The Pegula Ice Arena

University Park, PA

Thesis Report

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Department of Architectural Engineering
Construction Management Option

AE 481 W – Spring 2013
Faculty Advisor: Raymond Sowers

Pegula Ice Arena

University Park, PA

Project Overview

Owner:	The Pennsylvania State University
Construction Manager:	Mortenson Construction
Architect:	Crawford Architects
Structural Engineer:	Thorton Tomasetti
Civil Engineer:	Sweetland Engineer
MEP Engineer:	Moore Engineers
Project Cost:	$ 102 million
Size :	Size : 227,000 s.f.
Height:	3 Stories | 65 feet
Duration:	February, 2012 – August, 2013

Construction

- CM at Risk Contract | Guaranteed Maximum Price
- Construction Sequence Starts in the Center South portion of the Arena. Everything Moves in a Counter-Clockwise Fashion Around the Main Rink.
- Crane and Steel Shakeout Staged Inside the Main Rink

Structural System

- Micropiles Utilized Along Western Portion of Arena
- Cast-In-Place Concrete Foundations and Foundation Walls
- Structural Steel Frame: Moment and Braced Frame
    - W Columns and Beams
    - Rakers (Supports Seating Section)
    - Roof Joists
    - Roof Trusses over Main Ice Arena
- Precast Stadia
- Slab on Metal Deck with Shear Studs and Rebar

Architectural Features

- Two NHL-sized Ice Surfaces
    - Main Rink [6000+ seats]
    - Community Rink [300 seats]
- Occupancy
    - Strength and Conditioning
    - Skate Rental
    - Offices
    - Concessions
    - Tim Horton's Restaurant
    - Club Boxes
- Curtain Wall with Glazing Along Entire East Façade
- Pursuing LEED Silver Rating

Mechanical System

- 12 Air Handling Units
    - 2 AHU's Utilize Energy Recovery Wheels
    - 4 AHU's Function as Dehumidification Units
- 25% Glycol Line Incorporated into Mechanical System
- Radiant Finned Tube System Utilized Along East Curtain Wall
- Wet Pipe Sprinkler System

Electrical System

- 3 Transformers Located at the North West Corner
- Two Transformers Service the Building, One Utilized in Case of System Failure
- Oil filled, Pad Mounted Transformers
- Transformers Setback 15' from Building
- Transformers Carry 3000 amp, 480/277 Volt, 3 Phase, 4 Wire Service

Shane Marshall

Construction Management

Executive Summary

This senior thesis final report includes four different analyses of the 227,500 square foot Pegula Ice Arena located on University Park of the Pennsylvania State University. Once completed, this building is going to be the future home of Division 1 hockey for Penn State. The four analyses include: a detailed look into the sequencing of the community rink with a structural breadth; a retrospective look at the schedule to determine if the project could have been expedited by an altered sequence; an analysis into a new façade system with an architectural breadth; and research into different methods of performing a geotechnical analysis.

Analysis 1 | Community Rink Sequence off Critical Path

The project team at the Pegula Ice Arena took many steps to ensure they could start the finish work inside the building early enough to finish the project on time. In discussions with Heidi Brown, Mortenson PM, she proposed that the community rink be sequenced off the critical path. Doing this, allows for work trades to focus more on the main rink portion of the building where the bulk of finish work is located.

Ultimately, removing the community rink off the critical path proved to have the potential to save three weeks on overall duration. As beneficial to the project team removing the community rink off the critical path would be, it was entirely unbeneficial to the owner and architect. It raised the cost of the project by over $260,000 and significantly disrupted an architectural aspect inside the building. With this, it seems that there are more disadvantages than advantages, which is why this proposed changed would not be recommended.

A structural design was also performed determining the best possible solution in redistributing the loads to ensure the community rink could be scheduled off the critical path.

Analysis 2 | Building Sequence

After a detailed review of the community rink was finished a more retrospective look at the entire schedule was analyzed. Two different schedule analyses were performed as part of the building sequencing. The first was analyzing the feasibility of utilizing two crews throughout part of construction. If excavation, concrete, and steel were constructed with two crews the building could have been opened prior to the start of the 2013 school year. This would have helped allow the building manager to ensure the building was commissioned properly prior to the home opener and it also would have helped generate interest for the upcoming hockey season. However, due to the expected premium in cost and more importantly the challenges that would result in site logistics, this sequence would not be recommended.

The second sequence looked into was with regards to the project start location. The beginning of the project proved to be largely driven by the foundation wall which wraps around three sides of the

building. However, a completed foundation wall does not allow finish work to begin any sooner. In contrast, moving the SOG start location back would have allowed finish work to begin without interfering with the foundation wall. The newly proposed start point would have the potential to save two weeks of schedule while not interfering with any other project sequence.

Analysis 3 | Building Enclosure

Due to the finish date of this project it was necessary for the project team to accelerate the enclosure to ensure temporary heat could be provided prior to the start of winter. This was to ensure finishes could begin and finish as scheduled. This project also faced multiple safety incidents. Therefore, the removal of any potentially harmful work sequences drove to the decision to explore a new façade system.

The façade system analyzed and proposed contains insulation sandwiched between concrete. It was able to provide a safer system by removing scaffolding and exterior work during winter weather. As important as safety is, the newly proposed system does not save any overall schedule duration when compared to the original system. The newly proposed system would also add an additional $200,821 to the project. Subsequently, this proposed alternative system would not be recommended.

An architectural design was done by analyzing the thermal and moisture performance of the wall as well as architectural details that could be utilized as part of the contract drawings.

Analysis 4 | Geotechnical Investigation

A look into different ways to analyze subsurface conditions was done in the fourth and final analysis. Prior to construction, the Pegula Ice Arena site had a lacrosse field at that location. Penn State did not want to remove or damage this field until they had to which is why they utilized ground penetrating radar (GPR) over the field with bore holes surrounding the rest of the project site. The geotechnical report proved fairly accurate over boring locations but inaccurate over locations where GPR was utilized.

In a thorough comparison and review of the two methods of subsurface analysis; and discussions with THG Geophysics it was determined that GPR would not be recommended as the sole source of subsurface investigation. GPR is good for many things including roadway construction and utility line locations. However, GPR does not function well in clay type soils and cannot accurately identify soils at large depths.

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Mortenson construction

Penn State Nittany Lions

High Concrete Group LLC An Affiliate of High Industries Inc.

THG Geophysics

Special Thanks

Steve Laurila (Sr. PM), Jason Brown (Sr. Supt), Heidi Brown (PM), and Mortenson's Project Team

Marv Bevan (PM), Mark Bodenschatz (Assoc. AD for Facilities & Operations), and Penn State Project Team

Jeffrey Angstadt (VP of Operations) of Foreman Program and Construction Managers

PACE Industry Members

Family & Friends

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Building Introduction

Project Introduction

The Pegula Ice Arena is a direct result of a sizable donation made on behalf of Terence and Kim Pegula. Terence Pegula, a former Penn State student and current alumni; is an avid hockey fan and is the owner of the Buffalo Sabres. He wanted to bring hockey to Penn State and Penn State wanted hockey. Ice hockey is the only major sport that Penn State did not have as a Division 1 program. Knowing this, and that the Big 10 wanted to start a Division 1 ice hockey conference, Penn State jumped on the opportunity to build a state of the art collegiate hockey facility, through the Pegula's donation.

The Architect chosen to design the building was Crawford Architects. Unfortunately, since Penn State needed to have the new arena before the Big 10 aligned to create a Division 1 hockey conference, the design could not be completed before the building went out for bid. Because of this, Penn State decided to utilize a guaranteed maximum price contract. The job was awarded to M. A. Mortenson Company, who is serving as a CM at Risk while self-performing most of the concrete.

Site Overview

The future site of the Pegula Ice arena can be seen in yellow in figure 1. This was formerly the Penn State Lacrosse Field, which was most recently relocated outside of the Multi-Sport Indoor Facility. This location was chosen due to its vicinity to other sport complexes; most notably the Bryce Jordan Center and Beaver Stadium. Locating the Pegula Ice Arena adjacent to other sports facilities was important in part just to keep the sport complexes and their facilities close together; but also because no additional parking was designed to be added for the new ice arena. Therefore, the commuter lots located around Beaver Stadium and the Bryce Jordan Center will be used for the Pegula Ice Arena.

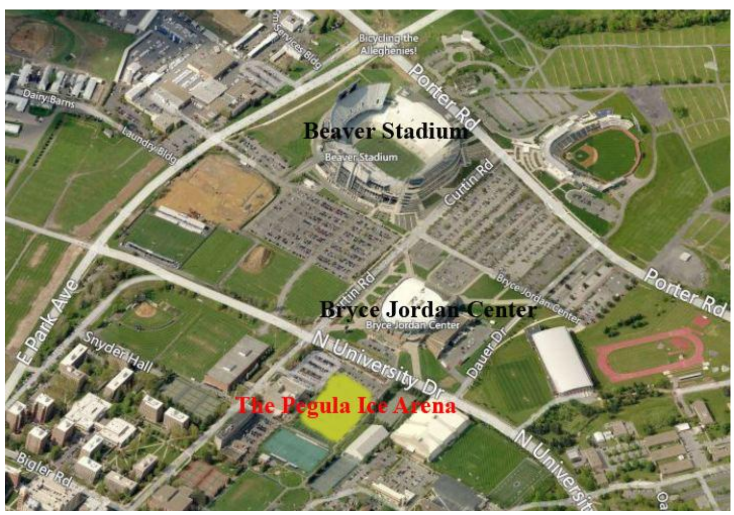


Figure 1: Birds-eye view | Bing Maps

Architectural Design

The Pegula Ice Arena is primarily designed to house the future Penn State Nittany Lions Division 1 hockey team. It has a main arena with approximately 6000 seats for spectators. The building also has a community rink with approximately 300 spectator seats. The community rink will be open to the public 360 days a year equipped with a skate rental center. In addition to this; the building will have approximately 5000 sf. of strength and conditioning space; offices for the coaching staff, facility managers, and Penn State Intercollegiate Athletics offices; and a restaurant on the main concourse.

Project Team Directory

Pennsylvania State University | Owner

Mortenson Construction | Construction Manager

Crawford Architects | Architect

Thornton Tomasetti | Structural Engineer

Sweetland Engineering | Civil Engineer

Moore Engineering | MEP Engineer

Lager Raabe Skafte | Landscape Architect

Client Information

The Pennsylvania State University is a public university with campuses and facilities located throughout Pennsylvania. The main campus is located in State College, Pennsylvania. It was founded in 1855 as an agricultural / farmers school.

The Pennsylvania State University is highly competitive in Division 1 athletics. There are multiple teams that compete for NCAA championship titles on a yearly basis. Some of these include football, baseball, basketball, wrestling and volleyball. It came to the attention of the Intercollegiate Athletics office, at Penn State, that hockey was the only mainstream sport that was not a competitive Division 1 program.

At this same time the Big 10 started actively seeking a competitive conference within collegiate hockey. It was decided that six teams would be needed to start a conference for hockey in the Big 10. Other schools such as Minnesota and Wisconsin had established teams but more needed to be added to make the Big 10 legitimate. For this reason, and the fact that ice hockey is a mainstream sport, Penn State decided to pursue a Division 1 Hockey program.

There were many hurdles to create a Division 1 hockey program; none larger than constructing a new facility. There is an existing ice arena, where Division 1 hockey will be played this year, but in order to legitimize the program they needed to build a new arena. The Pennsylvania State University primarily funds new construction by donations. Luckily for Penn State, they were able to receive one large donation to build the arena.

