Final Report

NORTHEAST HOSPITAL EXPANSION
123 Medical Lane, USA

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Construction Management Option
Advisor: Craig Dubler

April 8, 2015

NORTHEAST HOSPITAL EXPANSION
123 Medical Lane, USA

Building Information

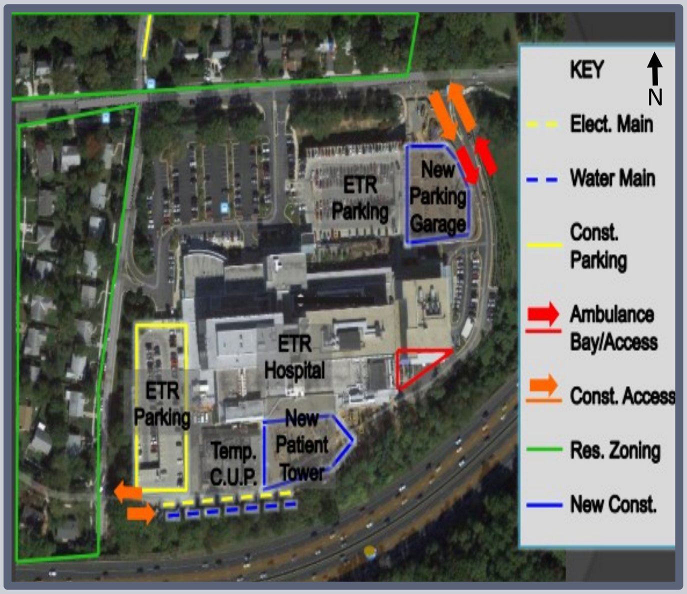
Function/Type: Hospital Addition
Size: 234,000 GSF
Stories: 7 Patient, 3 Mech, & 1 basement
Delivery Method: CM @ Risk
Construction Dates: Jan. 2013 - Sept. 2015

South Elev. Courtesy of Smith Group JJR

Project Team

Owner: Trinity Health
Owner Representative: KLMK Group
Architect: Smith Group JJR
CM: Whiting-Turner
Structural Engineer: McMullan & Assoc.
MEP FP Engineer: Leach Wallace Assoc. Inc.
Civil Engineer: Loiederman Soltesz Assoc.

Existing Conditions & New Construction



Architecture

- 180 Private patient rooms
- Relocation of Central Utility Plant
- Biowaste and autopsy room
- Connection bridge to existing wings

Structural

- Post tensioned concrete deck
- Cast-in-place concrete columns 7 Floors
- HSS steel columns 3 Mechanical Floors

Electrical

- 480/277V Distribution System
- (3) 2000KW emergency generators
- Primary Switchgear servicing
  - (2) Substations for patient rooms
  - (1) chiller substation
  - (1) emergency substation

Mechanical

- Boiler/Chiller System with Fan Coil Units
- Med Gas, Nitrogen, Oxygen, & CO_2 supplied to each patient room
- Acid Waste lines throughout
- (2) Critical Zone AHU & (7) Non Critical Zone AHU

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Advisor Craig Dubler

TRINITY HEALTH

WT WHITING-TURNER

http://www.engr.psu.edu/ae/thesis/portfolios/2015/jam6177/index.html

NORTHEAST HOSPITAL EXPANSION

EXECUTIVE SUMMARY

The Northeast Hospital Expansion project is located at 123 Medical Lane, USA. The project will consist of the construction of a new 10 story patient tower, new parking garage, renovation of select patient rooms in the existing hospital wings, and the relocation and upgrading of the central utility plant servicing the entire medical campus. This senior thesis report contains four different analyses on the Northeast Hospital Expansion project. To conduct these analyses, information was gathered from the project team, industry members, jobsite visits, knowledge gained while in attendance at the Penn State University, and research.

Analysis 1: IPD Methods Implementation

This first analysis consisted of research into how the Northeast Hospital Expansion could have benefitted from utilizing more integrated project delivery methods. From the case studies of Cardinal Glennon Children's Hospital, St. Clare Health Center, Encircle Health's Ambulatory Care Center, Cathedral Hill Hospital and the Health Sciences Facility III, it was determined that a multi-party contract, risk and reward pooling, and part-time co-location could have created a more efficient project environment.

Analysis 2: Patient Room Re-Design for Shared Wet Wall

The second analysis involved the re-design of typical patient room to allow the use of a shared wet wall between back-to-back rooms while maintaining ADA 2010 and prioritizing quality of care. Since plumbing systems would be combined to eliminate piping, all piping needed to be re-sized to meet changed system conditions creating a mechanical breadth. The shared wet wall would reduce the entire schedule by 93 days and create $405,507.75 in cost savings.

Analysis 3: SIPS Utilization for Patient Floors

The third analysis was attempting to create a more efficient workflow for the MEP and finishes work on the patient floors four, five, and six. Through implementing the ideologies of SIPS, the creation of a labor matrix, and examining labor loading throughout SIPS, the schedule could be accelerated 18 weeks and the project could potentially save $12,097.20 in labor costs.

Analysis 4: Preassembled Steel Connection Bridge

The fourth analysis broke the steel connection bridge linking the existing hospital to the new patient tower into different sections that could be preassembled prior to installation. This analysis contains a structural breadth that checked to verify that the crane could first lift the bridge sections and that the pick points would not damage any members in each section. Utilizing preassembled steel sections would reduce the schedule by six days while creating a safer work environment.

Acknowledgements

Industry Acknowledgements:

Whiting-Turner
Southland Industries
CBRE Healthcare

Academic:

Penn State Architectural Engineering Faculty
Dr. Craig Dubler – Faculty Advisor

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John Carbonneau – Southland Industries
Adam Davis – Penn State Office of Physical Plant
Mark Bittner – CBRE Healthcare
Jake Hughes – CBRE Healthcare
PACE Industry Members
My Friends, Family, and A-7

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Building Information

Project Summary

The Northeast Hospital Expansion includes the construction of a new ten story patient tower, central utility plant and a four-level parking garage. The patient tower allows for 150 new private patient rooms. Out patient floors include floors four through six with intensive care units on the third floor. Each floor with an area of 22,500 SF will house 30 patient rooms with the seventh floor reserved for future growth. Mechanical equipment occupies the basement and floors seven through ten. The ground floor allocates space for the linen storage, bio waste room, autopsy room, body holding room, and electrical equipment. A connection bridge on the ground floor lets occupants transverse between the new patient tower and the rest of the hospital campus. In total the new patient tower will occupy 234,000 SF.


-Courtesy of Smith Group JJR

Client Information

The Northeast Hospital Expansion is owned by Trinity Health. Trinity Health is one of the largest multi-institutional Catholic run health care systems in the US. Currently, the senior citizen population continues to rapidly grow in the Northeast Hospitals location and the hospital must expand to keep up with their surrounding population. Furthermore, senior citizens make up the hospitals number one client base. Beyond just focusing on the demographics, quality of care is always a main focus for Trinity health and they look to increase this quality through more private patient rooms and modernizing the surgery department. While construction is underway, the existing hospital and neighboring community must remain minimally effected. This means all access ways for the emergency ambulance and regular parking lot must remain open. The utilities must continuous supply the hospital during the transition from existing central utility plant to the new upgraded central utility plant. The hospital must also be able to meet all patient bed needs during the renovations. The design for the hospital also includes an extra patient bed floor that will remain unfinished until the need for 30 additional beds arises.

Project Team

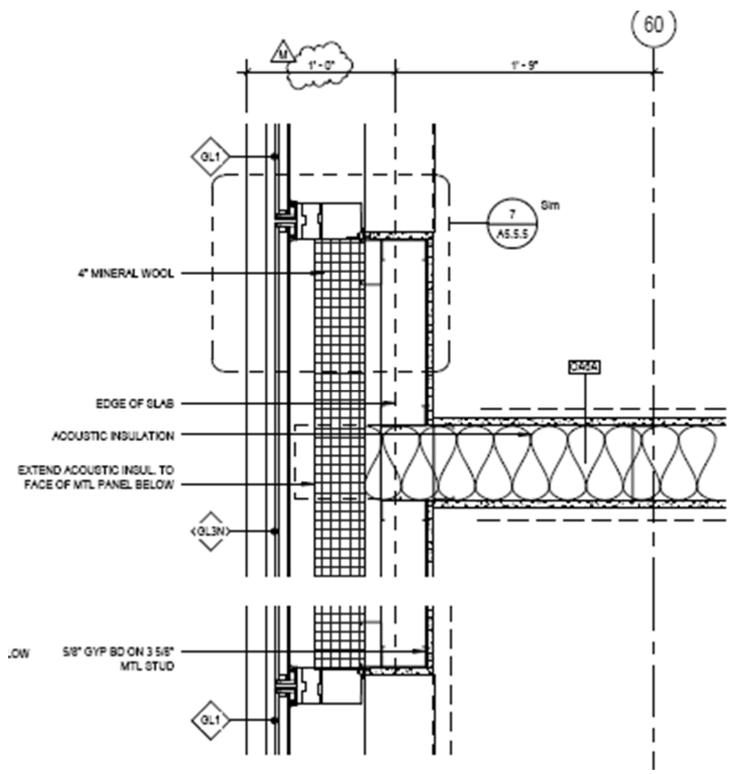
In order to satisfy the purpose and concerns of constructing the Northeast Hospital Expansion, Trinity Health needed to first hire KLMK Group, to act as the owner representative. KLMK consulted and advised Trinity Health during the architect and construction manager bid process. Since this project started KLMK has been merged into CBRE. The design for the new hospital expansion came from Smith Group JJR through a contract type unknown at this time. Along with Smith Group JJR, McMullan & Associates were brought on to design the concrete and steel structure. Loiederman Soltesz Associates designed the site work and retention walls to the south of the site. Leach Wallace Associates designed all the mechanical, electrical, plumbing and fire protection throughout the new patient tower. Whiting-Turner was later picked as the construction manager at risk with a GMP contract. Due to the complexities of the mechanical and electrical systems, Southland Industries and Dynalectric were brought on during the schematic phase of design as design assist subcontractors whom then were used for the actual construction. For a breakdown of the Whiting-turner project team structure please see the appendix.

Building Systems

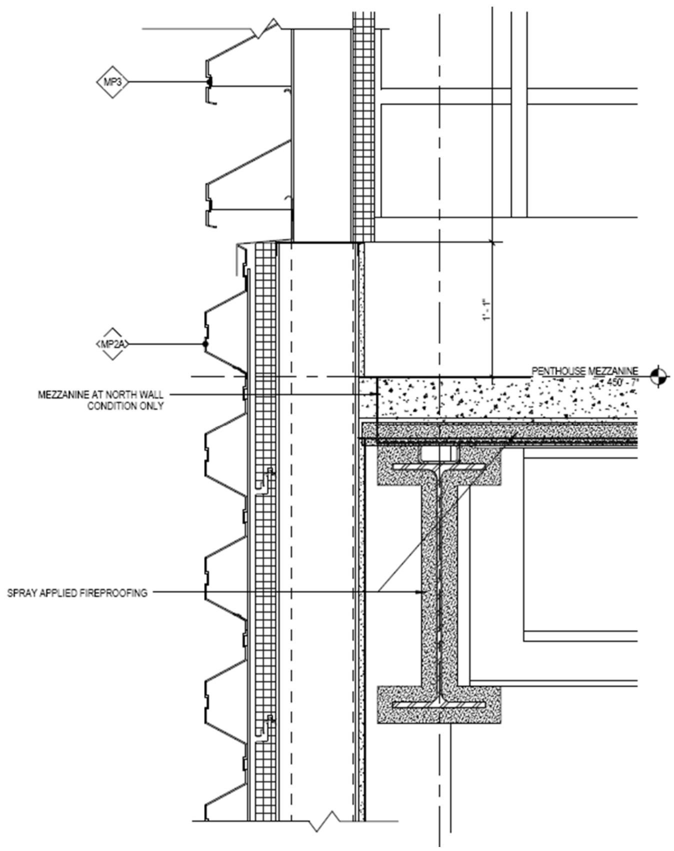
Superstructure

The superstructure is composed primarily of reinforced concrete columns supporting 10 1/2" thick slabs. All of the concrete slabs above the ground floor are post tensioned. To avoid drilling through the tensioned tendons the post tensioned slabs have been painted with the tendon locations. The concrete columns have a concrete strength of 4000psi and the slabs have a concrete strength of 3500psi. In total there will be 4026 CY of concrete, 1065.3 tons of reinforcement, and 12 tons of post-tensioning tendons. Once the structure reaches the mechanical penthouse levels, the structure switches from concrete to hollow structural steel tubing.

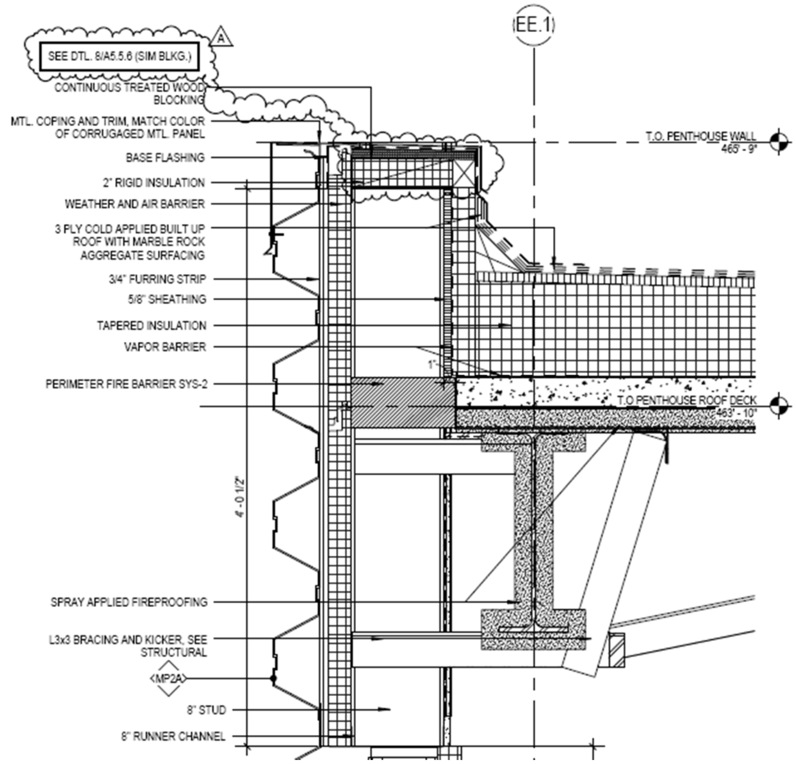
Building Façade



The exterior façade of the Northeast Hospital Expansion contains four main wall types. The South, East, and West walls from the ground floor to the sixth floor of the structure receives a curtain wall composed of 1 5/16" triple grazed insulated glass units (IGU) for noise reduction from the adjacent highway. The IGU's remain attached to the structure through mullions. A variety of glazing colors liven the exterior, ranging among blue, green, orange, rose, and yellow, but the most commonly used glazing is the clear laminate vision glazing. Spandrel glazing between floors masks the structure behind giving the building a continuous glimmer in the sun. Between the spandrels glazing and structure 4" of mineral wool insulation with an aluminum foil faced vapor retarder exists providing additional thermal and moisture resistance.

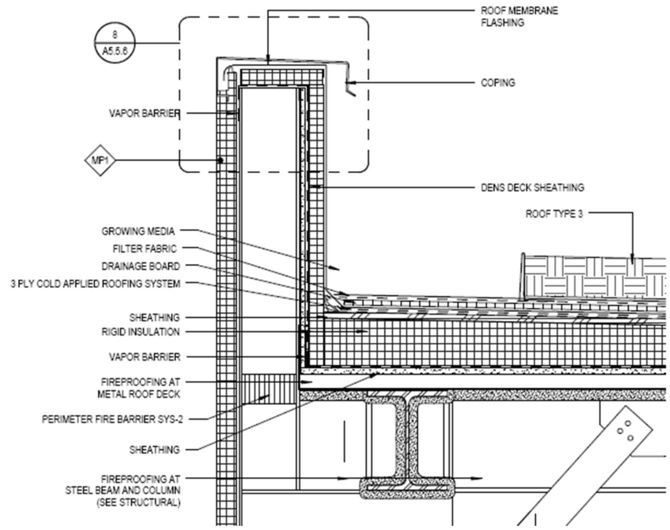


At the mechanical floors located at the top of building, more of a variety of wall types exist. Transitioning from the curtain wall on the sixth floor to the seventh floor mechanical space on the south facing wall, metal louvers clip fasten to 6" louver support framing and receive an insulated blank off panel. The east and west walls at this transition area obtain a 4" corrugated metal panel with fluid applied air barrier, 2" of insulation core material back up panel clip fastened to 8" of metal stud. The metal stud then gains 5/8" gypsum sheathing. On the north wall, primarily 3" of insulated metal panel clads the structure. The insulated metal panels clip fasten to 8" metal studs accompanied by a weather and air barrier, gypsum sheathing and ERS with 1 ½" rigid insulation. The insulated metal panel wall type covers a majority of the north-facing wall.



Roofing

Three different types of roofing enclose the roof of the Northeast Hospital Expansion. The portions of the patient tower's roof used for the walkway toward the mechanical roof top units uses built-up asphalt with a vapor barrier and 3" of tapered insulation sloped at ¼" per foot towards the roof drains. The rest of the patient tower roof is covered in a green roof made from growing media, filter fabric drainage board, 3 ply cold applied roofing system, sheathing, 3" of rigid insulation and a vapor barrier. Finally portions of the existing hospital space undergoing renovations receive another green roof system. The renovation green roof includes growing media, filter fabric drainage board, fleece back TPA Root Barrier set in water based adhesive, single ply tri-laminate water proofing felt set in solvent free adhesive, 5/8" Dens Deck set in green bio-based foam insulation adhesive, quick dry primer, and then the existing three ply of built-up roof system.



Mechanical

The building is heated and cooled by a typical boiler and chiller system located in the mechanical penthouse. The chill water lines and hot water lines run out to fan-coil units and radiant fin terminal units located through out the patient tower. High pressure steam and medium pressure steam are supplied to the rest of the campus by being piped from the mechanical penthouse down to the basement of the patient tower and through utility tunnels located to the north wall of the patient tower. Medical gas, nitrogen, oxygen, and carbon dioxide are also supplied to each patient room. The majority of AHU's are located in the mechanical penthouse with the exception of the autopsy unit. The autopsy unit is located in the basement and requires pre-filters and HEPA filters. The air supplied to the autopsy rooms is then 100% exhaust.

Electrical

Electrical distribution is accomplished by a 13.2kVA, 12000A, 750MVA, 3 phase, primary incoming utility switchgear located in the basement. The power is then stepped down to a 480/277V and distributed to three substations of 25000kVA, 480/277V and one substation of 2000kVA, 480/277V for the chillers in the pent house. From the substation electricity is distributed by separate lines to independent transformers at each piece of equipment or directly to the panels located on each floor. There are three 2000kW generators with emergency switchgear to be utilized for critical zones within the hospital in the event of a power outage to the campus. Lighting is accomplished by basic fluorescent tube lighting with occupancy controls.

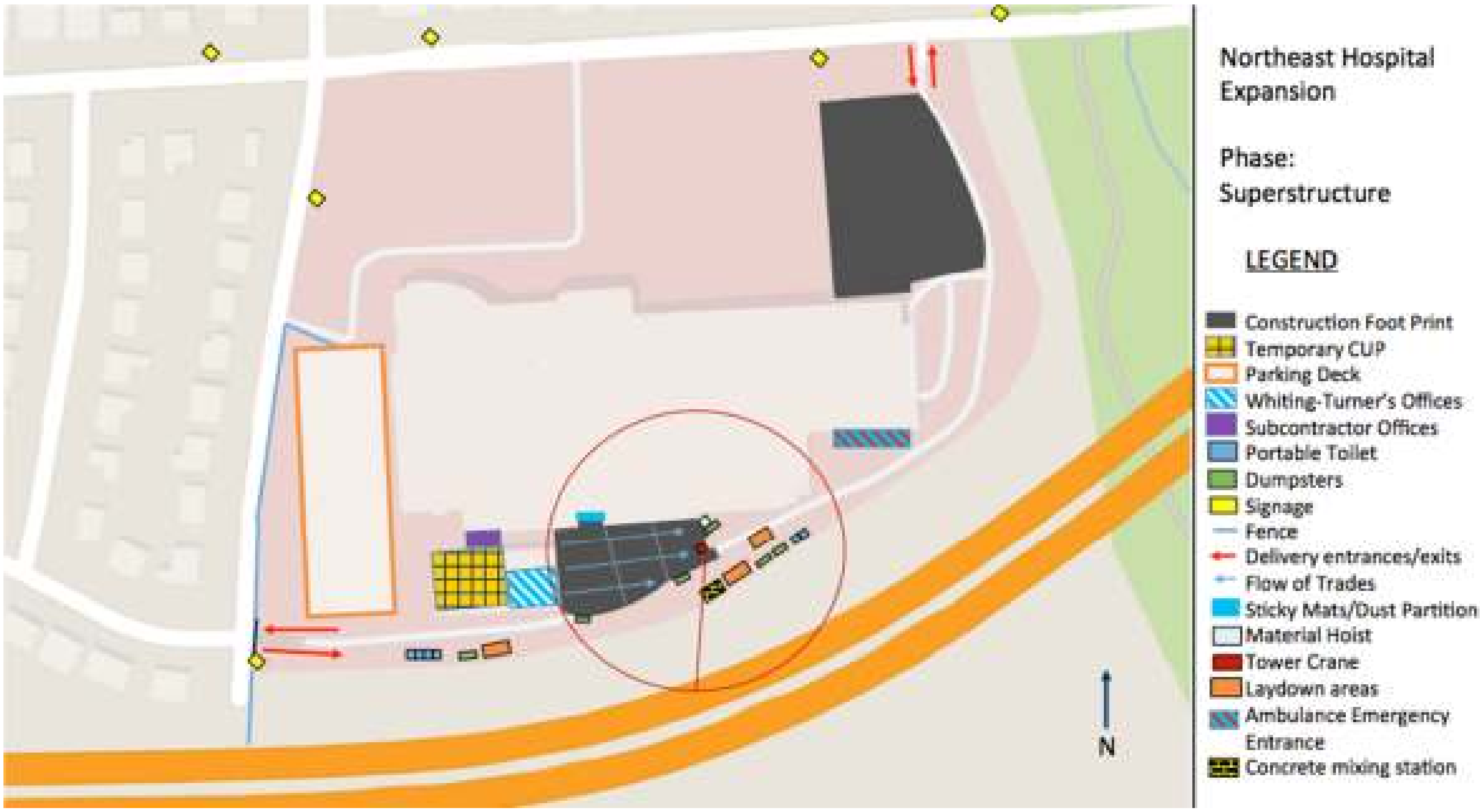
Sustainability

The design for the Northeast Hospital Expansion aims for LEED Silver. To achieve this level of sustainability, the project team utilizes several methods. Beyond just meeting the necessary pre-requisites such as testing and balancing of the HVAC to verify compliance with ASHRAE 62.1 and 90.1, the use of regional materials and the recycling of construction waste become key. Composite woods may not contain any urea formaldehyde and insulation may adhere only by solvent cements and adhesive primers. The domestic water pumps must comply with ASHRAE/IESNA 90.1 and healthcare plumbing fixtures must consume water in compliance with credits WE 1 and WE 3 for water use reduction. A green roof covers the top of the building to reduce the heat island effect and aid in storm water treatment. Finally by implementing single door pharmacy refrigerators with high efficiency top mounted refrigeration, the project team aims for an innovation credit.

Site Layout Planning

Excavation

Once mobilization occurs to the site. The first phase of the project is to excavate the foundation for the new patient tower. This involves the use of an excavator and numerous dump trucks to haul the soil away from the site. To accomplish this the site will use the road that wraps around the back of the existing hospital and conveniently parallels the site of the new patient tower. Dump trucks will enter the site at the Northeast entrance and drive to the excavation site. There the excavator will load their truck will dirt to haul away using the west side entrance. Soldier piles and lagging will need to be used at the excavator starts to dig down deeper. Along with the excavation a concrete pad must be formed for the tower crane that will be on site. To do this a concrete mixing station will be setup just south of the tower crane pad location.



Superstructure

Once the foundation is complete and the pad for the tower crane has been poured and cured, it is time for the superstructure to commence building. For this phase of the project a tower crane is erected on top of its concrete pad where it can begin to place concrete with a bucket. All of the concrete work will flow from west to east on the structure. The lay down areas are all located near the base of the crane with the exception of the one on the west side of the site. This lay down area is meant for work that takes place with the utilities feeding the new patient tower and the temporary central utility. A material hoist is also constructed to the north of the tower crane for an easier way to transport materials to the higher floors and to loosen the constraints with material being supplied to the upper floors.

<u>MEP & Finishes</u>

After the new patient tower is fully enclosed and all materials have been distributed to their appropriate floors, the finalizing of the MEP systems and finishes phase can commence. In this phase the lay down areas are now inside the patient tower and are located on the floors where the material is most needed. Work in flows in a zigzag pattern from north to south moving from the west to the east. At this point in time there is no longer a need for the tower crane since the building is fully enclosed and all of the heavy lifts have been completed. The material hoist has also been dismantled since the elevators in the building are now operational. All of the large equipment is already in place.

Project Cost Breakdown

The Northeast Hospital Expansion in its entirety is estimated to cost $230 million. Since this report primarily deals with the patient tower portion of this project, cost for the primary systems included in its construction can be seen below. The patient tower itself is estimated to cost $121 million. The other costs fund the construction of the new parking garage and all the renovation work occurring in the existing hospital.

System	Cost	Cost/SF	Percent
General Conditions	$13,027,770	$57.48	11.07%
Existing Conditions	$2,882,258	$12.72	2.45%
Concrete	$9,286,120	$40.97	7.89%
Masonry	$227,800	$1.01	0.19%
Metals	$3,648,900	$16.10	3.10%
Wood, Plastic and Composites	$2,703,662	$11.93	2.30%
Thermal & Moisture Protection	$5,141,354	$22.69	4.37%
Openings	$7,411,325	$32.70	6.30%
Finishes	$6,869,950	$30.31	5.84%
Specialties	$766,620	$3.38	0.65%
Equipment	$125,545	$0.55	0.11%
Furnishings	$136,700	$0.60	0.12%
Conveying Systems	$3,401,687	$15.01	2.89%
Fire Suppression	$1,283,620	$5.66	1.09%
Plumbing, Heating, Air Conditioning	$39,260,743	$173.23	33.35%
Electrical	$18,076,235	$79.76	15.35%
Earthwork	$2,623,839	$11.58	2.23%
Exterior Improvements	$110,650	$0.49	0.09%
Utilities	$748,666	$3.30	0.64%

Project Schedule

The Northeast Hospital Expansion project in total is scheduled to last 733 workdays from the notice to proceed until the sixth floor is complete and ready for occupancy. The project commenced on January 8th, 2013 and expects to undergo construction until September 6th, 2015. Over the course the two and half year time period, more than 390 activities must occur prior to full occupancy. Site work officially started on January 21st, 2013 and excavation and foundations finished on September 10th, 2013. After the foundation work was complete, concrete was poured to construct the superstructure, which topped out on the 20th of March 2014. The structure is then entirely water tight on May 15th, 2015. These activities and durations were derived with the assistance of the Whiting-Turner project team and have been assembled into Primavera6 for a more comprehendible format located in the appendix of this report.

Analysis #1: IDP Methods Implementation

Problem Identification

The Northeast hospital Expansion had numerous potential impacts to the projects schedule. Whether these potential impacts came from conflicts associated with new construction tying into existing structures or change orders occurring once work started, the project schedule was forced to condense in order to deliver the project on time. Through researching other delivery methods, the question has been raised on whether the CM at risk delivery method was the best delivery method to implement. As the construction industry is pressured to become more lean and efficient with its project delivery a more integrated approach is starting to take hold in the industry. Is it possible to utilize ideas from the integrate project delivery approach to create a more collaborative delivery method in order to mitigate the number of potential schedule impacts?

Background Information

The Northeast Hospital Project was bid as a guaranteed maximum price with the CM at risk. The two specialty contractors that won the installation of the mechanical, electrical and plumbing systems were brought onto the project during the design development phase for design assistance. When the time came for mobilization the general contractor, mechanical and plumbing subcontractor, and the electrical subcontractor each had their own job trailers on the site. The owner representatives for the project were located roughly two blocks from site in a separate building under the hospitals ownership. These factors may have led to possible miscommunications between project team members throughout the construction phase reducing profit margins for all involved parties. Through talking with several of the involved parties, there is a collective interest in having a more collaborative work environment.

Analysis Goals

From researching current applications of an IDP approach, speaking to members of the project team and other industry members, and examining similar case study projects utilizing an IDP methodology, it is expected that the application of IDP philosophies to the Northeast Hospital Expansion would have allowed for a more collaborative team environment. At the end of this analysis, recommendations will be provided of potentially helpful methods that could have been implemented to foster a more communal work environment. By harboring a collaborative team environment, it is thought to alleviate the amount of potential miscommunications between team members and therefore provide the owner an overall better service from the involved parties.

Process

Case Studies of Similar Project Types

Before the Northeast Hospital Expansion can be analyzed for potential methods for improved results, it is important to first gain an understanding of which methods work or have been known to work for similar facilities. To gain this understanding, a group of case studies conducted by the AIA at the School of Architecture for the University of Minnesota in 2012 were reviewed and compared to the Northeast Hospital Expansion project for their similarities and differences. Due to the massive number of case studies included in their overall study, the number of case studies utilized for this analysis was limited to the healthcare projects of similar square footage, cost, and purpose. After applying these criteria the following case studies were found suitable; Cardinal Glennon Children's Hospital Expansion, St. Clare Health Center, Encircle Health Ambulatory Care Center, and Cathedral Hill Hospital.

The Cardinal Glennon Children's Hospital Expansion was a healthcare project located in St. Louis, Missouri for SSM Healthcare. This project was a 138,000 square foot addition that cost $45.5 million. The delivery method originally chosen was traditional design-bid-build but after a lean construction seminar the owner decided to switch to a four party integrated contract. The reason this switch was made was because SSM Healthcare wanted to reduce the risk shifting between contracted entities and the project contained a large amount of complex technology. The new four-party contract was an IFOA (Integrate Form Of Agreement). This contract type is an agreement between the owner, architect, MEP engineer, and general contractor. This agreement put a significant portion of the design and builder's profits at risk thereby incentivizing them to create innovative solutions to maximize project quality while meeting SSM's needs. Furthermore, any cost savings generated by the design and builders were shared with the owner through a common profit pool. Prime trade contractors like ceiling framing and finishing, MEP and fire protection were also included in the profit pool. Each entity of the contract was equally held accountable for design omissions and construction errors by a collective sharing of the contingency. The team structure for this project consisted of three different groups; the owner's management team, the core team, and the IDP field team. The owner's management team made decisions for the project when approached by the core team or at their discretion. The core team consisted of the owner, architect, engineers, general contractor and major subcontractors. This group met weekly primarily to resolve major conflicts and make most decisions for the project. Finally the field team was a group of mid-level project members that met to solve minor or routine issues. Due to this team structure, decisions were made collaboratively and changes could be made quickly. One example from the project was an issue the field crew found with the first elevated floor deck. There was a conflict between the reinforcement in the flat slab and plumbing sleeves to serve the NICU rooms. By utilizing a "huddle," which is a team meeting meant to tackle a single problem and come to a solution, the team realized all they needed to do was shift the entire plan 3 ½" with respect to the column grid. Since the designers were a part of the large team and incentivized the necessary changes took three days. By employing an IDP approach the Cardinal Glennon Children's Hospital Expansion was completed six weeks ahead of schedule.

Moving on from the Cardinal Glennon Children's Hospital Expansion, the next case study looked at was the St. Clare Health Center in Fenton, Missouri. SSM Healthcare also owned this project, but this project was quite a bit larger. In total St. Clare Health Center cost $157 million for a 430,000 square foot, six-story 154 bed patient tower, an 85,000 square foot medical office, and a 75,000 square foot ambulatory care center. SSM chose IPD for basically the same reason as the Cardinal Glennon Children's Hospital Expansion, but instead of having the project team under a GMP the project team was brought on with a cost plus a fee. The theory behind SSM's decision to do so was to remove the financial risk from the contractor and ensure the team would work towards the good of the project. Much like with Cardinal Glennon, another multi-party IFOA was formed. The team structure also remained similar, except the field team was now forced to meet daily. One of the biggest changes between the two projects was the use of a "Big Room," or co-location space. This co-location space was a triple-wide trailer set onsite with a project management web site that shared design progress with the rest of the project team members. This space was used for coordination and detailing in 3D. Basically the MEP, structural, and architectural designers would develop their 2D drawings and meet at the co-location with the design-build MEP detailer. The team of designers would then create the 3D model in real time. This way any potential issues or conflicts could be resolved on the spot. The project director felt that the “Big Room” more than paid for itself since he noticed substantially fewer coordination errors and RFI’s.

After examining the two case studies on healthcare projects for SSM Healthcare, a case study was viewed on Encircle Health’s Ambulatory Care Center in Appleton, Wisconsin. The ambulatory Care Center was three-stories, 156,000 square feet, aiming for LEED Silver and designed and built for $38.6 million. The contract for this project was again a multi-party IFOA including the owner, architect, and contractor. Before the schematic design phase, the mechanical, electrical, plumbing and fire protection, and exterior glazing subcontractors signed a joining agreement allowing them to partake in the incentivized fee pooling. This fee pooling worked by the involved parties separating their costs and anticipated profits. Their planned profits were placed in a “risk pool.” By doing this, an individual party’s success was only measured by the projects success as a whole. If the costs $100 more to switch the type of insulation used on piping, but this change will save $200 in electrical work, no party lacks incentive to make the change. With the subcontractors being brought on so early for this project, the subcontractors were able to provide design services. Each of their engineers acted as the engineers-of-record for their trade. The joint agreement also allowed for shared costs of material lifts and cleanup, which savings could again be put into the profit pool. This project utilized the same team structure as the two other case studies. Due to that team structure, RFI’s were basically documentation of decisions made in the field eliminating much of the paperwork and tracking. The project team felt the greatest tool implemented on this project was information sharing. By the creation of a project web site, information could be exchanged by all project participants. In all, the entire project was completed on time in a matter of 18 months.

The final case study looked at was of the Cathedral Hill Hospital project. The Cathedral Hill Hospital project was built in San Francisco, California under the ownership of California Pacific Medical Center. The project consisted of the design and construction of a new 860,000 square foot, 14-floor hospital that would house 555 patient beds. The contract for this project again consisted of a multi-party IFOA, between the owner, architect, general contractor, and construction manager, which in retrospect was liked by all involved parties. Like with the other case studies, Cathedral Hill utilized a risk/rewards pool for all involved IFOA members. This was the first case study looked at however that included waivers on liability. Any of the liability that could be related to the agreement or the project would be covered by the risk pool account. The only exception to this waiver was for insurance-related conditions, willful misconduct, and intentional abandonment. There was also a line protecting the architect and consultants from the government requiring the over-stamping of a subcontractors equivalent shop drawings. The team structure for this project consisted of the same structure as the other project with the addition of cluster groups. Cluster groups were groups assigned to look over a specific portion of the project typically receiving an architect, engineers, and trade members. Another major difference between this case study and the other is how the project team was picked. Trades needed to be prequalified and submit a budget and profit margins. After this the firms were shortlisted and brought in for interviews with the CM/GC, design firms, design consultants, owner, and major subcontractors. In the interview the shortlisted firms were asked about their willingness to collaborate and their experiences with collaboration on other jobs. This placed a greater emphasis on the best value over the lowest cost. These trades were then brought onto the project during the design-development phase and pre-construction. By bringing these firms on they were able to provide the A/E teams design assistance that brought the owner a 200% return on investment. The final major difference between this project and the others was its use of a full time co-location. By taking space in a former bank building, all parties were able to work in the same space. This led to the breaking down of physical and social barriers between parties helping to assist in quicker decisions and keep team members aligned. This space was fit out with the same project web site as a few of the other studies assisting in the sharing of information with all parties.

Based on all of the case studies discussed above, several strategies for creating a more integrated project delivery should be taken away. All of the projects discussed utilized a multi-party integrated contract in the form of an IFOA. These contract types all utilized the concept of risk/reward pooling. Most of the projects also had team structures that consisted of an IDP field team, a core team, and an owner's management team for decision-making. These teams incorporated members from the different designers involved. Two of the projects implemented a co-location space where all parties could come together for easy face-to-face collaboration. Though the two projects utilized the space in different ways, part-time and full-time, the two different studies provide beneficial insight as to the advantages of utilizing co-location at different levels of sophistication. Other note worth methods that occurred were the initial team selection based on best value and willingness to collaborate, the on-boarding of major subcontractors during the schematic design phase for design services, joint agreements between subcontractors to share material lifts and cleanup costs, and switching from a GMP to cost plus a fee to eliminate financial liability. By apply some or all of these methods to other projects; it creates the potential for a more integrate approach to delivering a project successfully.

Contractor Exposure

In order to gauge how the Northeast Hospital Expansion could have benefitted from a more collaborative approach to delivering this project, it was important to converse with the contractors on their experiences with these delivery methods. From the information received, it quickly became evident that the IDP approach was nothing new.

Providing the best examples of how they are experiencing the implementation of IDP methods was the mechanical and plumbing contractor, Southland Industries. This contractor referred to another project they are currently involved with. At the University of Maryland's Baltimore campus, the contractor is involved with the pre-construction and early mechanical construction of the Health Sciences Facility III (HSFIII). This project includes the completion of a ten-story building totaling 428,970 square feet. The schools of medicine, dentistry, and pharmacy as a critical disease research group will occupy the building upon completion. This project was estimated at $305.4 million. What makes this project relevant is that it is that it is an IPD project. When this project was assembling a project team, the request for proposal (RFP) contained a section asking for a contractor's design-assist experience. Then again in the general requirements there is a section devoted to BIM coordination and the utilization of co-location.

4. <u>DESIGN-ASSIST EXPERIENCE</u>:
   a. PROJECT LIST: Provide a list of recent Design-Assist or Design-Build contracts. Note projects that were a GMP contract. Include basic information such as CM/GC, Owner, Architect, Engineer, contract amount, start date, completion date, project location. Include a brief summary narrative of your firm's experience providing preconstruction services as it relates to design-assist, scheduling and estimating for phases of the design process.
   b. ESTIMATING / VALUE ENGINEERING (VE): Explain your firm's processes in accurately estimating this project. Identify what measures are taken in minimizing any potential missing items that may not be clearly defined in the Schematic or Design Development Documents. Describe your firm's approach to value engineering during preconstruction and construction. Provide a minimum of three VE Items based on the Conceptual Documents and your recommendation on how to address these items assuming the intent of the design must be maintained.
   c. DOCUMENT REVIEWS: Describe your firm's approach to constructability reviews during preconstruction including how you would plan to address these items with the design team. Provide a minimum of 3 constructability items and your recommendations to these items based on your review of the documents included with the RFP, knowledge of local codes and practices, and past experiences.
   d. BIM: Provide a narrative of your firm's BIM capabilities including organization, in-house technicians, workflow, design integration methods, software utilized and industry standards followed. Include a narrative on similar project experience.
   e. COLOCATION: Elaborate on your experience sharing a project field office with a CM, Owner, AE and other trades. Discuss your approach to collaborating with these team members.
   f. PREFABRICATION / MODULARIZATION: Describe your in-house shop capability and prefab experience, including multi-trade collaboration.
   g. SCHEDULING: Explain your firm's ability to adhere to and prepare accurate schedules. List software used to produce schedules and any project specific scheduling tools or methods you can provide for this project. Identify personnel responsible to create your project schedules and their qualifications. Identify any special procedures or recommendations that could be implemented by your firm for this type of project.

By getting a glimpse of this portion of the RFP pictured above there are several things to be taken away as to how this project will be delivered. First since section 4 is about design-assist experience. This means the project team is looking to incorporate the main subcontractors early during the design development phase to aid in design reviews and value engineering of the proposed designs. This is can be more clearly viewed by reading item b and c. Looking at item e, one can see this project will be utilizing co-location. Though it is not clear from the RFP if the co-location here will be full-time or part-time, it is more important to notice that it appears the project team is performing selection based on a best value approach rather than lowest cost. The final thing to notice is item f. This item dealing with prefabrication and modularization specifically asks for the contractor to provide how their prefabrication abilities can include the other trades, further hinting at the importance placed on a contractor's willingness to collaborate with other trades. This portion of the RFP provides an example of how project teams can implement a best value approach that places emphasis on collaboration.

SECTION 013700
BIM COORDINATION

1. COORDINATION DRAWING PROCESS – GENERAL REQUIREMENTS.

1.8. In order to facilitate a truly collaborative and clash preventative process for the detailing and coordination of the project, a colocation approach will be utilized. This will require contractor's detailers to be located at the HSF3 site office for the entire duration of the coordination process. The contractor's foreman and project manager shall be onsite for the coordination meetings. The coordination co-location office may move to a different local office (IE. MC Dean's office) at the discretion of the lead coordinator and coordination team.

Furthermore the contractor was exposed to the required use of co-location in the general requirements' section on BIM coordination shown above. Item 1.8 explains how HSFIII will utilize a part-time co-location approach. This approach is primarily focused on the coordination and detailing of the MEP systems very similar to how co-location was utilized in the St. Clare Health Center case study. The difference between the two though is that unlike the St. Clare Health Center, HSFIII is requiring the foreman and project managers to attend onsite coordination meetings. By including the foreman the designers are obtaining additional design support from a constructability standpoint. The foremen at the same time are receiving a chance to mentally walk through the construction process and visualize any areas of difficulty. Due to limited job site space for HSFIII, the University of Maryland had to be convinced into allowing university office space for implementing co-location space.

To provide a more vivid picture as to which IPD methods were being implemented on HSFIII, the project team was followed-up with a few questions regarding liability waivers and risk/reward pooling. It was discovered that HSFIII would not be utilizing any liability waivers or risk/reward pool. Instead the project will be carried out on a GMP with 100% of the savings being returned to the owner.

