	$ -	$ -	$ 179.97

Total Cost				**$ 192,135.66**		**$ 4,119.00**		**$ 6,000.00**	**$ 202,254.66**

APPENDIX N: THERMAL COMFORT SURVEY

Multi-Use High Rise Thermal Comfort Verification Survey

Location Within Building

1. Which building are you located in?
    - Building 1
    - Building 2

2. On which floor is your workspace located?
    - ☐ First Floor
    - ☐ Second Floor
    - ☐ Third Floor
    - Fourth Floor
    - Fifth Floor
    - Sixth Floor
    - Seventh Floor *(Only pertains to Building 1 occupants)*
    - Eighth Floor *(Only pertains to Building 1 occupants)*
    - Ninth Floor *(Only pertains to Building 1 occupants)*

3. In which area of the building are you located?
    - ☐ North
    - ☐ East
    - ☐ South
    - ☐ West

Exact location (optional):

____

____

____

Temperature

Please rate the overall thermal comfort in your living space:

-3	-2	-1	0	1	2	3

Very Dissatisfied Very Satisfied

Please rate the thermal comfort in your living space during warm or hot weather:

-3	-2	-1	0	1	2	3

Too Cold Comfortable Too Hot

Please rate the thermal comfort in your living space during cool or cold weather:

-3	-2	-1	0	1	2	3

Too Cold Comfortable Too Hot

1. If you experience thermal discomfort (temperature and humidity), which of the following best describes it?

☐ Morning
☐ Afternoon
☐ Weekends
☐ Holidays
☐ Monday Mornings
☐ Always
☐ Other (Please explain below)

2. If you experience thermal discomfort (temperature and humidity), which of the following best describes it?

☐ Too much/ too little air movement
☐ Incoming sunlight heats up space
☐ Heat from office equipment
☐ Drafty windows
☐ Vented air is too hot
☐ Vented air is too cold
☐ My living space is hotter than other areas
☐ My living space is colder than other areas
☐ Hot floors and walls
☐ Cold floors and walls
☐ Other (Please explain below)

Please describe any other issues related to your thermal comfort in your workspace:

____

____

____

____

Air Quality

How satisfied are you with the air quality in your living space?

-3	-2	-1	0	1	2	3

Very Dissatisfied Very Satisfied

Overall, does the air quality enhance or interfere with your living?

-3	-2	-1	0	1	2	3

Interferes Enhances

1. If you are dissatisfied with the air quality in your living area, is it:

☐ Stuffy/Stale
☐ Odorous

2. If the air is odorous, is it due to:

☐ Tobacco Smoke
☐ Food
☐ Carpet/Furniture Systems
☐ Other (Please explain below)

Please describe any other aspects of the air quality in your living space that are important to you.