Terrence Pegula, and his wife Kim, donated 102 million dollars for the construction of a new ice arena at Penn State. The Pegula's are avid hockey fans and actually own the Buffalo Sabres. Terrence Pegula is a former Penn State engineering student. He founded East Resources, a natural gas drilling company, before selling it to Royal Dutch Shell for 4.7 billion dollars. Without the Pegula's generosity the Division 1 hockey program would not have been possible and the Pennsylvania State University is forever indebted to them.

The 102 million dollars was to pay for construction and design of the building. Penn State required that construction be finished by the home opener for the 2013/2014 hockey year. This is because; this will be the official start of the Big 10 Division 1 hockey conference.

Penn State demands the highest of quality in design and construction. They demand construction be met on time and on budget. They expect these things with no sacrifice in safety.

Project Delivery System

Mortenson is the single prime contractor working on the Pegula Ice Arena. The contract held between Penn State and Mortenson is a Guaranteed Max Price. Mortenson was awarded this job as a CM at risk. In order to make their price as competitive as they could, they decided to self-perform the concrete and other miscellaneous items. This did give them some contractor responsibilities.

The GMP went for a total of $89 million. A GMP was appropriate for the Pegula Ice Arena due to where the building was at in design once negotiations started. The design was to be at only 50 percent completion when the bids were due. This made it impossible to pursue a lump sum bid. The reason Penn State could not wait for the design to be finished was because they had to have a new arena before the home opener in October 2013.

Penn State then has a separate contract with Crawford Architects and Bohlin Cywinski Jackson (BCJ). Crawford Architects is serving as the lead architect and BCJ is serving as the enclosure consultant. Penn State has a lump sum contract with possible additional fees if asked to do more work. Both of these contracts were held in compliance with the American Institute of Architects (AIA).

Penn State also held the initial contract with the geotechnical engineer Pennoni. On top of this, Penn State hired a third party testing agency, CMT, and their own commissioning agent, Aramark Engineering Solutions. All of these contracts were issued via lump sum.

Subcontractors were picked via Mortenson's decision following Penn State conditions. The subcontractors had to be prequalified by both Mortenson and Penn State. Initial bids had to be formerly submitted through Penn State. This was Penn State's way of ensuring Mortenson could not unfairly ignore certain subcontractor bids. From here, Mortenson utilized their company wide best value decision process. This incorporates the goals and expectations Mortenson has, more or less in a checklist, and whichever subcontractor has the highest score is to receive the award. This was possible because Mortenson was under a guaranteed max price contract. If it was a lump sum, Mortenson would most likely have to accept the lowest bid. Once Mortenson had made their best value decision, the results are sent into Penn State in order to ensure no negligence has occurred, and once approved, Mortenson can officially award a lump sum contract.

Appendix A contains the project organizational chart.

Staffing Plan

Mortenson is headquartered in Minneapolis, Minnesota. Mortenson has regional offices primarily focused in the Midwest, but also has a National Projects Group which is in charge of the Pegula Ice Arena.

Appendix B is the staff organizational chart for the Pegula Ice Arena. In orange are the directors in charge of the national projects group. Derek Cunz is the Principal in Charge. He was largely responsible for seeking out this job. Gene Hodge started out as Senior Project Manager for this job but got promoted to Construction Executive part way through the job. Therefore, he handled a larger amount of work and primarily became responsible for Penn State relations.

From Gene, the chart splits in two directions. The one side is the project management side. This starts with Steve Laurila, the current Senior Project Manager on site. From here, it splits off into four sections. On the far right is the office administrator. There are then two full time Integrated Construction Coordinators. They are responsible for all BIM applications regarding the project, and any model coordination that needs to take place. Adjacent to that, is Nate Mallory, who is in charge of quality as well as MEP systems on site. Heidi Brown is another project manager located on site full time. She is responsible for cost management as well as schedule oversight. Beneath Heidi and Nate are three field engineers whom are in charge of submittals and inspections on predefined scopes of work. Finally, I am still working part time primarily maintaining document control as well as helping out where needed.

The other direction heading from Gene are the superintendents. There are three superintendents on site. Jason Brown is the Senior Superintendent who is in charge of the overall project supervision. Beneath the superintendents is Kyle Guenther. He is the full time Safety Engineer located on site.

Appendix B is the staff organizational chart for the Pegula Ice Arena.

Project Schedule Summary

Primavera Schedule

This schedule was broken down into design, preconstruction, procurement, construction, and project closeout. This schedule is not intended to show a critical path and does not have relationships between different trades but does give an overview of how the project is to be sequenced.

The project schedule is ultimately being pushed by the ice arena home opener October 11, 2013. This is the first men's Division 1 hockey game to be played in this state of the art collegiate facility. The penalty for delay was not disclosed but this is a must hit target date. Therefore, main components for the building are to be erected before August, which would allow for enough time to commission and furnish the building.

The Primavera Schedule can be viewed in full in Appendix C.

Construction Sequences

Excavation – The excavation for the building proved extremely difficult. Much of the soil was rock which required the use of blasting to remove the earth. This was a long process that was anything but cheap. After this, it was realized the western portion of the building pad was on loose soil. This required micropiles to be drilled throughout the western portion of the building pad; whereas the rest of the building needed minimal micropiles to rest on.

Foundation- The foundation started with spread footers, which like the rest of the building moved in a counter clockwise sequence. Following the spread footings were the continuous footings. This process moved slightly slower than expected. This was due to the excavation in the south, east, and north quadrants; which need jack hammered out due to all the rock.

Structure – The steel erection began June 12, 2012. The floors are formed, rebared, and then poured, with cast in place concrete. Topping off occurred December 7th, 2012.

Enclosure and Finishes – The enclosure began halfway through July, 2012. This consisted of metal studded panels, CMU, brick, and curtain wall with glazing. The interior finishes also started in October. This will have drywall put in first followed by paint, carpet, and terrazzo as finishes.

Building Systems Summary

Table 1: Summary Checklist

Building System Summary Checklist		
Description	Yes	No
Demolition Required	X	
Structural Steel Frame	X	
Cast in Place concrete	X	
Precast	X	
Mechanical System	X	
Electrical System	X	
Masonry	X	
Curtain Wall	X	
LEED	X	

Demolition

Demolition of existing materials was the first to take place. Existing on site was the former Penn State Lacrosse field. Underneath this was an advanced storm water drainage system, which was to minimize the amount of swamping and damage done to the field. These materials were disposed of as was bench seating located at the south end of the site.

There were also tennis courts located in the southeast corner of the site. The tennis courts as well as the shrubbery located around it were demolished. The asphalt parking lot located along University Drive was also demolished. The only items saved were the lacrosse field lights and the parking lot lights. On top of this any sports equipment was gathered and stored by the owner (i.e. goals, nets, etc.).

The utilities for the Pegula Ice Arena come from utilities lining Curtain Road (Reference Appendix D). Therefore, the parking lot adjacent to the Shields building was dug up in order to get the utilities underground to the ice arena. This is the demolition Penn State was most concerned with. Being that the utilities need to run so close to the building, overnight excavation was required as to not disturb the employees in Shields during the day.

Structural Steel Frame

The structural steel consists of a combination of moment and braced frames. There are W beams and columns located throughout the entire building. The roof consists of a combination of metal joists and trusses. Located on the south and north, of main rink, are roof joists as well as on the western side over the community rink. Over the main rink, there are to be trusses that span the width of the ice and seats. These trusses are being assembled in pieces. There are steel rakers that support the precast stadia, which are where the seats are located. Finally there are HSS columns located on the east curtain wall, facing University Drive, that were placed for aesthetic purposes.

The crane chosen to erect most of this steel is a Manitowoc 777 series 2. It has a capacity of 200 tons and for this job has a 180' main boom with a 40' fixed jib at a 15 degree offset. For this particular job the max radius required will be 170' with a factored load of 6,888 lbs. This will create a crane capacity of 65.6%. The maximum factored load for this project will be 14,039 lbs. with a radius of 60'. This will only create a crane capacity of 31.1%. The maximum crane capacity required is 73.6%. This will be due to a 11,928 lb. factored column, with a 136' radius created.

The steel is sequenced similarly to the rest of the building systems. It starts in the south, along grid line X9, and works counter clockwise around the building (SE 1). The crane and shakeout will be located inside the ice rink. Once sequence 10 is finished the Manitowoc starts construction on the roof trusses. The crane operator will work their way out of the ice rink, exiting along section 16 which will then be erected from the outside of the building.

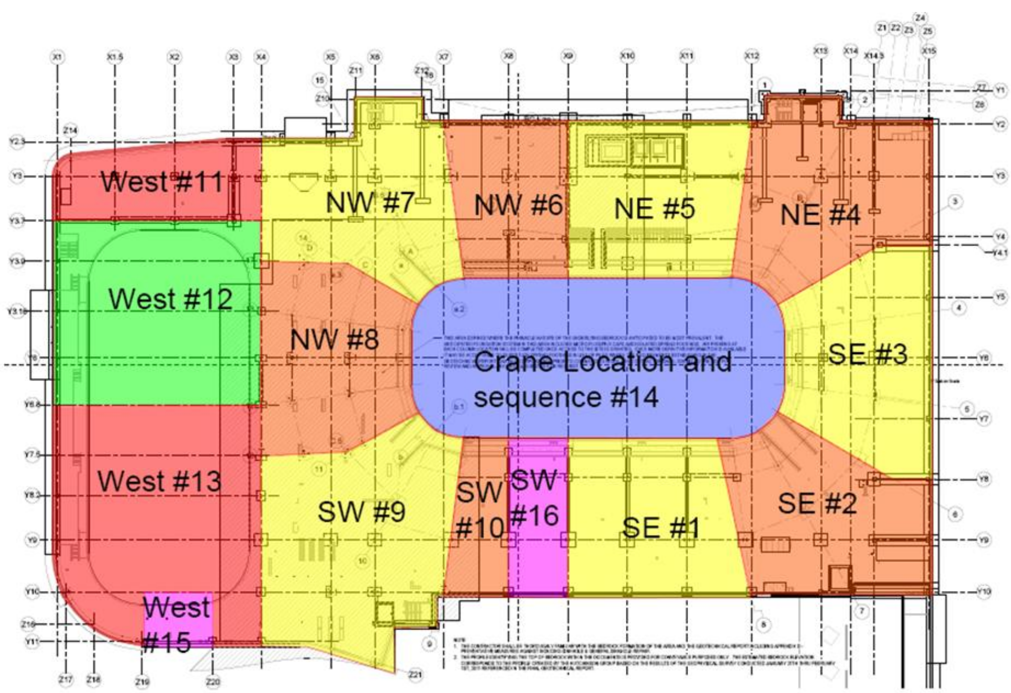


Figure 2: Steel Sequence

Cast in Place Concrete

The cast in place systems located throughout the building include micropiles, pile caps, column footers, wall footers, foundation walls, shear walls, a retaining wall, slab on grade, and slab on metal deck.

Lean fill was poured first below a number of the spread and foundation wall footers. This was to provide a level surface for the footers as well as help distribute the load. This also allowed a very workable base to build the form for foundations.

Along the shear, foundation, and retaining wall, vertical formwork was built. The majority of the walls are of the same widths which allowed for modular formwork to be set, with a crane, around the perimeter of the building. The only locations that needed to be specially formed were the north west and south west corners where the wall curves; and the retaining wall in the south east corner because it slopes downward. These forms also had built in slots for scaffolding at the top which allowed for quick and easy setup when scaffolding was needed to pour concrete.

Every cast in place concrete system utilized rebar. The micropiles and retaining wall utilized epoxied rebar with the expectation of high levels of moisture passing through. The flooring systems were also a rebar system instead of a wire mesh system with the SOG containing a vapor barrier beneath it.

There are three primary placement methods that were utilized in pouring concrete. One was a concrete pump. This was utilized along the entire foundation wall, SOG, and SOMD. The next system was direct chute. This was almost how all lean fill was poured and foundations when reachable. If the foundations were not reachable; then the crane and bucket placement method was used.