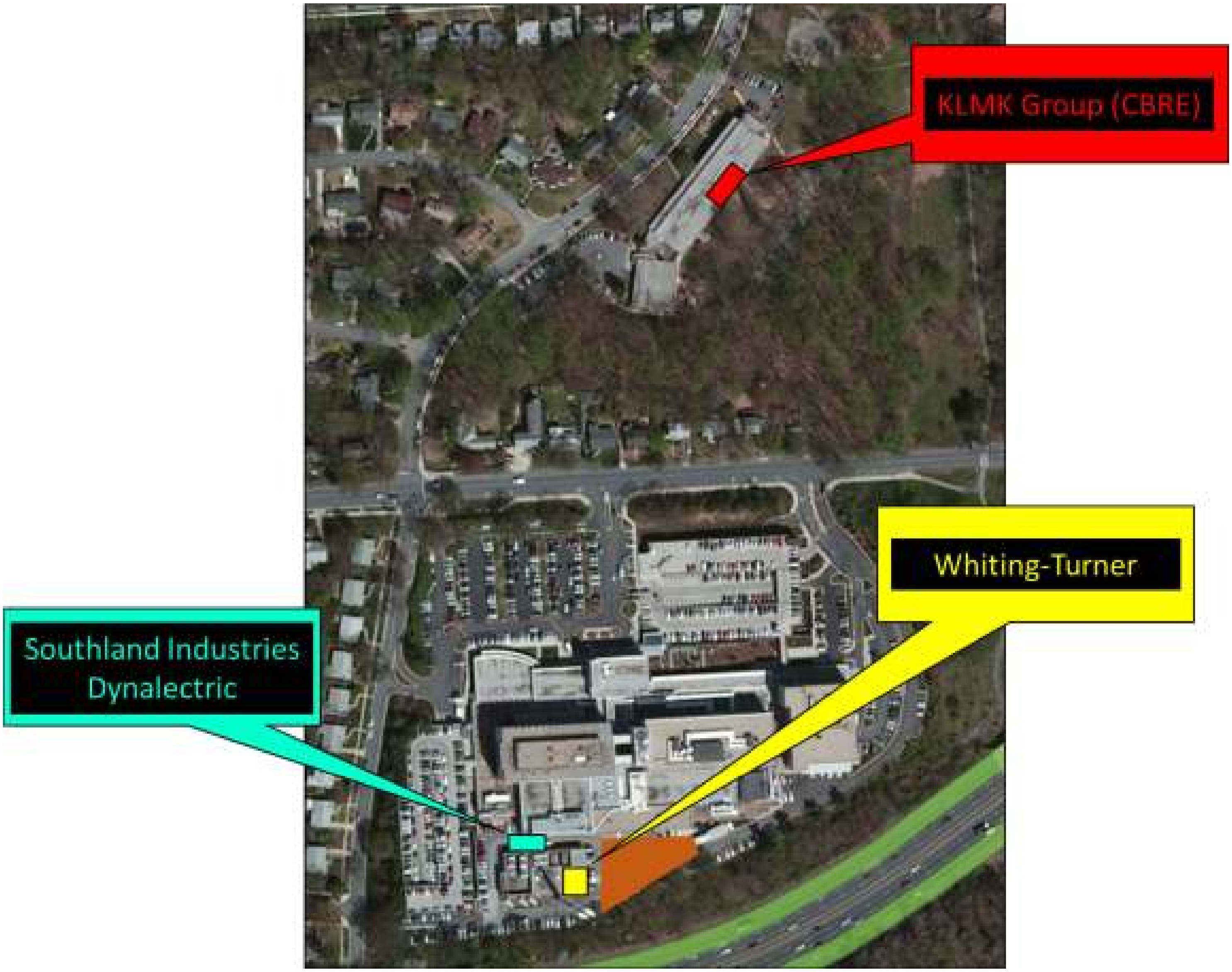
After looking into the HSFIII project, it was decided to add this project to the other case studies to compare which IPD methods were being implemented on each project examined. The comparison table can be seen below. The unfilled circles under co-location represents a part time use and a full circle reflects full-time use.

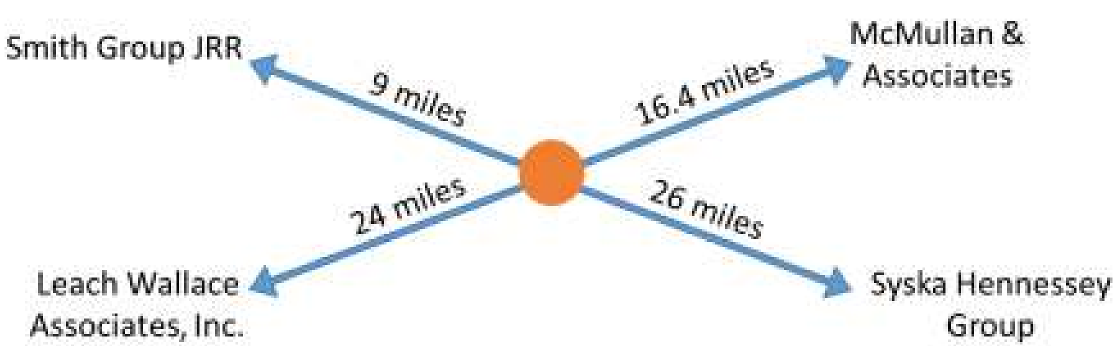
	Multi-party contract	Liability waivers	Risk/Reward pool	Integrated team structure	Early Involvement of key players	Co-location	Network Sharing
Cardinal Glennon Children's Hospital Expansion	●	□	●	●	●	○	
St. Clare Health Center	●	□	●	●	●		●
Encircle Health's Ambulatory Care Center	●	□	●	●	●		●
Cathedral Hill Hospital	●	●	●	●	●	●	●
Health Sciences Facility III	●			●	●	○	●

Current Project Delivery Approach

The Northeast Hospital Expansion is currently utilizing a CM at risk delivery method. This project delivery method allows for the owner to transfer the responsibility associated with the construction to the construction manager. Additionally the construction costs are fixed during design. The construction manager has complete control over their subcontractors and may choose to begin construction prior to the completion of the design. On the other hand this delivery method is known for reducing owner control of the project and any design changes after construction has started quickly become expensive to include. Since the construction manager has taken full responsibility for the construction of the project, this delivery method is also known for creating conflicts of interest between them and the contractors. This is because the construction manager has already agreed to a maximum price with the owner and is placing pressure on the contractors to provide them with a product that meets the schedule at the lowest cost possible.

Currently the jobsite plan has all the different parties spread across the site. The architect and designers are working out of their different office locations varying in distance from the site. The architect for the project is working out of an office located 9 miles away from site. The structural engineers on the project are working from their office located 16 miles from site. The MEP/FP engineers on the project are located 26 miles from site. The construction manager is located at the most southern part of the job site, utilizing space in the existing central utility plant. The main subcontractors on the job, Southland Industries and Dynalectric are in job trailers located between the north portion of the central utility plant and the southern part of the existing hospital. KLMK Group, recently acquired by CBRE, has setup their office in an office building owned by the hospital located to the north of the site. For a better visual representation of the different parties' office locations in relation to the job site please view the graphics on the next page. The job site is highlighted in orange in the first graphic and is represented by the orange circle in the second graphic. A further zoomed out map would have been utilized for the second graphic, but since this project's name and location are to remain confidential a simplistic representation has been used instead.


KLMK Group (CBRE)
Whiting-Turner
Southland Industries
Dynalectric


Smith Group JRR
9 miles
McMullan &
Associates
16.4 miles
24 miles
26 miles
Leach Wallace
Associates, Inc.
Syska Hennessey
Group

When looking at the project team structure currently implemented it can be seen that the Northeast Hospital Expansion has employed integrate project teams. These project teams are a combination of the clusters utilized in Cathedral Hill Hospital project and the field team, core team, and owner management team used in the other four case studies. These different teams were separated to cover the different divisions of the CSI Master Format. Each team had owner representation, designers, construction management, and subcontractors' involvement.

The main subcontractors for this job were the MEP subcontractors represented by Dynalectric and Southland Industries. They were both brought onto this project early during the design development phase for design assistance. There was no mention of a risk/reward pool or liability waivers for this project.

	Multi-party contract	Liability waivers	Risk/Reward pool	Integrated team structure	Early Involvement of key players	Co-location	Network Sharing
Cardinal Glennon Children's Hospital Expansion	●	○	●	●	●	○	
St. Clare Health Center	●	○	●	●	●		●
Encircle Health's Ambulatory Care Center	●	○	●	●	●		●
Cathedral Hill Hospital	●	●	●	●	●	●	●
Health Sciences Facility III	●			●	●	○	●
Northeast Hospital Expansion				●	●		●

Recommendations

Based on the analysis of the current project deliver methods and comparing them to similar projects in the United States there are several recommendations to be made that might have been able to deliver the project in a more collaborative manner. To start, it is believed that an IFOA could have been used to bind the owner representative, architect, engineers, and construction manager. By binding these parties to a single contract they would be incentivized to align their project goals and look to produce a project at best overall value. Since a large majority of project did not utilize liability waivers and there is little data to support their effectiveness, liability waivers are not suggested for the Northeast Hospital Expansion project. However the implementation of a risk/reward pool were the main subcontractors, construction management, architect, and engineers are members is highly suggested. Though this risk/rewards pool would not provide the owner with 100% return on any project savings, it would however incentivize the pool members to check each other's work and promote innovation to deliver a more efficient and innovative project. The team structure, early involvement of construction management and key subcontractors, and network sharing were excellent methods already applied to this project. The final suggestion in retrospect for this project would have been to potentially utilize a space for part-time co-location. This space could have been negotiated with the owner to allow additional office space from their building located north of the existing hospital. The owner's representatives already have established office space there. The project would have potentially benefited from a location where designers, detailers, project managers, and foreman could coordinate and detail 3D models in real-time 4-weeks prior to onsite construction. The reason part-time co-location is suggested over full-time co-location, is because the job site is already extremely constrained and does not have the space necessary for a fully co-located space. With these recommendations, it is hoped that less miscommunications and more collaborative project could have been delivered.

	Multi-party contract	Liability waivers	Risk/Reward pool	Integrated team structure	Early Involvement of key players	Co-location	Network Sharing
Cardinal Glennon Children's Hospital Expansion	●	○	●	●	●	○	
St. Clare Health Center	●	○	●	●	●		●
Encircle Health's Ambulatory Care Center	●	○	●	●	●		●
Cathedral Hill Hospital	●	●	●	●	●	●	●
Health Sciences Facility III	●			●	●	○	●
Northeast Hospital Expansion				●	●		●
Proposed Northeast Hospital Expansion	●		●	●	●	○	●

Analysis #2: Patient Room Re-Design for Shared Wet Walls

Problem Identification

The Northeast Hospital Expansion project experienced severe weather delays during the excavation of its foundation and the construction of its superstructure. Still attempting to turn the project over on time, the project team turned towards the mechanical and plumbing subcontractor to assist in making up the lost time. Though the subcontractor is trying to accelerate the schedule as fast as possible, they felt the time would need to be made up through alternative methods.

Background Information

During the excavation of the Northeast Hospital Expansion heavy down pours hindered the amount of work that could be accomplished. These heavy pours were then followed by a harsh winter the prevented much of the superstructure from being constructed. Together these weather phenomena created a total of 64 lost days of work. With the building finally enclosed, the project team is scrambling to make-up time and is heavily relying on the mechanical and plumbing subcontractor. This subcontractor has primarily implemented extra shifts and overtime to make-up as much time as possible. Through conversations with the subcontractor, it has become evident that there is potential to accelerate the schedule through the use of prefabrication and implementation of shared wet-walls in the patient rooms located on the 4th, 5th, and 6th floors of the building. Prefabrication has the potential to accelerate the construction that occurs on site since pipe can be pre-cut to length or even fully assembled off site so it just needs to be lifted into place on site. Shared wet-walls allow for less plumbing piping to be used in general, which could reduce the amount of labor necessary and reducing overall cost.

Analysis Goals

By analyzing the possible uses for prefabrication and determining whether a shared wet-wall is possible, it is this analysis' goal to present suggestions on how the schedule could be accelerated or have been reduced from the aid of hindsight. This analysis will also display a mechanical breadth through the re-design, layout, and sizing of the plumbing system contained within each private patient room.

Process

Research Plumbing Prefabrication Methods

Prefabrication can occur in a variety of ways. It can be an act as simple as pre-measuring and cutting pieces before being shipped to site, or as complex as the creation of an entire bathroom pod that can be lifted into its exact location. Though these different methods each have the potential to accelerate the schedule, one might be better suited for a specific project.

When it comes to prefabrication in general though, there are a few criteria that must be met for a project to actually benefit. First, which ever activity is being examined for prefabrication must lie on the critical path. If the activity does not, then the potential savings from accelerating the activity will never be seen on the overall project schedule. Second, the project must have highly repetitious parts. Repetitious parts allow for the same shop drawings to be used during the offsite construction. Without repetitious parts the contractor would spend more time detailing each shop drawing creating more work than never having implementing prefabrication. Finally, the contractor preforming the prefabrication must have the ability to construct portions of the project off-site and then be able to transport the prefabrication to site without damage.

For the Northeast Hospital Expansion, the activity to primarily review for prefabrication is the plumbing installation within each patient room. This activity falls on the critical path of the overall project schedule and there are a total of 90 essentially identical rooms located on the 4th floor through the 6th floor. It should also be noted that the 7th floor will eventually be fit out with the same layout as these floors once the hospital reaches capacity in future years. On top of these reasons, prefabrication for the plumbing system should be considered is that the subcontractor has their own fabrication shop devoted to assembling portions of a job before the material is delivered to site. Many of the subcontractor's other projects in the region heavily utilize prefabrication of branch plumbing piping.

Seeing as this project contains the necessary requirements for prefabrication to be successful. It is time to look at the potential methods this project can be utilized. As stated earlier, prefabrication can be implemented in a number of different ways. For plumbing systems though there seems to be four levels of sophistication that can be explored. The simplest method would be for the fabrication shop to simply cut the pipes to the necessary size and ship the proper length to site. The next step up would be for the fabrication shop to make minor connections to the branch piping. The following step would be for the pipe to be placed on a rack and shipped to sight as an almost complete system. Finally the most sophisticated method is to acquire the approval of the other trades and constructed a full unit that may be picked and put into place as a finished product. Since the Northeast Hospital Expansion project at this point has already been enclosed, it is recommended that the 3rd highest level of sophistication of prefabrication be utilized. To understand what the prefabricated product will look like when it is brought to site from the fabrication shop, an image of the piping racks can be seen below. The picture on the left depicts horizontal branch piping for hot and cold water supply. The picture on the right shows prefabricated sanitary, vent, and domestic cold water supply for water closets.

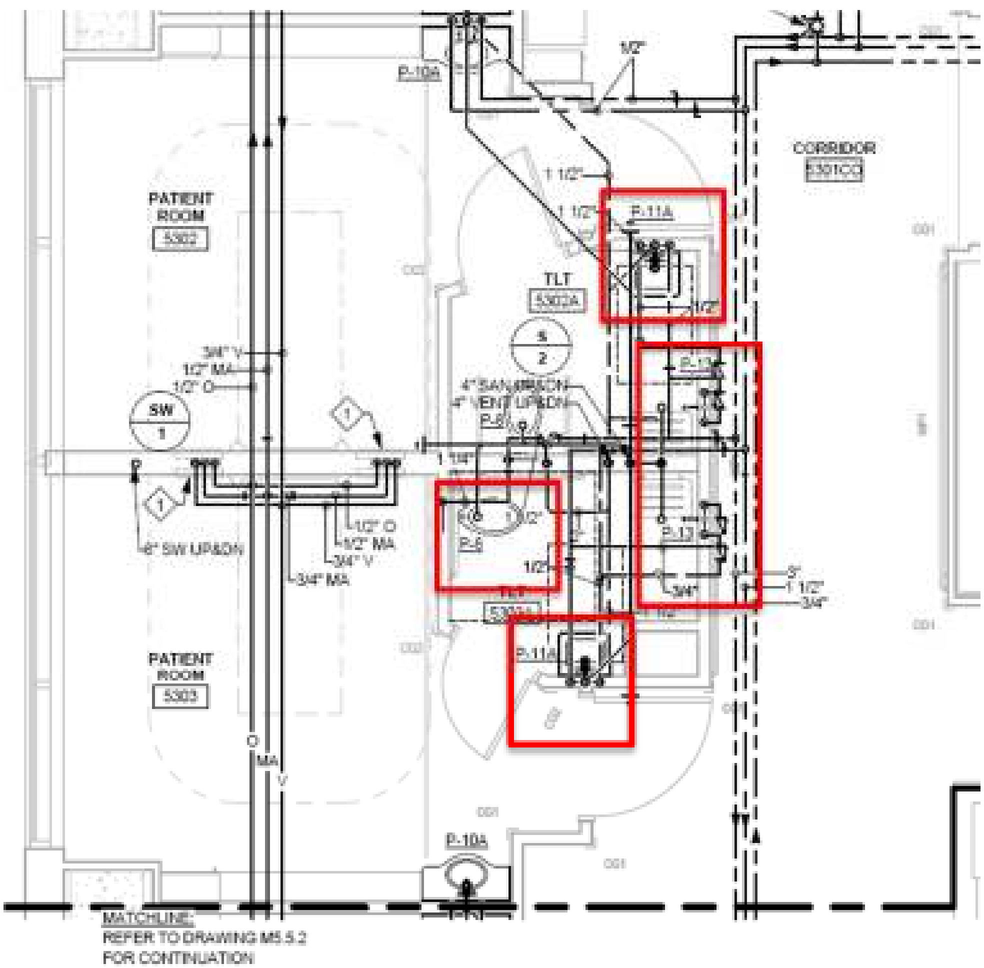
These racks allow workers to easily transport large amounts of preassembled piping systems from the trailers they are brought to site on and then rolled onto a material hoist or service elevator to bring them to the proper floor for installation. Once at their proper location the pieces are taken off the rack and lifted into place where the final connections are to be made.

The primary drawback to mobilizing the prefabricated piece to site in this fashion is that the length of pipe to be pre-assembled is limited to the rack size and the space necessary to maneuver the pipe racks dollies. For the Northeast Hospital Expansion, the prefabricated pipe would need to be limited to 8x4x7. Another issue present since this is a healthcare project is guaranteeing the insides of the pipes do not become contaminated during construction, transportation, and installation. The pipes need to be capped in a similar fashion as the red caps seen at the ends of each pipe in the pictures above. These caps attempt to prevent dust and debris from entering the pipes and ultimately contaminating the system it has inhabited.

Contaminated systems have the potential to diminish quality of care and bring down the overall quality of the project.

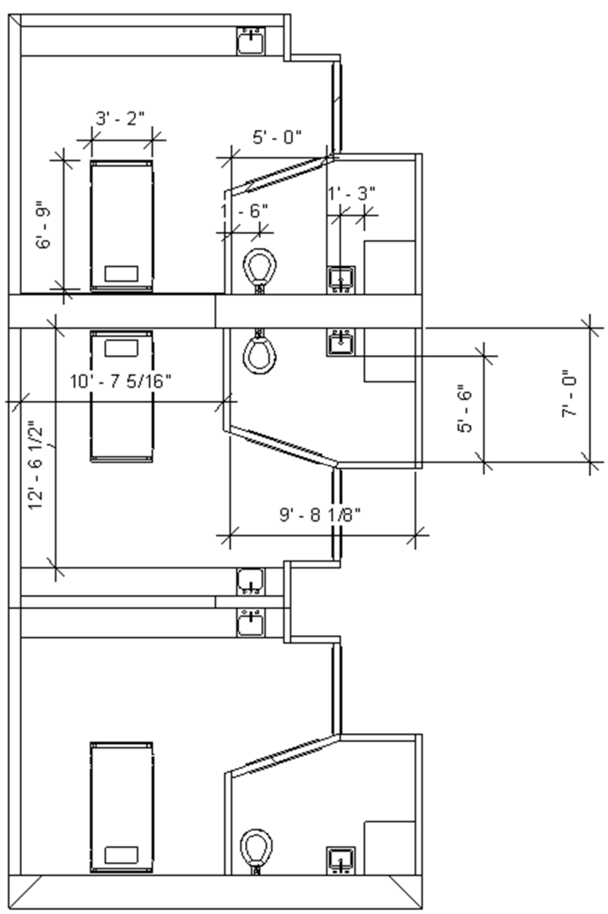
<u>Identification of Plumbing Fixtures to Relocate</u>

Now seeing that the Northeast Hospital Expansion project is well suited for prefabrication of its plumbing systems, the patient rooms need to be examined to exploit how the design maybe further optimized. Plumbing fixtures were identified that had an excessive amount of piping currently servicing them. If two of the same fixtures in back-to-back rooms where not capable of utilizing the same branch piping or were placed in a location that required extra fittings to reach, they were flagged to be potentially moved in a re-design of the space. By moving these fixtures to a more optimal location that would allow shared piping and less fittings, the amount of labor necessary would be diminished and the cost of materials would also be diminished.



On the previous page is the plumbing plan for two adjacent patient rooms that is located on the 4th, 5th, and 6th floors. Each floor has fifteen of these room pairings meaning there are a total of 30 rooms on each floor. From the picture it can be seen that a number of the plumbing fixtures have been identified as having the potential to be optimized with their locations. They are boxed in red. Starting from the right, it can be seen that the P-4 water closet was initially placed against an interior wall of the patient room. This water closet has the potential to be placed back-to-back with the P-4 water closet in the adjacent patient room giving them both the capability to share the same sanitary, vent and a majority of domestic water supply. Next the two P-11A lavatories may also have the potentials to be placed back-to-back instead of on the furthest interior wall from the supply mains. Again this would reduce the amount of hot water supply, cold water supply, sanitary and vent lines necessary. Finally the two shower heads where initially placed on the interior wall shared by the corridors. These showerheads were identified as potentially being able to be moved to the wall shared by both patient rooms to yet again reduce the amount of pipe and fittings necessary to supply and service each showerhead.

<u>Re-Designed Patient Room Layout</u>

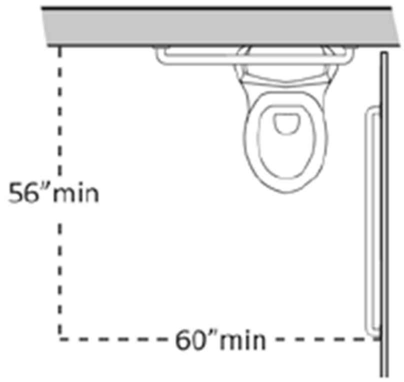


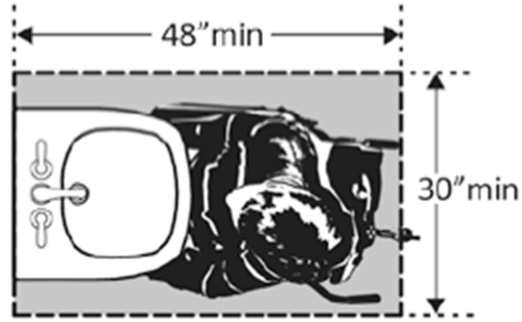
Review New Layout & Verify Quality of Care

The re-design of the patient room layout was not as simple as relocating the water closet, lavatories, and showerheads to the same shared wet wall. There were a number of other design and code considerations that needed to be taken into consideration. The three main factors taken into consideration for the re-design was creating a shared wet wall large enough to house all the necessary piping, maintaining ADA requirements, and keeping in mind the quality of care for the patients.

When looking to create a shared wet wall for the adjacent patient rooms, it was obvious from the beginning that the initial wall separating the two rooms would not be wide enough to house all the piping. This was first noticed when looking to move the P-4 water closet. The original design called a floor mounted Kohler Highcrest K-4302-L in both rooms. This created a problem since with a floor mounted water closet, core drills have to be completed to run the underfloor sanitary lines. In order to alleviate the need for this additional work, the new design suggests substituting the Kohler Highcrest floor mounted water closet with the Kohler Kingston K-4330 wall mounted water closet. The Kingston water closest was specified for use on the lower floors, has almost identical dimensions as the Highcrest, and remains ADA compliant. This substitution allows for a back-to-back water closet carrier to be selected for use within in the shared wet wall. Again selecting a closet carrier that was approved for use on a lower floor with the Kohler Kingston, the new design utilizes the Josam 12694 series closet carrier. This carrier would require the shared wet wall thickness to increase from 8” to 24” thick walls. The 24” thick wall also allows for plenty of space for the other piping needing to be housed in the new shared wet wall.

Next came the challenge of moving the lavatories to fit in between the showerheads and the water closets. Though there is plenty of space to fit the lavatories in a normal restroom, it needs to be remembered that this is a healthcare facility requiring ADA restrooms. Since this is the case, an ADA checklist provided by the Institute of Human Centered Design 2014 was utilized to properly place the lavatories. To do this, the water closet require a 60” minimum clearance from the sidewall and at least 56” from the rear wall. Similarly the lavatory needs at least a clear floor space for forward approach of at least 30” wide and 48” long. Example diagrams of these requirements can be seen below.

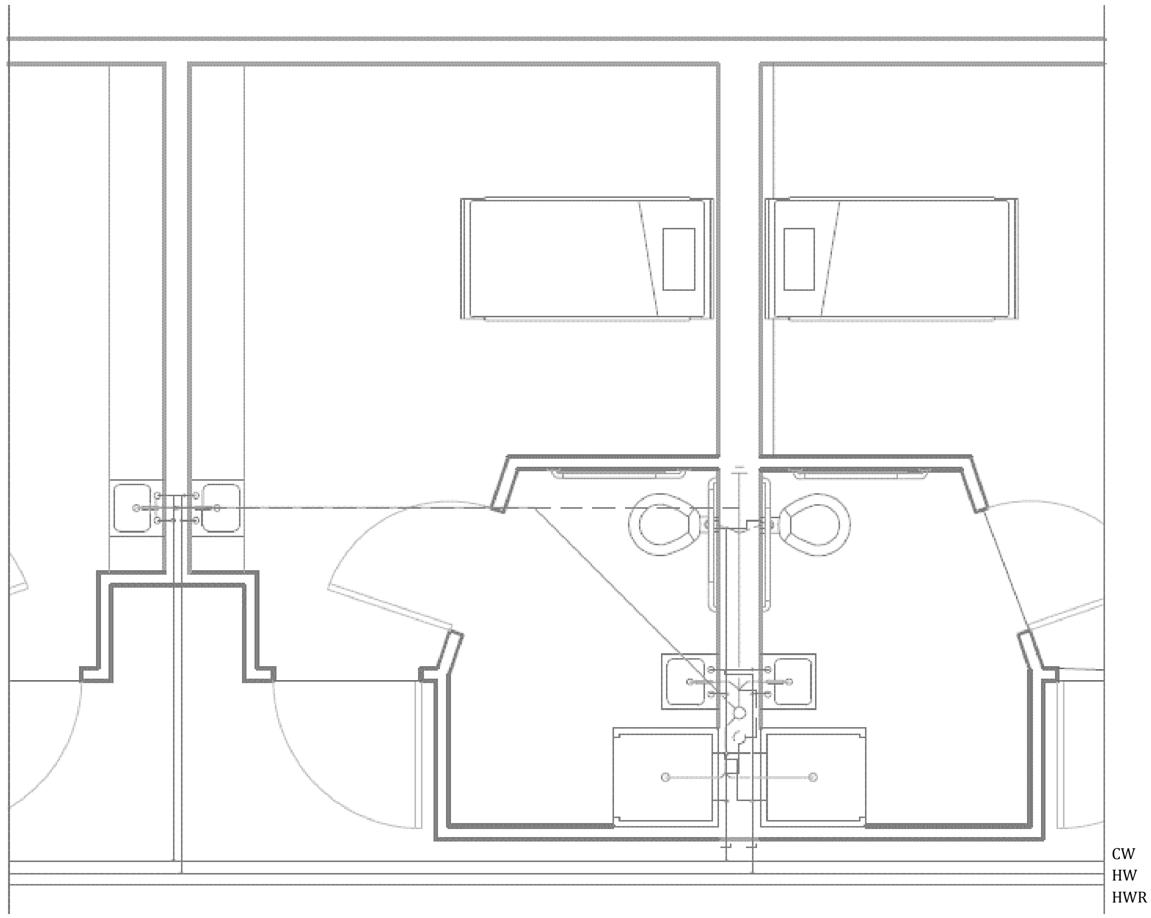




This challenge was overcome by widening the patient restrooms in both rooms. Widening the restrooms created enough space for all of the water fixtures to be placed back-to-back along the same shared wet wall while successfully maintaining ADA compliance. It should be noted that the re- designed restrooms still have a 60" cirlce of clearance to allow for a wheelchair to turn completely around and maneuver.

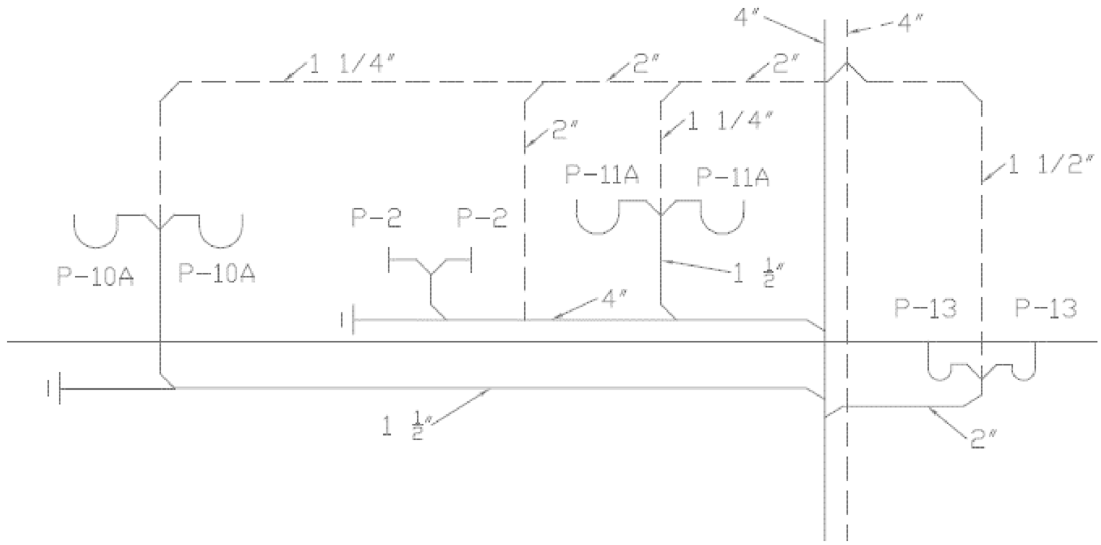
This new re-design did create concerns. By increasing the size of the shared wet wall and widening the patient restrooms, space needed to be subtracted from the patients bedroom space in order to stay within the original building's footprint. Decreasing patient bedroom space was thought to have a slight impact on the patient's quality of care that would be sacrificed to make room for a more efficent design. Seeing as the owner places patient quality of care as their primary concern this must not be sacrificed for potential cost and schedule savings. Luckily an article originally published on May 12, 2014 in Health Design magazine, documented an odd relationship between patient satisfaction and patient room size. In it Pittsburgh's UPMC was conducting a study on right-sizing patient rooms. They found that though most hospitals are increasing the size of their patient rooms, larger rooms do not always mean better. In fact, they are finding that smaller patient rooms increase patient satisfaction and quality of care. With a smaller room, patients are experiencing a greater responsiveness to their needs, better communication with the nurses, a greater likelihood of recommending the hospital, and more importantly patients fall less, and their readmission rates are decreasing. UPMC does go on to state that there is an optimum square footage associated with keeping smaller roomsizes. This squarefootage is 220SF. The re-designed patient room comes to 228SF. Since the re-designed room falls close to the UPMC optimum room size, hopefully the re-design room would allow for a higher quality in patient care.

Mechanical Breadth – Resize CW/HW Supply, Sanitary, & Vents



With the relocation of plumbing fixtures and the combining of supplies, sanitary lines, and vents it was necessary to check and potentially resize some of the piping originally specified. To conduct the checking and re-sizing of these pipes the 2009 International Plumbing code was utilized. Through discussions with Adam Davis, a design engineer at Penn State's Office of Physical Plant, it was determined that the sanitary system should be resized first.

For the resizing of the sanitary lines, Table 709.1: Drainage Fixture Units for Fixtures and Groups was used in combination with Table 710.1(2): Horizontal Fixture Branches and Stacks. Table 709.1 provides the minimum trap sizes required for each fixture along with each fixture's drainage fixture unit. These drainage fixture units correspond to the maximum number of drainage fixture units allowed by code for each size of sanitary pipe listed in Table 710.1(2). By working from the beginning to end of a sanitary line and adding the drainage fixture units of each connecting fixture, the size of the necessary pipe could be determined. This process produced the sizes seen below.



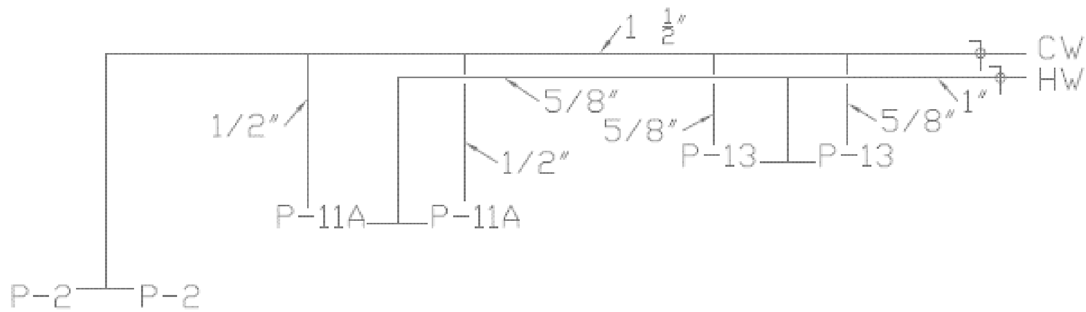
As an example let's look at how the sanitary line for the P-10A lavatories were conducted. First of all, a lavatory according to Table 709.1 has a drainage fixture unit of 1. Now looking at the re-design it can be seen that there are two P-10A lavatories utilizing the same sanitary line. This means that this sanitary line needs to be able to service a total of 2 drainage fixture units. With the total number of drainage fixture units determined, it is now time to look at Table 710.1(2) on the size of sanitary pipe necessary. Finally looking at Table 710.1(2), it can be seen that a pipe of 1 ½" diameter is large enough to service a total of 3 drainage fixture units. This means that our pipe will have a 1 ½" diameter. If the total drainage fixture units had been greater than 3, the next pipe size up should be considered until its maximum number of drainage fixture units is not surpassed. A similar method is used to calculate the slope of the sanitary lines. The only difference is that instead of using Table 710.1(2), Table 710.1(1) should be used in combination with Table 709.1. This processes produced the slope table seen below.

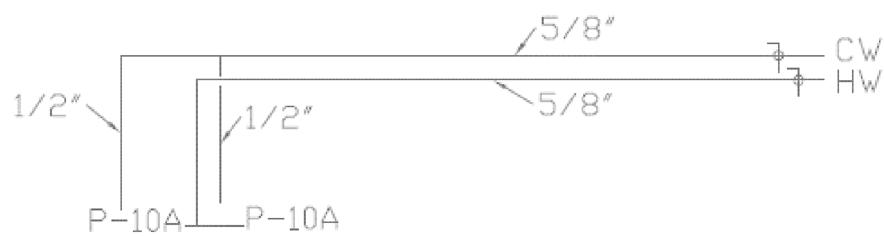
Slope of Sanitary Line for Re-Design Patient Room	
Sanitary Line Size	Slope per foot
1 1/2"	1/4"
2"	1/4"
4"	1/8"

After finishing re-sizing sanitary lines it only makes sense to size the vent piping. When it comes to vent piping there are two golden rules. The first rule is that all vents should have a minimum size of 1 ¼". The second rule is that all vents should not be less than half the diameter of the waste pipe it is serving. With these two rules in mind, re-sizing of vent piping can commence through the utilization of Table 916.1: Size and Developed Length of Stack Vents and Vent Stacks. This table starts with looking at the diameter of the sanitary lines to be vented. It then looks at the drainage fixture units found and calculated from Table 709.1. Finally this table looks at the length of vent piping necessary for the sanitary line to be connected to open air.

For an example of how this table was utilized let's look at how the vent piping for the two P-10A lavatories was sized. From the first example it can be seen that the sanitary piping was sized at 1 ½" diameter and it was determined to service a total of 2 drainage fixture units. This places the size of the vent piping at either ¼" or ½". Since there is only a distance of 35ft from the sanitary line to the main vent stack the size of the vent piping to be used here is 1 ¼" diameter. Something interesting to note about this vent line is that two other vents connect into it and one is a water closet vent. This means that since more fixtures are being serviced by the same vent, the vent needed to be increased in size to match the new total of drainage fixture units.

Finally after all of the sanitary and vents have been re-sized the hot water and domestic cold water supply can be re-sized. For the sizing of these pipes one must utilize Table E103.3 (2): Load Values Assigned to Fixtures, Table E103.3 (3) Table for Estimating Demand, and Figure E103.3 (3): Friction Loss in Smooth Pipe. The way these tables and figures work is quite similar to the tables used for sanitary and vent piping. When starting it is best to begin at the last fixture and work backwards towards the supply main. Next each fixture is associated with a water supply fixture unit that provides the load associated with each fixture. The value changes depending on whether the system in question is either cold or hot water supply. It should also be noted that the water closets for this project use a flush valve and not a flush tank. The loads associated with these two different types of water closets are vastly different since a flush valve doubles the load associated with the water closet from 5 with a flush tank to a 10 with flush valve. After determining the water supply fixture unit total for each pipe, this value must then be converted in gallons per minute utilizing Table E103.3 (3). This table is broken into two parts; one side is for loads from flush tanks, and the other side is for loads from a flush valve. Again there is almost twice as much of a load from the flush valve over the flush tank. Once the total gallons per minute is determined, look at Figure E103.3 (3) to find the intersection of a horizontal line drawn from the gallons per minute determined on the left side and the downward diagonal line for 8 ft/sec fluid velocity. From this intersection, find the two sizes of pipe denoted by upward diagonal lines that the point falls between. Finally the size of the pipe is given by the larger of the two pipe sizes. Using this process the following sizes were determined.





To provide another example, let's look at how the domestic cold water supply was sized for the P-2 water closets. Starting by looking at Table 103.2 (2), it can be seen that a water closet for public use and controlled by a flush valve has a cold water supply fixture value of 10. Since there are two water closets being supplied the water supply fixture units are multiplied by 2 giving the total value as 20. Now moving to Table E103.3 (3) and remembering there is a flush valve involved, the 20 water supply fixture units are converted to 35 gallons per minute. Next a horizontal line is drawn on Figure E103.3 (3) at 35 gallons per minute. This line then intersects with the 8ft/sec fluid velocity line creating a point between two pipe sizes. These two pipe sizes are 1 ½" and 1 ¼" diameter pipe. Since the 1 ½" diameter pipe is large than the 1 ¼" diameter pipe, the 1 ½" pipe is selected as the pipe size.

Cost and Schedule Impact

In order to provide the owner and project team with the potential saves associated with the implementation of a shared wet-wall and redesign of the patient rooms, an estimate was performed on for both the original design and the newly proposed design. These values do not reflect what the plumbing systems installed in the Northeast Hospital Expansion actually cost since the values and times used to bid the project could not be percisely determined. Instead both designs were estimated using the same data provided by RS Means Plumbing 2014. By using the same estimated values and costs from RS Means a more accurate comparison between the two systems could be made. Based on the results of this comparison, a relationship could then be drawn connecting the RS Means estimate to the actual project. The detailed estimates for each design can be seen on the following pages. The first estimate is for the original existing design. The second estimate is for the proposed shared wet-wall design.