APPENDIX O: MECHANICAL SYSTEM ESTIMATE

Mechancial System Estimate

Item	QTY	Unit	Mat'l $/Unit	Mat'l Total	Labor $/Unit	Labor Total	Equip $/Unit	Equip Total	Total Cost
Copper Pipe									
3/4"	28,404.06	LF	$ 7.80	$ 221,551.67	$ 6.20	$ 176,105.17	$ -		$ 397,656.84
1"	28.65	LF	$ 10.60	$ 303.69	$ 7.00	$ 200.55	$ -		$ 504.24
1-1/4"	388.28	LF	$ 13.25	$ 5,144.71	$ 8.20	$ 3,183.90	$ -		$ 8,328.61
1-1/2"	1,605.08	LF	$ 17.15	$ 27,527.12	$ 9.20	$ 14,766.74	$ -		$ 42,293.86
2"	330.31	LF	$ 26.50	$ 8,753.22	$ 11.50	$ 3,798.57	$ -		$ 12,551.78
2-1/2"	17.94	LF	$ 41.00	$ 735.34	$ 13.80	$ 247.50	$ -		$ 982.84
3"	36.38	LF	$ 58.00	$ 2,110.04	$ 15.35	$ 558.43	$ -		$ 2,668.47
4"	105.40	LF	$ 101.00	$ 10,645.40	$ 22.00	$ 2,318.80	$ -		$ 12,964.20
6"	95.97	LF	$ 305.00	$ 29,269.33	$ 34.00	$ 3,262.81	$ -		$ 32,532.14
Cast Iron Pipe									
1-1/2"	1,920.00	LF	$ 9.30	$ 17,856.00	$ 13.15	$ 25,248.00	$ -		$ 43,104.00
2"	5,581.20	LF	$ 9.30	$ 51,905.16	$ 13.15	$ 73,392.78	$ -		$ 125,297.94
3"	11,592.00	LF	$ 12.95	$ 150,116.40	$ 13.80	$ 159,969.60	$ -		$ 310,086.00
4"	9,396.00	LF	$ 16.85	$ 158,322.60	$ 15.05	$ 141,409.80	$ -		$ 299,732.40
Equipment									
Pressure Red. Valve	270.00	Ea.	$ 395.00	$ 106,650.00	$ 23.00	$ 6,210.00	$ -		$ 112,860.00
Dom. Water Pump	1.00	Ea.	$ 7,550.00	$ 7,550.00	$ 860.00	$ 860.00	$ -		$ 8,410.00
Sanatary Ejector	8.00	Ea.	$ 21.82	$ 174.54	$ 3,375.00	$ 27,000.00	$ 1,175.00	$ 9,400.00	$ 36,574.54
Bath Tub	160.00	Ea.	$ 4,950.00	$ 792,000.00	$ 1,025.00	$ 164,000.00	$ -		$ 956,000.00
Water Closet	190.00	Ea.	$ 585.00	$ 111,150.00	$ 143.00	$ 27,170.00	$ -		$ 138,320.00
Lavatory	250.00	Ea.	$ 1,700.00	$ 425,000.00	$ 276.00	$ 69,000.00	$ -		$ 494,000.00
Cloths Washer	160.00	Ea.	$ 399.00	$ 63,840.00	$ 209.00	$ 33,440.00	$ -		$ 97,280.00
Kitchen Sink	160.00	Ea.	$ 660.00	$ 105,600.00	$ 148.00	$ 23,680.00	$ -		$ 129,280.00
Shower Stall	30.00	Ea.	$ 2,925.00	$ 87,750.00	$ 173.00	$ 5,190.00	$ -		$ 92,940.00
Dish Washer	160.00	Ea.	$ 475.00	$ 76,000.00	$ 209.00	$ 33,440.00	$ -		$ 109,440.00
Water Heater	160.00	Ea.	$ 800.00	$ 128,000.00	$ 209.00	$ 33,440.00	$ -		$ 161,440.00
Total				**$ 2,587,955.21**		**$ 1,027,892.65**		**$ 9,400.00**	**$ 3,625,247.85**