Below is the sequence method for foundation walls and the SOG. Remember, all construction starts at the south point near the center (gridline X9). The piles were poured first; then the pile caps; next were the spread and foundation wall footers; followed by the foundation, shear, and retaining wall; which preceded the SOG and SOMD.

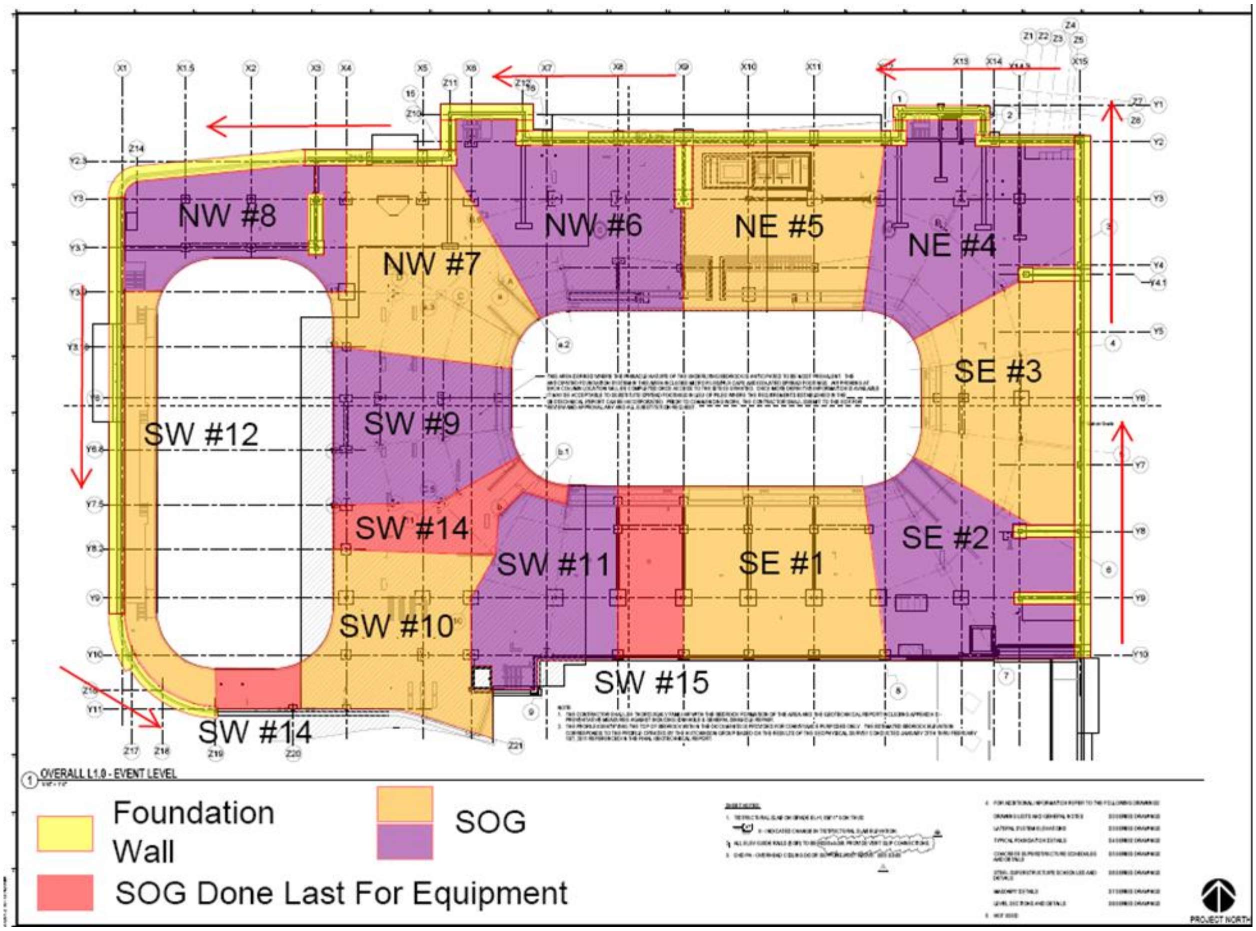


Figure 3: Foundation Wall and SOG Sequence

Precast

There are concrete precast stadia seats. These are being fabricated in Center Valley, Pennsylvania. This is a small town located just outside Allentown, PA. These sections are pre-stressed and get up to lengths of 30'. The precast stadia rest on 1" rubber pads which lie directly on the rakers. The precast stadia have pockets located on the face which allow the stadia to be bolted to the rakers. Once the nuts and bolts are in place caulking is applied to hide the bolt connection.

The precast seats are being installed during the night shift. This allows the same crane swinging the steel to be used for the precast stadia. Thus, the crane can obviously support the load, however the boom has to have a radius of 50' or shorter when placing the stadia. Along the ends, there are six, three on each side, locations for the crane to rig to the stadia. These are wire cables that are cemented into the concrete stadia, which get cut off after it is installed. Finally the gaps between the stadia are caulked with a preapproved color.

Photo 1: Precast Stadia | Courtesy of Mortenson

Mechanical System

The mechanical system incorporates 12 air handling units into its design. Most of these are located on the roof with the exception of one which is included in the event level with outside air running through duct to it. There are 6 AHUs that incorporate 100% outside air into their design, with 2 of those utilizing energy recovery wheels which should help push LEED certification and reduce energy costs. The other 4, of those 6, serve primarily as dehumidification units. Dehumidification is especially important within this building due to its primary function being ice hockey.

The mechanical system utilizes 25% glycol which is a refrigerant that is supposed to be more efficient as opposed to using just water. Finally, located along the curtain wall on the east side of the building; a radiant finned tube piping system is utilized. This is located at the base of the glazing and is meant to counteract any cold climate seeping through the window to make this area as comfortable as possible.

The mechanical room is located at the north west corner of the building and rests on the event level. Located in the mechanical room are multiple heat exchangers, variable frequency drives, and water pumps. There is also a sump pump among other items in the mechanical room.

The sprinkler system in the building is a wet pipe system. Per code the building is required to have a fire suppression system everywhere but over a floor area used for contest that is higher than 50'. The roof, from the ice is higher than 60', therefore no sprinkler system will be provided above the ice. Also, per code, standpipes are required at each level of an enclosed stairwell.

Electrical System

The electrical room is located on the event level in the north west corner of the building. There are three transformers all built up on concrete pads. Two service the building, while the third is in case of a system failure. The electrical conduit feeding from theses transformers carries 3,000 amp, 480 / 277 volt, 3 phase, 4 wire service. The transformers themselves are oil filled, pad mounted transformers. Since they are oil filled they have to be set 15' back from the building in order to protect against a fire hazard.

Masonry

The masonry around the building is similar to much of the surrounding area. It is standard red brick utilizing a stretcher bond and jack on jack technique which can be seen in Figure 4. It encompasses most of the wall enclosure with the exception to some glazed curtain wall.

There is an initial layer of CMU that gets erected. Every other level has ladder reinforcement which is to help sustain lateral loads. These ladders are three point welded to allow brick ties to be installed. These then tie into the red masonry and are hidden with mortar. There are also locations where the brick is tying into metal framed panels, located on the perimeter of the building.

Figure 4: Mock Up of Brick Enclosure | Courtesy of Mortenson

Curtain Wall

The most significant portion of curtain wall encompasses the entire east facade of the building and is visible along University Drive. The curtain wall will rest on an aluminum track frame which will house low e-coated insulating glass. The glass will be ultraclear with each glass lite a

1/4" thick and a 1/2" air space between each lite. Additional to this, each glass panel, along the east facade, will be approximately 11' x 4'.

Although Crawford Architects is the head architect, Bohlin Cywinski Jackson is the exterior façade consultant. They helped coordinate the system, and are largely in charge of the design of the curtain wall.

LEED

Penn State buildings are required by the Office of Physical Plant to be LEED certified. Therefore, Mortenson has implemented many practices to help achieve LEED status. There are separate dumpsters set up for recycled materials. Mortenson has been using regional materials and a minimum of 50 % wood in accordance with the Forrest Stewardship Council. Mortenson also had a concrete washout station that has been recycled for large aggregate. Finally, Mortenson has been extremely proactive in monitoring the indoor air quality by developing a management plan and performing a flush out of the ductwork systems.

Site Plans

Existing Conditions

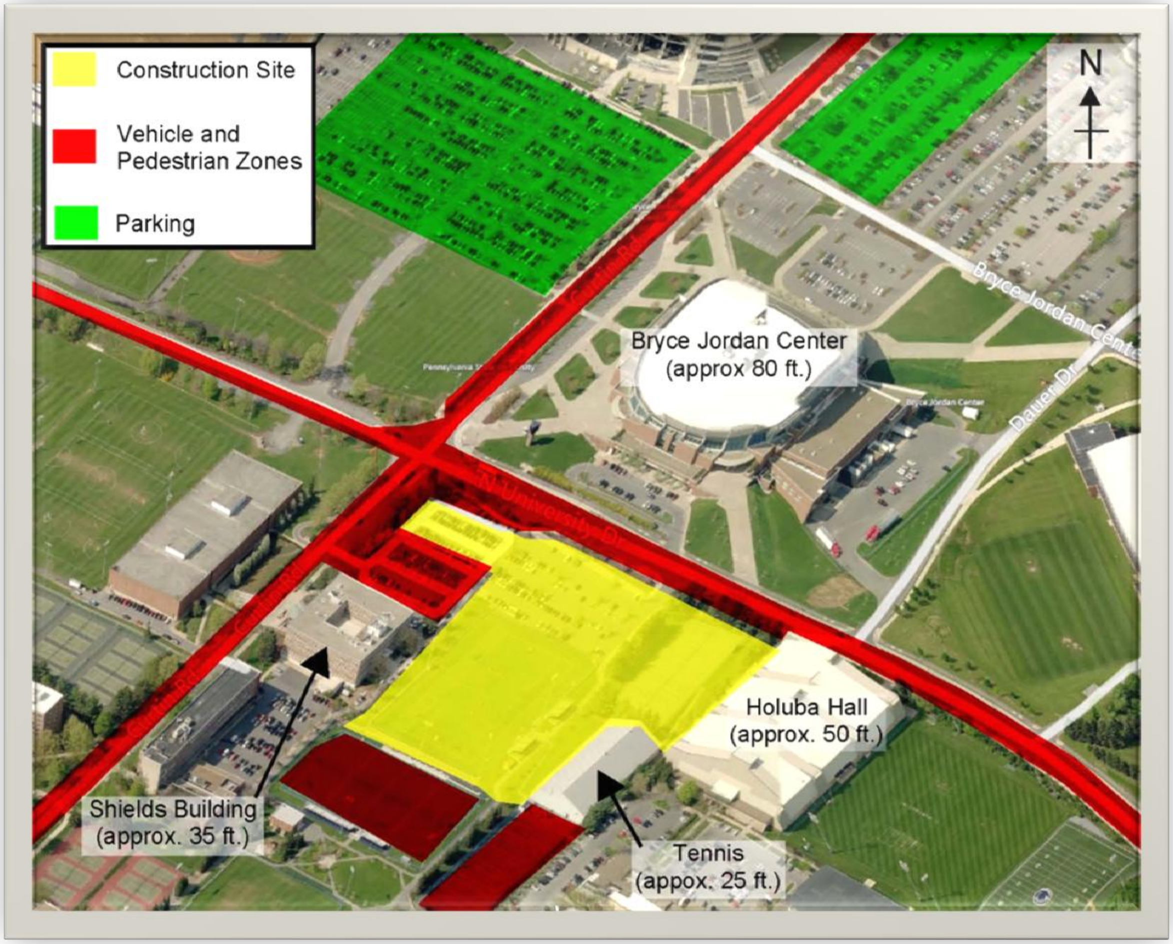


Figure 5: Existing Conditions

Figure 5 represents some of the existing conditions on site. As can be seen, parking is in green and is relatively close to the sight, which can be seen in yellow. In red, are vehicle and pedestrian zones. The roadways near the site are two way streets. There are also many sports complexes located around the site. Therefore, high levels of student traffic are located around this area. Therefore, particular attention to safety must be done in order to ensure students are kept free from any danger. With that, the site perimeter must be checked frequently to ensure no student traffic can cross through the project site.