Exisiting Design												
RSMeans #		Unit	Quantity	Labor hrs/Unit	Total Labor Hr	Mat/Unit	Tot Mat	Labor/unit	Tot Labor	Equip/Unit	Tot Equip	Total
	Cold and Hot Supply (Copper)											
	90 deg Elbows											
221113.250100	1/2"	ea	14	0.4	5.6	$ 3.08	$ 43.12	$ 23.00	$ 322.00		$ -	$ 365.12
221113.250120	3/4"	ea	13	0.421	5.473	$ 6.95	$ 90.35	$ 24.00	$ 312.00		$ -	$ 402.35
221113.250140	1 1/4"	ea	4	0.533	2.132	$ 25.50	$ 102.00	$ 30.50	$ 122.00		$ -	$ 224.00
	Tee											
221113.25.0619	1 1/2"-3/4"	ea	1	0.889	0.889	$ 61.50	$ 61.50	$ 51.00	$ 51.00		$ -	$ 112.50
221113.25.0500	3/4"	ea	6	0.667	4.002	$ 12.70	$ 76.20	$ 38.50	$ 231.00		$ -	$ 307.20
	Corner Tee											
221113.25.0619	1 1/2"-1 1/4"	ea	1	0.889	0.889	$ 61.50	$ 61.50	$ 51.00	$ 51.00		$ -	$ 112.50
	Copper Pipe											
221113.23.1140	1/2"	LF	75.25	0.103	7.75075	$ 4.47	$ 336.37	$ 5.90	$ 443.98		$ -	$ 780.34
221113.23.1180	3/4"	LF	47.67	0.108	5.14836	$ 7.80	$ 371.83	$ 6.20	$ 295.55		$ -	$ 667.38
221113.23.1220	1 1/4"	LF	16.17	0.143	2.31231	$ 13.25	$ 214.25	$ 8.20	$ 132.59		$ -	$ 346.85
221113.23.1240	1 1/2"	LF	8.83	0.16	1.4128	$ 17.15	$ 151.43	$ 9.20	$ 81.24		$ -	$ 232.67
SUBTOTAL					**35.60922**		**$ 1,508.55**		**$ 2,042.36**			**$ 3,550.91**
	Sanitary (Cast Iron)											
	45 deg Elbows											
221316.40.0062	2"	ea	19	0.889	16.891	$ 48.50	$ 921.50	$ 46.00	$ 874.00		$ -	$ 1,795.50
221316.40.0064	4"	ea	9	2.667	24.003	$ 296.00	$ 2,664.00	$ 138.00	$ 1,242.00		$ -	$ 3,906.00
	Double Y											
221316.40.0112	2"-2"-2"-1 1/2"	ea	2	2.286	4.572	$ 191.00	$ 382.00	$ 118.00	$ 236.00		$ -	$ 618.00
221316.40.0164	4"-4"-2"-2"	ea	1	3.2	3.2	$1,175.00	$ 1,175.00	$ 166.00	$ 166.00		$ -	$ 1,341.00
	Y-Fitting											
221316.40.0102	2"-2"-1 1/2"	ea	2	1.455	2.91	$ 79.00	$ 158.00	$ 75.50	$ 151.00		$ -	$ 309.00
221316.40.0102	2"-2"-2"	ea	2	1.455	2.91	$ 79.00	$ 158.00	$ 75.50	$ 151.00		$ -	$ 309.00
221316.40.0104	4"-4"-2"	ea	2	4	8	$ 650.00	$ 1,300.00	$ 207.00	$ 414.00		$ -	$ 1,714.00
221316.40.0104	4"-4"-4"	ea	3	4	12	$ 650.00	$ 1,950.00	$ 207.00	$ 621.00		$ -	$ 2,571.00
	Trap											
221316.40.0121	1 1/2"	ea	4	1.067	4.268	$ 101.00	$ 404.00	$ 55.50	$ 222.00		$ -	$ 626.00
221316.40.0122	2"	ea	2	1.231	2.462	$ 161.00	$ 322.00	$ 64.00	$ 128.00		$ -	$ 450.00
	Cleanout											
	2"	ea	2	2.22	4.44	$ 183.00	$ 366.00	$ 104.00	$ 208.00		$ -	$ 574.00
	4"	ea	1	2.22	2.22	$ 183.00	$ 183.00	$ 104.00	$ 104.00		$ -	$ 287.00
	Cast Iron											
221316.20.4200	2"	LF	68.25	0.239	16.31175	$ 9.40	$ 641.55	$ 12.35	$ 842.89		$ -	$ 1,484.44
221316.20.4400	4"	LF	15.58	0.276	4.30008	$ 16.95	$ 264.08	$ 14.30	$ 222.79		$ -	$ 486.88
SUBTOTAL					**108.48783**		**$ 10,889.13**		**$ 5,582.68**			**$ 16,471.81**
	Vent (CPVC)											
	45 deg Elbows											
221113.76.5940	1 1/2"	ea	13	0.44	5.72	$ 25.50	$ 331.50	$ 25.50	$ 331.50		$ -	$ 663.00
221113.76.5942	2"	ea	6	0.483	2.898	$ 29.00	$ 174.00	$ 25.00	$ 150.00		$ -	$ 324.00
	Y-Fitting											
221113.76.5970	1 1/2"-1 1/2"-1 1/2"	ea	1	0.661	0.661	$ 32.00	$ 32.00	$ 38.00	$ 38.00		$ -	$ 70.00
221113.76.5972	2"-2"-1 1/2"	ea	1	0.8	0.8	$ 36.00	$ 36.00	$ 41.50	$ 41.50		$ -	$ 77.50
221113.76.5978	4"-4"-1 1/2"	ea	1	1.455	1.455	$ 121.00	$ 121.00	$ 75.50	$ 75.50		$ -	$ 196.50
	Double Y											
221113.76.5978	4"-4"-2"-1 1/2"	ea	1	1.455	1.455	$ 121.00	$ 121.00	$ 75.50	$ 75.50		$ -	$ 196.50
	CPVC											
151085.20.5500	1 1/2"	LF	48.5	0.222	10.767	$ 5.20	$ 252.20	$ 7.40	$ 358.90		$ -	$ 611.10
151085.20.5510	2"	LF	11.83	0.271	3.20593	$ 6.05	$ 71.57	$ 8.10	$ 95.82		$ -	$ 167.39
SUBTOTAL					**26.96193**		**$ 1,139.27**		**$ 1,166.72**			**$ 2,305.99**
15082.00.0100	Insulation	Job	10%		17.105898		$ 1,353.70		$ 879.18			$ 2,232.87
TOTAL/ROOM PAIR					**188.164878**		**$ 14,890.65**		**$ 9,670.94**			**$ 24,561.59**

Proposed Shared Wet-Wall Design

RSMeans #		Unit	Quantity	Labor hrs/Unit	Total Labor Hr	Mat/Unit	Tot Mat	Labor/uni	Tot Labor	Equip/Unit	Tot Equip	Total
	Cold and Hot Supply (Copper)											
	90 deg Elbows											
221113.250100	1/2"	ea	5	0.4	2	$ 3.08	$ 15.40	$ 23.00	$ 115.00		$ -	$ 130.40
221113.250110	5/8"	ea	8	0.421	3.368	$ 10.65	$ 85.20	$ 24.00	$ 192.00		$ -	$ 277.20
221113.250130	1"	ea	4	0.5	2	$ 17.00	$ 68.00	$ 29.00	$ 116.00		$ -	$ 184.00
221113.250150	1 1/2"	ea	4	0.615	2.46	$ 40.50	$ 162.00	$ 35.50	$ 142.00		$ -	$ 304.00
	Tee											
221113.25.0490	5/8"	ea	1	0.667	0.667	$ 34.00	$ 34.00	$ 38.50	$ 38.50		$ -	$ 72.50
221113.25.0510	1"	ea	2	0.8	1.6	$ 39.50	$ 79.00	$ 46.00	$ 92.00		$ -	$ 171.00
221113.25.0530	1 1/2"	ea	5	1	5	$ 82.50	$ 412.50	$ 57.50	$ 287.50		$ -	$ 700.00
	Corner Tee											
221113.25.0490	5/8"	ea	2	0.667	1.334	$ 34.00	$ 68.00	$ 38.50	$ 77.00		$ -	$ 145.00
	Copper Pipe											
221113.23.1140	1/2"	LF	25.42	0.103	2.61826	$ 4.47	$ 113.63	$ 5.90	$ 149.98		$ -	$ 263.61
221113.23.1160	5/8"	LF	37.42	0.104	3.89168	$ 5.95	$ 222.65	$ 6.00	$ 224.52		$ -	$ 447.17
221113.23.1200	1"	LF	11.08	0.121	1.34068	$ 10.60	$ 117.45	$ 7.00	$ 77.56		$ -	$ 195.01
221113.23.1240	1 1/2"	LF	17.67	0.16	2.8272	$ 17.15	$ 303.04	$ 9.20	$ 162.56		$ -	$ 465.60
SUBTOTAL					**23.73882**		**$ 1,580.26**		**$ 1,367.62**			**$ 2,947.89**
	Sanitary (Cast Iron)											
	45 deg Elbows											
221316.40.0061	1 1/2"	ea	8	0.8	6.4	$ 45.50	$ 364.00	$ 41.50	$ 332.00		$ -	$ 696.00
221316.40.0062	2"	ea	6	0.889	5.334	$ 48.50	$ 291.00	$ 46.00	$ 276.00		$ -	$ 567.00
221316.40.0064	4"	ea	1	2.667	2.667	$296.00	$ 296.00	$138.00	$ 138.00		$ -	$ 434.00
	Double Y											
221316.40.0111	1 1/2"-1 1/2"-1 1/2"-1 1/2"	ea	2	1.6	3.2	$206.00	$ 412.00	$ 83.00	$ 166.00		$ -	$ 578.00
221316.40.0112	2"-2"-2"-1 1/2"	ea	1	2.286	2.286	$191.00	$ 191.00	$118.00	$ 118.00		$ -	$ 309.00
	Y-Fitting											
221316.40.0101	1 1/2"-1 1/2"-1 1/2"	ea	1	1.231	1.231	$ 67.50	$ 67.50	$ 64.00	$ 64.00		$ -	$ 131.50
221316.40.0104	4"-4"-1 1/2"	ea	2	4	8	$650.00	$ 1,300.00	$207.00	$ 414.00		$ -	$ 1,714.00
221316.40.0104	4"-4"-2"	ea	2	4	8	$650.00	$ 1,300.00	$207.00	$ 414.00		$ -	$ 1,714.00
221316.40.0104	4"-4"-4"	ea	1	4	4	$650.00	$ 650.00	$207.00	$ 207.00		$ -	$ 857.00
	Trap											
221316.40.0121	1 1/2"	ea	4	1.067	4.268	$101.00	$ 404.00	$ 55.50	$ 222.00		$ -	$ 626.00
221316.40.0122	2"	ea	2	1.231	2.462	$161.00	$ 322.00	$ 64.00	$ 128.00		$ -	$ 450.00
	Cleanout											
	1 1/2"	ea	1	2.22	2.22	$183.00	$ 183.00	$104.00	$ 104.00		$ -	$ 287.00
	4"	ea	1	2.22	2.22	$183.00	$ 183.00	$104.00	$ 104.00		$ -	$ 287.00
	Cast Iron											
221316.20.4100	1 1/2"	LF	24.83	0.225	5.58675	$ 9.15	$ 227.19	$ 11.65	$ 289.27		$ -	$ 516.46
221316.20.4200	2"	LF	9.67	0.239	2.31113	$ 9.40	$ 90.90	$ 12.35	$ 119.42		$ -	$ 210.32
221316.20.4400	4"	LF	6.33	0.276	1.74708	$ 16.95	$ 107.29	$ 14.30	$ 90.52		$ -	$ 197.81
SUBTOTAL					**47.53196**		**$ 5,437.89**		**$ 2,440.21**			**$ 7,878.10**
	Vent (CPVC)											
	45 deg Elbow											
221113.76.5938	1 1/4"	ea	5	0.396	1.98	$ 25.00	$ 125.00	$ 23.00	$ 115.00		$ -	$ 240.00
221113.76.5940	1 1/2"	ea	5	0.44	2.2	$ 25.50	$ 127.50	$ 25.50	$ 127.50		$ -	$ 255.00
221113.76.5942	2"	ea	7	0.483	3.381	$ 29.00	$ 203.00	$ 25.00	$ 175.00		$ -	$ 378.00
	Y-Fitting											
221113.76.5972	2"-2"-1 1/4"	ea	2	0.8	1.6	$ 36.00	$ 72.00	$ 41.50	$ 83.00		$ -	$ 155.00
	Double Y											
221113.76.5978	4"-4"-2"-1 1/2"	ea	1	1.455	1.455	$121.00	$ 121.00	$ 75.50	$ 75.50		$ -	$ 196.50
	CPVC											
151085.20.5490	1 1/4"	LF	28.42	0.19	5.3998	$ 4.57	$ 129.88	$ 6.35	$ 180.47		$ -	$ 310.35
151085.20.5500	1 1/2"	LF	12.42	0.222	2.75724	$ 5.20	$ 64.58	$ 7.40	$ 91.91		$ -	$ 156.49
151085.20.5510	2"	LF	14.5	0.271	3.9295	$ 6.05	$ 87.73	$ 8.10	$ 117.45		$ -	$ 205.18
SUBTOTAL					**22.70254**		**$ 930.69**		**$ 965.83**			**$ 1,896.51**
15082.00.0100	Insulation	Job	10%		9.397332		$ 794.88		$ 477.37			$ 1,272.25
				Plumbers								
TOTAL/ROOM PAIR					**93.97332**		**$ 7,948.84**		**$ 4,773.66**			**$ 13,994.75**

The estimates above display a drastic cost and schedule saving associated with the implementation of a share wet-wall. To better understand the cost saves associated with each part of the system, please view the tables below providing a summary of the cost and labor savings.

Material Cost Comparison Summary				
	Original	Proposed	Difference	Percent Change
CW and HW Supply	$1,508.55	$1,580.26	($71.71)	105%
Sanitary	$10,889.13	$5,437.89	$5,451.24	50%
Vent	$1,139.27	$930.69	$208.58	82%
Insulation	$1,353.70	$794.88	$558.82	59%
Total/Room Pair	**$14,890.65**	**$7,948.84**	**$6,941.81**	**53%**

Labor Cost Comparison Summary				
	Original	Proposed	Difference	Percent Change
CW and HW Supply	$2,042.36	$1,367.62	$674.74	67%
Sanitary	$5,582.68	$2,440.21	$3,142.47	44%
Vent	$1,166.72	$965.83	$200.89	83%
Insulation	$879.18	$477.37	$401.81	54%
Total/Room Pair	**$9,670.94**	**$4,773.66**	**$4,897.28**	**49%**

Labor Hours Comparison Summary				
	Original	Proposed	Difference	Percent Change
CW and HW Supply	35.6	23.7	11.9	67%
Sanitary	108.5	47.5	61	44%
Vent	27	22.7	4.3	84%
Insulation	17.1	9.4	7.7	55%
Total/Room Pair	**188.2**	**94**	**94.2**	**50%**

To put these numbers and percentages into perspective of the entire project, it should be remembered that this project contains 90 basically identical patient rooms. That means there are 30 rooms contained on the 4th, 5th and 6th floors. Since the re-design of the patient rooms uses a shared common wet-wall in its design, each floor can be seen as 15 pairs of patient rooms. Based on the original estimates material and labor cost for each floor would cost $368,423.82 or the total for all three floors would cost $1,105,271.47. The proposed re-design on the other cuts these cost to only $209,921.24 per floor or a total of $629,763.72 for all three floors.

Though the cost savings potential associated with the re-design and use of a shared wet-wall may apply directly to the project providing almost 50% material and labor reduction for the project, the schedule is not affected quite as directly. This is because according to the schedule currently in use by the project team not all of the in-wall plumbing installs are on the critical path. However all of the domestic water branch piping installs are on the critical path so this portion of the schedule can be reduced by 67% since domestic water branch piping is referring to the cold and hot water supplies. The current schedule has 2 days allotted for west floor install, 19 days for north floor install, 5 days for south floor install, and 2 days east floor install. That comes to a total of 28 days per floor for domestic water branch piping install. So applying the reduction associated with the re-design the schedule can be reduced to only taking 19 days to install domestic water branch piping per floor. Now when it comes to evaluate the impact in terms of the in-wall plumbing a few extra steps must be taken. When the schedule is referring to in-wall plumbing it is primarily talking about the sanitary and vent piping. Now in-wall plumbing only occurs on the critical path for 8 days in the west portion of each floor and 15 days in the south portion of each floor. This gives a total of 23 days on the critical path. Next in order to calculate the percent change associated by switching to the re-design patient rooms the sanitary and vent piping must be combined. To do this both sanitary and vent piping labor hours are combined for both the original design and proposed design. By dividing the proposed sanitary and vent total by the original sanitary and vent total a combined percent change is create. This percent change is 52%. Finally by applying this percent change to the 23 days on the critical path the schedule can be further reduced to 12 days for in-wall plumbing per floor. Putting these two reductions together allows each floor's schedule to be reduced by 31 days. With three floors having the same layouts, this design change has the potential to reduce the schedule by 93 days.

Recommendations

With the benefit of hindsight, electing to go with the proposed re-design of the patient rooms would be ideal over the originally design. The re-design coupled with prefabrication and the implementation of a shared wet-wall allowed for a schedule reduction of 31 days per floor for a total of 93 days and cost reduction from $1,105,271.47 to $629,763.72 it is hard to argue against the re-design.

Analysis #3: SIPS Utilization for Patient Floors

Problem Identification

When taking a site visit of the Northeast Hospital Expansion project it appeared that certain trades where significantly further along with the project than others when they were all supposed to be working on the same floors according to the project schedule. This was especially evident on the interior when the owner's representative noted that the mechanical and plumbing contractor seemed to be surpassing the electrical contractor, or that the electrical contractor was not able to keep up. As mentioned before, this project experienced massive time losses from harsh weather conditions during the construction of the superstructure.

Background Information

The Northeast Hospital Expansion has a total of 90 almost identical patient rooms located on the 4th, 5th, and 6th floors. These rooms being so repetitive allow for the potentially great opportunity for implementing a Short Interval Production Schedule (SIPS). The purpose of SIPS is to create a parade of trades through the project. By optimizing crew sizes and designating work zones belonging to specific trades for specific durations, over production and underproduction can be minimized creating a more efficient project delivery.

Currently trades are scheduled to be working in the same spaces at the same time. This can become difficult to grasp how the trades should be flowing through each floor. Also conflicts between trades can easily occur in these situations and some trades may end up being held up by another trade who is not able to meet their performance expectations. Conflicts that occur can be difficult to resolve since other trades may have already gone ahead and placed their work in turn creating issues for the trades that have yet to reach this portion of the project. When one trade is waiting on another to finish their work it not only holds up a projects completion, but it also cost the project additional money to keep the workers on site so once the slower trade finishes they can immediately finish their own work.

Analysis Goals

The purpose of this analysis is to first gain an understanding on the individual trade activities that must occur on each floor. After understanding the different trades, work zones will need to be defined. Once work zones have been created the sequence of trades must be understood and then applied to each work zone. With each trade applied to the work zones in the proper order, a duration must be specified for each trade to complete their work zone. Finally, the flow of work must be balanced so as to have minimal over production and underproduction between trades to create the most optimal delivery sequence. After these steps are taken, the new estimated floor completion time will be compared to the original floor completion time where recommendation will then be made.

Process

Understanding the Different Trades

In order to create work zones that are the correct size and contain the appropriate amount of work for each trade to attempt to balance workflow, a general understanding of each trade must be gained. First, all of the construction activities that are necessary for the completion of each patient floor must be identified. These activities were taken directly from the actual project schedule. Next, each activity had to be associated with the correct trade that would complete the activity. On top of just assigning correct trades, initial crew sizes were taken from RS Means 2015 Facility Construction since some subcontractor could not be reached for the actual crew sizes. RS Means also provided the hourly wages for each type of construction worker. By extracting the scheduled days for each activity, durations for each activity could be calculated and associated with each activity. Next, the typical patient floor's area was measured to be 22,500 SF. Using this SF value and the duration of each crew, a crew's productivity could be converted in to SF/day through the equation:

(Crew's SF/Day) = (SF/Floor)/(Original Duration)

Furthermore it was also felt important to understand how much each crew currently cost to complete each construction activity. To do this the following equations were used:

(Original Crew Size)*(Hourly Cost/Worker) = (Crew Cost/Day)

(Crew Cost/Day)*(Original Duration) = (Original Total Cost)

These values for each activity could then be totaled to give the total cost of each floor using the original project schedule and crew sizes. The following page contains the table summarizing the understanding of each trade gained from this step. Each activity is colored in association with each trade. The exception is that is telecommunication, though installed by an electrician, is colored differently since this would be conducted by a separate contractor.

Original Crew Understanding

SF/Floor: 22,500

Activity	Orig Crew Size	Worker Type	Hourly Cost/Worker	Cost/Day	Orig Durations	SF/Day	Original Total Cost
Layout and Top Track	2	Carpenter	$ 46.95	$ 751.20	41	549	$ 30,799.20
Sanitary Runouts	2	Plumber	$ 58.70	$ 939.20	39	577	$ 36,628.80
Dom Water Mains	2	Plumber	$ 58.70	$ 939.20	36	625	$ 33,811.20
Electrical Conduit Mains	2	Electrician	$ 54.70	$ 875.20	39	577	$ 34,132.80
Duct Mains	2	Sheetmetal	$ 55.95	$ 895.20	68	331	$ 60,873.60
Medical Gas Mains	3	Pipefitter	$ 59.75	$ 1,434.00	33	682	$ 47,322.00
HVAC Piping Mains	3	Pipefitter	$ 59.75	$ 1,434.00	37	608	$ 53,058.00
Sprinkler Mains	3	Sprinkler	$ 56.65	$ 1,359.60	31	726	$ 42,147.60
Medical Gas Branch	3	Pipefitter	$ 59.75	$ 1,434.00	30	750	$ 43,020.00
Sprinkler Branch	2	Sprinkler	$ 56.65	$ 906.40	28	804	$ 25,379.20
HVAC Branch	3	Pipefitter	$ 59.75	$ 1,434.00	34	662	$ 48,756.00
Domestic Water Branch	2	Plumber	$ 58.70	$ 939.20	31	726	$ 29,115.20
Duct Branch	2	Sheetmetal	$ 55.95	$ 895.20	34	662	$ 30,436.80
Frame Walls	2	Carpenter	$ 46.95	$ 751.20	35	643	$ 26,292.00
Insulate Ducts	2	Asbestos	$ 52.35	$ 837.60	30	750	$ 25,128.00
Door Frames	2	Carpenter	$ 46.95	$ 751.20	30	750	$ 22,536.00
Electrical Branch	1	Electrician	$ 54.70	$ 437.60	34	662	$ 14,878.40
In-Wall Plumbing	2	Plumber	$ 58.70	$ 939.20	62	363	$ 58,230.40
Piping and Plumbing Insulation	2	Abestos	$ 52.35	$ 837.60	3	7500	$ 2,512.80
Frame Ceiling and bulkheads	2	Carpenter	$ 46.95	$ 751.20	24	938	$ 18,028.80
Install Med Gas Headwall and Zone Valve	2	Pipefitter	$ 59.75	$ 956.00	15	1500	$ 14,340.00
In-Wall Controls Rough-in	1	Electrician	$ 54.70	$ 437.60	17	1324	$ 7,439.20
In-Wall Electrical Rough-in	1	Electrician	$ 54.70	$ 437.60	24	938	$ 10,502.40
Install Cable tray	2	Electrician	$ 54.70	$ 875.20	19	1184	$ 16,628.80
In-Wall Telecom/Security Rough-in	2	Electrician	$ 54.70	$ 875.20	29	776	$ 25,380.80
Install Light Fixtures	2	Electrician	$ 54.70	$ 875.20	23	978	$ 20,129.60
Pull and Terminate Electrical	2	Electrician	$ 54.70	$ 875.20	16	1406	$ 14,003.20
Pull and Terminate Control Wire	1	Electrician	$ 54.70	$ 437.60	16	1406	$ 7,001.60
Pull and Terminate Telecom/Security	2	Electrician	$ 54.70	$ 875.20	18	1250	$ 15,753.60
In-Wall Insulation	2	Asbestos	$ 52.35	$ 837.60	12	1875	$ 10,051.20
Install Ceiling	2	Carpenter	$ 46.95	$ 751.20	21	1071	$ 15,775.20
Cut-in Sprinkler Drops/Trim	1	Sprinkler	$ 56.65	$ 453.20	17	1324	$ 7,704.40
Install Air Distribution	1	Sheetmetal	$ 55.95	$ 447.60	32	703	$ 14,323.20
Hang/Tape/Finish Drywall	2	Carpenter	$ 46.95	$ 751.20	46	489	$ 34,555.20
Firestop and Caulk Wall Penetrations	1	Carpenter	$ 46.95	$ 375.60	36	625	$ 13,521.60
Paint Walls	2	Painter	$ 40.35	$ 645.60	19	1184	$ 12,266.40
Install Flooring	2	Floor Tiler	$ 43.60	$ 697.60	39	577	$ 27,206.40
Set and Hook-up Plumbing Fixtures	2	Plumber	$ 58.70	$ 939.20	23	978	$ 21,601.60
Final Paint	2	Painter	$ 40.35	$ 645.60	18	1250	$ 11,620.80
Final Clean	2	Laborers	$ 37.60	$ 601.60	19	1184	$ 11,430.40
						Total Labor Cost Per Floor:	$ 994,322.40

Defining Work Zones

After getting a brief understanding of the amount of work involved with each trade, it was time to determine how to break down each floor into smaller more manageable work zones. With smaller zones, the amount of time to complete a given area is reduced so that contractors would be able to more easily comprehend the amount of work that would need to be completed on what appears to be shorter deadline. Each zone was made large enough that each activity could be completed in a week's time for each zone. Since there are 30 patient rooms on each floor, it was easy enough to break each floor into five work zones for 15 total zones. This means it would take five weeks for one activity to clear a single floor or 15 weeks to be complete on all floors. On top of the six patient rooms there is a central office area that includes several restrooms and an elevator lobby on the north side of the addition. In order to account for these spaces some zones contain less patient rooms and more of the central office area or elevator lobby to balance the amount of work required in each space. Below the floor plans of the 4th, 5th, and 6th floors have been colored in and labeled. Each floor will have work starting on Zones 1, 6, and 11 respectively to limit the amount of construction traffic through finished work and finished spaces since the material hoist is located on the east side of the building.

Floor	Work Zone	SF	Start	Finish
4th	1	4450	3/5/14	12/3/14
	2	4510	3/12/14	12/10/14
	3	4450	3/19/14	12/17/14
	4	4560	3/26/14	12/24/14
	5	4530	4/2/14	12/31/14
5th	6	4450	4/9/14	1/7/15
	7	4510	4/16/14	1/14/15
	8	4450	4/23/14	1/21/15
	9	4560	4/30/14	1/28/15
	10	4530	5/7/14	2/4/15
6th	11	4450	5/14/14	2/11/15
	12	4510	5/21/14	2/18/15
	13	4450	5/28/14	2/25/15
	14	4560	6/4/14	3/4/15
	15	4530	6/11/14	3/11/15

Avg Zone SF:	4500
Zone duration:	273

<u>Work Flow Balancing</u>

With similar sized work zones established, crews needed to be re-evaluated to balance their productivity rates so crews would be moving at the same pace from zone to zone. Since each zone is on average 4,500 SF, each crew would need to complete 900 SF per day in order to complete a zone by the end of each week or five eight-hour business days. This meant that each crew originally under producing would need to add crew members, and crews over producing may need to down size the number of crew members. The proposed crew sizes to balance the workflow came from the following equation:

(Proposed SF/Day)/(Original SF/Day)]*(Original Crew Size)= (Proposed Crew Size)

Then in order to grasp the cost impact of adjusting the crew sizes, the proposed total labor costs were calculated for each activity. Each activities total was then summed for the proposed total labor cost per floor, and finally totaled for all three floors. Eight-hour workdays were assumed with 25 days to complete an entire floor. The equations used to calculate these values can be seen as follows:

(Proposed Crew Size)*(Hourly Cost/Worker)*8 Hrs*(25 days) = (Total Labor Costs)

(Total Per Floor)* 3 Floors = (Total Cost For All floors)

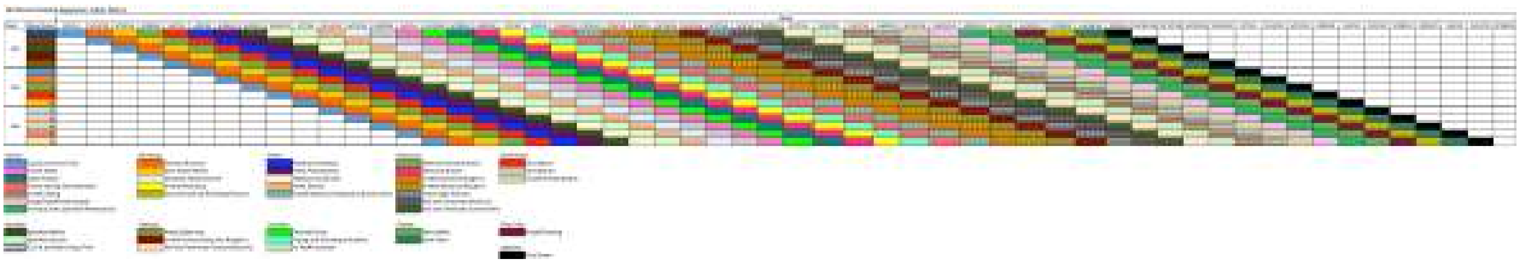
After adjusting crew sizes and re-totaling the total labor costs, it was determined that the proposed crew sizes could potentially result in a $4,032.40 savings per floor for a total of $12,097.20 on the entire project. A table containing the full results can be seen below for a more detailed listing the proposed crew sizes and new labor totals.

Crew Balancing — SF/Floor: 22,500 — Goal SF/week: 4500

Activity	Crew Size		Worker Type	Hourly Cost/Worker	Crew Cost/Day		Activity Duration		SF/Day		Total Labor costs	
	Original	Proposed			Original	Proposed	Original	Proposed	Original	Proposed	Original	Proposed
Layout and Top Track	2	3	Carpenter	$ 46.95	$ 751.20	$ 1,126.80	41	25	549	900	$ 30,799.20	$ 28,170.00
Sanitary Runouts	2	3	Plumber	$ 58.70	$ 939.20	$ 1,408.80	39	25	577	900	$ 36,628.80	$ 35,220.00
Dom Water Mains	2	3	Plumber	$ 58.70	$ 939.20	$ 1,408.80	36	25	625	900	$ 33,811.20	$ 35,220.00
Electrical Conduit Mains	2	3	Electrician	$ 54.70	$ 875.20	$ 1,312.80	39	25	577	900	$ 34,132.80	$ 32,820.00
Duct Mains	2	5	Sheetmetal	$ 55.95	$ 895.20	$ 2,238.00	68	25	331	900	$ 60,873.60	$ 55,950.00
Medical Gas Mains	3	4	Pipefitter	$ 59.75	$ 1,434.00	$ 1,912.00	33	25	682	900	$ 47,322.00	$ 47,800.00
HVAC Piping Mains	3	4	Pipefitter	$ 59.75	$ 1,434.00	$ 1,912.00	37	25	608	900	$ 53,058.00	$ 47,800.00
Sprinkler Mains	3	4	Sprinkler	$ 56.65	$ 1,359.60	$ 1,812.60	31	25	726	900	$ 42,147.60	$ 45,320.00
Medical Gas Branch	3	4	Pipefitter	$ 59.75	$ 1,434.00	$ 1,912.00	30	25	750	900	$ 43,020.00	$ 47,800.00
Sprinkler Branch	2	2	Sprinkler	$ 56.65	$ 906.40	$ 906.40	28	25	804	900	$ 25,379.20	$ 22,660.00
HVAC Branch	3	4	Pipefitter	$ 59.75	$ 1,434.00	$ 1,912.00	34	25	662	900	$ 48,756.00	$ 47,800.00
Domestic Water Branch	2	2	Plumber	$ 58.70	$ 939.20	$ 939.20	31	25	726	900	$ 29,115.20	$ 23,480.00
Duct Branch	2	3	Sheetmetal	$ 55.95	$ 895.20	$ 1,342.80	34	25	662	900	$ 30,436.80	$ 33,570.00
Frame Walls	2	3	Carpenter	$ 46.95	$ 751.20	$ 1,126.80	35	25	643	900	$ 26,292.00	$ 28,170.00
Insulate Ducts	2	2	Asbestos	$ 52.35	$ 837.60	$ 837.60	30	25	750	900	$ 25,128.00	$ 20,940.00
Door Frames	2	2	Carpenter	$ 46.95	$ 751.20	$ 751.20	30	25	750	900	$ 22,536.00	$ 18,780.00
Electrical Branch	1	1	Electrician	$ 54.70	$ 437.60	$ 437.60	34	25	662	900	$ 14,878.40	$ 10,940.00
In-Wall Plumbing	2	5	Plumber	$ 58.70	$ 939.20	$ 2,348.00	62	25	363	900	$ 58,230.40	$ 58,700.00
Piping and Plumbing Insulation	2	1	Abestos	$ 52.35	$ 837.60	$ 418.80	3	25	7500	900	$ 2,512.80	$ 10,470.00
Frame Ceiling and bulkheads	2	2	Carpenter	$ 46.95	$ 751.20	$ 751.20	24	25	938	900	$ 18,028.80	$ 18,780.00
Install Med Gas Headwall and Zone Valve	2	1	Pipefitter	$ 59.75	$ 956.00	$ 478.00	15	25	1500	900	$ 14,340.00	$ 11,950.00
In-Wall Controls Rough-in	1	1	Electrician	$ 54.70	$ 437.60	$ 437.60	17	25	1324	900	$ 7,439.20	$ 10,940.00
In-Wall Electrical Rough-in	1	1	Electrician	$ 54.70	$ 437.60	$ 437.60	24	25	938	900	$ 10,502.40	$ 10,940.00
Install Cable tray	2	2	Electrician	$ 54.70	$ 875.20	$ 875.20	19	25	1184	900	$ 16,628.80	$ 21,880.00
In-Wall Telecom/Security Rough-in	2	2	Electrician	$ 54.70	$ 875.20	$ 875.20	29	25	776	900	$ 25,380.80	$ 21,880.00
Install Light Fixtures	2	2	Electrician	$ 54.70	$ 875.20	$ 875.20	23	25	978	900	$ 20,129.60	$ 21,880.00
Pull and Terminate Electrical	2	1	Electrician	$ 54.70	$ 875.20	$ 437.60	16	25	1406	900	$ 14,003.20	$ 10,940.00
Pull and Terminate Control Wire	1	1	Electrician	$ 54.70	$ 437.60	$ 437.60	16	25	1406	900	$ 7,001.60	$ 10,940.00
Pull and Terminate Telecom/Security	2	1	Electrician	$ 54.70	$ 875.20	$ 437.60	18	25	1250	900	$ 15,753.60	$ 10,940.00
In-Wall Insulation	2	1	Asbestos	$ 52.35	$ 837.60	$ 418.80	12	25	1875	900	$ 10,051.20	$ 10,470.00
Install Ceiling	2	2	Carpenter	$ 46.95	$ 751.20	$ 751.20	21	25	1071	900	$ 15,775.20	$ 18,780.00
Cut-in Sprinkler Drops/Trim	1	1	Sprinkler	$ 56.65	$ 453.20	$ 453.20	17	25	1324	900	$ 7,704.40	$ 11,330.00
Install Air Distribution	1	1	Sheetmetal	$ 55.95	$ 447.60	$ 447.60	32	25	703	900	$ 14,323.20	$ 11,190.00
Hang/Tape/Finish Drywall	2	4	Carpenter	$ 46.95	$ 751.20	$ 1,502.40	46	25	489	900	$ 34,555.20	$ 37,560.00
Firestop and Caulk Wall Penetrations	1	1	Carpenter	$ 46.95	$ 375.60	$ 375.60	36	25	625	900	$ 13,521.60	$ 9,390.00
Paint Walls	2	2	Painter	$ 40.35	$ 645.60	$ 645.60	19	25	1184	900	$ 12,266.40	$ 16,140.00
Install Flooring	2	3	Floor Tiler	$ 43.60	$ 697.60	$ 1,046.40	39	25	577	900	$ 27,206.40	$ 26,160.00
Set and Hook-up Plumbing Fixtures	2	2	Plumber	$ 58.70	$ 939.20	$ 939.20	23	25	978	900	$ 21,601.60	$ 23,480.00
Final Paint	2	1	Painter	$ 40.35	$ 645.60	$ 322.80	18	25	1250	900	$ 11,620.80	$ 8,070.00
Final Clean	2	2	Laborers	$ 37.60	$ 601.60	$ 601.60	19	25	1184	900	$ 11,430.40	$ 15,040.00
TOTAL PER FLOOR											**$ 994,322.40**	**$ 990,290.00**
TOTAL FOR ALL FLOORS											**$ 2,982,967.20**	**$ 2,970,870.00**

Schedule Impact

In order to see the potential impact to the project schedule by implementing SIPs and to provide a visual for contractors to avoid confusion, a labor matrix was created using the newly proposed activity durations. This matrix started on the same date, 3/5/2014, just like the original schedule. The matrix consists of each activity receiving its own color so as to not cause confusion and a legend included at the bottom. A small image of the matrix is included below. For the full sized matrix please see the appendix.

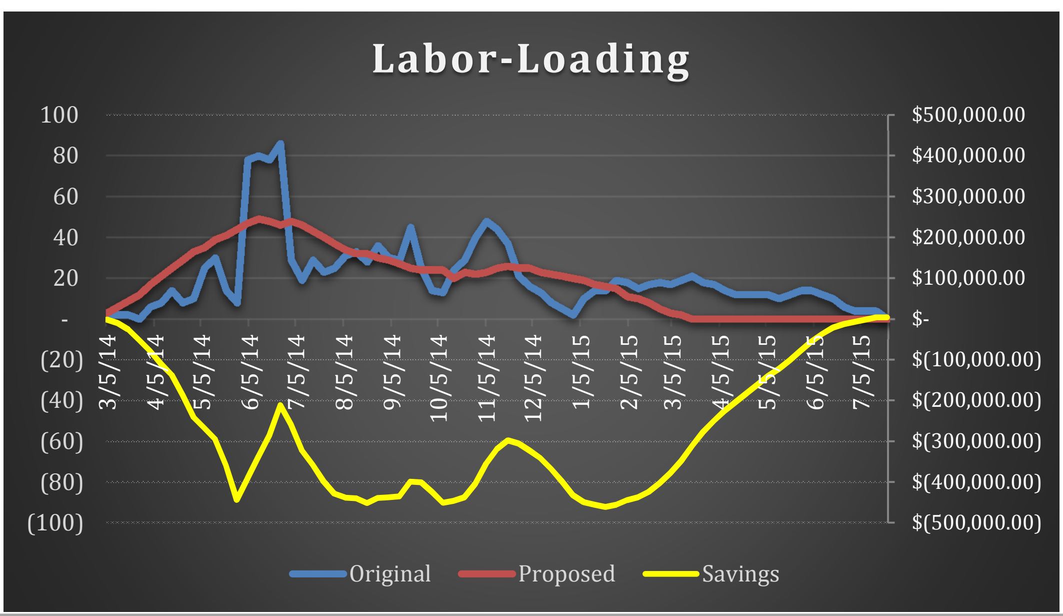


Constructing this labor matrix shows that the proposed crew sizes and work zones can potentially have all three floors built in 53 weeks. The original project schedule would have all three floors completed in a total of 71 weeks. This means the proposed schedule could reduce the project by 18 weeks. The sooner each floor can be turned over to the owner, the sooner the owner can provide a better quality of care to all patients in the existing and still operating hospital.

<u>Labor Loading</u>

The final portion of this analysis deals with viewing how the jobsite itself would be impacted by these crew adjustments and the implementation of work zones. To compare the proposed SIPS to the original project schedule a graph depicting the amount of workers that would be needed on the job site during a given week was created. As an added bonus this graph, seen below, also depicts the compounding cost differences as a project savings curve from implementing the SIPS schedule as compared to the original project schedule. This savings line was created using the equation:

$$\Sigma \left[\text{(Original Cost/Week)} - \text{(Proposed Cost/Week)} \right] = \text{Profit}$$



There are a number of important things that can be drawn from this labor-loading graph. First is that by comparing the two labor curves, it can be seen that the original scheduling of activities and crew sizes creates inconsistent and highly fluctuating periods of high labor intensity with low period with relaxed labor needs. The highest this curve gets is 86 workers at 6/25/14 and the lowest this curve reaches during construction is two workers on 12/31/14. These steep cliffs and valleys in the labor-loading reduce the potential learning curve workers receive from the repetitiveness of each floor since they are not continuously move from space to space working on the same activity in each room. Also by stacking so many workers at one time, workflow can be hindered by having to many people in one space at a time. With too many people in a single workspace, it is also possible for safety to be compromised. Looking at the proposed labor-loading curve, it can be seen that the curve is rather smooth with a gradual increase in workers on site until it peaks at 49 workers on 6/11/14 before the labor-loading regresses at a slow decline. Finally by examining the savings curve depicted in yellow, utilizing SIPS costs additional money up front in comparison to the original project schedule, but these higher up front costs turn a quick savings through the acceleration of the project schedule. These savings would begin to appear in the week of 7/1/15 since the SIPS would have completed weeks earlier and the original project would still need to continue to pay for the work still incomplete.

<u>Risks Associated with SIPS</u>

Though SIPS has the potential to bring about all of the positives discussed in the above sections, it does carry with it a few potential negatives. Just as SIPS has the potential to decrease the massive amount of workers that would be working in the same space normally, it can also detract from safety as well. SIPS does this by causing tradesmen to rush the completion of their work zones. Rushing an activity leads to workers putting themselves at additional safety risks and may cause a diminished quality in work. Beyond this, SIPS can be rather risky in that if a crew does not complete their work zone in the desired time frame the remaining sequence suffers and final completion might be delayed. To counter act the effects of a crew not meeting their deadline, an additional crew may need to be hired to move onto the next space to attempt to keep the parade of trades moving. Also if a reoccurring problem is encountered that takes major design changes to fix, the schedule lacks the flexibility to make these late changes easily.

Recommendations

Based on the SIPS implementation for patient floors analysis, several positives can be taken away. To begin, by implementing SIPS for these three floors the contractors would now have a well-defined sequence of activities as well as downsized work zones. This would help to prevent contractors from working out of sequences causing potential change orders or the need for re-work. The other added benefits of

SIPS include the potential 18-week reduction in the overall project schedule, increased learning curve, safety factors associated with a gradual labor loading, and $12,097.20 savings by switching from the original project schedule. Though SIPS has the potential to cause tradesmen to rush in order to complete their work and can be rather risky to meeting the final completion date, this strategy would still be suggested on the shear matter of the 18-week project acceleration alone let alone the other benefits.

Analysis #4: Preassembled Steel Connection Bridge

Problem Identification

During the construction of the superstructure of the patient tower for the Northeast Hospital Expansion, the owner representative stated that a potential 64 days were lost due to the weather. More specifically he was referring to the unnatural amount of snowstorms that occurred the previous winter. One area where the erection of steel in particular appeared to cause difficulty was at the connection bridge. This bridge was documented as having spent 17 extra days in the field to complete.

Background Information

The Northeast Hospital Expansion project is creating a patient tower located to the south of the Northeast Hospital's existing facilities. These two different buildings will be connected with a steel bridge located on the second floor of both buildings. This steel bridge is to be constructed on top of existing to remain operating rooms located on the first floor of the existing Northeast Hospital facility. These operating rooms will not be in use during the construction of the steel connection bridge. When it comes to looking at the existing project schedule, the steel connection bridge is estimated at taking 95 days to construct its structure. The project team tracked a total of 17 days of additional work that needed to occur in the field for the bridges construction.

Analysis Goals

This analysis will analyze how the steel connection bridge was actually constructed by the project team. It will then look to apply some form of preassembling of steel members while taking into consideration site limitations and optimal crane usage. This analysis will then contain a structural breadth that will verify that the preassembled steel members will be able to be lifted by the crane. The reason this analysis needs to occur is that the steel members may be lifted in such a way causing bending in their weaker y-axis. This is especially important since most designers do not take the construction process into consideration for their end design. Several lifting options will be proposed and checked. Next each potential lifting method will be analyzed from a constructability and safety standpoint. The safest and most feasible option will be selected and the impact to the project schedule will be assessed. Based on this analysis a recommendation on whether preassembling steel members could have been utilized.