APPENDIX P: GREY WATER RECAPTURE SYSTEM ESTIMATE

Mechancial System Estimate w/ Grey Water Recapture System

Item	QTY	Unit	Mat'l $/Unit	Mat'l Total	Labor $/Unit	Labor Total	Equip $/Unit	Equip Total	Total Cost
Copper Pipe									
3/4"	28,404.06	LF	$ 7.80	$ 221,551.67	$ 6.20	$ 176,105.17	$ -	$ -	$ 397,656.84
1"	28.65	LF	$ 10.60	$ 303.69	$ 7.00	$ 200.55	$ -	$ -	$ 504.24
1-1/4"	388.28	LF	$ 13.25	$ 5,144.71	$ 8.20	$ 3,183.90	$ -	$ -	$ 8,328.61
1-1/2"	1,605.08	LF	$ 17.15	$ 27,527.12	$ 9.20	$ 14,766.74	$ -	$ -	$ 42,293.86
2"	330.31	LF	$ 26.50	$ 8,753.22	$ 11.50	$ 3,798.57	$ -	$ -	$ 12,551.78
2-1/2"	17.94	LF	$ 41.00	$ 735.34	$ 13.80	$ 247.50	$ -	$ -	$ 982.84
3"	36.38	LF	$ 58.00	$ 2,110.04	$ 15.35	$ 558.43	$ -	$ -	$ 2,668.47
4"	105.40	LF	$ 101.00	$ 10,645.40	$ 22.00	$ 2,318.80	$ -	$ -	$ 12,964.20
6"	95.97	LF	$ 305.00	$ 29,269.33	$ 34.00	$ 3,262.81	$ -	$ -	$ 32,532.14
Cast Iron Pipe									
1-1/2"	1,920.00	LF	$ 9.30	$ 17,856.00	$ 13.15	$ 25,248.00	$ -	$ -	$ 43,104.00
2"	5,581.20	LF	$ 9.30	$ 51,905.16	$ 13.15	$ 73,392.78	$ -	$ -	$ 125,297.94
3"	11,592.00	LF	$ 12.95	$ 150,116.40	$ 13.80	$ 159,969.60	$ -	$ -	$ 310,086.00
4"	9,396.00	LF	$ 16.85	$ 158,322.60	$ 15.05	$ 141,409.80	$ -	$ -	$ 299,732.40
PVC						$ -		$ -	$ -
1-1/2"	2,160.00	LF	$ 11.00	$ 23,760.00	$ 13.55	$ 29,268.00	$ -	$ -	$ 53,028.00
2"	6,278.85	LF	$ 14.25	$ 89,473.61	$ 15.05	$ 94,496.69	$ -	$ -	$ 183,970.31
3"	13,041.00	LF	$ 29.00	$ 378,189.00	$ 16.60	$ 216,480.60	$ -	$ -	$ 594,669.60
4"	10,570.50	LF	$ 41.00	$ 433,390.50	$ 18.00	$ 190,269.00	$ -	$ -	$ 623,659.50
Equipment						$ -		$ -	$ -
Pressure Red. Valve	270.00	Ea.	$ 395.00	$ 106,650.00	$ 23.00	$ 6,210.00	$ -	$ -	$ 112,860.00
Dom. Water Pump	1.00	Ea.	$ 7,550.00	$ 7,550.00	$ 860.00	$ 860.00	$ -	$ -	$ 8,410.00
Sanatary Ejector	8.00	Ea.	$ 21.82	$ 174.54	$ 3,375.00	$ 27,000.00	$ 1,175.00	$ 9,400.00	$ 27,174.54
Bath Tub	160.00	Ea.	$ 4,950.00	$ 792,000.00	$ 1,025.00	$ 164,000.00	$ -	$ -	$ 956,000.00
Water Closet	190.00	Ea.	$ 585.00	$ 111,150.00	$ 143.00	$ 27,170.00	$ -	$ -	$ 138,320.00
Lavatory	250.00	Ea.	$ 1,700.00	$ 425,000.00	$ 276.00	$ 69,000.00	$ -	$ -	$ 494,000.00
Cloths Washer	160.00	Ea.	$ 399.00	$ 63,840.00	$ 209.00	$ 33,440.00	$ -	$ -	$ 97,280.00
Kitchen Sink	160.00	Ea.	$ 660.00	$ 105,600.00	$ 148.00	$ 23,680.00	$ -	$ -	$ 129,280.00
Shower Stall	30.00	Ea.	$ 2,925.00	$ 87,750.00	$ 173.00	$ 5,190.00	$ -	$ -	$ 92,940.00
Dish Washer	160.00	Ea.	$ 475.00	$ 76,000.00	$ 209.00	$ 33,440.00	$ -	$ -	$ 109,440.00
Water Heater	160.00	Ea.	$ 800.00	$ 128,000.00	$ 209.00	$ 33,440.00	$ -	$ -	$ 161,440.00
Storage Tank	1.00	Ea.	$ 47,100.00	$ 47,100.00	$ 4,550.00	$ 4,550.00	$ 1,900.00	$ 1,900.00	$ 51,650.00
Total				**$ 3,559,868.32**		**$ 1,562,956.94**		**$ 11,300.00**	**$ 5,122,825.26**