The general layout shows the building footprint, site perimeter, and where the project office trailers are to be located. The existing utilities plan shows the utility lines, light poles, fire hydrants, and bleachers.

Appendix D has the general layout plan and existing utilities plan.

Site Layout Planning

Excavation

Crew / Work

- Excavation / Removing Excavated Earth Offsite
- Micropiles
- Concrete for Micropiles

Temporary Facilities / Equipment

- Office Trailers
- Excavator
- Dump Trucks
- Concrete Trucks

Safety Concerns

- Blasting was Required (No one could be on site during blasting)
- Site Flagger needed at Construction Entrance for Dump Trucks

Foundation Wall and SOG

Crew / Work

- Formwork
- Rebar
- Crane Operator to Lift Formwork and Rebar
- Additional Concrete Trucks

Temporary Facilities / Equipment

- Hydraulic Boom Crane
- Storage Trailers
- Rebar Laydown Area
- Modular Formwork Laydown Area

Safety Concerns

- Daily Crane Inspections
- Daily Rigging Inspections
- Rebar Caps

Utility Tie In

Crew / Work

- Underground Utilities
- Excavation (Trenches)

Temporary Facilities / Equipment

- Excavators
- Dump Trucks

- Crane

Safety Concerns

- Additional Site Perimeter
- Road Closure
- Engineered Pick Plans for Precast Manholes
- Trench Boxes

Steel

Crew / Work

- Steel Erection
- Steel Finishing
- SOMD Form, Rebar, Pour

Temporary Facilities / Equipment

- Additional Office and Storage Trailers
- Crawler Crane with Latticed Boom and Jib
- Shakeout / Steel

Safety Concerns

- Daily Crane and Rigging Inspections
- Earth Beneath Crane
- Overhead Steel Swing Path
- Fall Protection (Retractables)
- Fire Watch for Welding

Interior Rough In

Crew / Work

- MEP Rough In
- Metal Stud Framing
- Drywall
- Fireproofing

Temporary Facilities / Equipment

- Additional Office and Storage Trailers
- Ductwork Staging Area
- JLG Lifts
- Fireproofing Staging Area

Safety Concerns

- MSDS on Fireproofing Material
- Leading Edge Training for Upper Stories

Exterior Enclosure

Crew / Work

- Masonry
- Curtain Wall
- Roofing

Temporary Facilities / Equipment

- Additional Office and Storage Trailers
- Grout Mix Station
- Scaffolding

Safety Concerns

- Daily Scaffolding Inspections
- Roof Perimeter / Leading Edge

Appendix E has site layout planning for different scopes of work.

Project Cost Evaluation

Building Construction Cost

Building Construction Cost: $89 M

Total Area: 227,500 SF

Building Construction Square Foot Cost: $ 390.21 / SF

Total Project Cost

Total Cost: $102 M

Square Foot Cost: $ 448.35 / SF

General Conditions Estimate

Detailed below is the general conditions estimate for the Pegula Ice Arena. The estimate is made up of staffing costs; bonding and insurance; general services; and temporary facilities and utilities.

Steve Laurila, the Senior Project Manager of Mortenson, assisted in the creation of this estimate. Due to privacy within Mortenson costs, Mr. Laurila requested that I not use direct costs that the company used. Therefore, this estimate was done with estimates obtained from my own experience, past projects that required general condition estimates, and RS Means data. However, Mr. Laurila did provide information that implies this estimate detailed below is approximately within five to ten percent of the actual estimate.

The final number obtained was $4,281,900. The general conditions costs must be monitored on a weekly basis. There are many concerns involved with overrunning on the budget the project management team has assembled. Any overruns in cost will directly affect the final fee Mortenson expects to receive and therefore must be maintained under the actual estimate.

The overall general conditions can be seen in Table 2, and additional breakdowns can be seen in Figure 6.

Table 2: General Conditions Estimate

General Conditions Estimate		
Staffing Plan	$	2,908,250
Bonding Insurance	$	994,000
General Services	$	94,550
Temporary Facilities & Utilities	$	285,100
Total	$	4,281,900

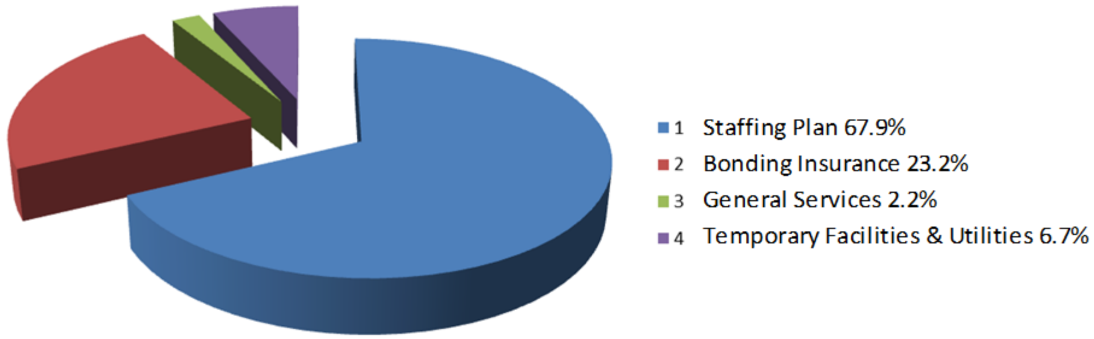


Figure 6: General Conditions Pie Chart

A Detailed General Conditions Estimate can be viewed in full in Appendix F.

Microsoft Project Schedule

This is the schedule breakdown. It should be noticed that actual construction runs from February 13, 2012 until July 29, 2013. This however, does not include FFE. It should be noted that although Mortenson did assist in the creation of this schedule, in no way does this represent their exact schedule of values or sequencing for construction.

Table 3: Pegula Ice Arena Project Schedule

Microsoft Project Schedule			
Phase	**Start**	**Finish**	**Duration**
Design & Procurement	11/30/2010	9/4/2012	460
Excavation	2/13/2012	8/22/2012	136
Excavation	2/13/2012	4/13/2012	43
Deep Foundations	4/11/2012	5/31/2012	36
Form, Rebar, Pour Spread Footings	3/27/2012	7/24/2012	85
Wall Footings	4/27/2012	7/2/2012	47
Foundation Walls & Elevator Pits	4/13/2012	8/22/2012	94
Structure	4/24/2012	11/17/2012	148
Underground & SOG	4/24/2012	8/31/2012	92
Steel Structure	5/31/2012	11/17/2012	121
Precast	8/6/2012	11/1/2012	62
Enclosure	8/10/2012	3/7/2013	149
Wall Enclosure Systems	8/10/2012	3/7/2013	149
Glazing Systems	12/6/2012	1/23/2013	34
Roof Systems	9/25/2012	12/25/2012	65
Conveying Systems	10/8/2012	1/28/2013	80
Elevators	10/8/2012	1/28/2013	80
Interior Rough-In	7/20/2012	3/20/2013	174
Hangers	7/23/2012	10/25/2012	67
Steel Stairs	7/24/2012	10/24/2012	66
Plumbing Rough-In	9/12/2012	2/12/2013	109
HVAC Rough-In	9/17/2012	2/22/2013	113
Electrical Rough-In	10/8/2012	3/20/2013	116
Architectural Rough-In	7/20/2012	3/5/2013	163
Equipment	10/4/2012	4/23/2013	144
Mechanical Equipment	10/4/2012	2/6/2013	89
Electrical Equipment	11/16/2012	11/26/2012	7
Specialty Equipment	12/3/2012	4/23/2013	101
Drywall & Interior Finishes	12/13/2012	7/29/2013	163
Drywall	12/13/2012	4/2/2013	79
Finishes	1/2/2013	7/29/2013	149
Project Closeout	7/11/2013	10/11/2013	66

The Microsoft Project Schedule can be viewed in full in Appendix G.

Analysis 1 | Community Rink Sequence off Critical Path

Problem Identification

In discussions with the project team at Pegula one of the frustrating parts during construction was that they had to maintain the community rink on the critical path during the structural sequencing of the building. The reason this was a nuance to the project team is that the finish work to follow in the community rink is very minimal in comparison to the finish work throughout the rest of the building. Therefore, had the team been able to focus their attention and efforts to support the main rink and later followed with the community rink, there could have potentially been positive schedule acceleration and cost implications associated with this.

Background Research

Technical Report 2 consisted of a scheduling analysis. In this portion an entire schedule was required which detailed the entire building and its sequences. During this process the building was broken down into four quadrants and subsequently scheduled in a counterclockwise fashion. The schedule had to sequence the structural systems in a way which included the community rink with the structural sequencing of the rest of the building. This was due to some of the air handling units and other mechanical equipment being located slightly over the community rink roof. Therefore, the roof joists had to be erected, which meant the columns/beams needed to be in place as well as the foundation wall. Before backfill could occur along this foundation wall the slab on grade needed to be in place which meant all the underground work needed to be in place. Therefore, all work sequences needed to be done the same way as the rest of the building simply to support the AHUs and mechanical equipment on the roof.

Preliminary Research and Proposed Solution

There are two potential solutions to help remove the community rink off the critical path of the building schedule. A new structural system could be built to redistribute the load in a slightly different fashion or the mechanical units could be moved. The more straight forward solution would be to move the mechanical units, however, the mechanical units extend out 15 feet. There simply isn't 15 feet of room to move the mechanical units back. If this was to happen it would significantly alter the architectural features of the building.

One of the cornerstones of the arena is the student section. It is as steep as code will allow and is the only section of seating that spans all three levels of the building. Much of this section would have to be removed in order to successfully relocate the mechanical units. With all of this, redistributing the structural loads is the only logical way to sequence the community rink off the critical path.

Methodology

- Retrieve the most up to date schedule from Mortenson Construction.
- Schedule the building to remove the community rink off the critical path.
- Ensure mechanical room equipment can still help support temporary heating throughout the building.
- Perform structural breadth.
- Perform any cost implications from more structural steel to decreased crane time.

Community Rink Detailed Schedule

The first step of this process was to break down certain construction activities per sequence of work. It seemed most appropriate to use similar breakdowns of work to that of which Mortenson Construction used. Doing this, allows as accurate a representation one can get to show how redesigning the schedule would affect Mortenson Construction's actual work. It should also be noted that the entire building was not broken down as part of this activity. The community rink lies along the western portion of the building and therefore only western sequences were identified as part of this analysis. Figures 7 through 14 represent different sequences of construction with their numbered tags. This will allow the upcoming schedules to be followed and understood.