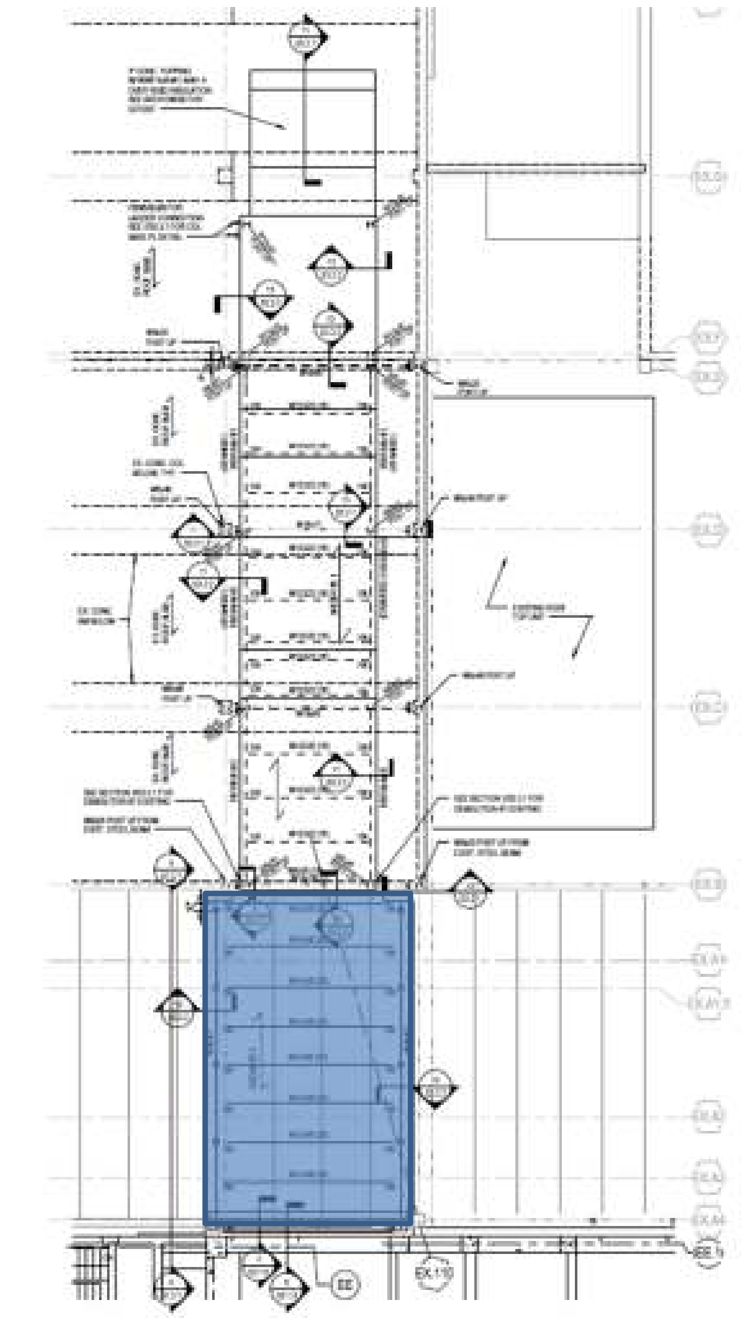
Process

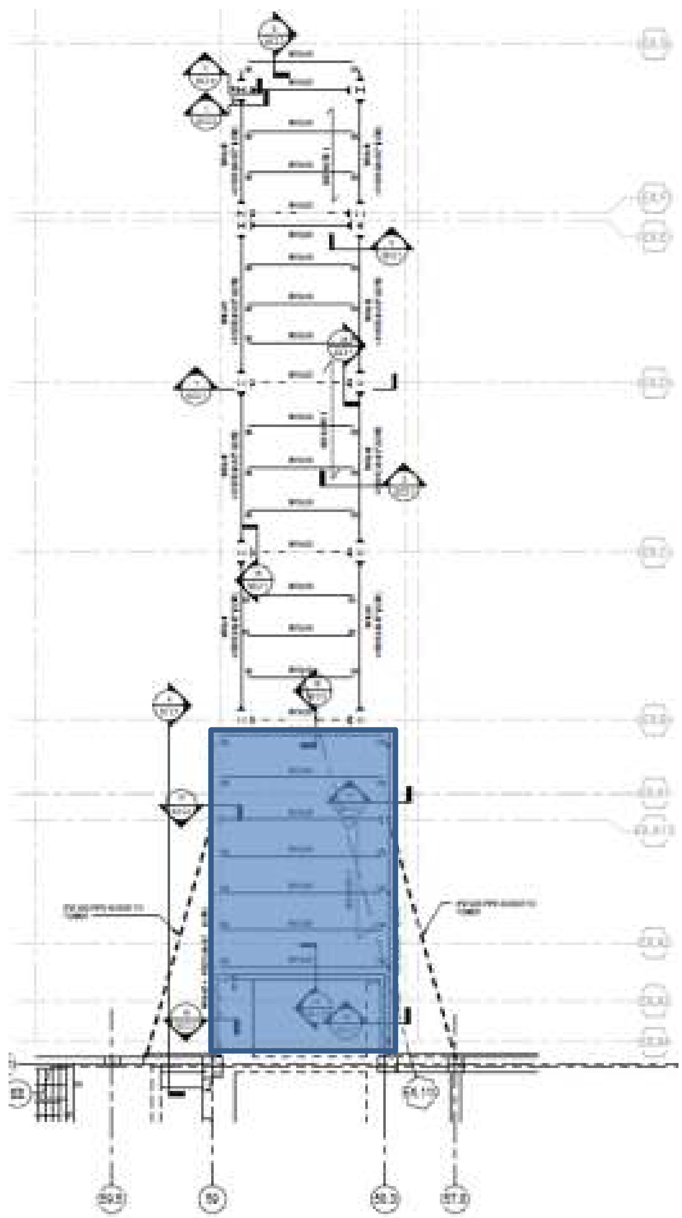
Examining Current Construction of Bridge

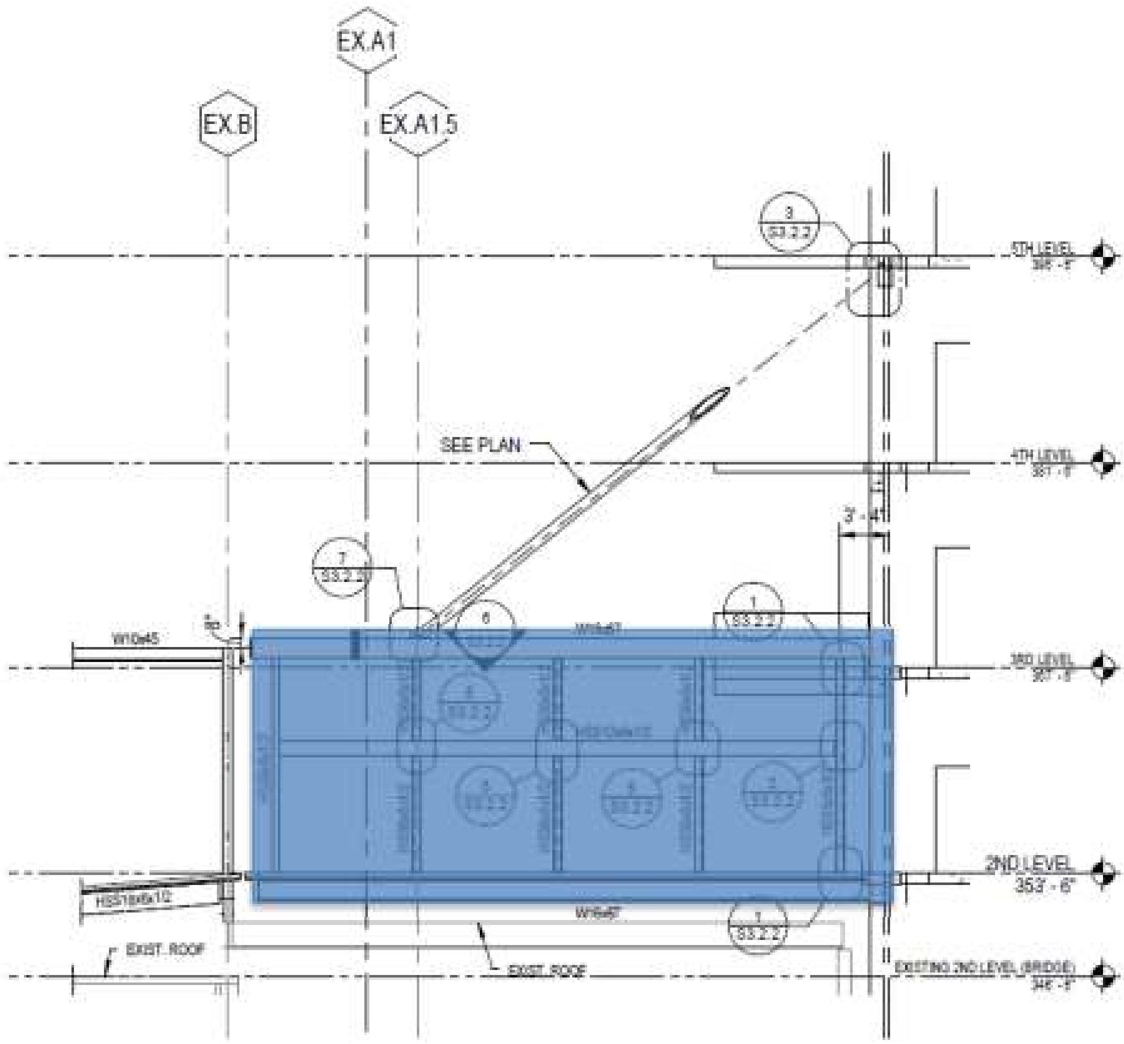
As stated earlier, the steel connection bridge is a steel bridge that will provide a way for employees, patients and guests to move from the existing Northeast Hospital facility located to the north of the new patient tower. This bridge will be constructed on top of existing to remain operating rooms located on the first floor of the existing hospital facility. This means there is not a lot of easy access to this location on the job site. The picture below provides a better visual with the bridge highlighted with yellow and the existing operated rooms outlined in red. The new patient tower being constructed is colored in blue.

In total this bridge will span 115 feet in length and 16 feet wide for a majority of the bridge. The only portion of the bridge that exceeds 16 feet is the final section connecting to the patient tower. This portion of the bridge, which is 50 feet in length and 23 feet wide, was preassembled by the current project team due to its complex nature and that this section is cantilevering out over the off the patient tower by two

8"Ø XXS pipe kickers. The reason these kickers were necessary it that there were no existing columns in this portion of the existing facility it was overhanging to transfer its loads. The plan drawings of the floor and roof of the bridge located on the bottom of the page provide better examples of the bridge. The preassembled portion has been highlighted in blue. An elevation has been included on the following page.

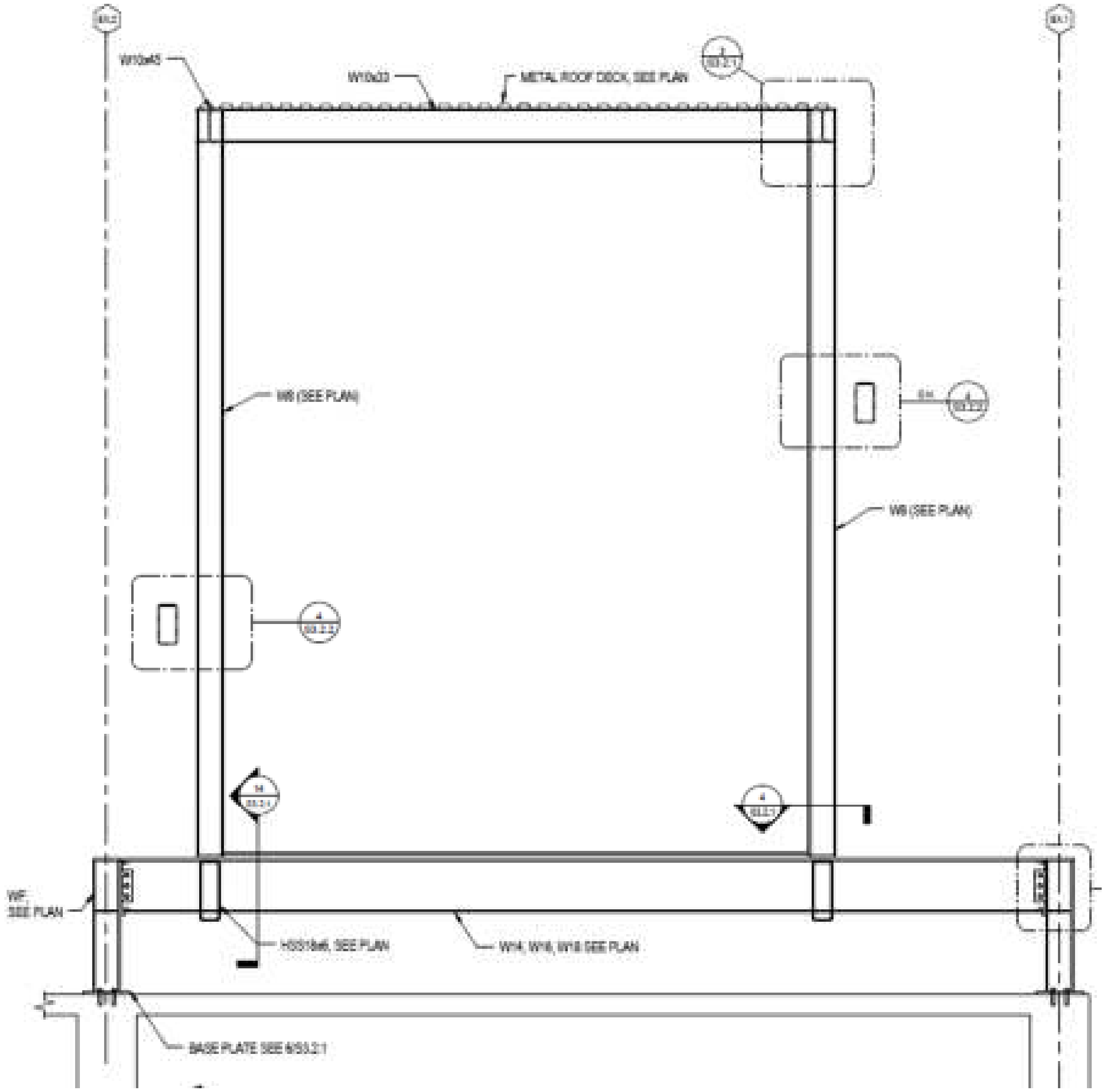




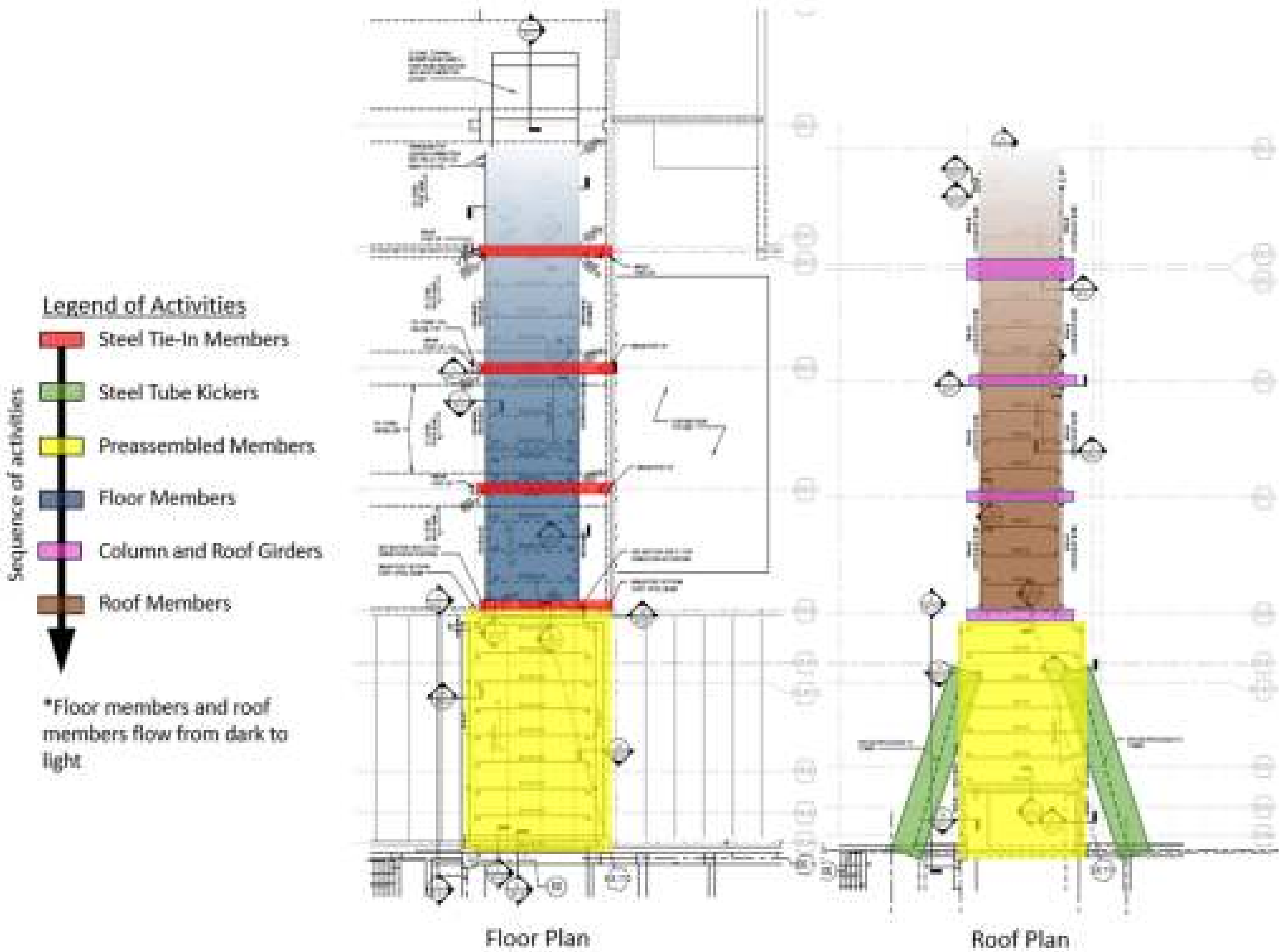


The elevation above provides a great look at how there is no existing column located in the already existing facility it is being built capable of supporting this section's load.

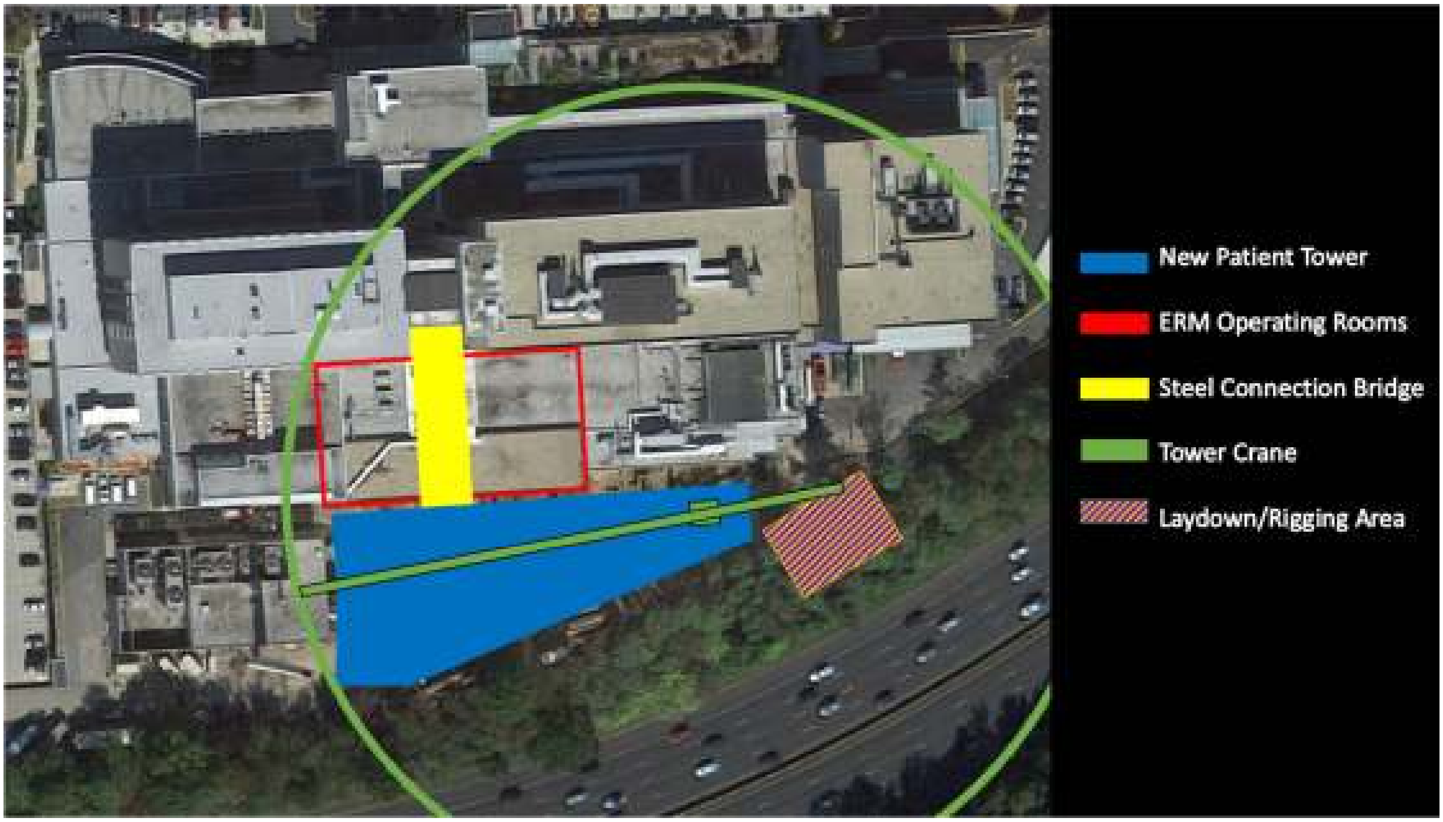
As stated above the rest of the bridge is to be supported by posting up from existing steel columns. Again this can be best understood by looking at a section of the bridge where these post ups occur and the load is transferred. In total there are four locations were these post ups occur. Such a section can be seen on the following page.



In order to get an understanding of how the project team went about sequencing the activities necessary for the bridges completion the project schedule of activities was referenced. The project schedule revealed that bridge's construction started with installing the steel members necessary for the tie-in to the existing roof's structure. This was followed by the installation of the two 8"Ø XXS pipe kickers from the fifth floor. Then the preassembled trusses of the south most section were installed and then detailed. The decking for the concrete floor was then placed on top of the now installed bridge section. Construction then flowed north from the preassembled southern section installing the tube steel and floor beams, followed by the columns and tube steel bracing the columns, and then finally placing the roof members and deck. After all members were installed and detailed the bridge's structure was complete by the placing the 3 ¼" lightweight concrete floor. Utilizing the plans from before, a visual representation of the steel installation process can be seen below.



Now that the sequence of activities has been described, let's dive a little deeper. One big difference between the placement of the south most bridge members and the rest of the bridge is that it was preassembled. The other members were placed individually. These members were lifted into place by a tower crane located east in the patient tower. This tower crane was used to lift all major picks with a lift capacity of 10,000 lbs. A simplified site logistics plan has been included on the following page that focuses on the crane and its radius to the bridge.



Creating Preassembled Bridge Sections

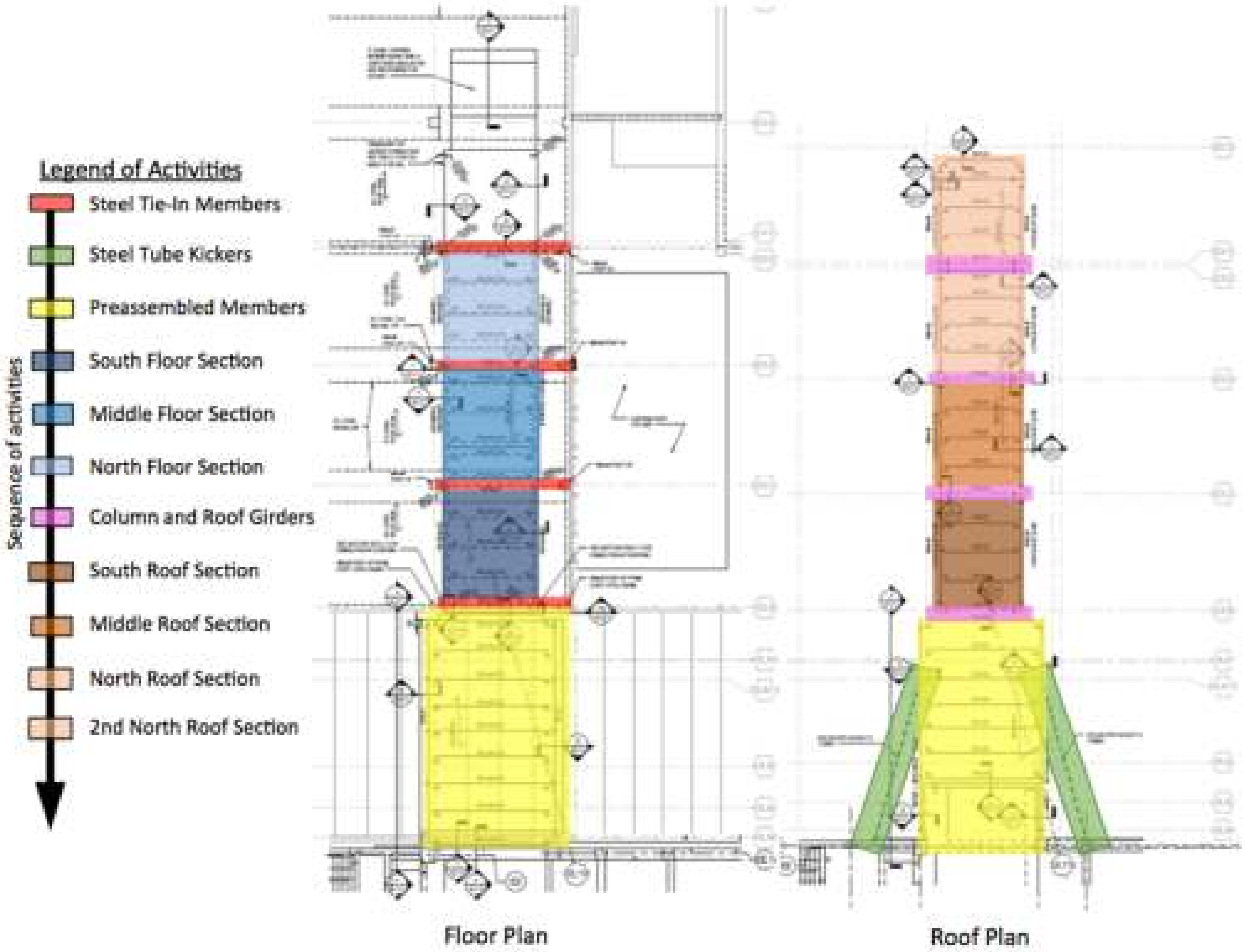
After understanding all of the information in the previous section, the idea to preassemble portions of the bridge came to fruition. By preassembling sections of the bridge instead of installing each member with a separate lift, it was thought this method had the potential to save time for the project or would have at least reduced the number of days lost to weather. Preassembling the members also has the potential to create a safer work environment with potentially better quality connections.

The reason the number of weather days lost could have been reduced is because by preassembling the members, some of the members could have been assembles off-site at the erectors fabrication shop. Though when asked whether the steel erector had a large fabrication facility, Whiting-Turner responded saying that it is not large enough for major preassembly. However their facility was large enough to preform minor work. Seeing that the southern-most portion of the bridge that is cantilevering was preassembled, it was determined that any preassembled members would have to be kept to a size as large or small than the southernmost portion of the bridge. The members would also have to take into consideration that the tower crane already installed for other major lifts on the job site has a maximum lifting weight of 10,000 lbs.

Preassembled members have the potential to make a job site safer in a number of ways. One way by preassembling the members is that the connections can be made in a controlled environment where the erectors are not exposed to the elements and the excessive heights. This obviously then reduces the number of field connections required that could cause injury in the form of caught-in-between injuries or strains from pushing or pulling members into place.

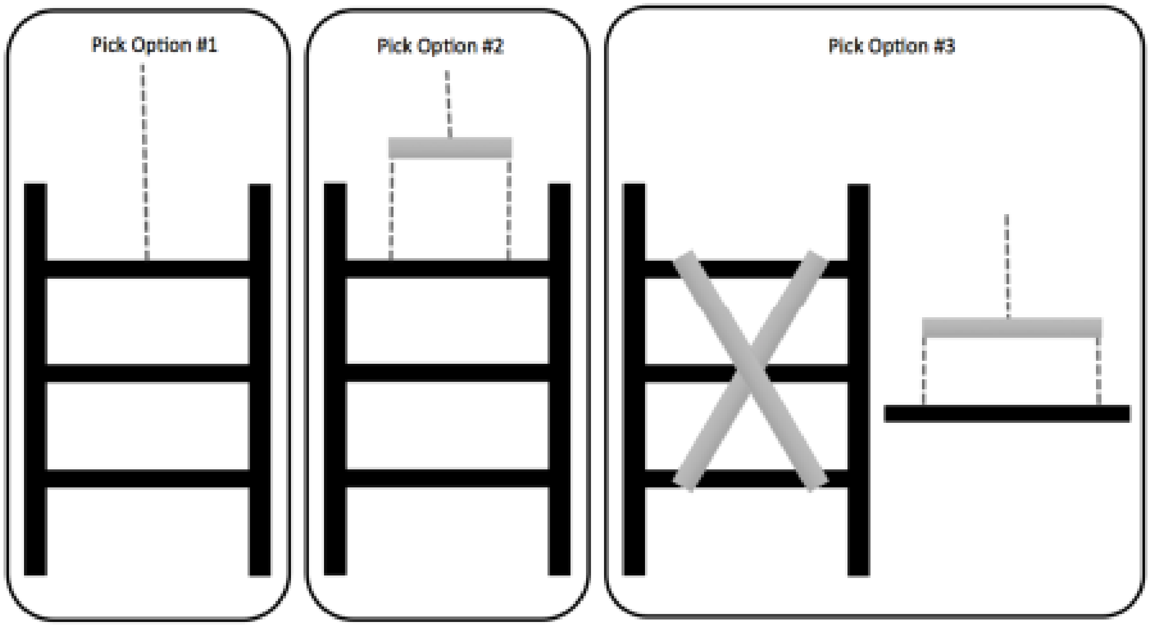
For the Northeast Hospital Expansion project to utilize preassembled steel members more than the project already has, the project team would need to look at the remaining sections of the steel bridge not being preassembled. By analyzing the current structure, it has been determined that the best members to preassemble would be the floor and roof members. The other members like the columns and steel members that tie-in to the existing structure for support would be difficult get the proper connections and plumb up. The floor and roof members though could be divided into three sections each. This would create a south, middle, and north floor sections and a south middle, north roof sections.

Preassembling these sections would change the way construction sequence looked slightly. Instead of placing each member separate, full sections would be installed in a single lift. The revised construction sequence would now be represented by the graphic on the next page.



Structural Breadth: Verifying Crane Lifts

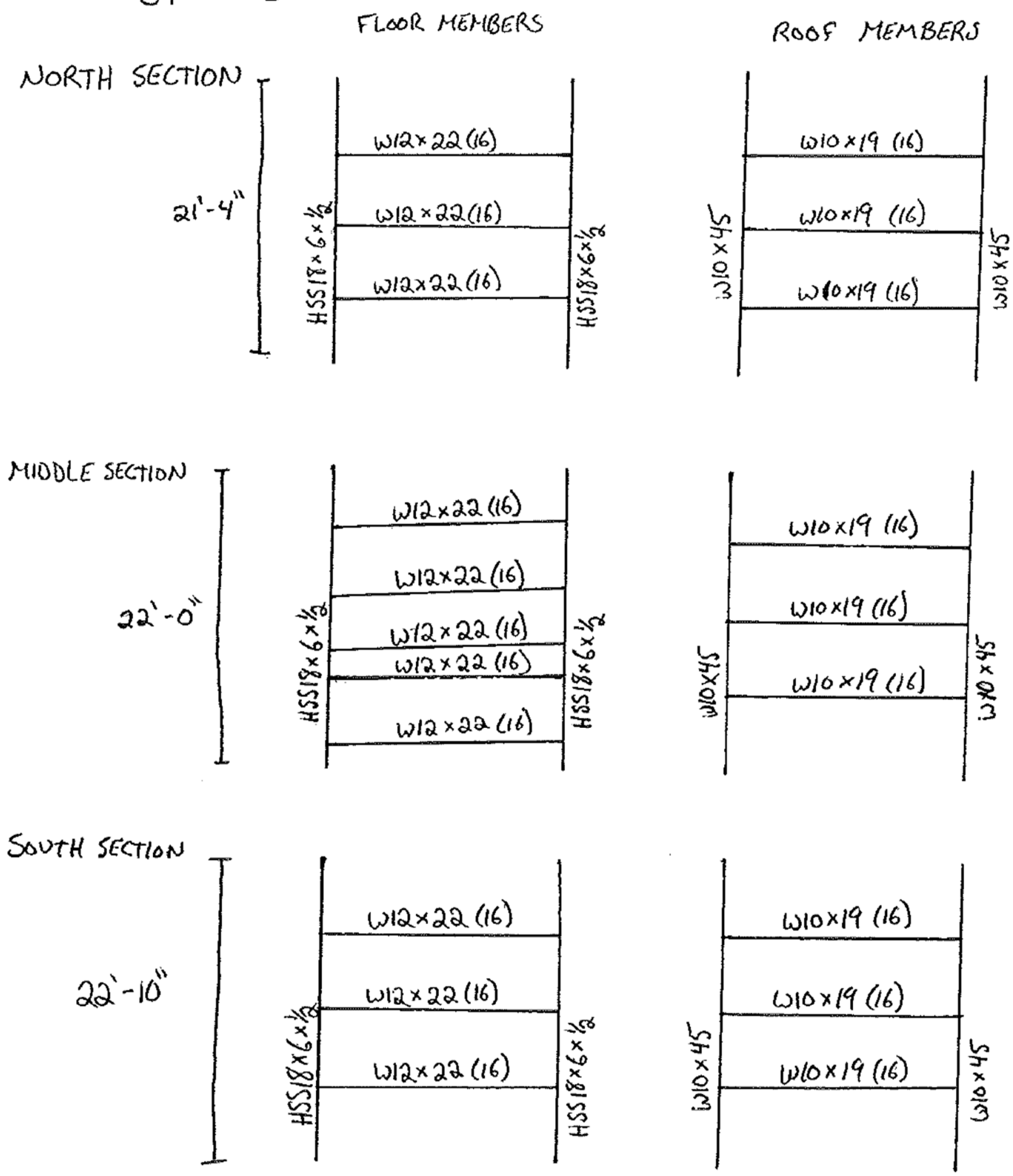
In order to verify that these sections are even possible to be lifted by the crane and installed as proposed some the weights of the preassembled members needs to be evaluated. Preassembled sections need to weigh less than 10,000 pounds for the tower crane to be able to lift them. After these section weights are verified to work, each section must have the different pick options checked to make sure the member would not fail in shear or bending. This is especially important since the first two picks will be lifting the members by its weak axis. There have been three different pick options chosen for evaluation. The first pick option suggested is to pick up each section from the center of one of its end beams and slowly hoisting the preassembled section into the air for installation. The second pick option suggested is to pick the members with two points of lift spaced 4 feet from either end of an end beam. The member would then be hoisted into the air slowly and installed. The third and final pick option looked at in this analysis is to pick the beam from a total of four lifting points (two on each of the end beams) and lifting the members horizontally and installed. To better represent these lifts please refer to the depictions shown below.



The following pages are the weight verifications of each preassembled section, and then the shear strength and flexural strength checks of the critical preassemblies. The critical preassemblies are the middle floor section and the south roof section because they weigh the most out of the floor and roof sections.

ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

STEEL BRIDGE PREFABRICATION



ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

MEMBER SELF WEIGHTS

W12×22 L=16'-0"

$(22 \frac{lbs}{ft})(16\ LF) = 352\ lbs.$

W10×19 L=16'-0"

$(19 \frac{lbs}{ft})(16\ LF) = 304\ lbs.$

W10×45 L=21'-4"

$(45 \frac{lbs}{ft})(21.3333LF) = 960\ lbs.$

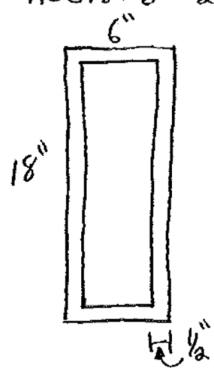
L=22'-0"

$(45 \frac{lbs}{ft})(22.0\ LF) = 990\ lbs.$

L=22'-10"

$(45 \frac{lbs}{ft})(22.8333LF) = 1{,}028\ lbs.$

HSS18×6×½



SELF WEIGHT OF CROSS SECTION *DENSITY OF A36 STEEL = 0.28 $\frac{lbs}{in^3}$

$(18")(16")(0.28 \frac{lbs}{in^3}) - [18" - 2(\tfrac{1}{2}")][6" - 2(\tfrac{1}{2}")](0.28 \frac{lbs}{in^3}) =$

$30.24 \frac{lb}{in} - 23.8 \frac{lb}{in} =$

$6.44 \frac{lb}{in}$

$6.44 \frac{lb}{in} (\frac{12\ in}{ft}) = 77.28 \frac{lbs.}{ft.}$

L=21'-4"

$(21.3333LF)(77.28 \frac{lbs}{ft}) = 1{,}650\ lbs.$

L=22'-0"

$(22.0\ LF)(77.28 \frac{lbs}{ft}) = 1{,}700\ lbs.$

L=22'-10"

$(22.8333LF)(77.28 \frac{lbs}{ft}) = 1{,}765\ lbs.$

ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

TOTAL SELF WEIGHTS

FLOOR MEMBERS w/ 1.4D

NORTH SECTION (2)(1,650 lbs) + (3)(352 lbs)
3,300 lbs. + 1,056 lbs
4,356 lbs. 1.4(4,356) = **6,098 lb**

MIDDLE SECTION (2)(1,700 lbs) + (5)(352 lbs)
3,400 lbs + 1,760 lbs
5,160 lbs. 1.4(5,160) = **7,224 lb**

SOUTH SECTION (2)(1,765 lbs) + (3)(352 lbs)
3,530 lbs + 1,056 lbs.
4,586 lbs. 1.4(~~5760~~ 4586) = **6,420 lb**

ROOF MEMBERS

NORTH SECTION (2)(960 lbs) + (3)(304 lbs)
1,920 lbs + 912 lbs.
2,832 lbs. 1.4(2,832) = **3,965 lb**

MIDDLE SECTION (2)(990 lbs) + (3)(304 lbs)
1,980 lbs + 912 lbs.
2,892 lbs. 1.4(2,892) = **4,049 lb**

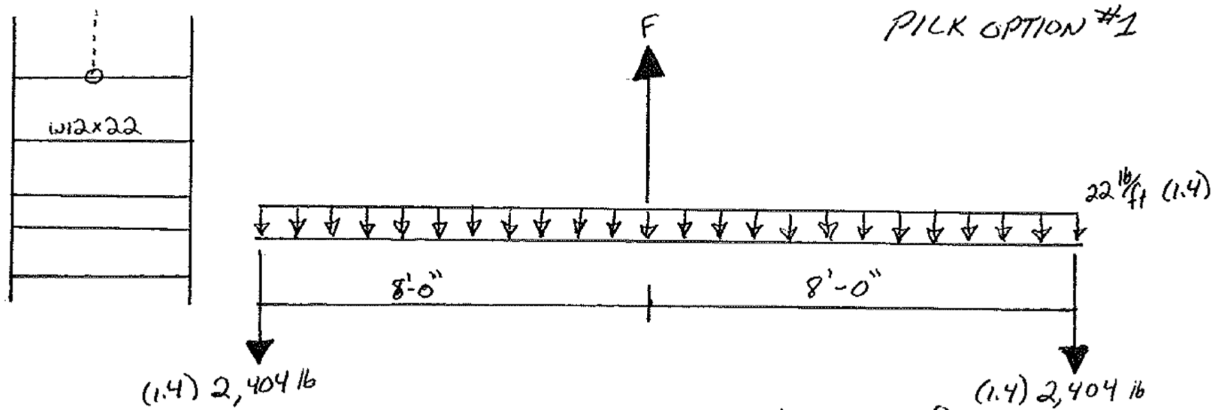
SOUTH SECTION (2)(1,028 lbs) + (3)(304 lbs)
2,056 lbs. + 912 lbs
2,968 lbs. 1.4(2,968) = **4,155 lb**

All total weights of each preassembly < 10,000 lbs

ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

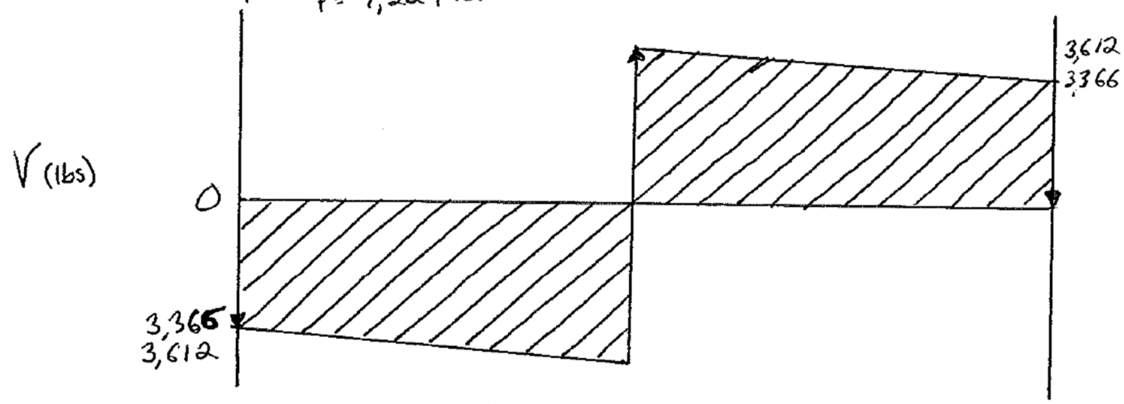
CHECKING FLEXURAL + SHEAR STRENGTH OF MIDDLE FLOOR SECTION

PICK OPTION #1

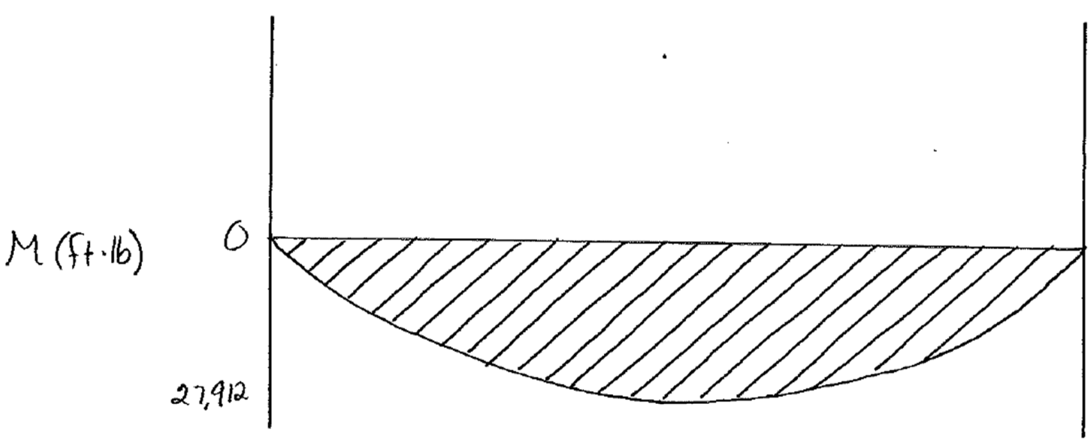


$\Sigma F_y = F - (2)(1.4)(2{,}404\ lb) - (16')(22\ lb/ft)(1.4) = 0$ ~~7,224 lb.~~

$F = 7{,}224\ lb.$



$M_{max} = (3366\ lb)(8') + (246\ lb)(8')(\tfrac{1}{2}) = 27{,}912\ ft \cdot lb.$



ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

MIDDLE FLOOR SECTION PICK OPTION #1
*Reference Material from AE 404
Pages from AISC Steel Construction Manual, 14th Ed.

SHEAR STRENGTH CHECK

$V_u \leq \phi V_n$

$V_u = 3,612$ lb.

$\phi = 1.0$

$V_n = 0.6 F_y A_w$

$F_y = 50$ ksi

$A_w = t_w d$

$t_w = 0.260$ in. $d = 12.3$ in. ⇒ Values for W12x22 (page 8)

$A_w = (0.260\text{ in})(12.3\text{ in})$

$A_w = 3.198\text{ in}^2$

$V_n = 0.6(50\text{ ksi})(3.198\text{ in}^2)$

$V_n = 95,940$ lb.

3,612 lb. ≤ 95,940 lb. okay ✓

FLEXURAL STRENGTH CHECK

$M_u \leq \phi M_n$

$M_u = 27,912$ ft·lb.

$\phi = 0.9$

$M_{ny} = F_y Z_y$ and $M_{nx} = F_y Z_x$

$F_y = 50$ ksi $Z_y = 3.66\text{ in}^3$ $Z_x = 29.3\text{ in}^3$

$M_{ny} = (50\text{ ksi})(3.66\text{ in}^3)$

$M_{ny} = 183,000$ in-lb.