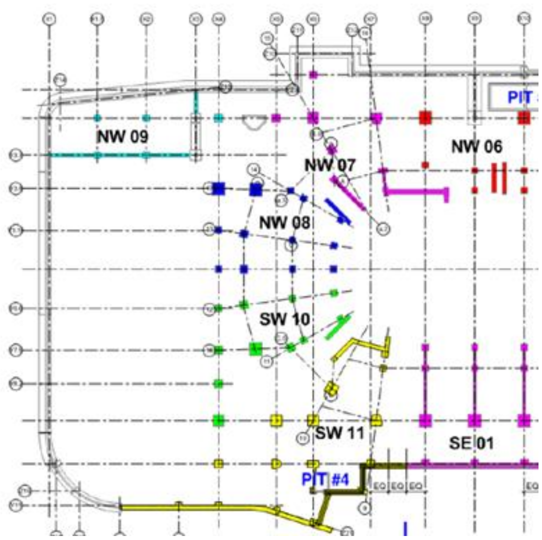


Figure 7: Spread Footers

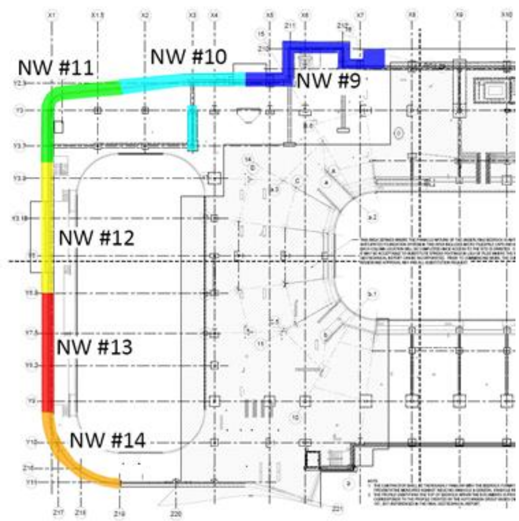


Figure 8: Strip Footers

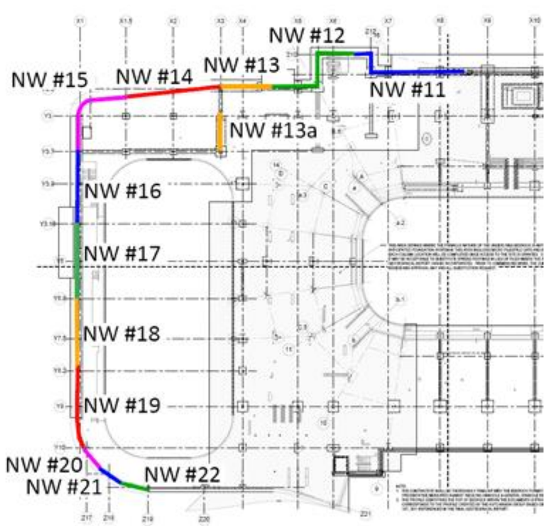


Figure 9: Foundation Wall

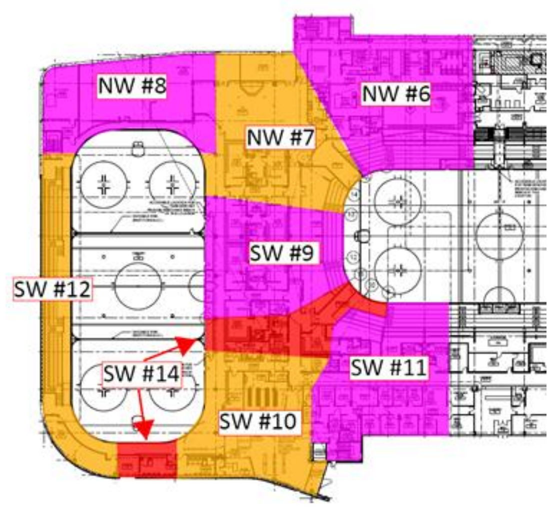


Figure 10: SOG

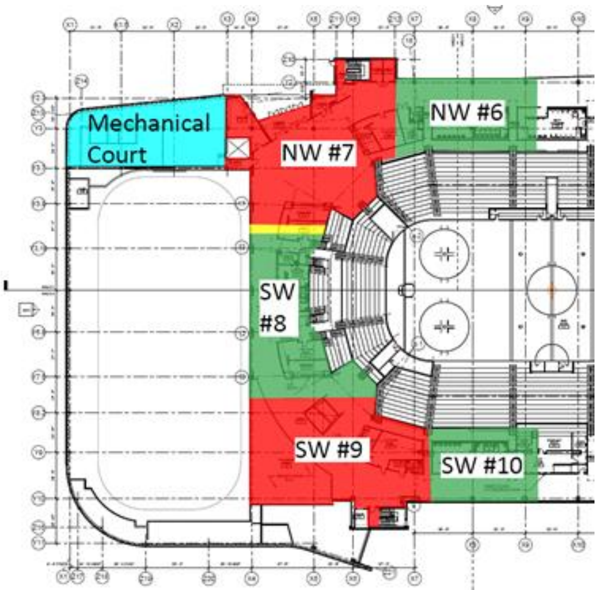


Figure 11: Main Concourse SOMD

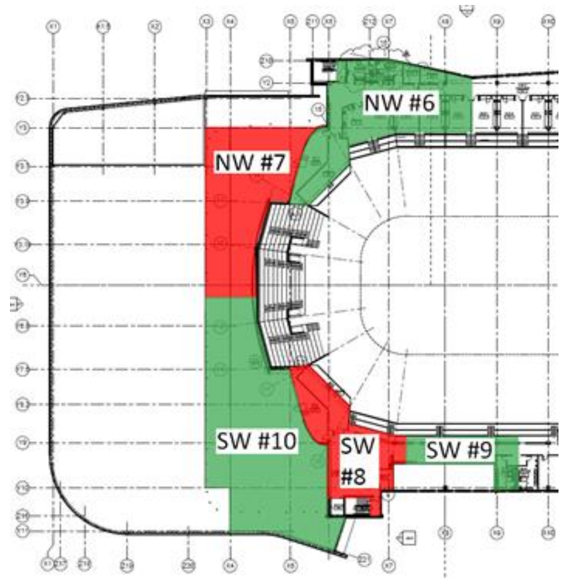


Figure 12: Club SOMD

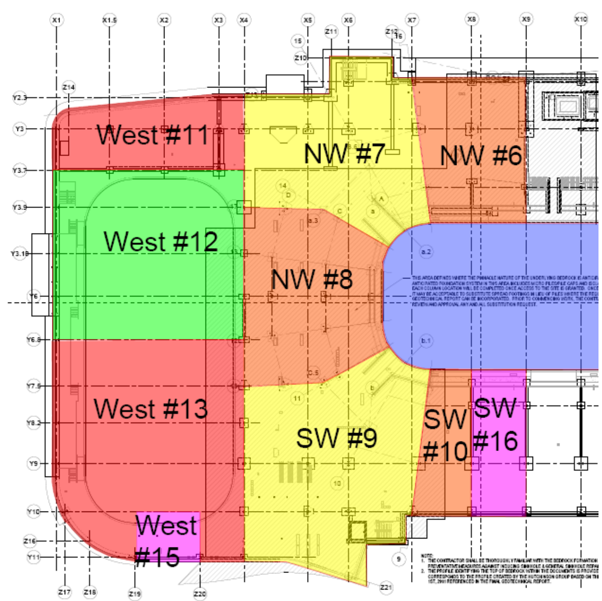


Figure 13: Steel

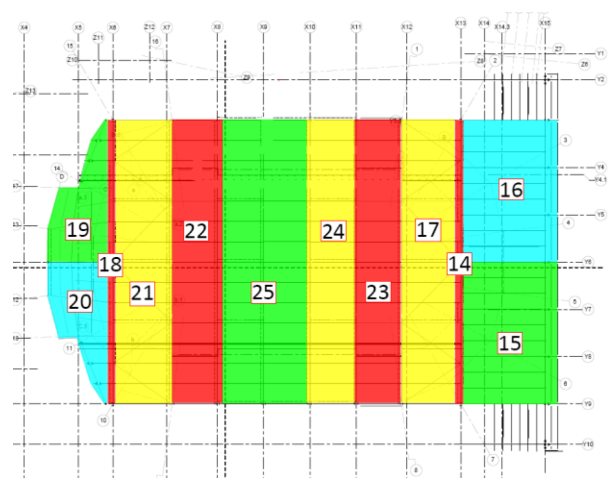


Figure 14: Arena Trusses

The difference in the numbering of the zones can be confusing. Stated again, it was done this way to mirror the breakdown with which Mortenson Construction utilized to allow for an accurate representation of the actual project sequencing.

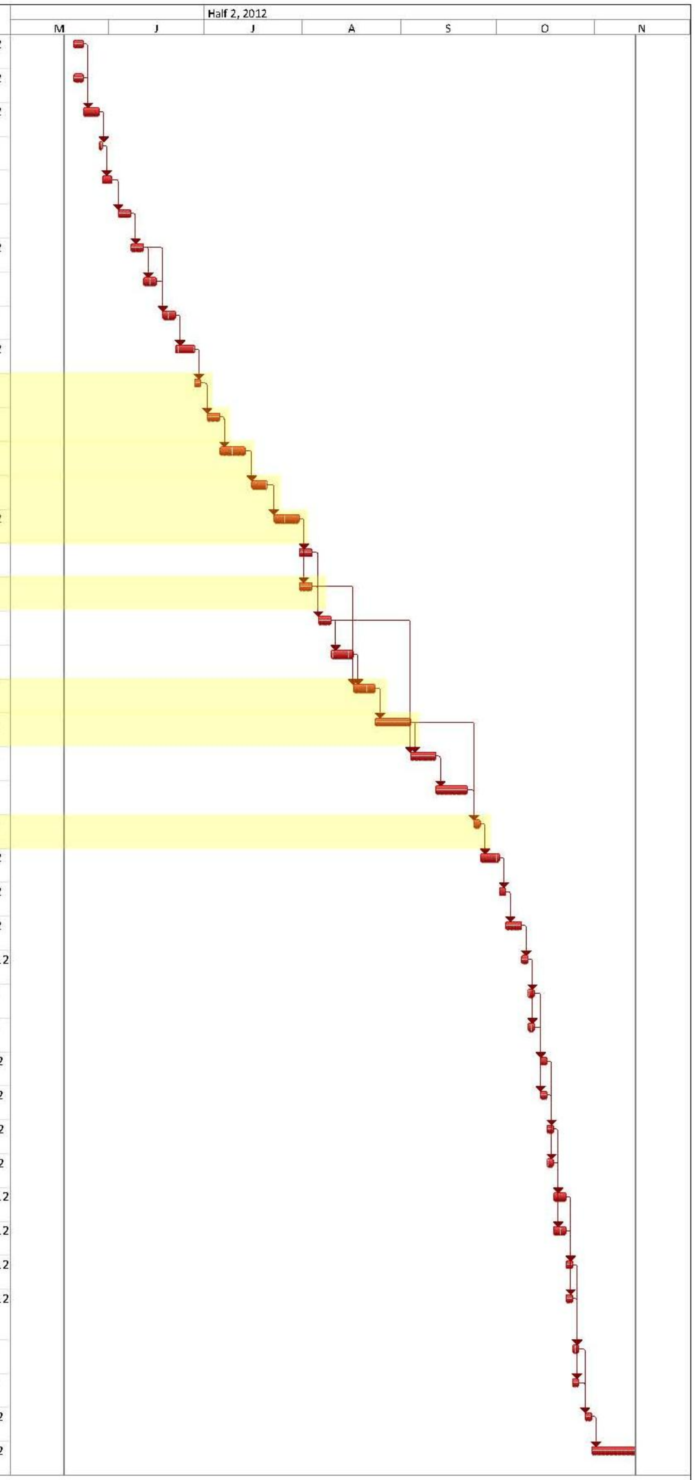
Schedule Baseline

After sequences were broken down, it was time to actually create a schedule. The schedules created were done in accordance with Mortenson Construction's original values and sequences. It should be understood that there were certain quality, safety, and weather related incidents that created project turbulence. Since these issues are not predictable it was decided to create the following schedules in ideal situations instead of including some of the issues the project team incurred throughout the project which may have caused the occasional delay.

The first schedule created was made as a baseline schedule. This was needed to find just where the critical path started within the community rink. The following page shows the baseline critical path of the structural activities for the community rink.

Appendix H has the detailed original schedule.

ID	Task Mode	Task Name	Duration	Start	Finish
2		Excavate Fdn Wall Footings - Arena Foundation Lvl NE #9	3 days	Mon 5/21/12	Wed 5/23/12
8		FRP Fdn Wall Footings - Arena Foundat ion Lvl NE #8	3 days	Mon 5/21/12	Wed 5/23/12
9		FRP Fdn Wall Footings - Arena Foundat ion Lvl NW #9 - 6D	3 days	Thu 5/24/12	Mon 5/28/12
16		Backfill Fdn Wall Footings - Arena Foundation Lvl NW #9	1 day	Tue 5/29/12	Tue 5/29/12
22		Excavate Spread Footings - Arena Foundation Lvl NW #7	3 days	Wed 5/30/12	Fri 6/1/12
27		FRP Spread Footings - Arena Foundation Lvl NW #7 - 6D	4 days	Mon 6/4/12	Thu 6/7/12
32		Backfill Spread Footings - Arena Foundation Lvl NW #7	2 days	Fri 6/8/12	Mon 6/11/12
37		FRP Fdn Wall - Ar ena Foundation Lvl NW #11 - 6D	4 days	Tue 6/12/12	Fri 6/15/12
38		FRP Fdn Wall - Ar ena Foundation Lvl NW #12 - 6D	4 days	Mon 6/18/12	Thu 6/21/12
39		FRP Fdn Wall - Ar ena Foundation Lvl NW #13	4 days	Fri 6/22/12	Wed 6/27/12
44		FRP Fdn Wall - Ar ena Foundation Lvl NW #13a	2 days	Thu 6/28/12	Fri 6/29/12
40		FRP Fdn Wall - Ar ena Foundation Lvl NW #14	4 days	Mon 7/2/12	Thu 7/5/12
42		FRP Fdn Wall - Ar ena Foundation Lvl NW #15	6 days	Fri 7/6/12	Fri 7/13/12
55		Underslab Electrical - Arena Event Lvl NW #8	5 days	Mon 7/16/12	Fri 7/20/12
60		Underslab Mech / Plumbing - Arena Event Lvl NW #8	6 days	Mon 7/23/12	Mon 7/30/12
62		Underslab Mech / Plumbing - Arena Event Lvl SW #10	4 days	Tue 7/31/12	Fri 8/3/12
67		Underslab Glycol Lines - Arena Event Lvl NW #8	4 days	Tue 7/31/12	Fri 8/3/12
68		Underslab Glycol Lines - Arena Event Lvl SW #9	4 days	Mon 8/6/12	Thu 8/9/12
71		FRP Slab on Grade - Arena Event Lvl SW #9	5 days	Fri 8/10/12	Thu 8/16/12
72		FRP Slab on Grade - Arena Event Lvl NW #8	5 days	Fri 8/17/12	Thu 8/23/12
73		FRP Slab on Grade - Arena Event Lvl SW #12	7 days	Fri 8/24/12	Mon 9/3/12
74		FRP Slab on Grade - Arena Event Lvl SW #10	6 days	Tue 9/4/12	Tue 9/11/12
81		Erect Structural Steel - Arena All Levels SW #9	8 days	Wed 9/12/12	Fri 9/21/12
82		Erect Structural Steel - Arena All Levels Community Rink #13	2 days	Mon 9/24/12	Tue 9/25/12
83		Erect Structural Steel - Arena All Levels SW #10	4 days	Wed 9/26/12	Mon 10/1/12
104		Erect Roof Trusses - Arena High Roof Truss Seq #14	2 days	Tue 10/2/12	Wed 10/3/12
100		Erect Steel & Bar Joists - Arena East Roof Seq #15 & #16	3 days	Thu 10/4/12	Mon 10/8/12
105		Erect Roof Trusses - Arena High Roof Truss Seq #17	2 days	Tue 10/9/12	Wed 10/10/12
106		Erect Roof Trusses - Arena High Roof Truss Seq #23	2 days	Thu 10/11/12	Fri 10/12/12
112		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #17	2 days	Thu 10/11/12	Fri 10/12/12
107		Erect Roof Trusses - Arena High Roof Truss Seq #24	2 days	Mon 10/15/12	Tue 10/16/12
113		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #23	2 days	Mon 10/15/12	Tue 10/16/12
108		Erect Roof Trusses - Arena High Roof Truss Seq #25	2 days	Wed 10/17/12	Thu 10/18/12
114		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #24	2 days	Wed 10/17/12	Thu 10/18/12
109		Erect Roof Trusses - Arena High Roof Truss Seq #18	2 days	Fri 10/19/12	Mon 10/22/12
115		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #25	2 days	Fri 10/19/12	Mon 10/22/12
110		Erect Roof Trusses - Arena High Roof Truss Seq #21	2 days	Tue 10/23/12	Wed 10/24/12
116		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #19 & #20	2 days	Tue 10/23/12	Wed 10/24/12
111		Erect Roof Trusses - Arena High Roof Truss Seq #22	2 days	Thu 10/25/12	Fri 10/26/12
117		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #21	2 days	Thu 10/25/12	Fri 10/26/12
118		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #22	2 days	Mon 10/29/12	Tue 10/30/12
121		Lay Roof Truss Metal Deck - Arena High Roof West (GL x10- x4.5)	10 days	Wed 10/31/12	Tue 11/13/12



Project: Mission1
Date: Fri 2/1/13

Critical

Figure 15: Community Rink Original Critical Path

Key Points from Schedule 1

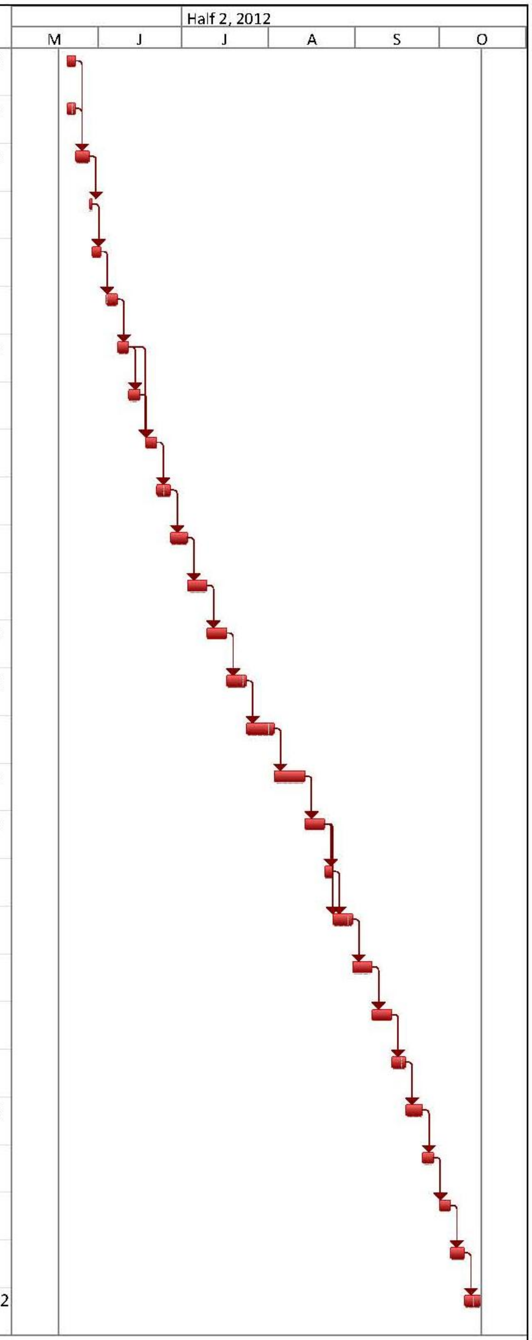
- The community rink's first item on the critical path is the foundation wall 13a.
- The foundation wall remains on the critical path along the mechanical room up to pour 15.
- There is a lot of underground work that remains on the critical path underneath the mechanical / electrical room (Underground SOG 8)
- Both SOG pours in the community rink (8 and 12) are on the critical path.
- Only structural steel sequence 13 in the community rink is on the critical path.
- The trusses control the end of the schedule.
- The last day the crane controls the schedule of the structural steel is October 24th.
- A separate crane was brought in to assist with the bar joist erection over the community rink.
- The crane was on the project from July 16th until October 26th. This is a 102 actual days and 74 working days.
- The last slab pour finishes on November 6th.

As pointed out in the key points, the critical path first starts in the community rink for the 13a foundation wall. From here there is a lot of underground work that will be going on throughout this portion of the building. This is because the mechanical and electrical room sit on top of this slab location. Finally, the last activity that requires the use of the crane for structural purposes ends on October 26th. This is the last truss sequence 22. After this date the mechanical units can be set in place.

Schedule 2

Now that the critical path has been determined for the baseline schedule it is important that activities that could potentially affect the critical path are removed from the schedule. Therefore, any work going on in the community rink after and including FRP foundation wall 13a was removed from the schedule. The purpose of doing this was to observe just how much time could be saved assuming nothing on the project was driven by the community rink. The critical path can be seen on the following page.

ID	Task Name	Duration	Start	Finish
2	Excavate Fdn Wall Footings - Arena Foundation Lvl NE #9	3 days	Mon 5/21/12	Wed 5/23/12
8	FRP Fdn Wall Footings - Arena Foundat ion Lvl NE #8	3 days	Mon 5/21/12	Wed 5/23/12
9	FRP Fdn Wall Footings - Arena Foundat ion Lvl NW #9 - 6D	3 days	Thu 5/24/12	Mon 5/28/12
16	Backfill Fdn Wall Footings - Arena Foundation Lvl NW #9	1 day	Tue 5/29/12	Tue 5/29/12
22	Excavate Spread Footings - Arena Foundation Lvl NW #7	3 days	Wed 5/30/12	Fri 6/1/12
27	FRP Spread Footings - Arena Foundation Lvl NW #7 - 6D	4 days	Mon 6/4/12	Thu 6/7/12
32	Backfill Spread Footings - Arena Foundation Lvl NW #7	2 days	Fri 6/8/12	Mon 6/11/12
37	FRP Fdn Wall - Ar ena Foundation Lvl NW #11 - 6D	4 days	Tue 6/12/12	Fri 6/15/12
38	FRP Fdn Wall - Ar ena Foundation Lvl NW #12 - 6D	4 days	Mon 6/18/12	Thu 6/21/12
40	Underslab Electrical - Arena Event Lvl NW #6	3 days	Fri 6/22/12	Tue 6/26/12
45	Underslab Mech / Plumbing - Arena Event Lvl NW #6	4 days	Wed 6/27/12	Mon 7/2/12
46	Underslab Mech / Plumbing - Arena Event Lvl NW #7	5 days	Tue 7/3/12	Mon 7/9/12
51	Underslab Glycol Lines - Arena Event Lvl NW #6	5 days	Tue 7/10/12	Mon 7/16/12
55	FRP Slab on Grade - Arena Event Lvl NW #7	5 days	Tue 7/17/12	Mon 7/23/12
60	Erect Structural Steel - Arena All Levels NW #7	8 days	Tue 7/24/12	Thu 8/2/12
65	Plumb/Bolt/Weld Structural Steel - Arena All Levels NW #7	7 days	Fri 8/3/12	Mon 8/13/12
70	Lay Metal Deck - Arena All Levels NW #7	5 days	Tue 8/14/12	Mon 8/20/12
94	FRP Slab on Metal Deck - Arena Main Conc NW #7A (Lower)	3 days	Tue 8/21/12	Thu 8/23/12
95	FRP Slab on Metal Deck - Arena Main Conc NW #7	5 days	Fri 8/24/12	Thu 8/30/12
96	FRP Slab on Metal Deck - Arena Club Lbl NW #6	5 days	Fri 8/31/12	Thu 9/6/12
97	FRP Slab on Metal Deck - Arena Main Conc SW #8	5 days	Fri 9/7/12	Thu 9/13/12
98	FRP Slab on Metal Deck - Arena Club Lvl NW #7	3 days	Fri 9/14/12	Tue 9/18/12
99	FRP Slab on Metal Deck - Arena Main Conc SW #9	4 days	Wed 9/19/12	Mon 9/24/12
103	FRP Slab on Metal Deck - Arena Club Lvl SW #10	4 days	Tue 9/25/12	Fri 9/28/12
100	FRP Slab on Metal Deck - Arena Club Lbl SW #8	4 days	Mon 10/1/12	Thu 10/4/12
101	FRP Slab on Metal Deck - Arena Main Conc SW #10	3 days	Fri 10/5/12	Tue 10/9/12
102	FRP Slab on Metal Deck - Arena Club Lvl SW #9	4 days	Wed 10/10/12	Mon 10/15/12