$27,912\text{ ft}\cdot\text{lb.} \leq (0.9)(183\text{ in}\cdot\text{kip})\left(\frac{1\text{ ft}}{12\text{ in}}\right)$

27,912 ft·lb ≤ 13,725 ft·lb FAILS ✗

$M_{nx} = (50\text{ ksi})(29.3\text{ in}^3)$

$M_{nx} = 1,465,000$ in-lb.

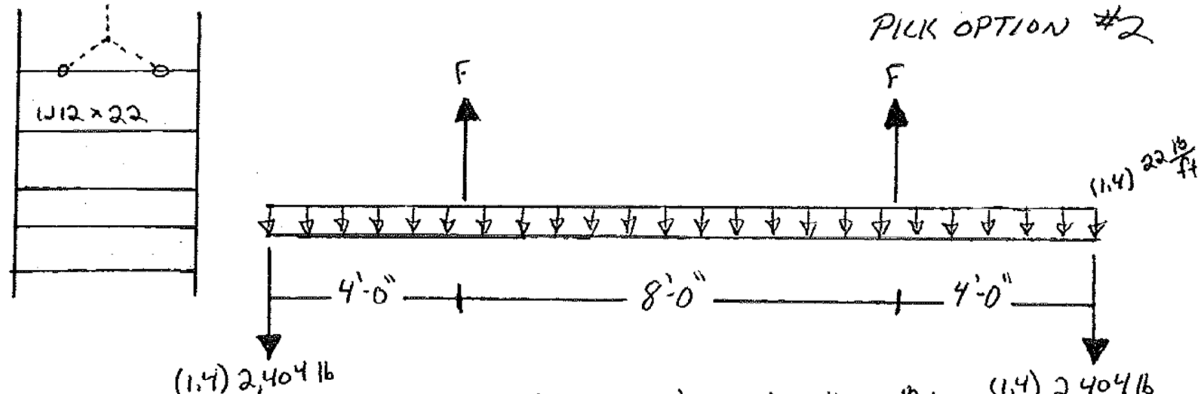
$27,912\text{ ft}\cdot\text{lb.} \leq (0.9)(1,465\text{ in}\cdot\text{kip})\left(\frac{1\text{ ft}}{12\text{ in}}\right)$

27,912 ft·lb ≤ 109,875 ft·lb okay ✓

ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

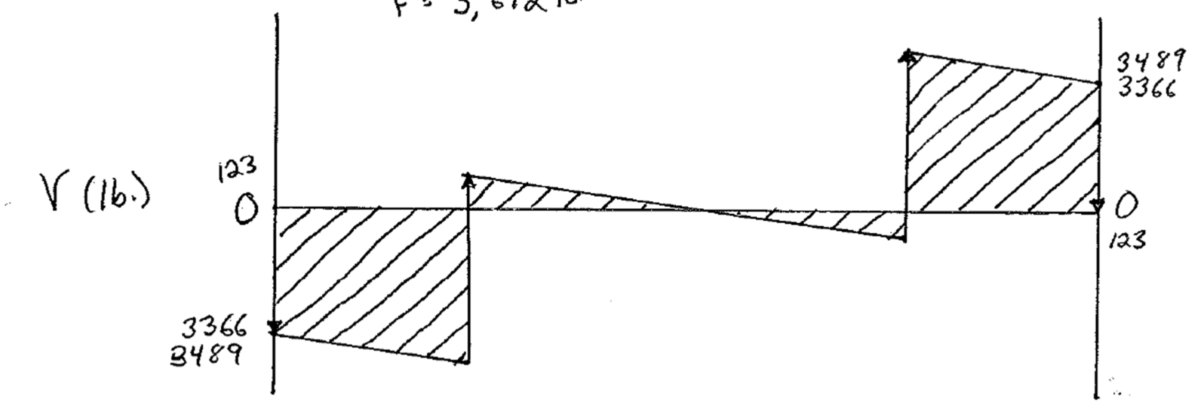
CHECKING FLEXURAL + SHEAR STRENGTH OF MIDDLE FLOOR SECTION

PICK OPTION #2

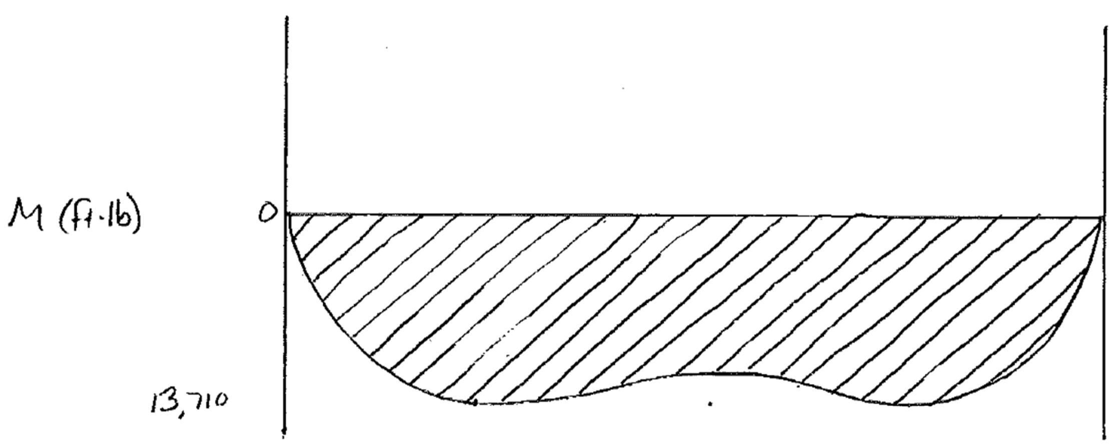


$\Sigma F_y = 2F - (2)(1.4)(2{,}404\text{ lb}) - (1.4)(16')(22\tfrac{\text{lb}}{\text{ft}}) = 0$

$F = 3{,}612\text{ lb}$



$M_{max} = 3366(4') + (123)(4')(\tfrac{1}{2}) = 13{,}710\text{ ft·lb}$



ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

SHEAR STRENGTH CHECK

MIDDLE FLOOR SECTION PICK OPTION #2
*Reference Material from AE 404
Pages from AISC Steel Construction Manual, 14th ED.

$V_u \leq \phi V_n$

$V_u = 3{,}489$ lb.

$\phi = 1.0$

$V_n = 95{,}940$ lb. (see V_n calculation in PICK OPTION #1)

$3{,}489$ lb $\leq 95{,}940$ lb. okay ✓

FLEXURAL STRENGTH CHECK

$M_u \leq \phi M_n$

$M_u = 13{,}710$ ft·lb.

$\phi = 0.9$ (See M_{ny} + M_{nx} calculations in PICK OPTION #1)

$M_{ny} = 183{,}000$ in·lb. and $M_{nx} = 1{,}465{,}000$ in·lb.

$13{,}710 \text{ ft·lb.} \leq (0.9)(183{,}000 \text{ in·lb})\left(\frac{1 \text{ ft}}{12 \text{ in}}\right)$

$13{,}710$ ft·lb $\leq 13{,}725$ ft·lb Okay ✓

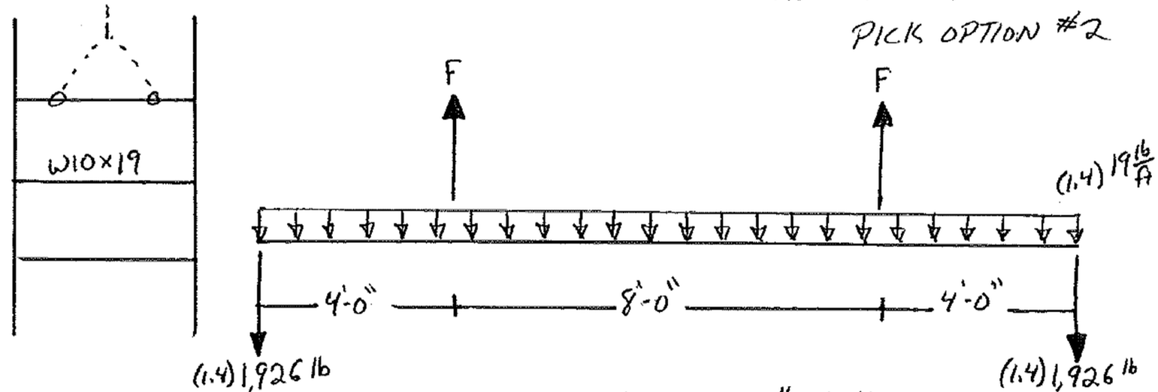
$13{,}710 \text{ ft·lb} \leq (0.9)(1{,}465{,}000 \text{ in·lb})\left(\frac{1 \text{ ft}}{12 \text{ in}}\right)$

$13{,}710$ ft·lb $\leq 109{,}875$ ft·lb Okay ✓

ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

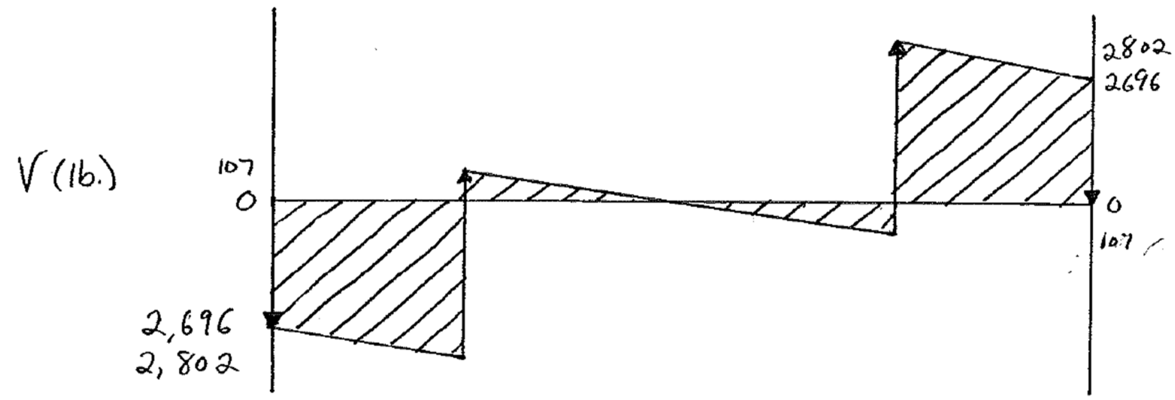
CHECKING FLEXURAL + SHEAR STRENGTH OF SOUTH ROOF SECTION

PICK OPTION #2

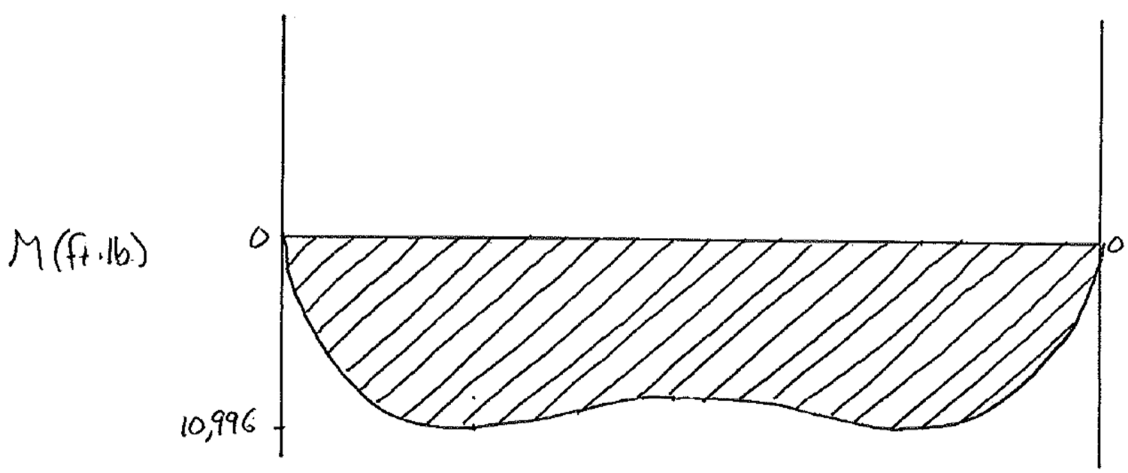


$\Sigma F_y = 2F - (2)(1.4)(1{,}926\ lb) - (1.4)(19\frac{lb}{ft})(16') = 0$

$F = 2{,}909\ lb.$



$M_{max} = 2696(4') + 106(4')(\frac{1}{2}) = 10{,}996\ ft \cdot lb$



ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

SHEAR STRENGTH CHECK

SOUTH ROOF SECTION PICK OPTION #2

*Reference Materials from AE 404
Pages from AISC Steel Construction Manual, 14th Ed.

$V_u \leq \phi V_n$

$V_u = 2{,}802$ lb.

$\phi = 1.0$

$V_n = 0.6\, F_y\, A_w$

$F_y = 50$ ksi

$A_w = t_w d$

$t_w = 0.250$ in $\quad d = 10.2$ in $\Rightarrow$ values for W10x19 (Page 8)

$A_w = (0.250\text{ in})(10.2\text{ in})$

$A_w = 2.55\text{ in}^2$

$V_n = 0.6\,(50\text{ ksi})(2.55\text{ in}^2)$

$V_n = 76{,}500$ lbs

2,802 lb. ≤ 76,500 lb. okay ✓

FLEXURAL STRENGTH CHECK

$M_u \leq \phi M_n$

$M_u = 10{,}996$ ft·lb

$\phi = 0.9$

$M_{n_y} = F_y Z_y$ and $M_{n_x} = F_y Z_x$

$F_y = 50$ ksi $\quad Z_y = 3.35\text{ in}^3 \quad Z_x = 21.6\text{ in}^3$

$M_{n_y} = (50\text{ ksi})(3.35\text{ in}^3)$

$M_{n_y} = 167{,}500$ in·lb.

$10{,}996\text{ ft·lb} \leq (0.9)(167{,}500\text{ in·lb})\left(\frac{1\text{ ft}}{12\text{ in}}\right)$

10,996 ft·lb ≤ 12,563 ft·lb okay ✓

$M_{n_x} = (50\text{ ksi})(21.6\text{ in}^3)$

$M_{n_x} = 1{,}080{,}000$ in·lb

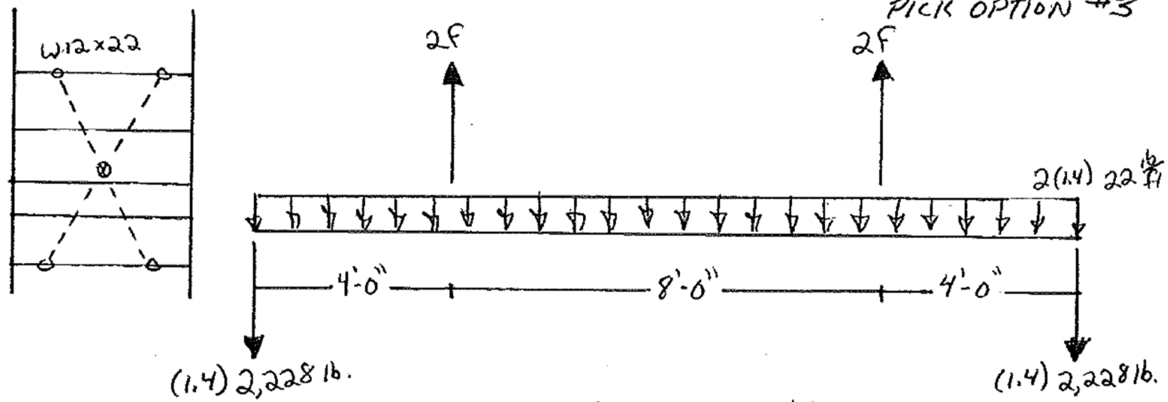
$10{,}996\text{ ft·lb} \leq (0.9)(1{,}080{,}000\text{ in·lb})\left(\frac{1\text{ ft}}{12\text{ in}}\right)$

10,996 ft·lb ≤ 81,000 ft·lb okay ✓

ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

CHECKING FLEXURAL+SHEAR STRENGTH OF MIDDLE FLOOR SECTION

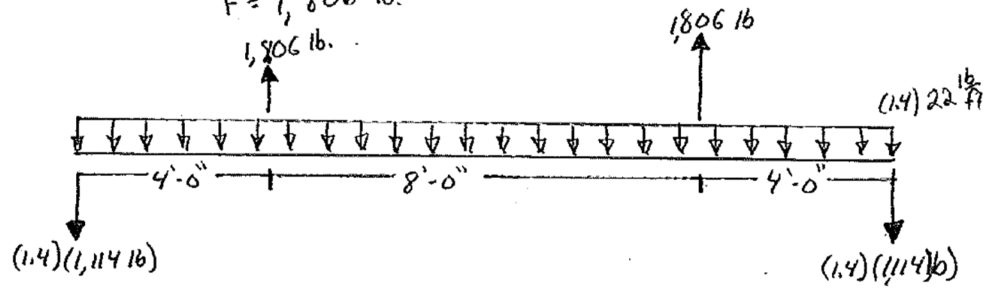
PICK OPTION #3

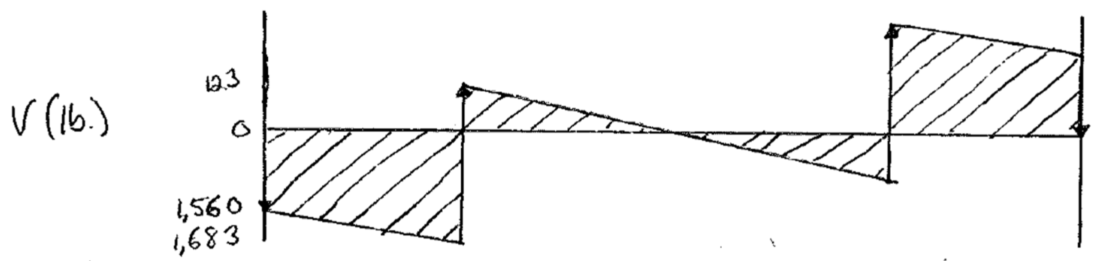


$$\Sigma F_y = 4F - 2(1.4)(2{,}228) - 2(1.4)(22\ \tfrac{lb}{ft})(16') = 0$$

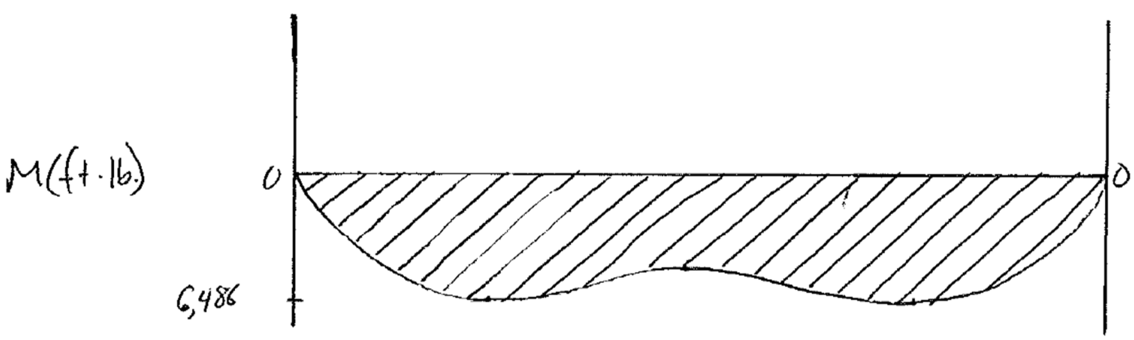
$$F = 1{,}806\ lb.$$

SINGLE W12x22





$$M_{Max} = 1560(4') + 123(4')(\tfrac{1}{2}) = 6{,}486\ ft \cdot lb.$$



ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

MIDDLE FLOOR SECTION PICK OPTION #3

*Reference Material from AE 404

Pages from AISC Steel Manual, 14th Ed.

SHEAR STRENGTH CHECK

$V_u \le \phi V_n$

$V_u = 1{,}683$ lb.

$\phi = 1.0$

$V_n = 95{,}940$ lb. (see V_n calculation in PICK OPTION #1)

$1{,}683\text{ lb} \le 95{,}940\text{ lb}$ okay ✓

FLEXURAL STRENGTH CHECK

$M_u \le \phi M_n$

$M_u = 6{,}486$ ft·lb

$\phi = 0.9$

(see $M_{ny} + M_{nx}$ calculations in PICK OPTION #1)

$M_{ny} = 183{,}000$ in·lb and $M_{nx} = 1{,}465{,}000$ in·lb

$6{,}486\text{ ft·lb} \le (0.9)(183{,}000\text{ in·lb})\left(\frac{1\text{ ft}}{12\text{ in}}\right)$

$6{,}486\text{ ft·lb} \le 13{,}725\text{ ft·lb}$ okay ✓

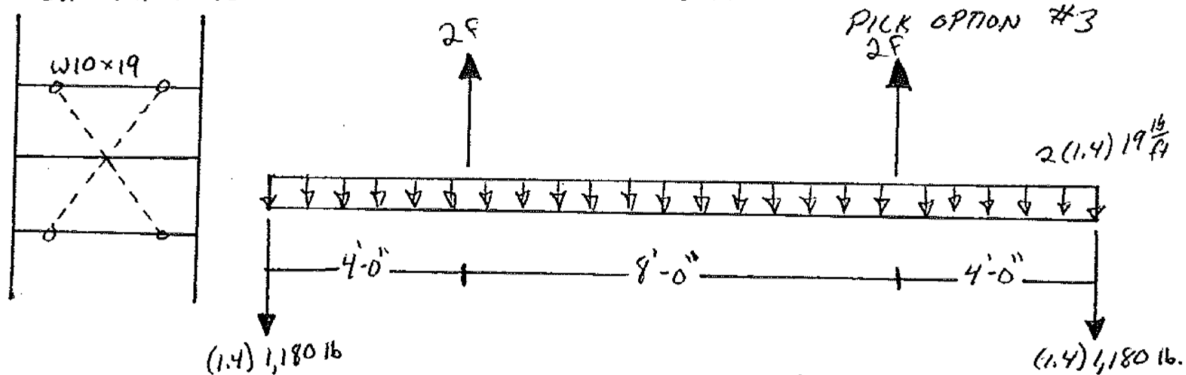
$6{,}486\text{ ft·lb} \le (0.9)(1{,}465{,}000\text{ in·lb})\left(\frac{1\text{ ft}}{12\text{ in}}\right)$

$6{,}486\text{ ft·lb} \le 109{,}875\text{ ft·lb}$ okay ✓

ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

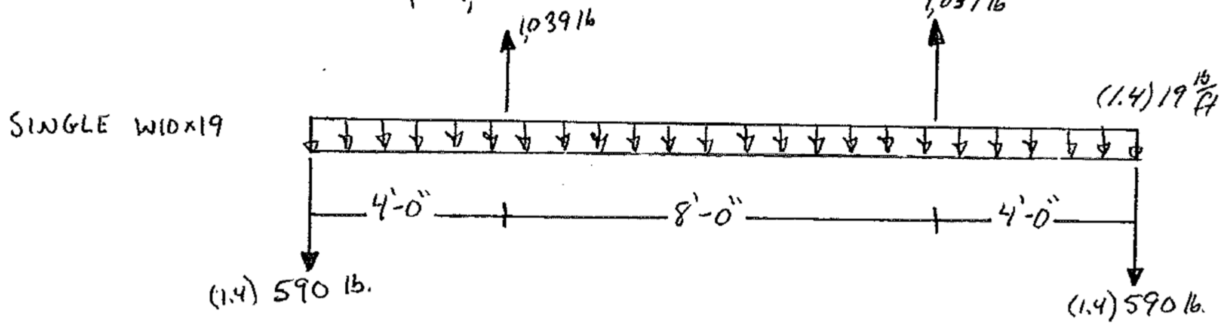
CHECKING FLEXURAL + SHEAR STRENGTH OF SOUTH ROOF SECTION

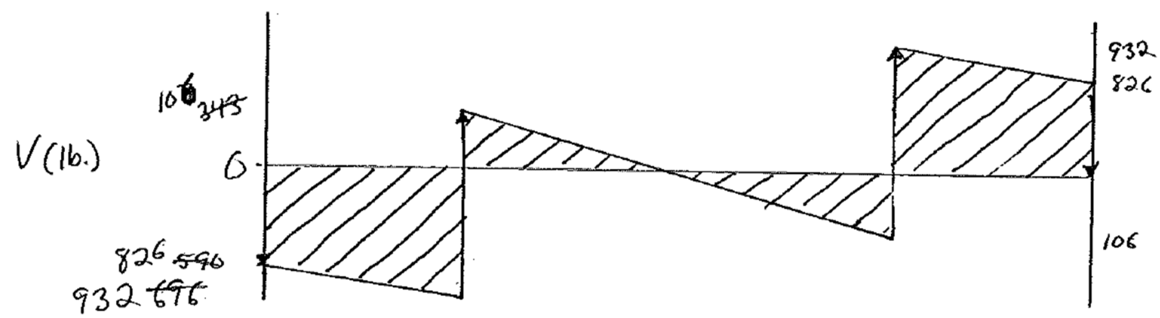
PICK OPTION #3



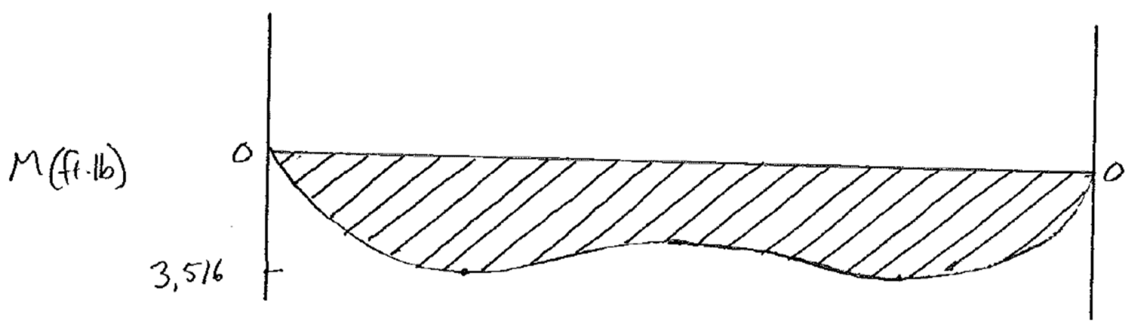
$\Sigma F_y = 4F - 2(1.4)\,1{,}180 - 2(1.4)(19\tfrac{lb}{ft})(16')$

$F = 1{,}039$ lb.





$M_{max} = 826(4') + 106(4')(\tfrac{1}{2}) = 3{,}516$ ft·lb.



ANALYSIS #4 STRUCTURAL BREADTH Joshua Miller 2015

SOUTH ROOF SECTION PICK OPTION #3
*Reference Materials from AE 404
Pages from AISC Steel Construction Manual, 14th Ed.

SHEAR STRENGTH CHECK

$V_u \leq \phi V_n$

$V_u = 932$ lb.

$\phi = 1.0$

$V_n = 76{,}500$ lbs. (see V_n calculations for SOUTH ROOF SECTION PICK OPTION #2)

932 lb ≤ 76,500 lb. okay ✓

FLEXURAL STRENGTH CHECK

$M_u \leq \phi M_n$

$M_u = 3{,}516$ ft·lb

$\phi = 0.9$

$M_{n_y} = F_y Z_y$ and $M_{n_x} = F_y Z_x$

$M_{n_y} = 167{,}500$ in·lb $M_{n_x} = 1{,}080{,}000$ in·lb

(see $M_{n_y} + M_{n_x}$ calculations for SOUTH ROOF SECTION PICK OPTION #3)

$3{,}516 \text{ ft·lb} \leq (0.9)(167{,}500 \text{ in·lb})\left(\frac{1 \text{ ft}}{12 \text{ in}}\right)$ $3{,}516 \text{ ft·lb} \leq (0.9)(1{,}080{,}000 \text{ in·lb})\left(\frac{1 \text{ ft}}{12 \text{ in}}\right)$

3,516 ft·lb ≤ 12,563 ft·lb okay ✓

3,516 ft·lb ≤ 81,000 ft·lb okay ✓

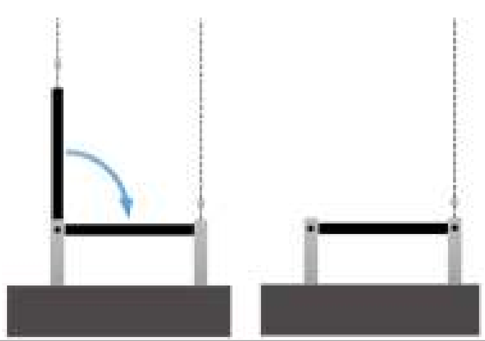
In summary of the structural breadth, all of the preassemblies are light enough to be lifted by the tower crane. When it came to the pick options, pick option #1 passed the shear strength test and the flexural test in the x-axis. The issue with pick option #1 though was that it failed the flexural test in the y-axis. This means that if the middle floor section was lifted using pick option #1 the W12x22 beam could potentially bend in the y-axis, therefore failing. Pick options #2 and #3 passed both the shear and flexural tests in both axial directions, meaning they are suitable pick options to implement.

Constructability/Safety Evaluation of Lift Methods

After conducting lift verifications on the proposed preassembled member sections, it was determined that preassembly of the bridge into sections is structurally possible for this project. Now in order to decide upon which pick option to move forward with, each option must be placed under scrutiny as to the means and methods of how each member will actually be installed and tightened up. Since pick option #1 failed to pass all of the structural tests, it will not be considered for a constructability and safety evaluation. This will leave only pick options #2 and #3 for these evaluations.

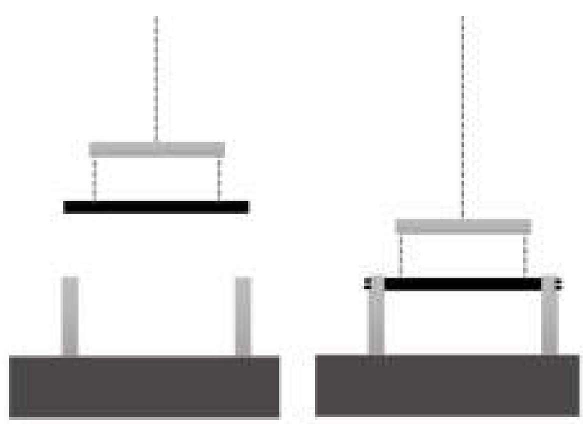
Pick Option #1: Not considered for evaluation

Pick Option #2: This pick option requires the use of two pick points located on the end member. The preassembled sections will be delivered to the site, laid up right on an angle on the bed of the delivery trucks trailer. The truck will take the members to the laydown and rigging area, where the tower crane will lift the members from the delivery truck. Once the member is in the air, the tower crane will move the preassembled members through the air until the member is directly over head its furthest south connection. The members will be lowered and pinned to the tie-in or roof girder members. Once pinned the crane can begin to lower the members again. Due to the pin connection the members will rotate until level. With all members level, the final connections can be made and tightened at both ends of the section.



Though this process seems reasonable and simple enough, there are several issues. For starters, when the members are being lifted off the delivery truck the tower crane will need to turn the preassembled sections up right. By turning the members upright, there is the potential for the members to swing or slide on the trailer's bed. This causes quite the safety concerns for the ironworkers that would need to hold tag lines to keep the members from swinging out of control. The most glaring issue with this pick option is when it comes to creating the necessary pin connection for the member to be lowered and rotated into place. The original connection suggested is not a pin connection at tie-in and roof columns, but instead the connection is a pin connection with the floor girders and the roof members have a moment connection with the roof girders. With a pin connection at the girder, the rotation is prevented in the desired axis to allow the member to be lowered into place. In order to utilize this pick option, new connections would have had to be designed by the structural engineer. Also from the safety stand point it would be even more difficult to perform this lowering rotation. Ironworkers would have to close by assisting the members to lower in the correct direction with taglines. As the members neared being level the potential for a pinch-point and crushing hazards greatly increase.

Pick Option #3: This pick option requires the use of four pick points with two pick points located on each of the two end members of each preassembled section. The members would preferably be delivered laying flat on the bed of the delivery truck, but more likely would be delivered upright and on an angle just like pick option #2. The members would be lifted off the trailer in the laydown and rigging area. With the members in the air and level, the tower crane would transport the members to their desired location on the connection bridge. Once the members are directly above their location, the tower crane will lower the members into there exact location. Once there, ironworkers will make the final four connections and tighten them up before the pick points are released and the crane rotates back to the laydown and rigging area for the next preassembled section.



When it comes to looking at this pick option in terms of its means and methods, this pick option has two main difficulties. The first is that when the members are delivered to site, they will most likely need to be up right and on their sides. This means that in order to perform the pick as suggested only two pick points on the same side of the section can be used, but must be attached with one attached to each of the two end members. This will allow the section to be picked up in a similar fashion as pick option #2 just the member would be rotated 90 degrees. Once the section is lifted off the delivery truck the other two pick points can be attached and the members re-lifted. This will allow the section to be level for installation. Having the members level for installation removes the need for the pin connection and the lowered rotation of the section. This removes the safety concerns with a massive swing preassembled section. The pinch and crushing hazards still exist at each of the four connections as normal with any steel installation. Overall this pick option appears to be the most practical and safest out of the three options proposed in this analysis.

Schedule Impact

In order to evaluate the potential schedule savings preassembling the different bridge sections could bring the overall project schedule, RS Means 2015 Facility Construction was utilized to put together an estimate for the necessary number of labor hours. First an estimate of the original construction activities was put together to determine how long it would take to construct the just the floor and roof portions of the connection bridge. This estimate included all the bolt connections and field wields that needed to occur to install all of the steel members. The second estimate only considered the bolt connections and field welds that would need to take place if each section was preassembled and all possible bolt connections and welds were completed prior to delivery. By preassembling a majority of angles and plates that originally needed to be bolted or welded in the field for each connection. The estimates can be seen on the following pages as well as a comparison between them.

Original Construction

RSMeans #		Unit	Quantity	Labor hrs/Unit	Total Labor Hr
	South/North Floor Section				
	Members				
051223.751302	W 12X22	LF	48	0.064	3.072
051223.175700	HSS 18X6X1/2	EA	2	1.167	2.334
	Welded Shear Studs				
	3-1/4 Dia. X 3-1/2"				
050523.870400	Studs	EA	48	0.016	0.768
	Clip Angles				
051223.400476	L 3-1/2x3-1/2	LF	6	0.421	2.526
	Plates				
051223.650450	3/4"X1'-0 1/2"	SF	4	0	0
051223.650400	1/2"X8"	SF	4	0	0
	Bolts				
050523.250220	3/4" dia. A325 Bolts	EA	34	0.07	2.38
SUBTOTAL					**11.08**
	Middle Floor Section				
	Members				
051223.751302	W 12X22	LF	80	0.064	5.12
051223.175700	HSS 18X6X1/2	EA	2	1.167	2.334
	Welded Shear Studs				
	3-1/4 Dia. X 3-1/2"				
050523.870400	Studs	EA	80	0.016	1.28
	Clip Angles				
051223.400476	L 3-1/2"x3-1/2"X1/4"	LF	10	0.421	4.21
	Plates				
051223.650450	3/4"X1'-0 1/2"	EA	4	0	0
051223.650400	1/2"X8"	EA	4	0	0
	Bolts				
050523.250220	3/4" dia. A325 Bolts	EA	46	0.07	3.22
SUBTOTAL					**16.164**
	Roof Section				
	Members				
051223.750702	W10X19	LF	48	0.093	4.464
051223.175700	HSS 12X6X1/2	EA	2	1.167	2.334
	Clip Angles				
051223.400476	L 3-1/2X3-1/2"X1/4"	LF	20	0.421	8.42
	Bolts				
050523.250220	3/4" Dia. A325 Bolts	EA	80	0.07	5.6
	Welds				
050521.900020	Field Weld	HR	8	1	8
SUBTOTAL					**28.818**

Preassembled Construction

RSMeans #		Unit	Quantity	Labor hrs/Unit	Total Labor Hr
	South/North Floor Section				
	Members				
051223.751302	W 12X22	LF	48	0.064	3.072
051223.175700	HSS 18X6X1/2	EA	2	1.167	2.334
	Bolts				
050523.250220	3/4" dia. A325 Bolts	EA	34	0.07	2.38
SUBTOTAL					**7.786**
	Middle Floor Section				
	Members				
051223.751302	W 12X22	LF	80	0.064	5.12
051223.175700	HSS 18X6X1/2	EA	2	1.167	2.334
	Bolts				
050523.250220	3/4" dia. A325 Bolts	EA	46	0.07	3.22
SUBTOTAL					**10.674**
	Roof Section				
	Members				
051223.750702	W10X19	LF	48	0.093	4.464
051223.175700	HSS 12X6X1/2	EA	2	1.167	2.334
	Clip Angles				
051223.400476	L 3-1/2X3-1/2"X1/4"	EA	8	0.421	3.368
	Bolts				
050523.250220	3/4" Dia. A325 Bolts	EA	32	0.07	2.24
	Welds				
050521.900020	Field Welds	HR	8	1	8
SUBTOTAL					**20.406**

Original Construction

	Labor Hours
South Floor Section	11.08
Middle Floor Section	16.164
North Floor Section	11.08
South Roof Section	28.818
Middle Roof Section	28.818
North Roof Section	28.818
2nd North Roof Section	28.818
Total Labor Hours	**153.596**

Preassembled Construction

	Labor Hours
South Floor Section	7.786
Middle Floor Section	10.674
North Floor Section	7.786
South Roof Section	20.406
Middle Roof Section	20.406
North roof Section	20.406
2nd North Roof Section	20.406
Total Labor Hours	**107.87**

Method	Duration (Days)
Original Construction	19.2
Preassembled Construction	13.5
Potential On-Site Savings	**5.7**

Recommendations

Based on the analysis of potentially implementing the preassembly of steel sections of the connection bridge, this method has the potential of reducing the amount of time necessary for completing the bridge by almost 6 days. At the same time preassembly of members reduces the number of connections ironworkers need to make in the field at excessive heights and putting themselves at risk of pinch points and crushing hazards. This method also allows work to be completed indoors where weather would have less effect on impacting the project schedule. Though this factor cannot really be quantified or estimated as to its exact impact it is another benefit this method allows. The potential down side to this method is that earlier planning and involvement would be needed. Earlier involvement and more upfront planning could add additional costs since the steel erector and fabricator would need to be in communication with the project team sooner. Though with more planning and involvement it is possible more savings could be found in the process out-weighing the additional costs. Overall with the safer environment and schedule savings, preassembling steel members should be considered for future projects.

Conclusion

After conducting these analyses of implementing more IPD methods, installing a shared wet wall between patient rooms, utilizing SIPS for more efficient project scheduling and labor loading, and preassembling steel bridge sections prior to their installation conclusions have been made as to each analyses' effectiveness.

Analysis #1: IDP Methods Implementation

After researching several case studies of other healthcare project across the United States and one project in which a subcontractor on this job is currently involved in, many IDP methods have successfully made project more successful. Due to these successes and the want for a more integrate project approach, the Northeast Hospital Expansion would have benefitted greatly from the utilization of a multi-party contract, risk and reward pooling, and part-time co-location.

Analysis #2: Patient room Re-Design for Shared Wet Wall

The re-design of the patient rooms was highly successful in reducing the project schedule and reducing overall plumbing costs. Based on the adjusted schedule, a shared wet wall would have saved the project 93 days. The revised estimate proves a cost reduction of $475,507.07overall, or $5283.42 per room in labor and materials. For these reasons, the re-design was highly recommended.

Analysis #3: SIPS Utilization for Patient Floors

Employing SIPS to the patient floors four, five, and six, resulted in a massive schedule acceleration and minor cost saves. By adjusting crew sizes and specifying smaller uniform work zones, the project was able to be completed 18 weeks ahead of schedule and compared to the original project schedule generated $12,097.20 in savings. Due to these savings and acceleration SIPS was recommended.

Analysis #4: Preassembled Steel Connection Bridge

Breaking the steel connection bridge into different sections for preassembly prior to lifting created a minor schedule acceleration of 6 days. Though this process did not produce major quantitative benefits, it does make the job site a safer environment. By reducing the number of connections required to make at a high elevation, iron workers are exposed to far less risk. For this reason, preassembly of the steel connection bridge is recommended for the Northeast Hospital Expansion.