Project: Mission2
Date: Fri 2/1/13

Critical

Figure 16: Project Critical Path with Community Rink off the Critical Path

Key Points from Schedule 2

- Topping out occurs September 25th. This is a save in 31 actual days or 23 working days.
- The actual last structural activity (SOMD) ends October 15th vs. November 13th which is an actual save in construction duration of 29 actual days or 21 working days
- The crane stops controlling the critical path of the schedule and instead the slab on metal deck pours start to control.
- The crane was on the project from July 9th until September 25th. This is a 78 actual days and 56 working days.
- The last slab on metal deck pour occurs October 15th. This saves 22 actual days and 16 working days.

Removing the community rink off the critical path saves a substantial amount of time. The crane would be able to save 18 working days of crane time. There are also 16 working days saving on the SOMD pours which would allow finishes to begin more quickly.

Schedule 3

Schedule 2 implies there is a significant amount of time saved on the project by removing the community rink off the critical path. However, this schedule entirely removed the community rink from the schedule. Therefore, in order to accurately represent what the schedule would look like the community rink needs back logged from the last date of crane usage until the FRP of foundation wall 13a. Steel sequence 11, 12, and 13 will need crane time in order to be erected and therefore will add additional crane time usage. The following page shows the back logged schedule for the community rink.

ID		Task Name	Duration	Start	Finish
104		Erect Structural Steel - Arena All Levels Community Rink #13	2 days	Tue 10/2/12	Wed 10/3/12
105		Erect Structural Steel - Arena All Levels Community Rink #12	2 days	Fri 9/28/12	Mon 10/1/12
106		Erect Structural Steel - Arena Mech Court NW #11	2 days	Wed 9/26/12	Thu 9/27/12
107		FRP Slab on Grade - Arena Event Lvl SW #12	7 days	Fri 8/17/12	Mon 8/27/12
108		FRP Slab on Grade - Arena Event Lvl NW #8	5 days	Tue 7/31/12	Mon 8/6/12
109		Underslab Mech / Plumbing - Arena Event Lvl NW #8	6 days	Mon 7/23/12	Mon 7/30/12
110		Underslab Electrical - Arena Event Lvl SW #12	2 days	Wed 8/15/12	Thu 8/16/12
111		Underslab Electrical - Arena Event Lvl NW #8	5 days	Mon 7/16/12	Fri 7/20/12
112		FRP Fdn Wall - Ar ena Foundation Lvl SW #22	2 days	Mon 8/13/12	Tue 8/14/12
113		FRP Fdn Wall - Ar ena Foundation Lvl SW #21	3 days	Wed 8/8/12	Fri 8/10/12
114		FRP Fdn Wall - Ar ena Foundation Lvl SW #20	3 days	Fri 8/3/12	Tue 8/7/12
115		FRP Fdn Wall - Ar ena Foundation Lvl SW #19	2 days	Wed 8/1/12	Thu 8/2/12
116		FRP Fdn Wall - Ar ena Foundation Lvl SW #18	4 days	Thu 7/26/12	Tue 7/31/12
117		FRP Fdn Wall - Ar ena Foundation Lvl SW #17	4 days	Fri 7/20/12	Wed 7/25/12
118		FRP Fdn Wall - Ar ena Foundation Lvl NW #16	4 days	Mon 7/16/12	Thu 7/19/12
119		FRP Fdn Wall - Ar ena Foundation Lvl NW #15	6 days	Fri 7/6/12	Fri 7/13/12
120		FRP Fdn Wall - Ar ena Foundation Lvl NW #14	4 days	Mon 7/2/12	Thu 7/5/12
121		FRP Fdn Wall - Ar ena Foundation Lvl NW #13a	2 days	Thu 6/28/12	Fri 6/29/12

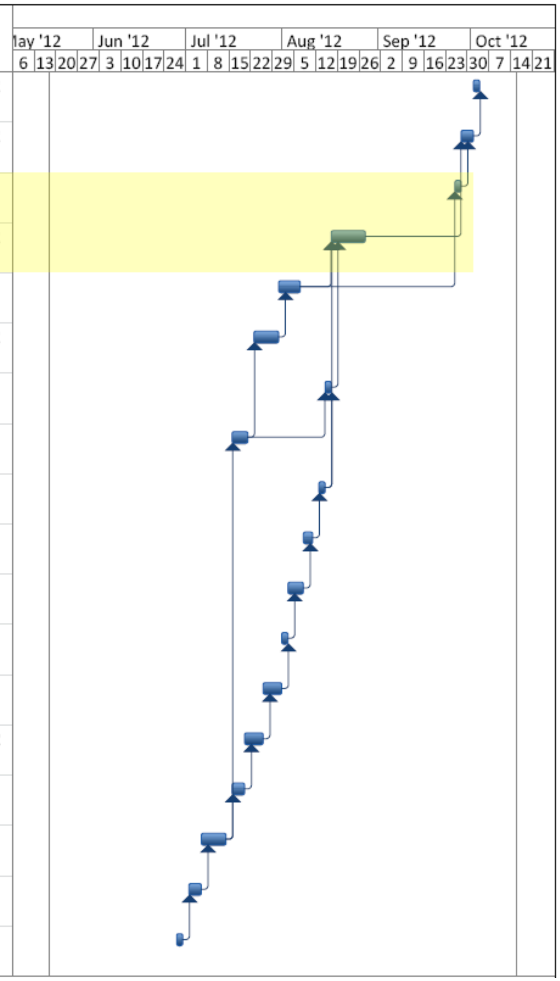


Figure 17: Back Schedule

Key Points from Schedule 3

- Structural sequence 11, 12, and 13 take an additional 6 days of crane time.
- FRP sequence 13a is tied back to FRP 13 as its successor.
- There is nearly a month of float from the finish of FRP SOG SW#12 (8/27/12) to the beginning of Erect Structural Steel – Arena Mech. Court NW #11 (9/26/12).

The most significant aspect of this schedule shows that nearly a month of float can be accrued for the community rink if it is pulled off the critical path.

Schedule 4

An additional schedule needs to be created to know what controls the community rink. It will either be controlled by enclosure trades or the mechanical equipment.

ID		Task Name	Duration	Start	Finish
122		Plumb/Bolt/Weld Structural Steel - Arena Mech Court NW #11	4 days	Fri 9/28/12	Wed 10/3/12
123		Plumb/Bolt/Weld Structural Steel - Arena All Levels Community Ice Rink #12	2 days	Thu 10/4/12	Fri 10/5/12
124		Plumb/Bolt/Weld Structural Steel - Arena All Levels Community Ice Rink #13	2 days	Mon 10/8/12	Tue 10/9/12
125		Lay Metal Deck - Arena Mech Court NW #11	3 days	Thu 10/4/12	Mon 10/8/12
126		FRP Slab on Metal Deck - Arena Mech Court NW	5 days	Tue 10/9/12	Mon 10/15/12
127		Erect Steel / Bar Joists - Arena Roof Community Ice Rink #12	3 days	Mon 10/8/12	Wed 10/10/12
128		Erect Steel / Bar Joists - Arena Roof Community Ice Rink #13	3 days	Thu 10/11/12	Mon 10/15/12
129		Lay Roof Deck - Arena Roof Community Ice Rink #12	5 days	Thu 10/11/12	Wed 10/17/12
130		Lay Roof Deck - Arena Roof Community Ice Rink #13	5 days	Thu 10/18/12	Wed 10/24/12
131		Complete Roof Deck - Arena Roof Community Ice Rink	4 days	Thu 10/25/12	Tue 10/30/12
132		Start Exterior CMU Install Along North Community Rink	1 day?	Thu 9/27/12	Thu 9/27/12
133		Set Pumps in Mechanical Room	1 day?	Thu 11/29/12	Thu 11/29/12

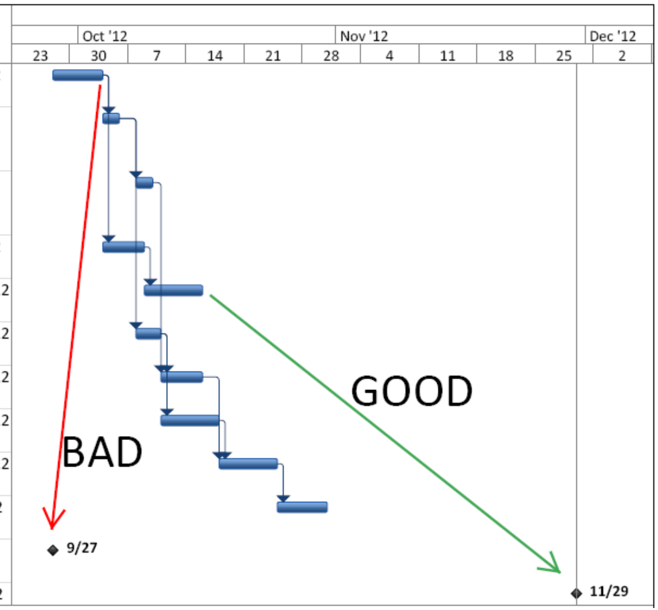
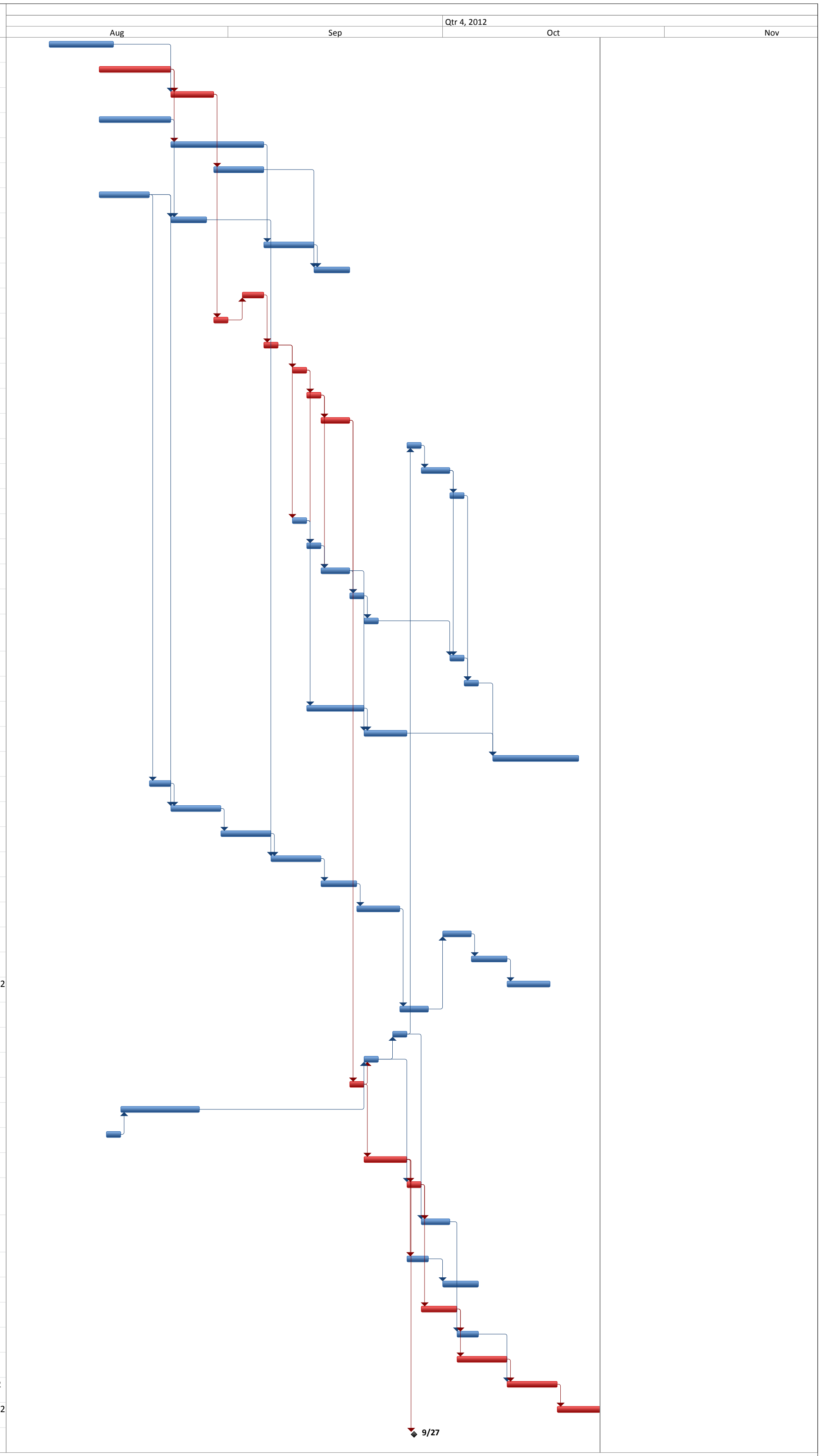