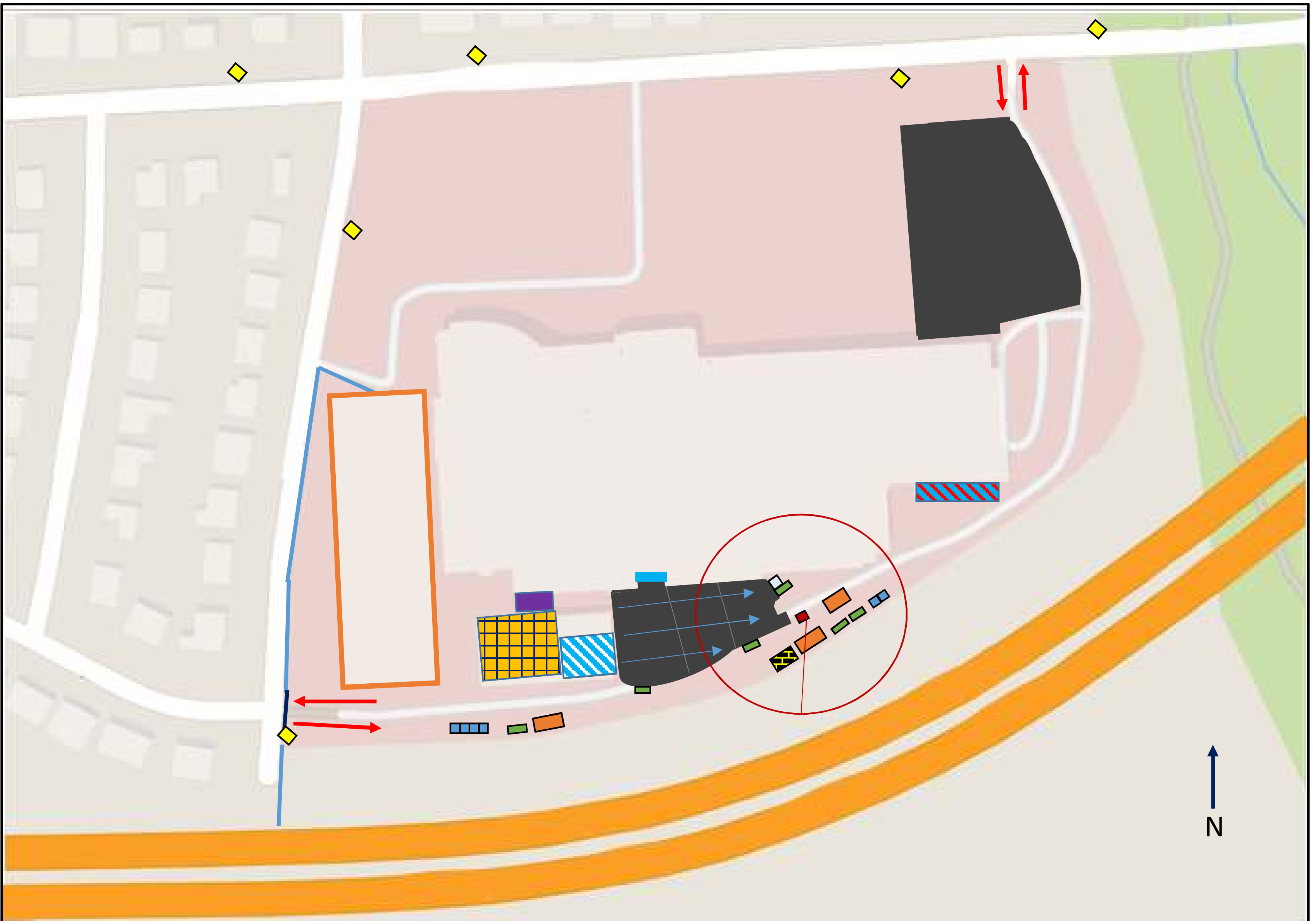
Appendix A: Building Information

Northeast Hospital Expansion

Phase: Excavation

LEGEND

- Construction Foot Print
- Temporary CUP
- Parking Deck
- Whiting-Turner's Offices
- Subcontractor Offices
- Portable Toilet
- Dumpsters
- Signage
- Fence
- Delivery entrances/exits
- Tower Crane Pad
- Laydown areas
- Ambulance Emergency Entrance
- Concrete mixing station
- Dump Truck
- Excavator
- Soldier Piles and Lagging



Northeast Hospital Expansion

Phase: Superstructure

LEGEND

- Construction Foot Print
- Temporary CUP
- Parking Deck
- Whiting-Turner's Offices
- Subcontractor Offices
- Portable Toilet
- Dumpsters
- Signage
- Fence
- Delivery entrances/exits
- Flow of Trades
- Sticky Mats/Dust Partition
- Material Hoist
- Tower Crane
- Laydown areas
- Ambulance Emergency Entrance
- Concrete mixing station

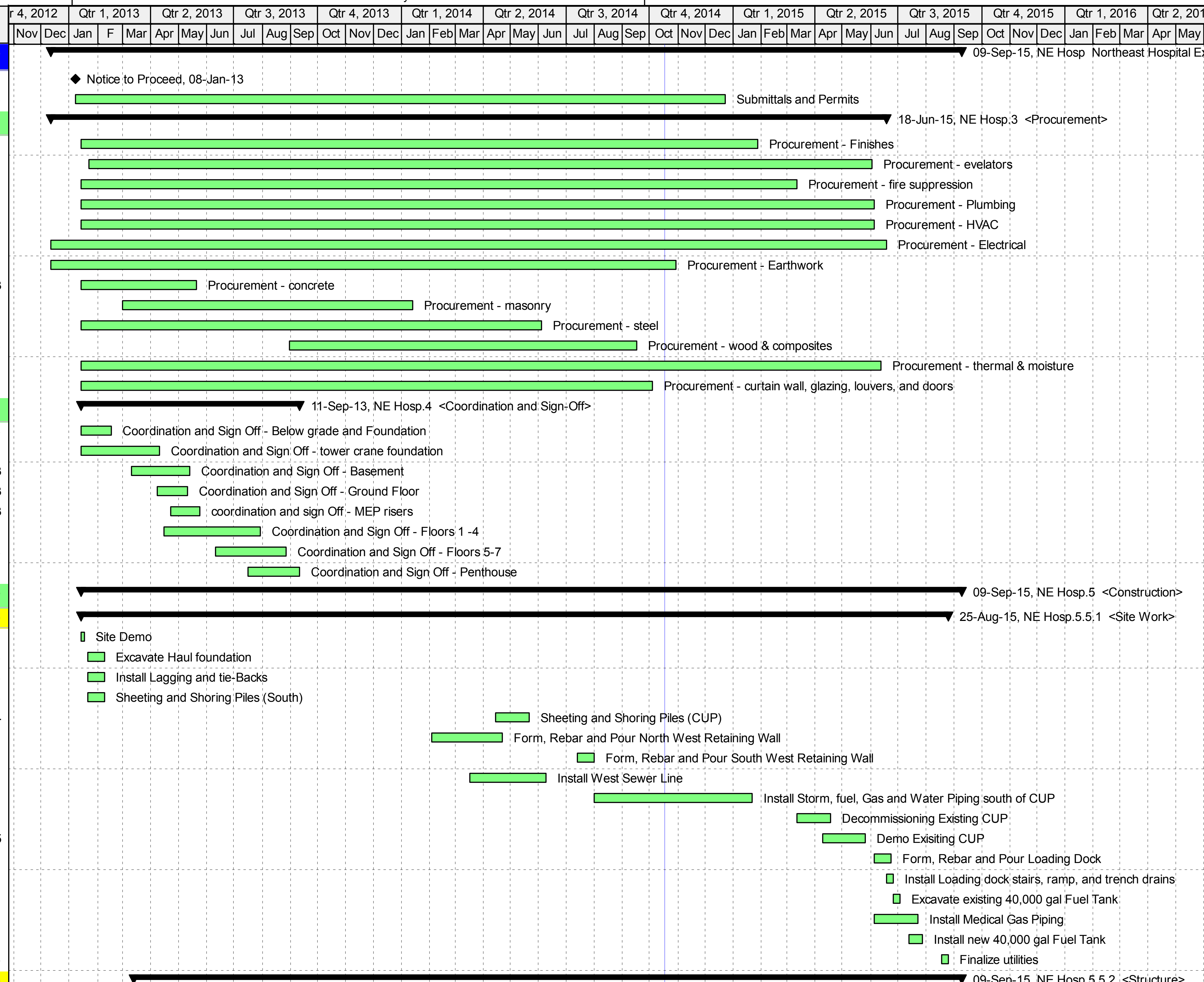
Northeast Hospital Expansion

Phase: MEP & Finishes

LEGEND

- Construction Foot Print
- Temporary CUP
- Parking Deck
- Whiting-Turner's Offices
- Subcontractor Offices
- Portable Toilet
- Dumpsters
- Signage
- Fence
- Delivery entrances/exits
- Flow of Trades
- Sticky Mats/Dust Partition
- Laydown areas
- Ambulance Emergency Entrance

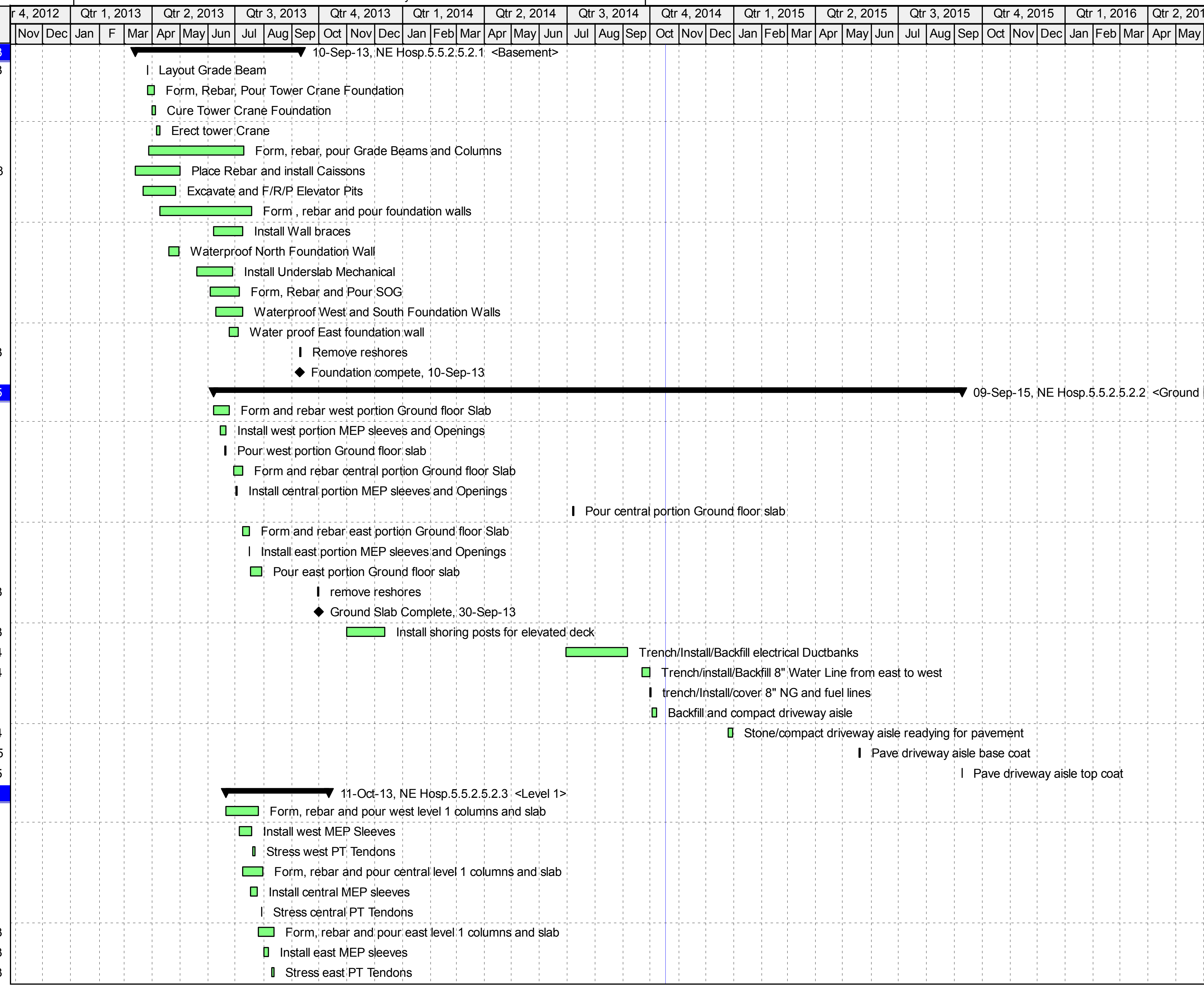
Activity ID	Activity Name	Original Duration	Start	Finish
NE Hosp	**Northeast Hospital I**	733	12-Dec-12	09-Sep-15
1	Notice to Proceed	0	08-Jan-13	
2	Submittals and Permits	511	08-Jan-13	23-Dec-14
NE Hosp.3	**<Procurement>**	657	12-Dec-12	18-Jun-15
10	Procurement - Finishes	532	14-Jan-13	27-Jan-15
11	Procurement - evelators	615	23-Jan-13	02-Jun-15
12	Procurement - fire suppres	563	14-Jan-13	11-Mar-15
13	Procurement - Plumbing	624	14-Jan-13	04-Jun-15
14	Procurement - HVAC	624	14-Jan-13	04-Jun-15
15	Procurement - Electrical	657	12-Dec-12	18-Jun-15
16	Procurement - Earthwork	491	12-Dec-12	29-Oct-14
4	Procurement - concrete	91	14-Jan-13	20-May-13
5	Procurement - masonry	227	01-Mar-13	13-Jan-14
6	Procurement - steel	363	14-Jan-13	04-Jun-14
7	Procurement - wood & con	272	31-Aug-13	16-Sep-14
8	Procurement - thermal & m	630	14-Jan-13	12-Jun-15
9	Procurement - curtain wall,	450	14-Jan-13	03-Oct-14
NE Hosp.4	**<Coordination anc**	173	14-Jan-13	11-Sep-13
18	Coordination and Sign Off -	25	14-Jan-13	15-Feb-13
19	Coordination and Sign Off -	63	14-Jan-13	10-Apr-13
20	Coordination and Sign Off -	46	11-Mar-13	13-May-13
21	Coordination and Sign Off -	25	08-Apr-13	10-May-13
22	coordination and sign Off -	25	22-Apr-13	24-May-13
23	Coordination and Sign Off -	77	15-Apr-13	30-Jul-13
24	Coordination and Sign Off -	56	11-Jun-13	27-Aug-13
25	Coordination and Sign Off -	41	17-Jul-13	11-Sep-13
NE Hosp.5	**<Construction>**	710	14-Jan-13	09-Sep-15
NE Hosp.5.5.1	**<Site Work>**	682	14-Jan-13	25-Aug-15
29	Site Demo	4	14-Jan-13	17-Jan-13
30	Excavate Haul foundation	15	21-Jan-13	08-Feb-13
31	Install Lagging and tie-Back	15	21-Jan-13	08-Feb-13
32	Sheeting and Shoring Piles	15	21-Jan-13	08-Feb-13
33	Sheeting and Shoring Piles	27	15-Apr-14	21-May-14
34	Form, Rebar and Pour Nor	55	04-Feb-14	21-Apr-14
35	Form, Rebar and Pour Sou	14	14-Jul-14	31-Jul-14
36	Install West Sewer Line	61	17-Mar-14	09-Jun-14
37	Install Storm, fuel, Gas and	124	01-Aug-14	21-Jan-15
38	Decommissioning Existing (	27	12-Mar-15	17-Apr-15
39	Demo Exisiting CUP	34	09-Apr-15	26-May-15
40	Form, Rebar and Pour Loa	13	05-Jun-15	23-Jun-15
41	Install Loading dock stairs,	6	19-Jun-15	26-Jun-15
42	Excavate existing 40,000 ga	6	26-Jun-15	03-Jul-15
43	Install Medical Gas Piping	35	05-Jun-15	23-Jul-15
44	Install new 40,000 gal Fuel	11	13-Jul-15	27-Jul-15
45	Finalize utilities	6	18-Aug-15	25-Aug-15
NE Hosp.5.5.2	**<Structure>**	651	13-Mar-13	09-Sep-15



Actual Level of Effort | Remaining Work | Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

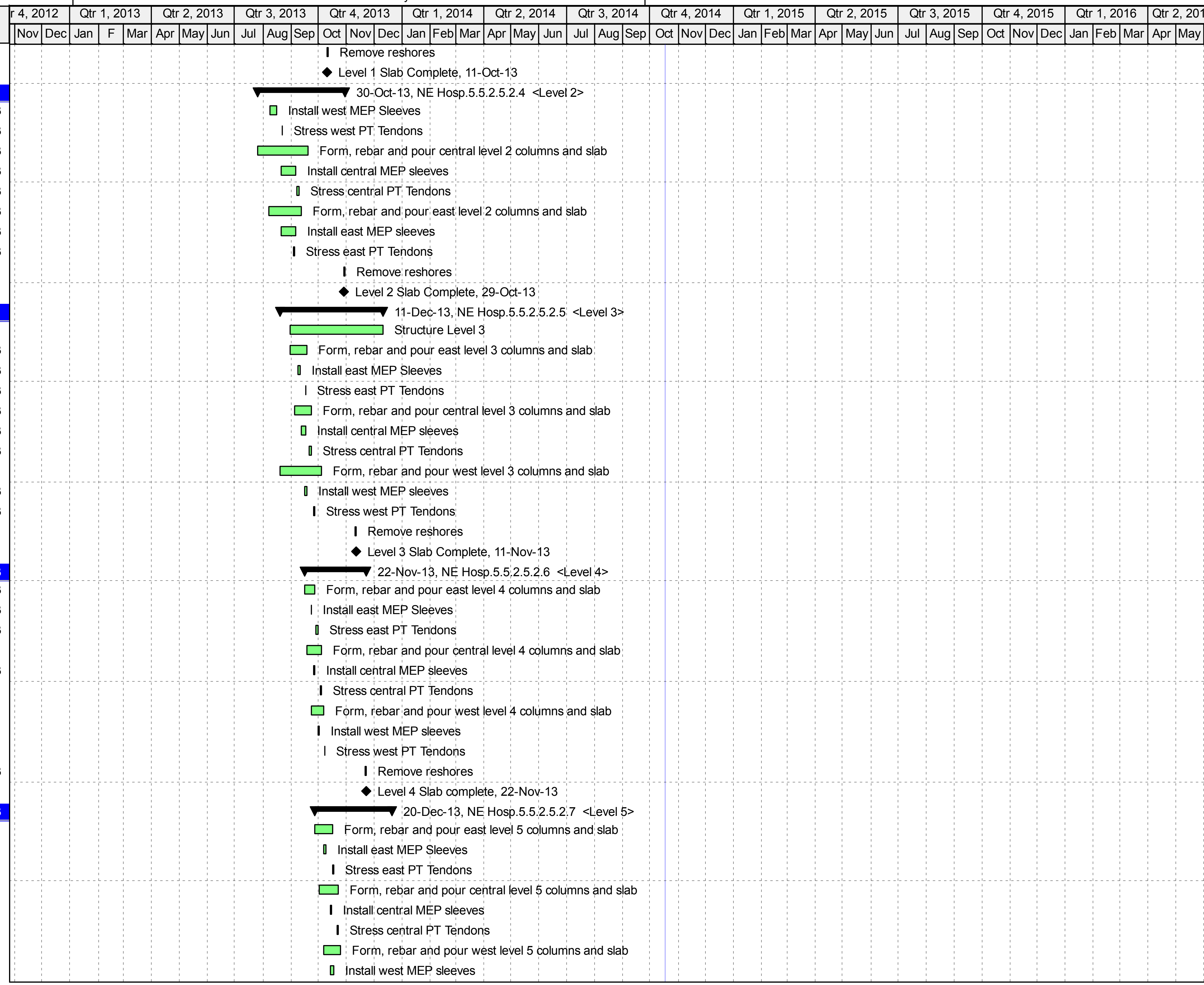
Activity ID	Activity Name	Original Duration	Start	Finish
NE Hosp.5.5.2.5.2.1 <Basement>		**130**	**13-Mar-13**	**10-Sep-13**
48	Layout Grade Beam	1	26-Mar-13	26-Mar-13
49	Form, Rebar, Pour Tower (	5	27-Mar-13	02-Apr-13
50	Cure Tower Crane Founda	3	01-Apr-13	03-Apr-13
51	Erect tower Crane	2	05-Apr-13	08-Apr-13
52	Form, rebar, pour Grade B	75	28-Mar-13	10-Jul-13
53	Place Rebar and install Cai	36	13-Mar-13	01-May-13
54	Excavate and F/R/P Elevat	26	21-Mar-13	25-Apr-13
55	Form , rebar and pour four	73	09-Apr-13	18-Jul-13
56	Install Wall braces	22	07-Jun-13	08-Jul-13
57	Waterproof North Foundat	7	19-Apr-13	29-Apr-13
58	Install Underslab Mechanic	29	20-May-13	27-Jun-13
59	Form, Rebar and Pour SO	25	03-Jun-13	05-Jul-13
60	Waterproof West and Sout	22	10-Jun-13	09-Jul-13
61	Water proof East foundatio	8	24-Jun-13	03-Jul-13
62	Remove reshores	1	10-Sep-13	10-Sep-13
63	Foundation compete	0	10-Sep-13	
NE Hosp.5.5.2.5.2.2 <Ground Floor>		**589**	**07-Jun-13**	**09-Sep-15**
65	Form and rebar west portic	12	07-Jun-13	24-Jun-13
66	Install west portion MEP sle	5	14-Jun-13	20-Jun-13
67	Pour west portion Ground f	1	20-Jun-13	20-Jun-13
68	Form and rebar central por	6	29-Jun-13	08-Jul-13
69	Install central portion MEP :	1	02-Jul-13	02-Jul-13
70	Pour central portion Groun	1	08-Jul-14	08-Jul-14
71	Form and rebar east portio	6	09-Jul-13	16-Jul-13
72	Install east portion MEP sle	1	16-Jul-13	16-Jul-13
73	Pour east portion Ground fl	8	18-Jul-13	29-Jul-13
74	remove reshores	1	30-Sep-13	30-Sep-13
75	Ground Slab Complete	0	30-Sep-13	
76	Install shoring posts for ele\	30	01-Nov-13	12-Dec-13
77	Trench/Install/Backfill electr	50	30-Jun-14	05-Sep-14
78	Trench/install/Backfill 8" Wa	7	22-Sep-14	30-Sep-14
79	trench/Install/cover 8" NG a	2	30-Sep-14	01-Oct-14
80	Backfill and compact drivew	3	03-Oct-14	07-Oct-14
81	Stone/compact driveway ai:	3	26-Dec-14	30-Dec-14
82	Pave driveway aisle base c	1	19-May-15	19-May-15
83	Pave driveway aisle top coa	1	09-Sep-15	09-Sep-15
NE Hosp.5.5.2.5.2.3 <Level 1>		**81**	**21-Jun-13**	**11-Oct-13**
86	Form, rebar and pour west	26	21-Jun-13	26-Jul-13
87	Install west MEP Sleeves	10	05-Jul-13	18-Jul-13
88	Stress west PT Tendons	1	20-Jul-13	22-Jul-13
89	Form, rebar and pour centi	17	09-Jul-13	31-Jul-13
90	Install central MEP sleeves	6	18-Jul-13	25-Jul-13
91	Stress central PT Tendons	1	30-Jul-13	30-Jul-13
92	Form, rebar and pour east	11	27-Jul-13	12-Aug-13
93	Install east MEP sleeves	4	01-Aug-13	06-Aug-13
94	Stress east PT Tendons	1	10-Aug-13	12-Aug-13



Actual Level of Effort | Remaining Work | ◆ Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish
95	Remove reshores	1	11-Oct-13	11-Oct-13
96	Level 1 Slab Complete	0	11-Oct-13	
NE Hosp.5.5.2.5.2.4 <Level 2>		**68**	**27-Jul-13**	**30-Oct-13**
100	Install west MEP Sleeves	6	09-Aug-13	16-Aug-13
101	Stress west PT Tendons	1	22-Aug-13	22-Aug-13
102	Form, rebar and pour centi	39	27-Jul-13	19-Sep-13
103	Install central MEP sleeves	12	21-Aug-13	05-Sep-13
104	Stress central PT Tendons	1	07-Sep-13	09-Sep-13
105	Form, rebar and pour east	26	08-Aug-13	12-Sep-13
106	Install east MEP sleeves	12	21-Aug-13	05-Sep-13
107	Stress east PT Tendons	1	04-Sep-13	04-Sep-13
108	Remove reshores	2	29-Oct-13	30-Oct-13
109	Level 2 Slab Complete	0	29-Oct-13	
NE Hosp.5.5.2.5.2.5 <Level 3>		**82**	**20-Aug-13**	**11-Dec-13**
111	Structure Level 3	73	31-Aug-13	11-Dec-13
112	Form, rebar and pour east	13	31-Aug-13	18-Sep-13
113	Install east MEP Sleeves	2	09-Sep-13	10-Sep-13
114	Stress east PT Tendons	1	17-Sep-13	17-Sep-13
115	Form, rebar and pour centi	13	05-Sep-13	23-Sep-13
116	Install central MEP sleeves	4	12-Sep-13	17-Sep-13
117	Stress central PT Tendons	1	21-Sep-13	23-Sep-13
118	Form, rebar and pour west	34	20-Aug-13	04-Oct-13
119	Install west MEP sleeves	3	16-Sep-13	18-Sep-13
120	Stress west PT Tendons	1	26-Sep-13	26-Sep-13
121	Remove reshores	1	11-Nov-13	11-Nov-13
122	Level 3 Slab Complete	0	11-Nov-13	
NE Hosp.5.5.2.5.2.6 <Level 4>		**50**	**16-Sep-13**	**22-Nov-13**
125	Form, rebar and pour east	10	16-Sep-13	27-Sep-13
126	Install east MEP Sleeves	1	23-Sep-13	23-Sep-13
127	Stress east PT Tendons	1	28-Sep-13	30-Sep-13
128	Form, rebar and pour centi	12	19-Sep-13	04-Oct-13
129	Install central MEP sleeves	1	26-Sep-13	26-Sep-13
130	Stress central PT Tendons	1	04-Oct-13	04-Oct-13
131	Form, rebar and pour west	10	24-Sep-13	07-Oct-13
132	Install west MEP sleeves	1	01-Oct-13	01-Oct-13
133	Stress west PT Tendons	1	08-Oct-13	08-Oct-13
134	Remove reshores	1	22-Nov-13	22-Nov-13
135	Level 4 Slab complete	0	22-Nov-13	
NE Hosp.5.5.2.5.2.7 <Level 5>		**61**	**27-Sep-13**	**20-Dec-13**
138	Form, rebar and pour east	14	27-Sep-13	16-Oct-13
139	Install east MEP Sleeves	3	07-Oct-13	09-Oct-13
140	Stress east PT Tendons	1	17-Oct-13	17-Oct-13
141	Form, rebar and pour centi	16	02-Oct-13	23-Oct-13
142	Install central MEP sleeves	2	14-Oct-13	15-Oct-13
143	Stress central PT Tendons	1	22-Oct-13	22-Oct-13
144	Form, rebar and pour west	15	07-Oct-13	25-Oct-13
145	Install west MEP sleeves	3	15-Oct-13	17-Oct-13



Actual Level of Effort | Remaining Work | Milestone
Actual Work | Critical Remaining Work | summary

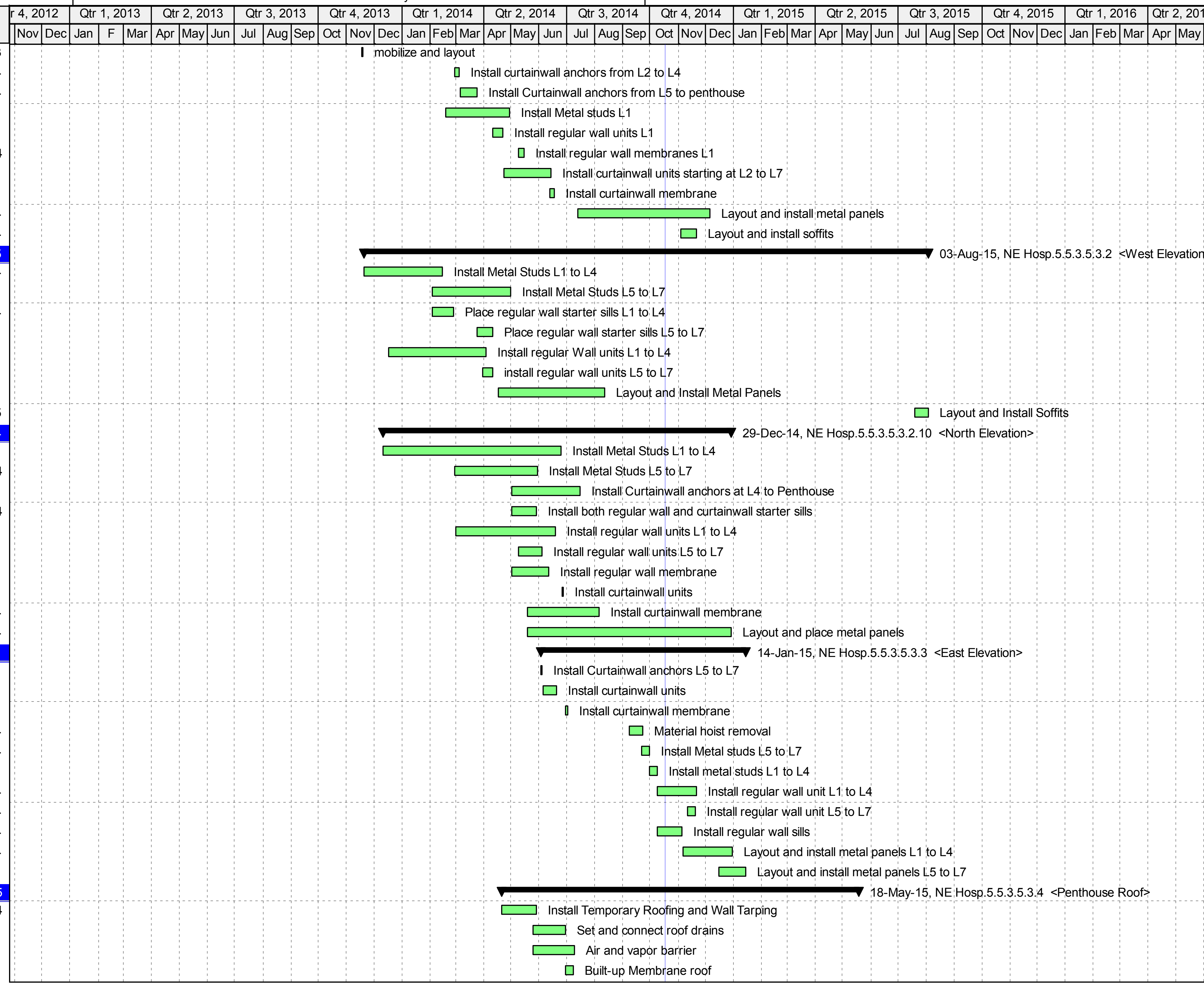
TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish
146	Stress west PT Tendons	1	25-Oct-13	25-Oct-13
147	Remove reshores	10	09-Dec-13	20-Dec-13
148	Level 5 Slab Complete	0	19-Dec-13	
NE Hosp.5.5.2.5.2.8 <Level 6>		**61**	**15-Oct-13**	**07-Jan-14**
151	Form, rebar and pour east	13	15-Oct-13	31-Oct-13
152	Install east MEP Sleeves	3	22-Oct-13	24-Oct-13
153	Stress east PT Tendons	1	31-Oct-13	31-Oct-13
154	Form, rebar and pour centi	9	21-Oct-13	31-Oct-13
155	Install central MEP sleeves	3	25-Oct-13	29-Oct-13
156	Stress central PT Tendons	1	02-Nov-13	04-Nov-13
157	Form, rebar and pour west	12	23-Oct-13	07-Nov-13
158	Install west MEP sleeves	2	30-Oct-13	31-Oct-13
159	Stress west PT Tendons	1	07-Nov-13	07-Nov-13
160	Remove reshores	20	11-Dec-13	07-Jan-14
161	Level 7 Slab Complete	0	06-Jan-14	
NE Hosp.5.5.2.5.2.9 <Level 7>		**47**	**29-Oct-13**	**01-Jan-14**
164	Form, rebar and pour east	10	29-Oct-13	11-Nov-13
165	Install east MEP Sleeves	2	04-Nov-13	05-Nov-13
166	Stress east PT Tendons	1	12-Nov-13	12-Nov-13
167	Form, rebar and pour centi	12	31-Oct-13	15-Nov-13
168	Install central MEP sleeves	4	05-Nov-13	08-Nov-13
169	Stress central PT Tendons	1	15-Nov-13	15-Nov-13
170	Form, rebar and pour west	10	05-Nov-13	18-Nov-13
171	Install west MEP sleeves	2	11-Nov-13	12-Nov-13
172	Stress west PT Tendons	1	19-Nov-13	19-Nov-13
173	Remove reshores	2	31-Dec-13	01-Jan-14
174	Level 7 slab Complete	0	31-Dec-13	
NE Hosp.5.5.2.5.2.10 <Penthouse>		**186**	**11-Nov-13**	**28-Jul-14**
177	Form, rebar and pour east	11	11-Nov-13	25-Nov-13
178	Install east MEP Sleeves	2	18-Nov-13	19-Nov-13
179	Stress east PT Tendons	1	26-Nov-13	26-Nov-13
180	Form, rebar and pour centi	20	13-Nov-13	10-Dec-13
181	Install central MEP sleeves	6	20-Nov-13	27-Nov-13
182	Stress central PT Tendons	1	06-Dec-13	06-Dec-13
183	Form, rebar and pour west	19	18-Nov-13	12-Dec-13
184	Install west MEP sleeves	1	02-Dec-13	02-Dec-13
185	Stress west PT Tendons	1	10-Dec-13	10-Dec-13
186	Remove reshores	3	03-Jan-14	07-Jan-14
187	Erect East Columns and Be	18	13-Jan-14	05-Feb-14
188	Erect Central Columns and	6	04-Feb-14	11-Feb-14
189	Erect West columns and Be	6	11-Feb-14	18-Feb-14
190	Detail columns and Beams	34	04-Feb-14	21-Mar-14
191	Top Out	0	20-Mar-14	
192	Remove tower Crane	4	09-Jul-14	14-Jul-14
193	Infill tower Crane	11	14-Jul-14	28-Jul-14
NE Hosp.5.5.3 <Envelope>		**446**	**18-Nov-13**	**03-Aug-15**
NE Hosp.5.5.3.5.3.1 <South Elevati		**275**	**18-Nov-13**	**05-Dec-14**

Actual Level of Effort | Remaining Work | Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

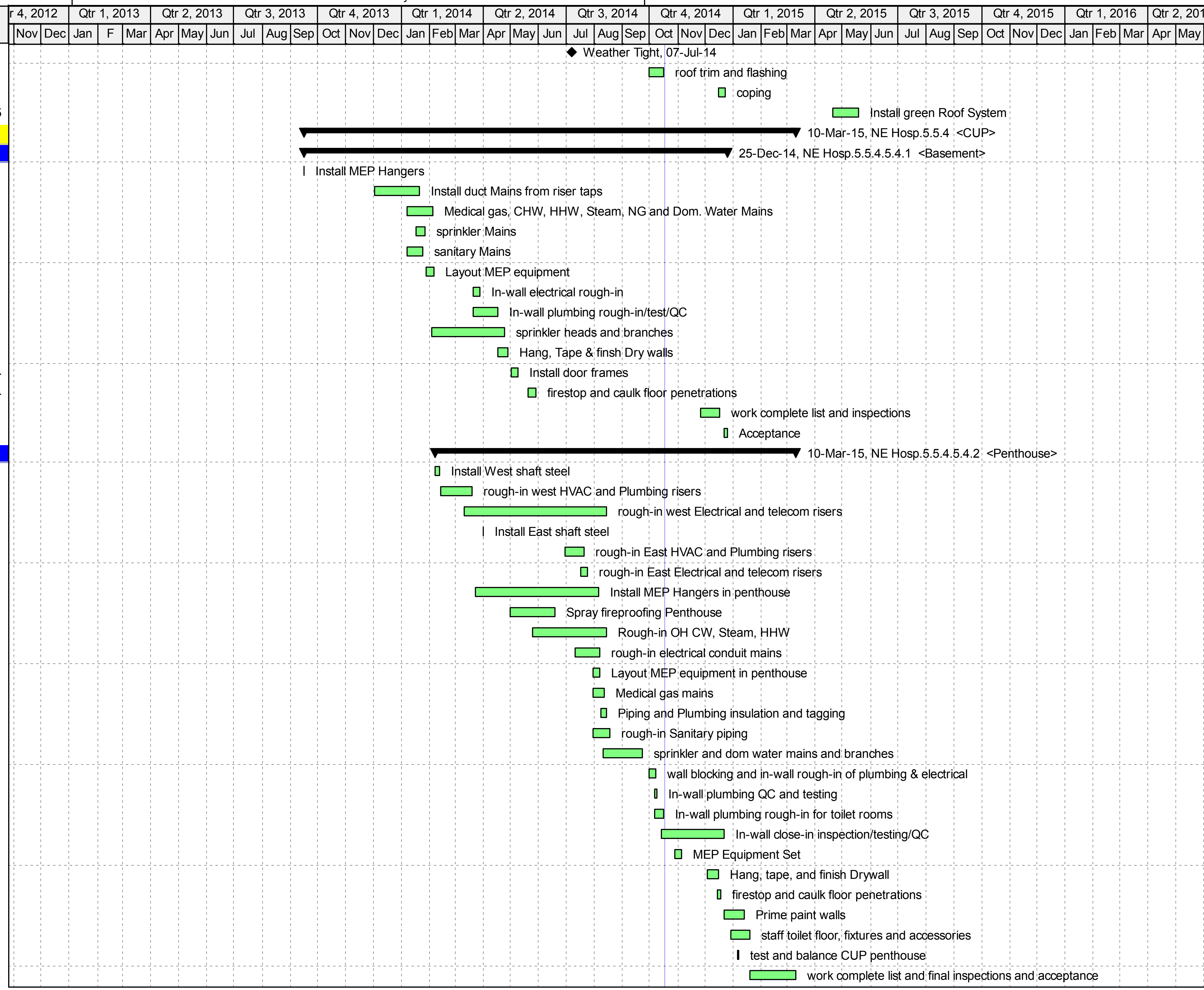
Activity ID	Activity Name	Original Duration	Start	Finish
197	mobilize and layout	1	18-Nov-13	18-Nov-13
198	Install curtainwall anchors fi	4	28-Feb-14	05-Mar-14
199	Install Curtainwall anchors f	13	06-Mar-14	24-Mar-14
200	Install Metal studs L1	51	18-Feb-14	29-Apr-14
201	Install regular wall units L1	7	11-Apr-14	21-Apr-14
202	Install regular wall membra	5	09-May-14	15-May-14
203	Install curtainwall units start	37	24-Apr-14	13-Jun-14
204	Install curtainwall membran	3	13-Jun-14	17-Jun-14
205	Layout and install metal pa	105	14-Jul-14	05-Dec-14
206	Layout and install soffits	14	04-Nov-14	20-Nov-14
NE Hosp.5.5.3.5.3.2 <West Elevatio		**443**	**21-Nov-13**	**03-Aug-15**
209	Install Metal Studs L1 to L4	62	21-Nov-13	14-Feb-14
210	Install Metal Studs L5 to L7	62	04-Feb-14	30-Apr-14
211	Place regular wall starter si	17	04-Feb-14	26-Feb-14
212	Place regular wall starter si	13	25-Mar-14	10-Apr-14
213	Install regular Wall units L1	77	18-Dec-13	03-Apr-14
214	install regular wall units L5 t	9	31-Mar-14	10-Apr-14
215	Layout and Install Metal Pa	83	17-Apr-14	11-Aug-14
216	Layout and Install Soffits	11	20-Jul-15	03-Aug-15
NE Hosp.5.5.3.5.3.2.10 <North Elev		**274**	**11-Dec-13**	**29-Dec-14**
219	Install Metal Studs L1 to L4	140	11-Dec-13	24-Jun-14
220	Install Metal Studs L5 to L7	66	28-Feb-14	30-May-14
221	Install Curtainwall anchors a	54	02-May-14	16-Jul-14
222	Install both regular wall anc	20	02-May-14	29-May-14
223	Install regular wall units L1	79	01-Mar-14	19-Jun-14
224	Install regular wall units L5	19	09-May-14	04-Jun-14
225	Install regular wall membra	29	02-May-14	11-Jun-14
226	Install curtainwall units	2	26-Jun-14	27-Jun-14
227	Install curtainwall membran	57	19-May-14	05-Aug-14
228	Layout and place metal pa	161	19-May-14	29-Dec-14
NE Hosp.5.5.3.5.3.3 <East Elevatior		**162**	**03-Jun-14**	**14-Jan-15**
231	Install Curtainwall anchors I	1	03-Jun-14	03-Jun-14
232	Install curtainwall units	11	06-Jun-14	20-Jun-14
233	Install curtainwall membran	3	30-Jun-14	02-Jul-14
234	Material hoist removal	10	09-Sep-14	22-Sep-14
235	Install Metal studs L5 to L7	7	22-Sep-14	30-Sep-14
236	Install metal studs L1 to L4	8	30-Sep-14	09-Oct-14
237	Install regular wall unit L1 t	32	09-Oct-14	21-Nov-14
238	Install regular wall unit L5 t	7	11-Nov-14	19-Nov-14
239	Install regular wall sills	20	09-Oct-14	05-Nov-14
240	Layout and install metal pa	39	07-Nov-14	30-Dec-14
241	Layout and install metal pa	22	16-Dec-14	14-Jan-15
NE Hosp.5.5.3.5.3.4 <Penthouse Rc		**281**	**21-Apr-14**	**18-May-15**
244	Install Temporary Roofing a	28	21-Apr-14	28-May-14
245	Set and connect roof drains	26	25-May-14	30-Jun-14
246	Air and vapor barrier	33	25-May-14	09-Jul-14
247	Built-up Membrane roof	7	30-Jun-14	08-Jul-14



Actual Level of Effort | Remaining Work | ◆ Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

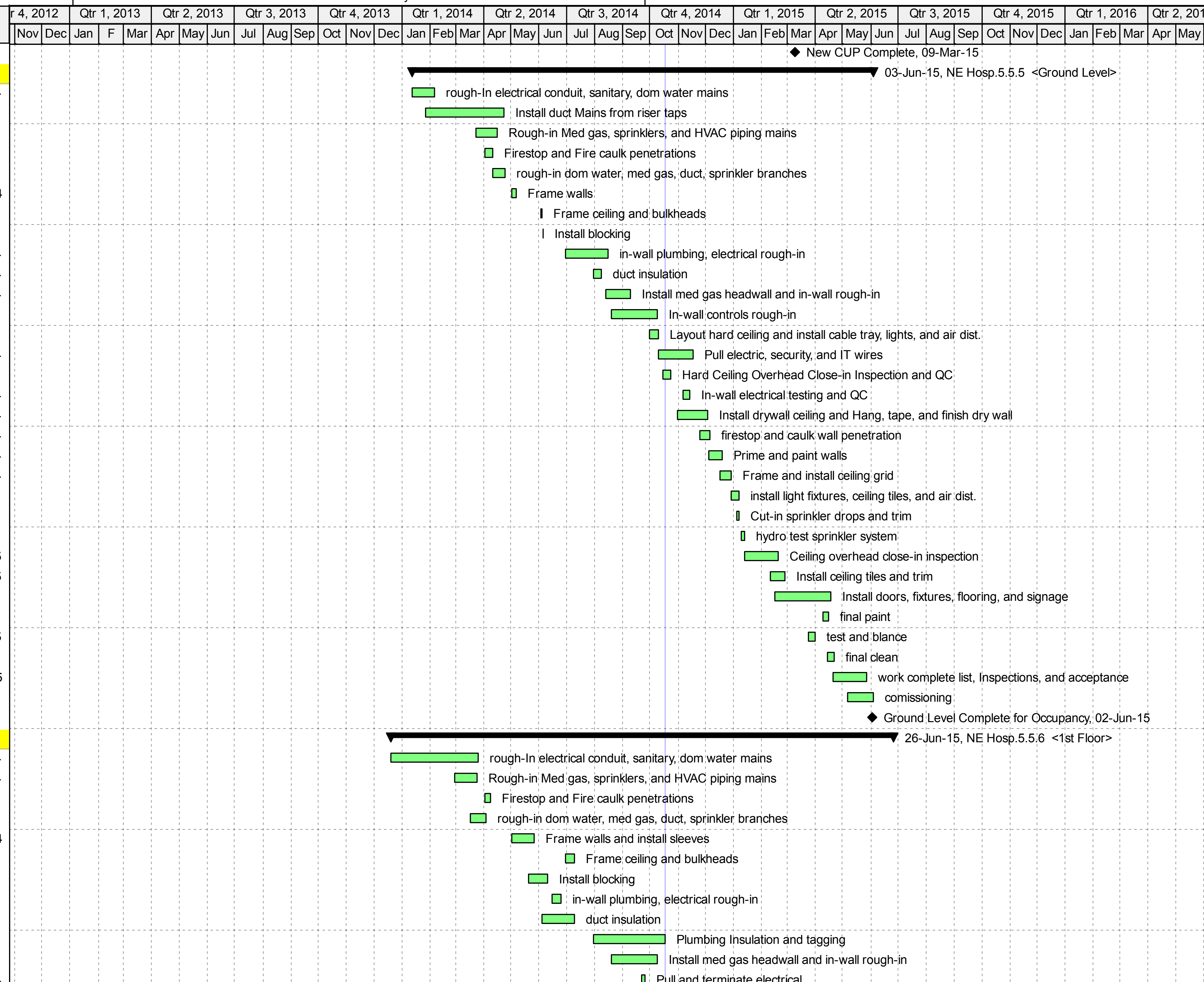
Activity ID	Activity Name	Original Duration	Start	Finish
248	Weather Tight	0	07-Jul-14	
249	roof trim and flashing	13	30-Sep-14	16-Oct-14
250	coping	6	16-Dec-14	23-Dec-14
251	Install green Roof System	20	21-Apr-15	18-May-15
NE Hosp.5.5.4 <CUP>		**387**	**16-Sep-13**	**10-Mar-15**
NE Hosp.5.5.4.5.4.1 <Basement>		**334**	**16-Sep-13**	**25-Dec-14**
255	Install MEP Hangers	1	16-Sep-13	16-Sep-13
256	Install duct Mains from riser	35	03-Dec-13	20-Jan-14
257	Medical gas, CHW, HHW, :	20	08-Jan-14	04-Feb-14
258	sprinkler Mains	7	17-Jan-14	27-Jan-14
259	sanitary Mains	13	08-Jan-14	24-Jan-14
260	Layout MEP equipment	6	29-Jan-14	05-Feb-14
261	In-wall electrical rough-in	6	21-Mar-14	28-Mar-14
262	In-wall plumbing rough-in/te	19	21-Mar-14	16-Apr-14
263	sprinkler heads and branch	58	04-Feb-14	24-Apr-14
264	Hang, Tape & finsh Dry wa	8	17-Apr-14	28-Apr-14
265	Install door frames	6	02-May-14	09-May-14
266	firestop and caulk floor pen	7	21-May-14	29-May-14
267	work complete list and insp	16	26-Nov-14	17-Dec-14
268	Acceptance	4	22-Dec-14	25-Dec-14
NE Hosp.5.5.4.5.4.2 <Penthouse>		**283**	**07-Feb-14**	**10-Mar-15**
271	Install West shaft steel	4	07-Feb-14	12-Feb-14
272	rough-in west HVAC and P	24	14-Feb-14	19-Mar-14
273	rough-in west Electrical anc	113	11-Mar-14	14-Aug-14
274	Install East shaft steel	1	01-Apr-14	01-Apr-14
275	rough-in East HVAC and Pl	16	30-Jun-14	21-Jul-14
276	rough-in East Electrical anc	6	17-Jul-14	24-Jul-14
277	Install MEP Hangers in pen	98	24-Mar-14	06-Aug-14
278	Spray fireproofing Penthou	35	01-May-14	18-Jun-14
279	Rough-in OH CW, Steam, I	59	26-May-14	14-Aug-14
280	rough-in electrical conduit r	20	11-Jul-14	07-Aug-14
281	Layout MEP equipment in p	6	31-Jul-14	07-Aug-14
282	Medical gas mains	8	31-Jul-14	11-Aug-14
283	Piping and Plumbing insula	5	08-Aug-14	14-Aug-14
284	rough-in Sanitary piping	13	31-Jul-14	18-Aug-14
285	sprinkler and dom water m	32	11-Aug-14	23-Sep-14
286	wall blocking and in-wall rou	6	30-Sep-14	07-Oct-14
287	In-wall plumbing QC and te	2	07-Oct-14	08-Oct-14
288	In-wall plumbing rough-in fc	8	07-Oct-14	16-Oct-14
289	In-wall close-in inspection/te	50	14-Oct-14	22-Dec-14
290	MEP Equipment Set	6	29-Oct-14	05-Nov-14
291	Hang, tape, and finish Dryw	8	04-Dec-14	15-Dec-14
292	firestop and caulk floor pen	4	15-Dec-14	18-Dec-14
293	Prime paint walls	17	22-Dec-14	13-Jan-15
294	staff toilet floor, fixtures and	15	30-Dec-14	19-Jan-15
295	test and balance CUP pent	2	06-Jan-15	07-Jan-15
296	work complete list and final	36	20-Jan-15	10-Mar-15



Actual Level of Effort | Remaining Work | Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

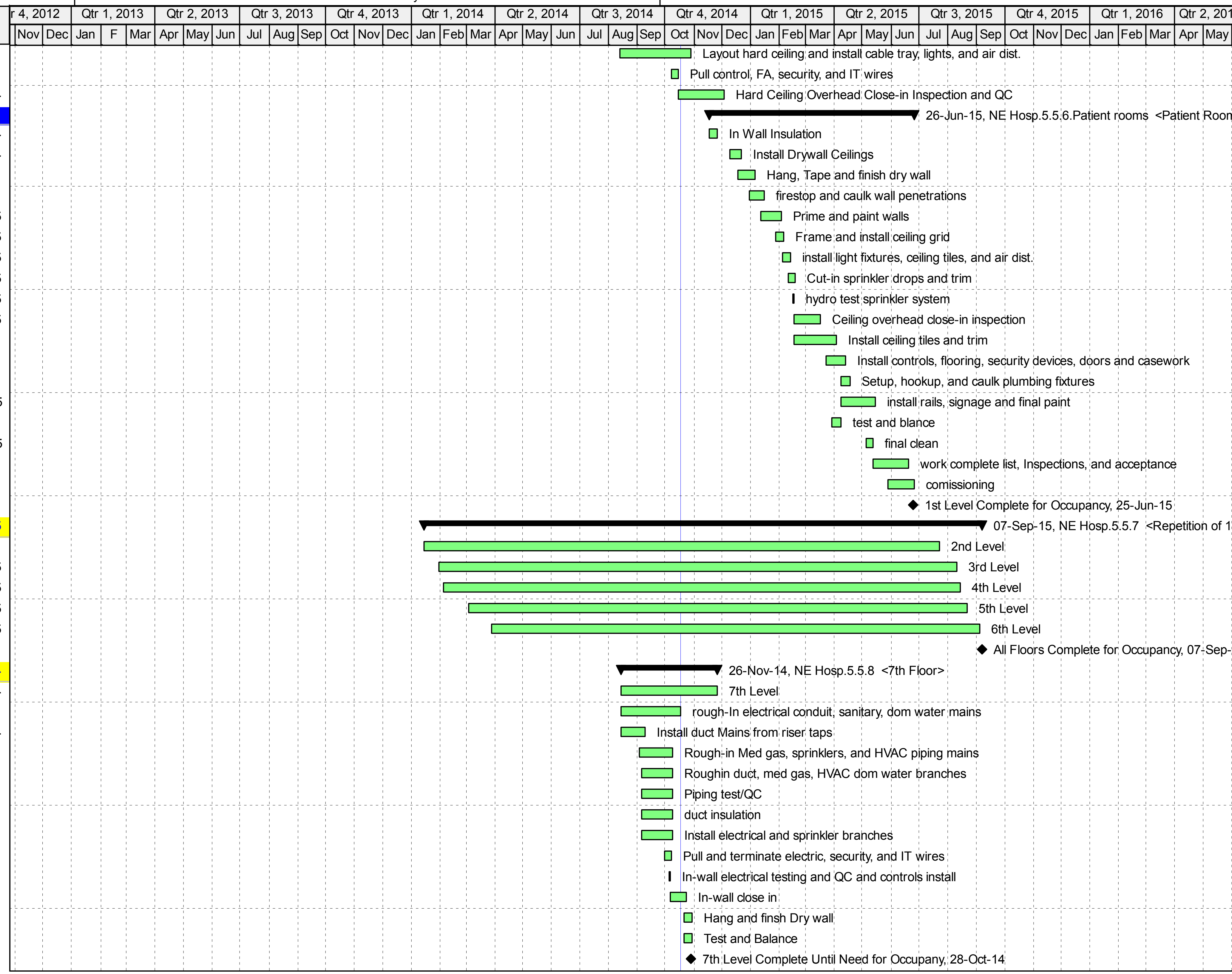
Activity ID	Activity Name	Original Duration	Start	Finish
297	New CUP Complete	0	09-Mar-15	
NE Hosp.5.5.5 <Ground Level>		**363**	**13-Jan-14**	**03-Jun-15**
300	rough-In electrical conduit,	18	13-Jan-14	05-Feb-14
301	Install duct Mains from riser	63	27-Jan-14	23-Apr-14
302	Rough-in Med gas, sprinkle	17	24-Mar-14	15-Apr-14
303	Firestop and Fire caulk per	6	03-Apr-14	10-Apr-14
304	rough-in dom water, med g	10	11-Apr-14	24-Apr-14
305	Frame walls	3	02-May-14	06-May-14
306	Frame ceiling and bulkheac	1	03-Jun-14	03-Jun-14
307	Install blocking	1	05-Jun-14	05-Jun-14
308	in-wall plumbing, electrical r	35	30-Jun-14	15-Aug-14
309	duct insulation	7	31-Jul-14	08-Aug-14
310	Install med gas headwall ar	19	14-Aug-14	09-Sep-14
311	In-wall controls rough-in	37	20-Aug-14	09-Oct-14
312	Layout hard ceiling and inst	9	30-Sep-14	10-Oct-14
313	Pull electric, security, and IT	27	10-Oct-14	17-Nov-14
314	Hard Ceiling Overhead Clo	7	15-Oct-14	23-Oct-14
315	In-wall electrical testing anc	5	07-Nov-14	13-Nov-14
316	Install drywall ceiling and Ha	25	31-Oct-14	03-Dec-14
317	firestop and caulk wall pene	9	25-Nov-14	05-Dec-14
318	Prime and paint walls	11	05-Dec-14	19-Dec-14
319	Frame and install ceiling gri	9	17-Dec-14	29-Dec-14
320	install light fixtures, ceiling ti	7	29-Dec-14	06-Jan-15
321	Cut-in sprinkler drops and t	3	05-Jan-15	07-Jan-15
322	hydro test sprinkler system	3	09-Jan-15	13-Jan-15
323	Ceiling overhead close-in ir	27	13-Jan-15	18-Feb-15
324	Install ceiling tiles and trim	13	10-Feb-15	26-Feb-15
325	Install doors, fixtures, floori	45	16-Feb-15	17-Apr-15
326	final paint	5	09-Apr-15	15-Apr-15
327	test and blance	6	24-Mar-15	31-Mar-15
328	final clean	5	15-Apr-15	21-Apr-15
329	work complete list, Inspecti	27	21-Apr-15	27-May-15
330	comissioning	20	07-May-15	03-Jun-15
331	Ground Level Complete for	0	02-Jun-15	
NE Hosp.5.5.6 <1st Floor>		**396**	**20-Dec-13**	**26-Jun-15**
334	rough-In electrical conduit,	68	20-Dec-13	25-Mar-14
335	Rough-in Med gas, sprinkle	17	28-Feb-14	24-Mar-14
336	Firestop and Fire caulk per	4	03-Apr-14	08-Apr-14
337	rough-in dom water, med g	13	18-Mar-14	03-Apr-14
338	Frame walls and install slee	17	02-May-14	26-May-14
339	Frame ceiling and bulkheac	8	30-Jun-14	09-Jul-14
340	Install blocking	16	20-May-14	10-Jun-14
341	in-wall plumbing, electrical r	8	16-Jun-14	25-Jun-14
342	duct insulation	26	04-Jun-14	09-Jul-14
343	Plumbing Insulation and tag	57	31-Jul-14	17-Oct-14
344	Install med gas headwall ar	37	20-Aug-14	09-Oct-14
345	Pull and terminate electrical	4	22-Sep-14	25-Sep-14



Legend: Actual Level of Effort; Actual Work; Remaining Work; Critical Remaining Work; Milestone; summary

TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish
346	Layout hard ceiling and inst	54	14-Aug-14	28-Oct-14
347	Pull control, FA, security, ar	6	08-Oct-14	15-Oct-14
348	Hard Ceiling Overhead Clo	36	15-Oct-14	03-Dec-14
NE Hosp.5.5.6.Patient rooms <Pati		**159**	**18-Nov-14**	**26-Jun-15**
350	In Wall Insulation	6	18-Nov-14	25-Nov-14
351	Install Drywall Ceilings	9	10-Dec-14	22-Dec-14
352	Hang, Tape and finish dry v	12	19-Dec-14	05-Jan-15
353	firestop and caulk wall pene	12	31-Dec-14	15-Jan-15
354	Prime and paint walls	16	12-Jan-15	02-Feb-15
355	Frame and install ceiling gri	7	28-Jan-15	05-Feb-15
356	install light fixtures, ceiling ti	7	04-Feb-15	12-Feb-15
357	Cut-in sprinkler drops and t	6	10-Feb-15	17-Feb-15
358	hydro test sprinkler system	1	16-Feb-15	16-Feb-15
359	Ceiling overhead close-in ir	21	17-Feb-15	17-Mar-15
360	Install ceiling tiles and trim	34	17-Feb-15	03-Apr-15
361	Install controls, flooring, sec	16	23-Mar-15	13-Apr-15
362	Setup, hookup, and caulk p	8	08-Apr-15	17-Apr-15
363	install rails, signage and fina	27	08-Apr-15	14-May-15
364	test and blance	7	30-Mar-15	07-Apr-15
365	final clean	6	05-May-15	12-May-15
366	work complete list, Inspectio	28	13-May-15	19-Jun-15
367	comissioning	21	29-May-15	26-Jun-15
368	1st Level Complete for Occ	0	25-Jun-15	
NE Hosp.5.5.7 <Repetition of 1st fl		**448**	**15-Jan-14**	**07-Sep-15**
370	2nd Level	396	15-Jan-14	23-Jul-15
371	3rd Level	396	30-Jan-14	10-Aug-15
372	4th Level	396	05-Feb-14	14-Aug-15
373	5th Level	396	03-Mar-14	21-Aug-15
374	6th Level	396	28-Mar-14	04-Sep-15
375	All Floors Complete for Occ	0	07-Sep-15	
NE Hosp.5.5.8 <7th Floor>		**74**	**15-Aug-14**	**26-Nov-14**
377	7th Level	74	15-Aug-14	26-Nov-14
378	rough-In electrical conduit,	46	15-Aug-14	17-Oct-14
379	Install duct Mains from riser	18	15-Aug-14	09-Sep-14
380	Rough-in Med gas, sprinkle	27	03-Sep-14	09-Oct-14
381	Roughin duct, med gas, H\	24	06-Sep-14	09-Oct-14
382	Piping test/QC	24	06-Sep-14	09-Oct-14
383	duct insulation	24	06-Sep-14	09-Oct-14
384	Install electrical and sprinkle	24	06-Sep-14	09-Oct-14
385	Pull and terminate electric,	5	01-Oct-14	07-Oct-14
386	In-wall electrical testing anc	1	06-Oct-14	06-Oct-14
387	In-wall close in	13	07-Oct-14	23-Oct-14
388	Hang and finsh Dry wall	8	21-Oct-14	29-Oct-14
389	Test and Balance	8	21-Oct-14	29-Oct-14
390	7th Level Complete Until N	0	28-Oct-14	



Actual Level of Effort | Remaining Work | ◆ Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

Appendix B: Patient Room Re-Design for Shared Wet Wall

Highcrest™
Bowl
K-4302-L

Features
- Vitreous china.
- With bedpan lugs.
- 10" (254 mm) or 12" (305 mm) rough-in.
- 1-1/2" top spud.
- 11-3/8" (289 mm) x 10-3/8" (264 mm) water area.
- 2-1/4" (57 mm) passageway.
- 1.6 gpf (6 lpf).
- 26" (660 mm) x 14-1/2" (368 mm) x 16-1/2" (419 mm).

Recommended Accessories
K-4670-C Commercial Toilet Seat
K-4670-CA Commercial Toilet Seat
K-10674
K-10957
K-13516

Components
Additional included component/s: Spud, and Bolt cap accessory pack.

ADA | **CSA B651** | **OBC**

Codes/Standards
ASME A112.19.2/CSA B45.1
DOE - Energy Policy Act 1992
ADA
ICC/ANSI A117.1
CSA B651
OBC

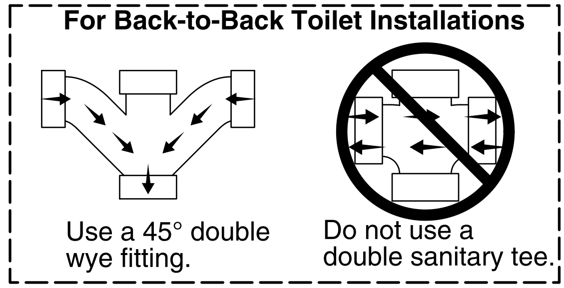
KOHLER® One-Year Limited Warranty
See website for detailed warranty information.

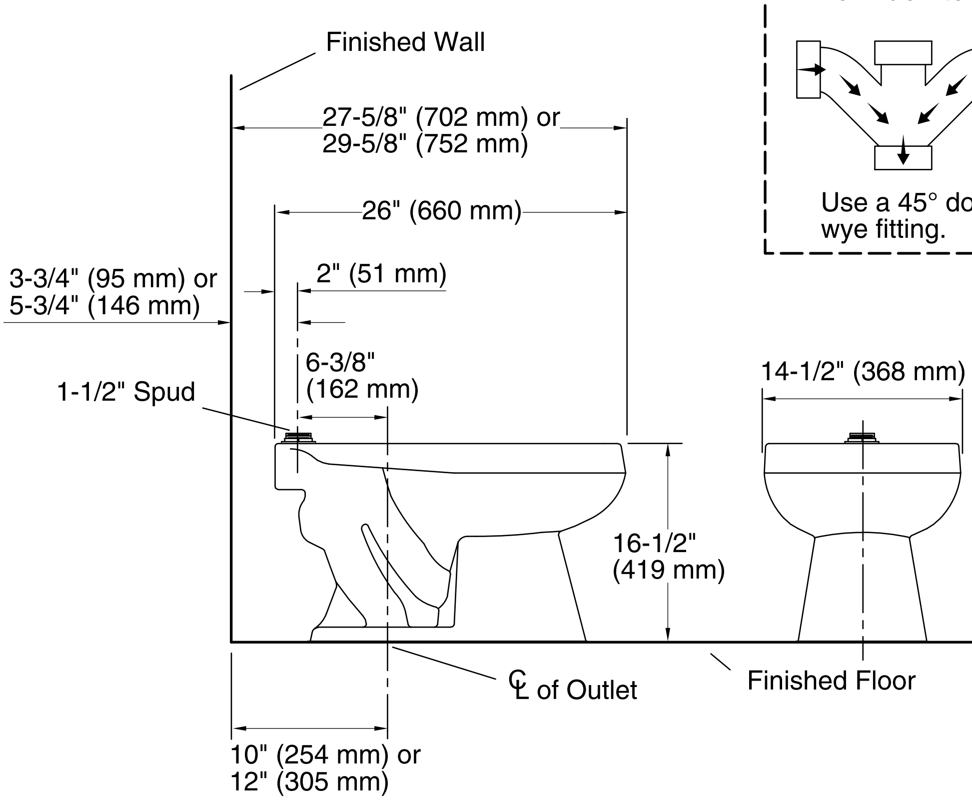
Available Color/Finishes
Color tiles intended for reference only.

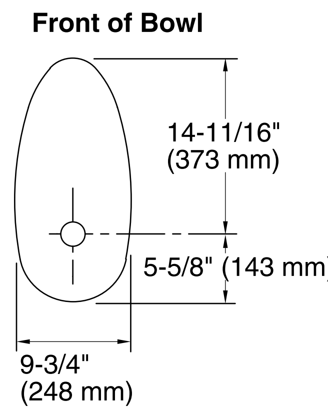
Color	Code	Description
	0	White
	96	Biscuit
	47	Almond

KOHLER

Highcrest™
Bowl
K-4302-L







Technical Information

All product dimensions are nominal.

Bowl shape:	Elongated front
Flush type:	Siphon jet
Spud size:	1-1/2", Inlet, Top
Trap passageway:	2-1/4" (57 mm)
Water surface size:	11-3/8" x 10-3/8" (289 mm x 264 mm)
Rim to water surface:	6" (152 mm)
Rough-in:	10" or 12" (254 or 305 mm)
Seat-mounting holes:	5-1/2" (140 mm)

Fixture Supply Requirements

Min static pressure:	35 psi (241.3 kPa)
Max static pressure:	80 psi (551.6 kPa)
Min flowing pressure:	25 psi (172.4 kPa)
Min flow rate:	25 gpm (94.6 lpm)

Notes

Install this product according to the installation guide.

Refer to manufacturer and local codes for flush valve requirements.

For back-to-back toilet installations: Use only a 45° double wye fitting.

ADA, OBC, CSA B651 compliant when installed to the specific requirements of these regulations.

The Model Plumbing Codes require the installation of elongated open-front toilet seats on public bathrooms.

KOHLER®

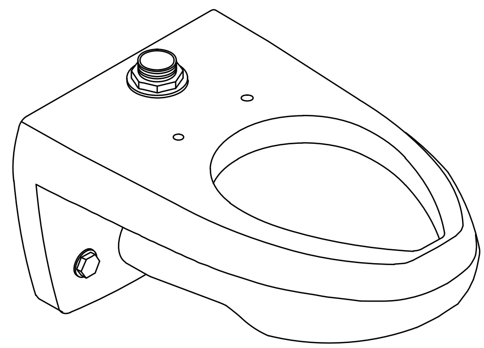
KINGSTON™

ELONGATED TOILET BOWL
K-4330

ADA	CSA B651	OBC

Features

- *Vitreous china*
- *Elongated bowl*
- *Siphon jet*
- *With bedpan lugs (-L)*
- *1-1/2″ top spud*
- *Wall-mount*
- *1.6 gpf (6.0 lpf)*
- *12-3/8″ (314 mm) x 11-3/8″ (289 mm) water area*



Codes/Standards Applicable

Specified model meets or exceeds the following:

- *ADA*
- *ICC/ANSI A117.1*
- *CSA B651*
- *OBC*
- *ASME A112.19.2/CSA B45.1*

Colors/Finishes

- 0: White
- Other: Refer to Price Book for additional colors/finishes

Accessories

- 0: White
- CP: Polished Chrome
- Other: Refer to Price Book for additional colors/finishes

Specified Model

Model	Description	Colors/Finishes	
K-4330	Elongated toilet bowl	❑ 0	❑ Other_____
K-4330-L	Elongated toilet bowl - with bedpan lugs	❑ 0	❑ Other_____

Recommended Accessories				
K-4670-C	Lustra™ open front seat	❑ 0	❑ Other_____	
K-4670-CA	Lustra open front seat (with anti-microbial agent)	❑ 0		
K-10674	WAVE exposed toilet flushometer – 1.6 gpf (6.0 lpf)			❑ CP
K-10957	Touchless DC toilet flushometer – 1.6 gpf (6.0 lpf)			❑ CP
K-13516	Manual toilet flushometer – 1.6 gpf (6.0 lpf)			❑ CP

Product Specification

The elongated toilet bowl shall be made of vitreous china. Bowl shall be wall-mount with a 1-1/2″ top spud. Bowl shall have 12-3/8″ (314 mm) by 11-3/8″ (289 mm) water area. Bowl shall be 1.6 gpf (6.0 lpf). Bowl shall have optional bedpan lugs (-L). Bowl shall have siphon jet. Elongated toilet bowl shall be Kohler Model K-4330-______ or K-4330-L-______.

USA/Canada: 1-800-4KOHLER
(1-800-456-4537)
www.kohler.com

KINGSTON™

Technical Information

Fixture*:	
Configuration	top spud, elongated
Water per flush	1.6 gpf (6.0 lpf)*
Spud size	1-1/2″
Passageway	2-1/4″ (57 mm)
Water area	12-3/8″ (314 mm) x 11-3/8″ (289 mm)
Water depth from rim	5-1/4″ (133 mm)
Seat post hole centers	5-1/2″ (140 mm)
Minimum static pressure required	35 psi (241.3 kPa)
Maximum static pressure	80 psi (551.6 kPa)
Minimum flowing pressure required	25 psi (172.4 kPa)
Required supply minimum	25 gal/min (94.6 l/min)
* Based upon use of a 1.6 gal (6.0 L) flushometer.	

Included components:	
Spud	18357

Installation Notes

Install this product according to the installation guide.

For back-to-back toilet installations: Use only a 45° double wye fitting.

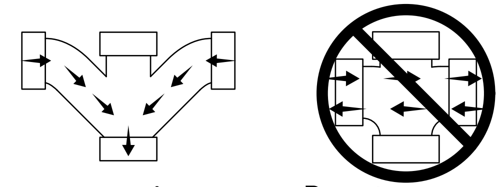
Will comply with the Americans with Disabilities Act **(ADA)** when installed per the requirements of the 2010 ADA Standards for Accessible Design, Section 604 Water Closets, of the Act. The Model Plumbing Codes require the installation of elongated open-front toilet seats in public bathrooms.

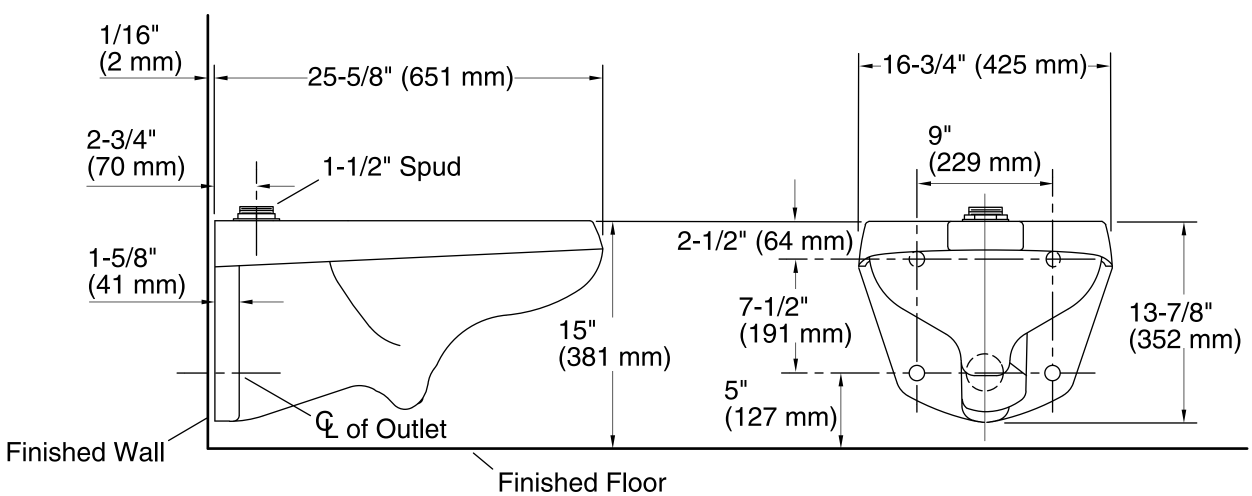
Refer to manufacturer and local codes for flushometer requirements.

Will comply with **CSA B651** when installed per Clause 4.3.6 of the standard.

Will comply with **OBC** Barrier Free requirements when installed per Clause 3.8.3.8 and 3.8.3.9.

For Back-to-Back Toilet Installations





Product Diagram

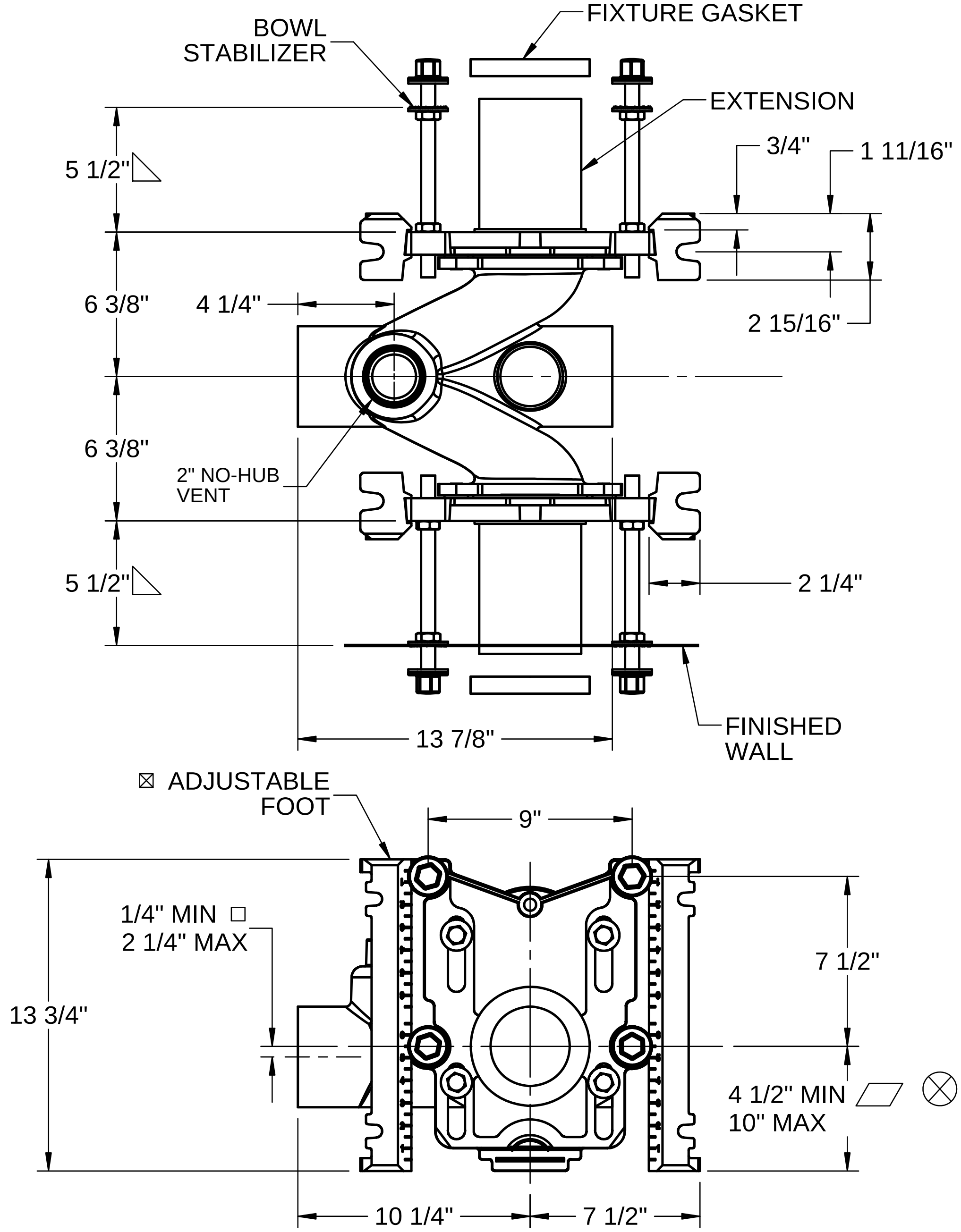
SPECIFICATION:

JOSAM 12694 SERIES COATED CAST IRON DOUBLE HORIZONTAL 4" NO-HUB FITTING WITH 2" NO-HUB VENT AND ADJUSTABLE CARRIER BODY, ABS EXTENSION WITH INTEGRAL TEST CAP, PYLON FEET, ANCHOR FOOT, PLATED HARDWARE AND NEOPRENE FIXTURE GASKET, INVERTIBLE FOR SIPHON JET OR BLOWOUT CLOSETS.

CLOSET CARRIER

BACK-TO-BACK

SERIES **12694**



FOR DIMENSION SHORTER THAN 5-1/2" (1" MIN), CUT EXTENSION. FOR LONGER EXTENSION (10-1/2" MAX), SPECIFY (-10)

⊠ RECOMMEND FEET BE SECURED TO FLOOR WITH 1/2" BOLTS AND ANCHORS (BY OTHERS).

⊗ FOR SIPHON JET ROUGHING OVER 6" OR BLOWOUT ROUGHING OVER 12-1/2" SPECIFY ON ORDER.

SIPHON JET DIMS SHOWN. FOR BLOWOUT DIMS, USE:

□ MIN 2" & MAX 4"

▱ MIN 11" & MAX 16 1/2"

◎ AUX INLET IS 6" OFFSET FROM VENT

☐	-PF	PYLON FOOT, STD.
☐	-OR	O-RING CARRIER
☐	-SD	SPECIAL DUTY 500 LB CARRIER
☐	-HS	HUB & SPIGOT
☐	-AUX	AUXILIARY INLET (2" NO-HUB)
☐	-HUB AUX	AUXILIARY INLET (2" HUB)
☐	-VP	VANDAL-PROOF TRIM
☐	-1	POSITIONING FRAME

☐	-6	SUPPLY PIPE SUPPORT (SPECIFY TYPE OF PIPE)
☐	-10	ABS EXTENSION THROUGH 10-1/2" WALL
☐	-24	FLOOR MOUNTED BACK OUTLET CHINA BOWL
☐	-30	CAST IRON ADJ. EXTENSION W/ CONNECTOR
☐	-30-2	CI ADJ. EXTENSION W/ CONNECTOR & TEST CAP
☐	-32	CARRIER FOR WIDE CHASE INSTALLATIONS
☐	-35	CARRIER FOR WHEELCHAIR HIGH ROUGH
☐	-58	HORIZONTAL NO-HUB CAST LONG BARREL
☐	-XSD	EXTRA SPECIAL DUTY 1,000 LB CARRIER

DATE OF LAST CHANGE: 04/25/14

DIMENSIONS ARE SUBJECT TO MANUFACTURERS TOLERANCES AND CHANGE WITHOUT NOTICE. WE CAN ASSUME NO RESPONSIBILITY FOR USE OF SUPERSEDED OR VOID DATA.

JOSAM COMPANY
MICHIGAN CITY, INDIANA

NOTES

KOHLER®

Kingston™
Wall-Mount Bathroom Sink
K-2006

Features
- With hanger.
- With overflow.
- 4" (102 mm) centers.
- 21-1/4"L x 18-1/8"W

Material
- Vitreous china.

Installation
- Wall-mount.
- Drilled for concealed arm carrier.

Recommended Accessories
K-8998 P-Trap

Components
Additional included component/s: Hanger (2 Required).

ADA	CSA B651	OBC

Codes/Standards
ASME A112.19.2/CSA B45.1
ADA
ICC/ANSI A117.1
CSA B651
OBC

KOHLER® One-Year Limited Warranty
See website for detailed warranty information.

Available Color/Finishes
Color tiles intended for reference only.

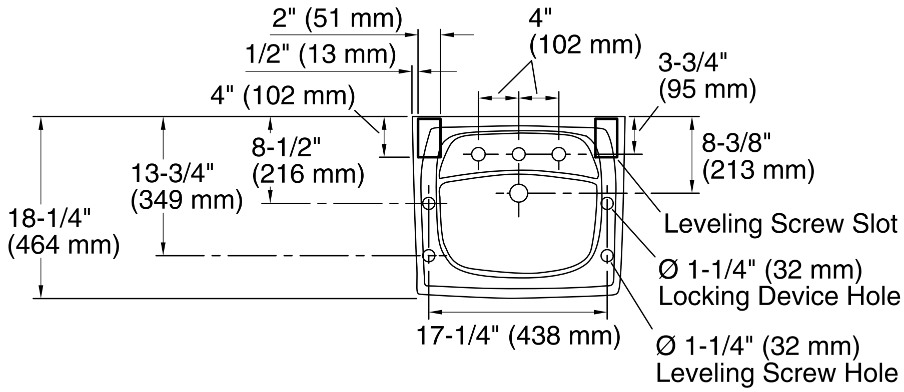
Color	Code	Description
	0	White
	96	Biscuit
	47	Almond
	7	Black Black™

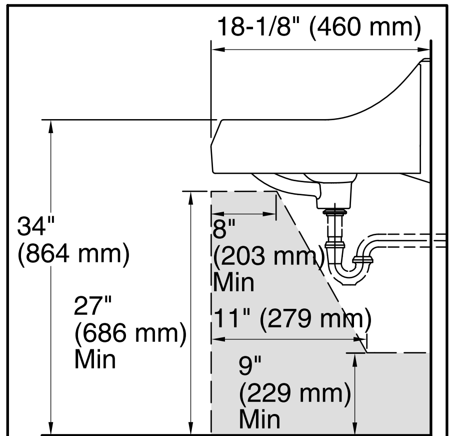
KOHLER

Kingston™

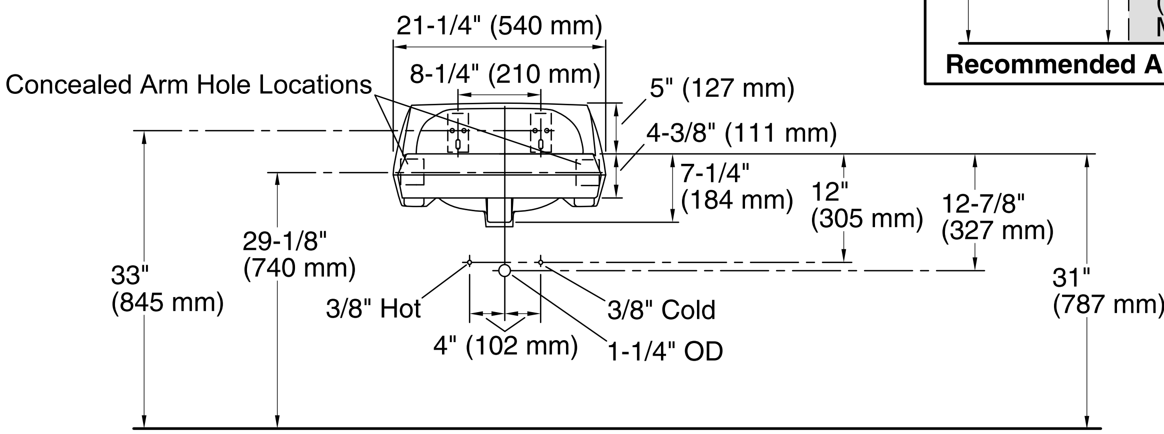
Wall-Mount Bathroom Sink

K-2006





Recommended ADA Installation



Standard Installation

Technical Information

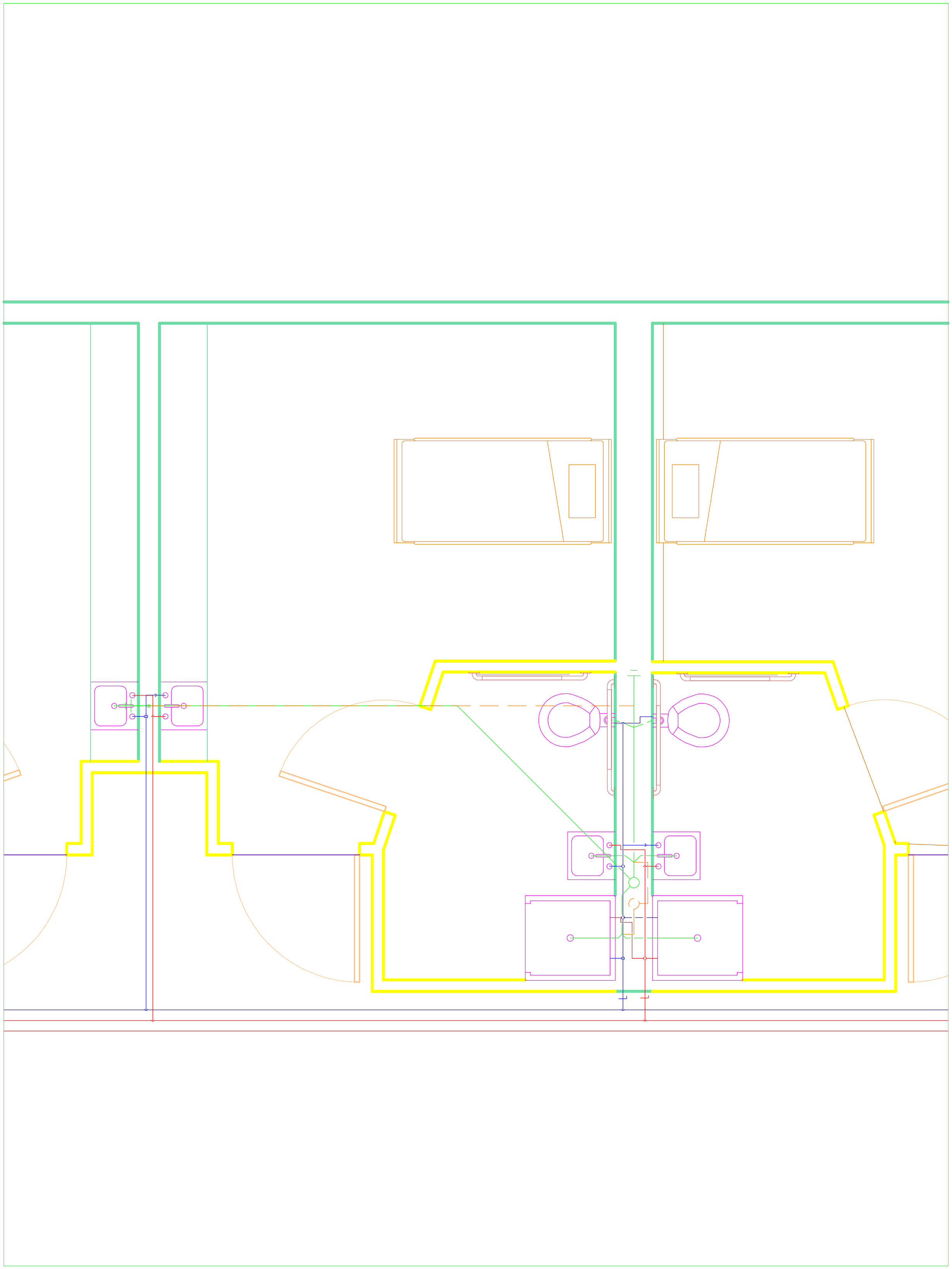
All product dimensions are nominal.

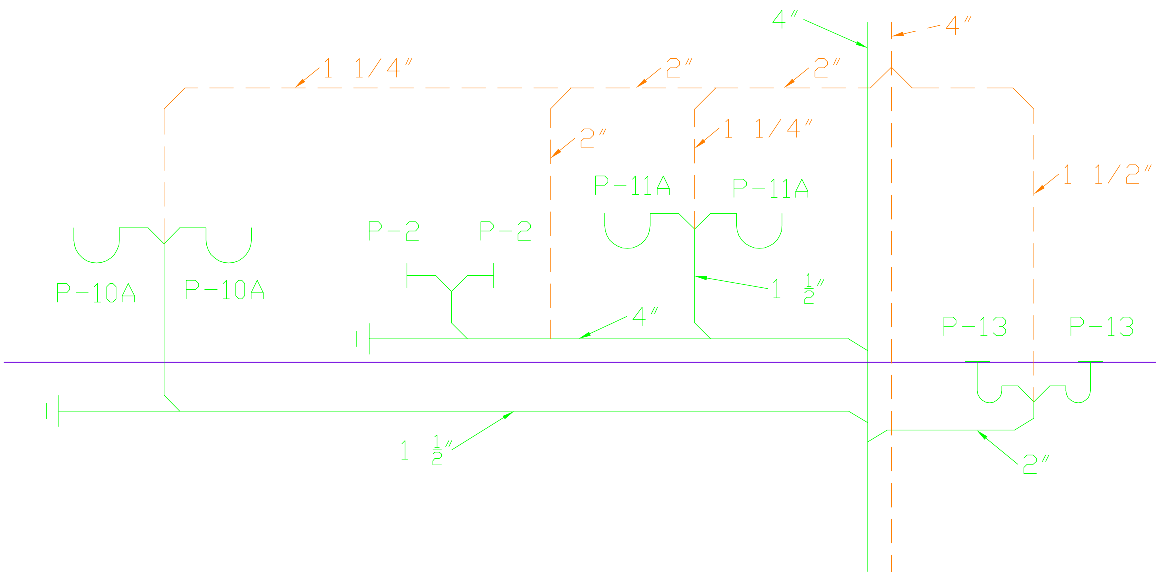
Bowl configuration:	Single
Installation:	Wall-mount
Bowl area (Center)	Length: 16" (406 mm) Width: 10" (254 mm) Water depth: 3-1/8" (79 mm)
Number of deck holes:	3
Faucet hole(s):	1-3/8" (35 mm)
Soap/Lotion hole:	1-1/4" (32 mm)
Drain hole:	1-3/4" (44 mm)

Notes

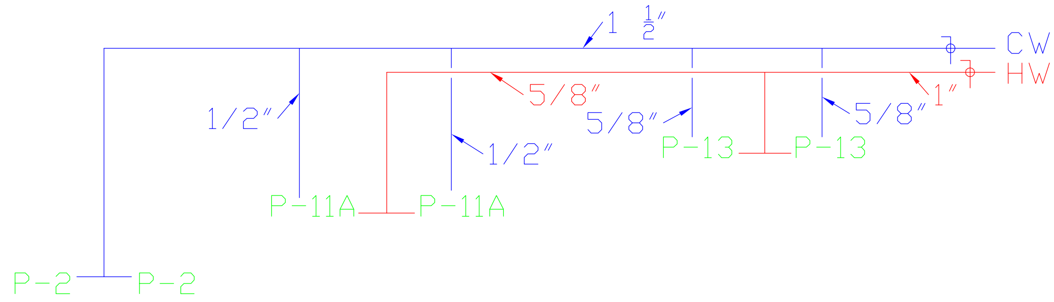
Install this product according to the installation guide.

ADA, OBC, CSA B651 compliant when installed to the specific requirements of these regulations.

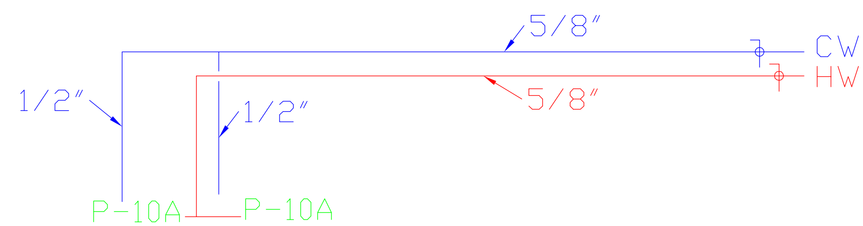




4"
4"
1 1/4"
2"
2"
2"
1 1/4"
1 1/2"
P-11A
P-11A
P-2
P-2
P-10A
P-10A
1 1/2"
4"
P-13
P-13
1 1/2"
2"



1 ½"
CW
HW
1/2"
5/8"
5/8"
1"
5/8"
1/2"
P-13
P-13
P-11A
P-11A
P-2
P-2



5/8"
CW
HW
1/2"
1/2"
5/8"
P-10A
P-10A

Appendix C: SIPS Utilization for Patient Floors

Original Crew Understanding SF/Floor: 22,500

Activity	Orig Crew Size	Worker Type	Hourly Cost/Worker	Cost/Day	Orig Durations	SF/Day	Original Total Cost
Layout and Top Track	2	Carpenter	$ 46.95	$ 751.20	41	549	$ 30,799.20
Sanitary Runouts	2	Plumber	$ 58.70	$ 939.20	39	577	$ 36,628.80
Dom Water Mains	2	Plumber	$ 58.70	$ 939.20	36	625	$ 33,811.20
Electrical Conduit Mains	2	Electrician	$ 54.70	$ 875.20	39	577	$ 34,132.80
Duct Mains	2	Sheetmetal	$ 55.95	$ 895.20	68	331	$ 60,873.60
Medical Gas Mains	3	Pipefitter	$ 59.75	$ 1,434.00	33	682	$ 47,322.00
HVAC Piping Mains	3	Pipefitter	$ 59.75	$ 1,434.00	37	608	$ 53,058.00
Sprinkler Mains	3	Sprinkler	$ 56.65	$ 1,359.60	31	726	$ 42,147.60
Medical Gas Branch	3	Pipefitter	$ 59.75	$ 1,434.00	30	750	$ 43,020.00
Sprinkler Branch	2	Sprinkler	$ 56.65	$ 906.40	28	804	$ 25,379.20
HVAC Branch	3	Pipefitter	$ 59.75	$ 1,434.00	34	662	$ 48,756.00
Domestic Water Branch	2	Plumber	$ 58.70	$ 939.20	31	726	$ 29,115.20
Duct Branch	2	Sheetmetal	$ 55.95	$ 895.20	34	662	$ 30,436.80
Frame Walls	2	Carpenter	$ 46.95	$ 751.20	35	643	$ 26,292.00
Insulate Ducts	2	Asbestos	$ 52.35	$ 837.60	30	750	$ 25,128.00
Door Frames	2	Carpenter	$ 46.95	$ 751.20	30	750	$ 22,536.00
Electrical Branch	1	Electrician	$ 54.70	$ 437.60	34	662	$ 14,878.40
In-Wall Plumbing	2	Plumber	$ 58.70	$ 939.20	62	363	$ 58,230.40
Piping and Plumbing Insulation	2	Abestos	$ 52.35	$ 837.60	3	7500	$ 2,512.80
Frame Ceiling and bulkheads	2	Carpenter	$ 46.95	$ 751.20	24	938	$ 18,028.80
Install Med Gas Headwall and Zone Valve	2	Pipefitter	$ 59.75	$ 956.00	15	1500	$ 14,340.00
In-Wall Controls Rough-in	1	Electrician	$ 54.70	$ 437.60	17	1324	$ 7,439.20
In-Wall Electrical Rough-in	1	Electrician	$ 54.70	$ 437.60	24	938	$ 10,502.40
Install Cable tray	2	Electrician	$ 54.70	$ 875.20	19	1184	$ 16,628.80
In-Wall Telecom/Security Rough-in	2	Electrician	$ 54.70	$ 875.20	29	776	$ 25,380.80
Install Light Fixtures	2	Electrician	$ 54.70	$ 875.20	23	978	$ 20,129.60
Pull and Terminate Electrical	2	Electrician	$ 54.70	$ 875.20	16	1406	$ 14,003.20
Pull and Terminate Control Wire	1	Electrician	$ 54.70	$ 437.60	16	1406	$ 7,001.60
Pull and Terminate Telecom/Security	2	Electrician	$ 54.70	$ 875.20	18	1250	$ 15,753.60
In-Wall Insulation	2	Asbestos	$ 52.35	$ 837.60	12	1875	$ 10,051.20
Install Ceiling	2	Carpenter	$ 46.95	$ 751.20	21	1071	$ 15,775.20
Cut-in Sprinkler Drops/Trim	1	Sprinkler	$ 56.65	$ 453.20	17	1324	$ 7,704.40
Install Air Distribution	1	Sheetmetal	$ 55.95	$ 447.60	32	703	$ 14,323.20
Hang/Tape/Finish Drywall	2	Carpenter	$ 46.95	$ 751.20	46	489	$ 34,555.20
Firestop and Caulk Wall Penetrations	1	Carpenter	$ 46.95	$ 375.60	36	625	$ 13,521.60
Paint Walls	2	Painter	$ 40.35	$ 645.60	19	1184	$ 12,266.40
Install Flooring	2	Floor Tiler	$ 43.60	$ 697.60	39	577	$ 27,206.40
Set and Hook-up Plumbing Fixtures	2	Plumber	$ 58.70	$ 939.20	23	978	$ 21,601.60
Final Paint	2	Painter	$ 40.35	$ 645.60	18	1250	$ 11,620.80
Final Clean	2	Laborers	$ 37.60	$ 601.60	19	1184	$ 11,430.40
						Total Labor Cost Per Floor:	**$ 994,322.40**

Crew Balancing

SF/Floor: 22,500 Goal SF/week: 4500

Activity	Crew Size		Worker Type	Hourly	Crew Cost/Day		Activity Duration		SF/Day		Total Labor costs	
	Original	Proposed		Cost/Worker	Original	Proposed	Original	Proposed	Original	Proposed	Original	Proposed
Layout and Top Track	2	3	Carpenter	$ 46.95	$ 751.20	$ 1,126.80	41	25	549	900	$ 30,799.20	$ 28,170.00
Sanitary Runouts	2	3	Plumber	$ 58.70	$ 939.20	$ 1,408.80	39	25	577	900	$ 36,628.80	$ 35,220.00
Dom Water Mains	2	3	Plumber	$ 58.70	$ 939.20	$ 1,408.80	36	25	625	900	$ 33,811.20	$ 35,220.00
Electrical Conduit Mains	2	3	Electrician	$ 54.70	$ 875.20	$ 1,312.80	39	25	577	900	$ 34,132.80	$ 32,820.00
Duct Mains	2	5	Sheetmetal	$ 55.95	$ 895.20	$ 2,238.00	68	25	331	900	$ 60,873.60	$ 55,950.00
Medical Gas Mains	3	4	Pipefitter	$ 59.75	$ 1,434.00	$ 1,912.00	33	25	682	900	$ 47,322.00	$ 47,800.00
HVAC Piping Mains	3	4	Pipefitter	$ 59.75	$ 1,434.00	$ 1,912.00	37	25	608	900	$ 53,058.00	$ 47,800.00
Sprinkler Mains	3	4	Sprinkler	$ 56.65	$ 1,359.60	$ 1,812.80	31	25	726	900	$ 42,147.60	$ 45,320.00
Medical Gas Branch	3	4	Pipefitter	$ 59.75	$ 1,434.00	$ 1,912.00	30	25	750	900	$ 43,020.00	$ 47,800.00
Sprinkler Branch	2	2	Sprinkler	$ 56.65	$ 906.40	$ 906.40	28	25	804	900	$ 25,379.20	$ 22,660.00
HVAC Branch	3	4	Pipefitter	$ 59.75	$ 1,434.00	$ 1,912.00	34	25	662	900	$ 48,756.00	$ 47,800.00
Domestic Water Branch	2	2	Plumber	$ 58.70	$ 939.20	$ 939.20	31	25	726	900	$ 29,115.20	$ 23,480.00
Duct Branch	2	3	Sheetmetal	$ 55.95	$ 895.20	$ 1,342.80	34	25	662	900	$ 30,436.80	$ 33,570.00
Frame Walls	2	3	Carpenter	$ 46.95	$ 751.20	$ 1,126.80	35	25	643	900	$ 26,292.00	$ 28,170.00
Insulate Ducts	2	2	Asbestos	$ 52.35	$ 837.60	$ 837.60	30	25	750	900	$ 25,128.00	$ 20,940.00
Door Frames	2	2	Carpenter	$ 46.95	$ 751.20	$ 751.20	30	25	750	900	$ 22,536.00	$ 18,780.00
Electrical Branch	1	1	Electrician	$ 54.70	$ 437.60	$ 437.60	34	25	662	900	$ 14,878.40	$ 10,940.00
In-Wall Plumbing	2	5	Plumber	$ 58.70	$ 939.20	$ 2,348.00	62	25	363	900	$ 58,230.40	$ 58,700.00
Piping and Plumbing Insulation	2	1	Abestos	$ 52.35	$ 837.60	$ 418.80	3	25	7500	900	$ 2,512.80	$ 10,470.00
Frame Ceiling and bulkheads	2	2	Carpenter	$ 46.95	$ 751.20	$ 751.20	24	25	938	900	$ 18,028.80	$ 18,780.00
Install Med Gas Headwall and Zone Valve	2	1	Pipefitter	$ 59.75	$ 956.00	$ 478.00	15	25	1500	900	$ 14,340.00	$ 11,950.00
In-Wall Controls Rough-in	1	1	Electrician	$ 54.70	$ 437.60	$ 437.60	17	25	1324	900	$ 7,439.20	$ 10,940.00
In-Wall Electrical Rough-in	1	1	Electrician	$ 54.70	$ 437.60	$ 437.60	24	25	938	900	$ 10,502.40	$ 10,940.00
Install Cable tray	2	2	Electrician	$ 54.70	$ 875.20	$ 875.20	19	25	1184	900	$ 16,628.80	$ 21,880.00
In-Wall Telecom/Security Rough-in	2	2	Electrician	$ 54.70	$ 875.20	$ 875.20	29	25	776	900	$ 25,380.80	$ 21,880.00
Install Light Fixtures	2	2	Electrician	$ 54.70	$ 875.20	$ 875.20	23	25	978	900	$ 20,129.60	$ 21,880.00
Pull and Terminate Electrical	2	1	Electrician	$ 54.70	$ 875.20	$ 437.60	16	25	1406	900	$ 14,003.20	$ 10,940.00
Pull and Terminate Control Wire	1	1	Electrician	$ 54.70	$ 437.60	$ 437.60	16	25	1406	900	$ 7,001.60	$ 10,940.00
Pull and Terminate Telecom/Security	2	1	Electrician	$ 54.70	$ 875.20	$ 437.60	18	25	1250	900	$ 15,753.60	$ 10,940.00
In-Wall Insulation	2	1	Asbestos	$ 52.35	$ 837.60	$ 418.80	12	25	1875	900	$ 10,051.20	$ 10,470.00
Install Ceiling	2	2	Carpenter	$ 46.95	$ 751.20	$ 751.20	21	25	1071	900	$ 15,775.20	$ 18,780.00
Cut-in Sprinkler Drops/Trim	1	1	Sprinkler	$ 56.65	$ 453.20	$ 453.20	17	25	1324	900	$ 7,704.40	$ 11,330.00
Install Air Distribution	1	1	Sheetmetal	$ 55.95	$ 447.60	$ 447.60	32	25	703	900	$ 14,323.20	$ 11,190.00
Hang/Tape/Finish Drywall	2	4	Carpenter	$ 46.95	$ 751.20	$ 1,502.40	46	25	489	900	$ 34,555.20	$ 37,560.00
Firestop and Caulk Wall Penetrations	1	1	Carpenter	$ 46.95	$ 375.60	$ 375.60	36	25	625	900	$ 13,521.60	$ 9,390.00
Paint Walls	2	2	Painter	$ 40.35	$ 645.60	$ 645.60	19	25	1184	900	$ 12,266.40	$ 16,140.00
Install Flooring	2	3	Floor Tiler	$ 43.60	$ 697.60	$ 1,046.40	39	25	577	900	$ 27,206.40	$ 26,160.00
Set and Hook-up Plumbing Fixtures	2	2	Plumber	$ 58.70	$ 939.20	$ 939.20	23	25	978	900	$ 21,601.60	$ 23,480.00
Final Paint	2	1	Painter	$ 40.35	$ 645.60	$ 322.80	18	25	1250	900	$ 11,620.80	$ 8,070.00
Final Clean	2	2	Laborers	$ 37.60	$ 601.60	$ 601.60	19	25	1184	900	$ 11,430.40	$ 15,040.00
TOTAL PER FLOOR											**$ 994,322.40**	**$ 990,290.00**
TOTAL FOR ALL FLOORS											**$ 2,982,967.20**	**$ 2,970,870.00**

Northeast Hospital Expansion: Labor Matrix

		Week																																																				
Floor	Work Zone	3/5/14	3/12/14	3/19/14	3/26/14	4/2/14	4/9/14	4/16/14	4/23/14	4/30/14	5/7/14	5/14/14	5/21/14	5/28/14	6/4/14	6/11/14	6/18/14	6/25/14	7/2/14	7/9/14	7/16/14	7/23/14	7/30/14	8/6/14	8/13/14	8/20/14	8/27/14	9/3/14	9/10/14	9/17/14	9/24/14	10/1/14	10/8/14	10/15/14	10/22/14	10/29/14	11/5/14	11/12/14	11/19/14	11/26/14	12/3/14	#######	#######	#######	#######	1/7/15	1/14/15	1/21/15	1/28/15	2/4/15	2/11/15	2/18/15	2/25/15	3/4/15	3/11/15	######
	1																																																							
	2																																																							
4th	3																																																							
	4																																																							
	5																																																							
	6																																																							
	7																																																							
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	11																																																							
	12																																																							
6th	13																																																							
	14																																																							
	15																																																							

Framer
- Layout and Top Track
- Frame Walls
- Door Frames
- Frame Ceiling and bulkheads
- Install Ceiling
- Hang/Tape/Finish Drywall
- Firestop and Caulk Wall Penetrations

Plumbing
- Sanitary Runouts
- Dom Water Mains
- Domestic Water Branch
- In-Wall Plumbing
- Set and Hook-up Plumbing Fixtures

Fitters
- Medical Gas Mains
- HVAC Piping Mains
- Medical Gas Branch
- HVAC Branch
- Install Med Gas Headwall and Zone Valve

Electrician
- Electrical Conduit Mains
- Electrical Branch
- In-Wall Controls Rough-in
- In-Wall Electrical Rough-in
- Install Light Fixtures
- Pull and Terminate Electrical
- Pull and Terminate Control Wire

Sheetmetal
- Duct Mains
- Duct Branch
- Install Air Distribution

Sprinkler
- Sprinkler Mains
- Sprinkler Branch
- Cut-in Sprinkler Drops/Trim

Telecom
- Install Cable tray
- In-Wall Telecom/Security Rough-in
- Pull and Terminate Telecom/Security

Insulator
- Insulate Ducts
- Piping and Plumbing Insulation
- In-Wall Insulation

Painter
- Paint Walls
- Final Paint

Floor Tiler
- Install Flooring

Laborers

Original

Labor Type	3/5/2014	3/12/2014	3/19/2014	3/26/2014	4/2/2014	4/9/2014	4/16/2014	4/23/2014	4/30/2014	5/7/2014	5/14/2014	5/21/2014	5/28/2014	6/4/2014	6/11/2014	6/18/2014	6/25/2014
Carpenters	2				4	2	2				4	2	2	12	14	12	12
Plumbers		2	2			2	6	4	4	4	2	2	2	12	12	12	14
Fitters										12	12	6		24	24	24	30
Electricians						2	4	2	2					6	6	6	6
Sheetmetal					2	2	2	2	4	4	4	2	4	10	10	10	10
Sprinkler										5	8	2		10	10	10	10
Insulator														4	4	4	4
Painter																	
Floor Tiler																	
Laborer																	
Total Worker #	2	2	2	-	6	8	14	8	10	25	30	14	8	78	80	78	86
Labor Cost Per Week	$ 3,454.69	$ 4,319.28	$ 4,319.28	$ -	$ 11,026.31	$ 15,915.85	$ 28,579.36	$ 16,780.44	$ 20,897.37	$ 53,672.77	$ 62,515.52	$ 29,248.96	$ 16,007.83	$ 160,608.08	$ 164,062.76	$ 160,608.08	$ 178,116.98
Labor Cost to Date	$ 3,454.69	$ 7,773.97	$ 12,093.25	$ 12,093.25	$ 23,119.56	$ 39,035.41	$ 67,614.77	$ 84,395.21	$ 105,292.59	$ 158,965.35	$ 221,480.87	$ 250,729.83	$ 266,737.66	$ 427,345.74	$ 591,408.50	$ 752,016.58	$ 930,133.56

Labor Type	7/2/2014	7/9/2014	7/16/2014	7/23/2014	7/30/2014	8/6/2014	8/13/2014	8/20/2014	8/27/2014	9/3/2014	9/10/2014	9/17/2014	9/24/2014	10/1/2014
Carpenters			2	2	2		2	2			4	10	4	2
Plumbers	6	4	6	4	2	2	4	6	6	6	6	14	12	6
Fitters	12	6	12	12	9	12	9	6	18	12	9	6		
Electricians	2	2	3	1	1	1	3	3	3	3	3	5	3	2
Sheetmetal	4	4	4	2	4	6	8	8	6	4	2	2	2	
Sprinkler	5	3	2	2	5	8	5	3	3	5	5	2		
Insulator					2	2	2					6	4	4
Painter														
Floor Tiler														
Laborer														
Total Worker #	29	19	29	23	25	31	33	28	36	30	29	45	25	14
Labor Cost Per Week	$ 62,017.00	$ 40,339.65	$ 61,231.51	$ 48,770.35	$ 52,077.87	$ 65,587.58	$ 68,655.96	$ 58,359.96	$ 77,167.59	$ 64,029.47	$ 60,227.11	$ 90,601.88	$ 50,683.48	$ 28,141.55
Labor Cost to Date	$ 992,150.56	$ 1,032,490.21	$ 1,093,721.72	$ 1,142,492.06	$ 1,194,569.93	$ 1,260,157.51	$ 1,328,813.47	$ 1,387,173.43	$ 1,464,341.02	$ 1,528,370.50	$ 1,588,597.60	$ 1,679,199.48	$ 1,729,882.97	$ 1,758,024.52

Labor Type	10/8/2014	10/15/2014	10/22/2014	10/29/2014	11/5/2014	11/12/2014	11/19/2014	11/26/2014	12/3/2014	12/10/2014	12/17/2014	12/24/2014	12/31/2014	1/7/2015	1/14/2015	1/21/2015
Carpenters	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Plumbers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fitters	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Electricians	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sheetmetal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sprinkler	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Insulator	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Painter	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Floor Tiler	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Laborer	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Worker #	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Labor Cost Per Week	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Labor Cost to Date	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Labor Type	1/28/2015	2/4/2015	2/11/2015	2/18/2015	2/25/2015	3/4/2015	3/11/2015	3/18/2015	3/25/2015	4/1/2015	4/8/2015	4/15/2015	4/22/2015	4/29/2015	5/6/2015	5/13/2015	5/20/2015	5/27/2015	6/3/2015	6/10/2015	6/17/2015	6/24/2015	7/1/2015	7/8/2015	7/15/2015	7/22/2015
Carpenters	14	12	8	11	9	6	4	3	2				2													
Plumbers						2	2	4	4	2	4	2	4	4	6	4	4	4	4	2	2					
Fitters																										
Electricians																										
Sheetmetal	1	1	1		1	2	2	2	2	1	1	1														
Sprinkler		1				1	1	2	2	2	1	1														
Insulator	2	2																								
Painter	2	2	2	4	6	4	6	4	2	6			2	2	2	2	2	6	4	6	4	2	2	2	2	
Floor Tiler			4	2	2	2	4	4	4	2	6	6	4	4	4	2	2	2								
Laborer								2	2	4	2	2		2		2	4	2	6	4	4	4	2	2	2	
Total Worker #	19	18	15	17	18	17	19	21	18	17	14	12	12	12	12	10	12	14	14	12	10	6	4	4	4	-
Labor Cost Per Week	$ [illegible]3,062.36	$ 31,691.89	$ 25,262.64	$ 28,147.07	$ 29,719.89	$ 30,030.77	$ 32,753.32	$ 37,227.12	$ 32,530.73	$ 28,194.90	$ 25,172.50	$ 20,853.22	$ 21,478.67	$ 20,790.68	$ 22,343.26	$ 17,582.49	$ 20,349.18	$ 23,520.58	$ 22,876.74	$ 18,759.81	$ 15,790.76	$ 8,502.43	$ 5,735.74	$ 5,735.74	$ 5,735.74	$ -
Labor Cost to Date	$ [illegible]1,241.32	$ 2,492,933.21	$ 2,518,195.85	$ 2,546,342.92	$ 2,576,062.81	$ 2,606,093.58	$ 2,638,846.90	$ 2,676,074.02	$ 2,708,604.76	$ 2,736,799.65	$ 2,761,972.16	$ 2,782,825.38	$ 2,804,304.05	$ 2,825,094.73	$ 2,847,437.99	$ 2,865,020.48	$ 2,885,369.66	$ 2,908,890.25	$ 2,931,766.98	$ 2,950,526.79	$ 2,966,317.55	$ 2,974,819.98	$ 2,980,555.72	$ 2,986,291.46	$ 2,992,027.20	$ 2,992,027.20

Proposed

Labor Type	3/5/2014	3/12/2014	3/19/2014	3/26/2014	4/2/2014	4/9/2014	4/16/2014	4/23/2014	4/30/2014	5/7/2014	5/14/2014	5/21/2014	5/28/2014	6/4/2014	6/11/2014	6/18/2014	6/25/2014
Carpenters	3	3	3	3	3	3	3	3	3	3	3	3	3	6	6	5	5
Plumbers		3	6	6	6	6	6	6	6	6	6	8	8	8	8	8	5
Fitters						4	8	8	12	12	16	16	16	16	16	16	16
Electricians				3	3	3	3	3	3	3	3	3	3	3	3	3	4
Sheetmetal					5	5	5	5	5	5	5	5	8	8	8	8	8
Sprinkler								4	4	6	6	6	6	6	6	6	6
Insulator															2	2	2
Painter																	
Floor Tiler																	
Laborer																	
Total Worker #	3	6	9	12	17	21	25	29	33	35	39	41	44	47	49	48	46
Labor Cost Per Week	$ 5,634.00	$ 12,678.00	$ 19,722.00	$ 26,286.00	$ 37,476.00	$ 47,036.00	$ 56,596.00	$ 65,660.00	$ 75,220.00	$ 79,752.00	$ 89,312.00	$ 94,008.00	$ 100,722.00	$ 106,356.00	$ 110,544.00	$ 108,666.00	$ 103,810.00
Labor Cost to Date	$ 5,634.00	$ 18,312.00	$ 38,034.00	$ 64,320.00	$ 101,796.00	$ 148,832.00	$ 205,428.00	$ 271,088.00	$ 346,308.00	$ 426,060.00	$ 515,372.00	$ 609,380.00	$ 710,102.00	$ 816,458.00	$ 927,002.00	$ 1,035,668.00	$ 1,139,478.00

Labor Type	7/2/2014	7/9/2014	7/16/2014	7/23/2014	7/30/2014	8/6/2014	8/13/2014	8/20/2014	8/27/2014	9/3/2014	9/10/2014	9/17/2014	9/24/2014	10/1/2014
Carpenters	5	5	7	7	7	7	7	7	7	7	7	4	4	4
Plumbers	7	7	7	7	7	7	7	7	7	5	5	5	5	5
Fitters	16	16	16	13	9	9	5	5	1	1	1	1	1	1
Electricians	4	1	1	1	2	3	5	7	9	10	11	12	12	12
Sheetmetal	8	8	3	3	3	3	3	3	3	3				
Sprinkler	6	6	6	6	6	2	2							
Insulator	2	3	3	3	3	3	3	3	3	3	3	3	2	2
Painter														
Floor Tiler														
Laborer														
Total Worker #	48	46	43	40	37	34	32	32	30	29	27	25	24	24
Labor Cost Per Week	$ 108,506.00	$ 104,036.00	$ 96,602.00	$ 89,432.00	$ 82,060.00	$ 75,184.00	$ 70,000.00	$ 69,844.00	$ 64,660.00	$ 62,152.00	$ 57,626.00	$ 54,180.00	$ 52,086.00	$ 52,086.00
Labor Cost to Date	$ 1,247,984.00	$ 1,352,020.00	$ 1,448,622.00	$ 1,538,054.00	$ 1,620,114.00	$ 1,695,298.00	$ 1,765,298.00	$ 1,835,142.00	$ 1,899,802.00	$ 1,961,954.00	$ 2,019,580.00	$ 2,073,760.00	$ 2,125,846.00	$ 2,177,932.00

Labor Type	10/8/2014	10/15/2014	10/22/2014	10/29/2014	11/5/2014	11/12/2014	11/19/2014	11/26/2014	12/3/2014	12/10/2014	12/17/2014	12/24/2014	12/31/2014	1/7/2015	1/14/2015	1/21/2015
Carpenters	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Plumbers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fitters	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Electricians	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sheetmetal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sprinkler	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Insulator	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Painter	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Floor Tiler	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Laborer	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Worker #	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Labor Cost Per Week	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Labor Cost to Date	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Labor Type	1/28/2015	2/4/2015	2/11/2015	2/18/2015	2/25/2015	3/4/2015	3/11/2015	3/18/2015
Carpenters	5	1						
Plumbers	3	3	3	3				
Fitters								
Electricians								
Sheetmetal								
Sprinkler								
Insulator								
Painter	3	3	3	1	1	1		
Floor Tiler	2	2	2	2	2			
Laborer	2	2	2	2	2	2	2	
Total Worker #	15	11	10	8	5	3	2	-
Labor Cost Per Week	$ [illegible]7,772.00	$ 20,260.00	$ 18,382.00	$ 15,154.00	$ 8,110.00	$ 4,622.00	$ 3,008.00	$ -
Labor Cost to Date	$ [illegible]0,394.00	$ 2,930,654.00	$ 2,949,036.00	$ 2,964,190.00	$ 2,972,300.00	$ 2,976,922.00	$ 2,979,930.00	

Week	3/5/2014	3/12/2014	3/19/2014	3/26/2014	4/2/2014	4/9/2014	4/16/2014	4/23/2014	4/30/2014	5/7/2014	5/14/2014	5/21/2014	5/28/2014	6/4/2014	6/11/2014	6/18/2014	6/25/2014
Original	2	2	2	-	6	8	14	8	10	25	30	14	8	78	80	78	86
Proposed	3	6	9	12	17	21	25	29	33	35	39	41	44	47	49	48	46
Difference	$ (2,179.31)	$ (8,358.72)	$ (15,402.72)	$ (26,286.00)	$ (26,449.69)	$ (31,120.15)	$ (28,016.64)	$ (48,879.56)	$ (54,322.63)	$ (26,079.23)	$ (26,796.48)	$ (64,759.04)	$ (84,714.17)	$ 54,252.08	$ 53,518.76	$ 51,942.08	$ 74,306.98
Savings	$ (2,179.31)	$ (10,538.03)	$ (25,940.75)	$ (52,226.75)	$ (78,676.44)	$ (109,796.59)	$ (137,813.23)	$ (186,692.79)	$ (241,015.41)	$ (267,094.65)	$ (293,891.13)	$ (358,650.17)	$ (443,364.34)	$ (389,112.26)	$ (335,593.50)	$ (283,651.42)	$ (209,344.44)

Week	7/2/2014	7/9/2014	7/16/2014	7/23/2014	7/30/2014	8/6/2014	8/13/2014	8/20/2014	8/27/2014	9/3/2014	9/10/2014	9/17/2014	9/24/2014	10/1/2014
Original	29	19	29	23	25	31	33	28	36	30	29	45	25	14
Proposed	48	46	43	40	37	34	32	32	30	29	27	25	24	24
Difference	$ (46,489.00)	$ (63,696.35)	$ (35,370.49)	$ (40,661.65)	$ (29,982.13)	$ (9,596.42)	$ (1,344.04)	$ (11,484.04)	$ 12,507.59	$ 1,877.47	$ 2,601.11	$ 36,421.88	$ (1,402.52)	$ (23,944.45)
Savings	$ (255,833.44)	$ (319,529.79)	$ (354,900.28)	$ (395,561.94)	$ (425,544.07)	$ (435,140.49)	$ (436,484.53)	$ (447,968.57)	$ (435,460.98)	$ (433,583.50)	$ (430,982.40)	$ (394,560.52)	$ (395,963.03)	$ (419,907.48)

Week	10/8/2014	10/15/2014	10/22/2014	10/29/2014	11/5/2014	11/12/2014	11/19/2014	11/26/2014	12/3/2014	12/10/2014	12/17/2014	12/24/2014	12/31/2014	1/7/2015	1/14/2015	1/21/2015
Original	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Proposed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Difference	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Savings	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Week	1/28/2015	2/4/2015	2/11/2015	2/18/2015	2/25/2015	3/4/2015	3/11/2015	3/18/2015	3/25/2015	4/1/2015	4/8/2015	4/15/2015	4/22/2015	4/29/2015	5/6/2015	5/13/2015	5/20/2015	5/27/2015	6/3/2015	6/10/2015	6/17/2015	6/24/2015	7/1/2015	7/8/2015	7/15/2015	7/22/2015
Original	19	18	15	17	18	17	19	21	18	17	14	12	12	12	12	10	12	14	14	12	10	6	4	4	4	-
Proposed	15	11	10	8	5	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Difference	$ [illegible]5,290.36	$ 11,431.89	$ 6,880.64	$ 12,993.07	$ 21,609.89	$ 25,408.77	$ 29,745.32	$ 37,227.12	$ 32,530.73	$ 28,194.90	$ 25,172.50	$ 20,853.22	$ 21,478.67	$ 20,790.68	$ 22,343.26	$ 17,582.49	$ 20,349.18	$ 23,520.58	$ 22,876.74	$ 18,759.81	$ 15,790.76	$ 8,502.43	$ 5,735.74	$ 5,735.74	$ 5,735.74	$ -
Savings	$ ([illegible]49,152.68)	$ (437,720.79)	$ (430,840.15)	$ (417,847.08)	$ (396,237.19)	$ (370,828.42)	$ (341,083.10)	$ (303,855.98)	$ (271,325.24)	$ (243,130.35)	$ (217,957.84)	$ (197,104.62)	$ (175,625.95)	$ (154,835.27)	$ (132,492.01)	$ (114,909.52)	$ (94,560.34)	$ (71,039.75)	$ (48,163.02)	$ (29,403.21)	$ (13,612.45)	$ (5,110.02)	$ 625.72	$ 6,361.46	$ 12,097.20	$ 12,097.20

Appendix D: Preassembled Steel Connection Bridge

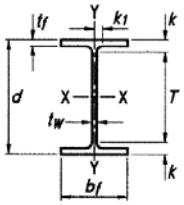

Table 1-1 (continued)
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k: k_{des}	Distance k: k_{det}	k_1	T	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W12×58	17.0	12.2	12 1/4	0.360	3/8	3/16	10.0	10	0.640	5/8	1.24	1 1/2	15/16	9 1/4	5 1/2
×53	15.6	12.1	12	0.345	3/8	3/16	10.0	10	0.575	9/16	1.18	1 3/8	15/16	9 1/4	5 1/2
W12×50	14.6	12.2	12 1/4	0.370	3/8	3/16	8.08	8 1/8	0.640	5/8	1.14	1 1/2	15/16	9 1/4	5 1/2
×45	13.1	12.1	12	0.335	5/16	3/16	8.05	8	0.575	9/16	1.08	1 3/8	15/16	↓	↓
×40	11.7	11.9	12	0.295	5/16	3/16	8.01	8	0.515	1/2	1.02	1 3/8	7/8	↓	↓
W12×35[c]	10.3	12.5	12 1/2	0.300	5/16	3/16	6.56	6 1/2	0.520	1/2	0.820	1 3/16	3/4	10 1/8	3 1/2
×30[c]	8.79	12.3	12 3/8	0.260	1/4	1/8	6.52	6 1/2	0.440	7/16	0.740	1 1/8	3/4	↓	↓
×26[c]	7.65	12.2	12 1/4	0.230	1/4	1/8	6.49	6 1/2	0.380	3/8	0.680	1 1/16	3/4	↓	↓
W12×22[c]	6.48	12.3	12 1/4	0.260	1/4	1/8	4.03	4	0.425	7/16	0.725	15/16	5/8	10 3/8	2 1/4[g]
×19[c]	5.57	12.2	12 1/8	0.235	1/4	1/8	4.01	4	0.350	3/8	0.650	7/8	9/16	↓	↓
×16[c]	4.71	12.0	12	0.220	1/4	1/8	3.99	4	0.265	1/4	0.565	13/16	9/16	↓	↓
×14[c,v]	4.16	11.9	11 7/8	0.200	3/16	1/8	3.97	4	0.225	1/4	0.525	3/4	9/16	↓	↓
W10×112	32.9	11.4	11 3/8	0.755	3/4	3/8	10.4	10 3/8	1.25	1 1/4	1.75	1 15/16	1	7 1/2	5 1/2
×100	29.3	11.1	11 1/8	0.680	11/16	3/8	10.3	10 3/8	1.12	1 1/8	1.62	1 13/16	1	↓	↓
×88	26.0	10.8	10 7/8	0.605	5/8	5/16	10.3	10 1/4	0.990	1	1.49	1 11/16	15/16	↓	↓
×77	22.7	10.6	10 5/8	0.530	1/2	1/4	10.2	10 1/4	0.870	7/8	1.37	1 9/16	7/8	↓	↓
×68	19.9	10.4	10 3/8	0.470	1/2	1/4	10.1	10 1/8	0.770	3/4	1.27	1 7/16	7/8	↓	↓
×60	17.7	10.2	10 1/4	0.420	7/16	1/4	10.1	10 1/8	0.680	11/16	1.18	1 3/8	13/16	↓	↓
×54	15.8	10.1	10 1/8	0.370	3/8	3/16	10.0	10	0.615	5/8	1.12	1 5/16	13/16	↓	↓
×49	14.4	10.0	10	0.340	5/16	3/16	10.0	10	0.560	9/16	1.06	1 1/4	13/16	↓	↓
W10×45	13.3	10.1	10 1/8	0.350	3/8	3/16	8.02	8	0.620	5/8	1.12	1 5/16	13/16	7 1/2	5 1/2
×39	11.5	9.92	9 7/8	0.315	5/16	3/16	7.99	8	0.530	1/2	1.03	1 3/16	13/16	↓	↓
×33	9.71	9.73	9 3/4	0.290	5/16	3/16	7.96	8	0.435	7/16	0.935	1 1/8	3/4	↓	↓
W10×30	8.84	10.5	10 1/2	0.300	5/16	3/16	5.81	5 3/4	0.510	1/2	0.810	1 1/8	11/16	8 1/4	2 3/4[g]
×26	7.61	10.3	10 3/8	0.260	1/4	1/8	5.77	5 3/4	0.440	7/16	0.740	1 1/16	11/16	↓	↓
×22[c]	6.49	10.2	10 1/8	0.240	1/4	1/8	5.75	5 3/4	0.360	3/8	0.660	15/16	5/8	↓	↓
W10×19	5.62	10.2	10 1/4	0.250	1/4	1/8	4.02	4	0.395	3/8	0.695	15/16	5/8	8 3/8	2 1/4[g]
×17[c]	4.99	10.1	10 1/8	0.240	1/4	1/8	4.01	4	0.330	5/16	0.630	7/8	9/16	↓	↓
×15[c]	4.41	9.99	10	0.230	1/4	1/8	4.00	4	0.270	1/4	0.570	13/16	9/16	↓	↓
×12[c,f]	3.54	9.87	9 7/8	0.190	3/16	1/8	3.96	4	0.210	3/16	0.510	3/4	9/16	↓	↓

[c] Shape is slender for compression with $F_y = 50$ ksi.
[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.
[g] The actual size, combination and orientation of fastener components should be compared with the geometry of the cross section to ensure compatibility.
[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with $F_y = 50$ ksi.

Table 1-1 (continued)
W-Shapes
Properties

W12-W10

Nominal Wt.	Compact Section Criteria $\frac{b_f}{2t_f}$	Compact Section Criteria $\frac{h}{t_w}$	Axis X-X I	Axis X-X S	Axis X-X r	Axis X-X Z	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r	Axis Y-Y Z	r_{ts}	h_o	Torsional Properties J	Torsional Properties C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
58	7.82	27.0	475	78.0	5.28	86.4	107	21.4	2.51	32.5	2.81	11.6	2.10	3570
53	8.69	28.1	425	70.6	5.23	77.9	95.8	19.2	2.48	29.1	2.79	11.5	1.58	3160
50	6.31	26.8	391	64.2	5.18	71.9	56.3	13.9	1.96	21.3	2.25	11.6	1.71	1880
45	7.00	29.6	348	57.7	5.15	64.2	50.0	12.4	1.95	19.0	2.23	11.5	1.26	1650
40	7.77	33.6	307	51.5	5.13	57.0	44.1	11.0	1.94	16.8	2.21	11.4	0.906	1440
35	6.31	36.2	285	45.6	5.25	51.2	24.5	7.47	1.54	11.5	1.79	12.0	0.741	879
30	7.41	41.8	238	38.6	5.21	43.1	20.3	6.24	1.52	9.56	1.77	11.9	0.457	720
26	8.54	47.2	204	33.4	5.17	37.2	17.3	5.34	1.51	8.17	1.75	11.8	0.300	607
22	4.74	41.8	156	25.4	4.91	29.3	4.66	2.31	0.848	3.66	1.04	11.9	0.293	164
19	5.72	46.2	130	21.3	4.82	24.7	3.76	1.88	0.822	2.98	1.02	11.9	0.180	131
16	7.53	49.4	103	17.1	4.67	20.1	2.82	1.41	0.773	2.26	0.983	11.7	0.103	96.9
14	8.82	54.3	88.6	14.9	4.62	17.4	2.36	1.19	0.753	1.90	0.961	11.7	0.0704	80.4
112	4.17	10.4	716	126	4.66	147	236	45.3	2.68	69.2	3.08	10.2	15.1	6020
100	4.62	11.6	623	112	4.60	130	207	40.0	2.65	61.0	3.04	10.0	10.9	5150
88	5.18	13.0	534	98.5	4.54	113	179	34.8	2.63	53.1	2.99	9.81	7.53	4330
77	5.86	14.8	455	85.9	4.49	97.6	154	30.1	2.60	45.9	2.95	9.73	5.11	3630
68	6.58	16.7	394	75.7	4.44	85.3	134	26.4	2.59	40.1	2.92	9.63	3.56	3100
60	7.41	18.7	341	66.7	4.39	74.6	116	23.0	2.57	35.0	2.88	9.52	2.48	2640
54	8.15	21.2	303	60.0	4.37	66.6	103	20.6	2.56	31.3	2.85	9.49	1.82	2320
49	8.93	23.1	272	54.6	4.35	60.4	93.4	18.7	2.54	28.3	2.84	9.44	1.39	2070
45	6.47	22.5	248	49.1	4.32	54.9	53.4	13.3	2.01	20.3	2.27	9.48	1.51	1200
39	7.53	25.0	209	42.1	4.27	46.8	45.0	11.3	1.98	17.2	2.24	9.39	0.976	992
33	9.15	27.1	171	35.0	4.19	38.8	36.6	9.20	1.94	14.0	2.20	9.30	0.583	791
30	5.70	29.5	170	32.4	4.38	36.6	16.7	5.75	1.37	8.84	1.60	10.0	0.622	414
26	6.56	34.0	144	27.9	4.35	31.3	14.1	4.89	1.36	7.50	1.58	9.86	0.402	345
22	7.99	36.9	118	23.2	4.27	26.0	11.4	3.97	1.33	6.10	1.55	9.84	0.239	275
19	5.09	35.4	96.3	18.8	4.14	21.6	4.29	2.14	0.874	3.35	1.06	9.81	0.233	104
17	6.08	36.9	81.9	16.2	4.05	18.7	3.56	1.78	0.845	2.80	1.04	9.77	0.156	85.1
15	7.41	38.5	68.9	13.8	3.95	16.0	2.89	1.45	0.810	2.30	1.01	9.72	0.104	68.3
12	9.43	46.6	53.8	10.9	3.90	12.6	2.18	1.10	0.785	1.74	0.983	9.66	0.0547	50.9