Figure 18: Community Rink Control Schedule

Key Points from Schedule 4

- The first set of equipment set in the mechanical room is the pumps. This equipment does not start getting installed until November 29th. This is only tied to the above work happening which is the FRP of the mechanical court. This activity finishes October 15th and therefore in no way conflicts with the altered schedule.
- The enclosure needs to begin on September 27th. This is tied to the plumbing of mechanical court NW #11 which does not finish until October 3rd. Therefore, this needs to be rescheduled. This updated schedule can be seen on the next page.

ID		Task Name	Duration	Start	Finish
58		FRP Slab on Grade - Arena Event Lvl SW #11	7 days	Tue 8/7/12	Wed 8/15/12
62		Erect Structural Steel - Arena All Levels SW #9	8 days	Tue 8/14/12	Thu 8/23/12
63		Erect Structural Steel - Arena All Levels SW #10	4 days	Fri 8/24/12	Wed 8/29/12
66		Plumb/Bolt/Weld Structural Steel - Arena All Levels NW #8	8 days	Tue 8/14/12	Thu 8/23/12
67		Plumb/Bolt/Weld Structural Steel - Arena All Levels NW #9	9 days	Fri 8/24/12	Wed 9/5/12
68		Plumb/Bolt/Weld Structural Steel - Arena All Levels SW #10	5 days	Thu 8/30/12	Wed 9/5/12
70		Lay Metal Deck - Arena All Levels NW #7	5 days	Tue 8/14/12	Mon 8/20/12
71		Lay Metal Deck - Arena All Levels NW #8	3 days	Fri 8/24/12	Tue 8/28/12
72		Lay Metal Deck - Arena All Levels SW #9	5 days	Thu 9/6/12	Wed 9/12/12
73		Lay Metal Deck - Arena All Levels SW #10	3 days	Thu 9/13/12	Mon 9/17/12
74		Erect Steel & Bar Joists - Arena East Roof Seq #15 & #16	3 days	Mon 9/3/12	Wed 9/5/12
75		Erect Roof Trusses - Arena High Roof Truss Seq #14	2 days	Thu 8/30/12	Fri 8/31/12
76		Erect Roof Trusses - Arena High Roof Truss Seq #17	2 days	Thu 9/6/12	Fri 9/7/12
77		Erect Roof Trusses - Arena High Roof Truss Seq #23	2 days	Mon 9/10/12	Tue 9/11/12
78		Erect Roof Trusses - Arena High Roof Truss Seq #24	2 days	Wed 9/12/12	Thu 9/13/12
79		Erect Roof Trusses - Arena High Roof Truss Seq #25	2 days	Fri 9/14/12	Mon 9/17/12
80		Erect Roof Trusses - Arena High Roof Truss Seq #18	2 days	Wed 9/26/12	Thu 9/27/12
81		Erect Roof Trusses - Arena High Roof Truss Seq #21	2 days	Fri 9/28/12	Mon 10/1/12
82		Erect Roof Trusses - Arena High Roof Truss Seq #22	2 days	Tue 10/2/12	Wed 10/3/12
83		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #17	2 days	Mon 9/10/12	Tue 9/11/12
84		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #23	2 days	Wed 9/12/12	Thu 9/13/12
85		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #24	2 days	Fri 9/14/12	Mon 9/17/12
86		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #25	2 days	Tue 9/18/12	Wed 9/19/12
87		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #19 & #20	2 days	Thu 9/20/12	Fri 9/21/12
88		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #21	2 days	Tue 10/2/12	Wed 10/3/12
89		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #22	2 days	Thu 10/4/12	Fri 10/5/12
90		Lay Roof Truss Metal Deck - Arena High Roof East (GL x15-x12)	6 days	Wed 9/12/12	Wed 9/19/12
91		Lay Roof Truss Metal Deck - Arena High Roof East (GL x12-x10)	4 days	Thu 9/20/12	Tue 9/25/12
93		Lay Roof Truss Metal Deck - Arena High Roof West (GL x10- x4.5)	10 days	Mon 10/8/12	Fri 10/19/12
94		FRP Slab on Metal Deck - Arena Main Conc NW #7A (Lower)	3 days	Tue 8/21/12	Thu 8/23/12
95		FRP Slab on Metal Deck - Arena Main Conc NW #7	5 days	Fri 8/24/12	Thu 8/30/12
96		FRP Slab on Metal Deck - Arena Club Lbl NW #6	5 days	Fri 8/31/12	Thu 9/6/12
97		FRP Slab on Metal Deck - Arena Main Conc SW #8	5 days	Fri 9/7/12	Thu 9/13/12
98		FRP Slab on Metal Deck - Arena Club Lvl NW #7	3 days	Fri 9/14/12	Tue 9/18/12
99		FRP Slab on Metal Deck - Arena Main Conc SW #9	4 days	Wed 9/19/12	Mon 9/24/12
100		FRP Slab on Metal Deck - Arena Club Lbl SW #8	4 days	Mon 10/1/12	Thu 10/4/12
101		FRP Slab on Metal Deck - Arena Main Conc SW #10	3 days	Fri 10/5/12	Tue 10/9/12
102		FRP Slab on Metal Deck - Arena Club Lvl SW #9	4 days	Wed 10/10/12	Mon 10/15/12
103		FRP Slab on Metal Deck - Arena Club Lvl SW #10	4 days	Tue 9/25/12	Fri 9/28/12
104		Erect Structural Steel - Arena All Levels Community Rink #13	2 days	Mon 9/24/12	Tue 9/25/12
105		Erect Structural Steel - Arena All Levels Community Rink #12	2 days	Thu 9/20/12	Fri 9/21/12
106		Erect Structural Steel - Arena Mech Court NW #11	2 days	Tue 9/18/12	Wed 9/19/12
107		FRP Slab on Grade - Arena Event Lvl SW #12	7 days	Fri 8/17/12	Mon 8/27/12
110		Underslab Electrical - Arena Event Lvl SW #12	2 days	Wed 8/15/12	Thu 8/16/12
122		Plumb/Bolt/Weld Structural Steel - Arena Mech Court NW #11	4 days	Thu 9/20/12	Tue 9/25/12
123		Plumb/Bolt/Weld Structural Steel - Arena All Levels Community Ice Rink #12	2 days	Wed 9/26/12	Thu 9/27/12
124		Plumb/Bolt/Weld Structural Steel - Arena All Levels Community Ice Rink #13	2 days	Fri 9/28/12	Mon 10/1/12
125		Lay Metal Deck - Arena Mech Court NW #11	3 days	Wed 9/26/12	Fri 9/28/12
126		FRP Slab on Metal Deck - Arena Mech Court NW	5 days	Mon 10/1/12	Fri 10/5/12
127		Erect Steel / Bar Joists - Arena Roof Community Ice Rink #12	3 days	Fri 9/28/12	Tue 10/2/12
128		Erect Steel / Bar Joists - Arena Roof Community Ice Rink #13	3 days	Wed 10/3/12	Fri 10/5/12
129		Lay Roof Deck - Arena Roof Community Ice Rink #12	5 days	Wed 10/3/12	Tue 10/9/12
130		Lay Roof Deck - Arena Roof Community Ice Rink #13	5 days	Wed 10/10/12	Tue 10/16/12
131		Complete Roof Deck - Arena Roof Community Ice Rink	4 days	Wed 10/17/12	Mon 10/22/12
132		Start Exterior CMU Install Along North Community Rink	0 days	Thu 9/27/12	Thu 9/27/12



Project: Mission5
Date: Sat 2/2/13

Task | Project Summary | Critical

Figure 19 | Original Schedule Critical Path

Appendix I has the finalized new schedule.

Key Points from Final Schedule

- In order to ensure the enclosure starts on time, steel sequence 11, 12, and 13 needed pushed back. Due to a lack of float in the crane time these needed to interrupt truss erection.
- Steel needs to start by September 18th inside the community rink.

Final Analysis

Table 4 and 5 can be seen below detailing the savings on crane time and schedule.

Table 4: Crane Driven Activities

Crane Driven Activities			
	Original Schedule	New Schedule	
Start Date	7/16/2012	7/16/2012	
Finish Date	10/26/2012	10/3/2012	Total Days Saved
Actual Days	103	80	23
Working Days	75	58	17

Table 5: Finish Work Driven Activities

Finish Work Driven Activities (FRP SW #9 Ends)			
	Original Schedule	New Schedule	
Start Date	5/18/2012	5/18/2012	
Finish Date	11/6/2012	10/15/2012	Total Days Gained
Actual Days	174	151	22
Working Days	123	107	16

In review of both the original and new schedule it can be noticed that this project was scheduled similarly to a short interval production schedule in that every sequence immediately is followed by the one trailing it. In discussions with the project team, the original schedule created for this report had too much float in crane activities. Typically speaking crane driven activities should lie very close to the critical path and subsequently have little to no float. The actual project incorporated this by getting out ahead almost three entire SOG pours before the first steel sequence began (SE #1 which is not shown on this schedule). Thus moving back to the schedule it appears the start of steel erection NW #6 can have a delayed start in both the original and new schedule. The new original schedule gained 23 days vs. 3 days gained in the actual schedule. This means the crane could actually only save **3 days** as compared to 17 days which is shown in Table 4. Finish Work can still commence 16 days ahead of the original schedule.

Structural Breadth

It should be understood there is one large caveat in successfully performing this analysis. On the west roof rests mechanical air handling units. These units extend partially over the bar joists which support the community rink. This image can be seen in figure 20.

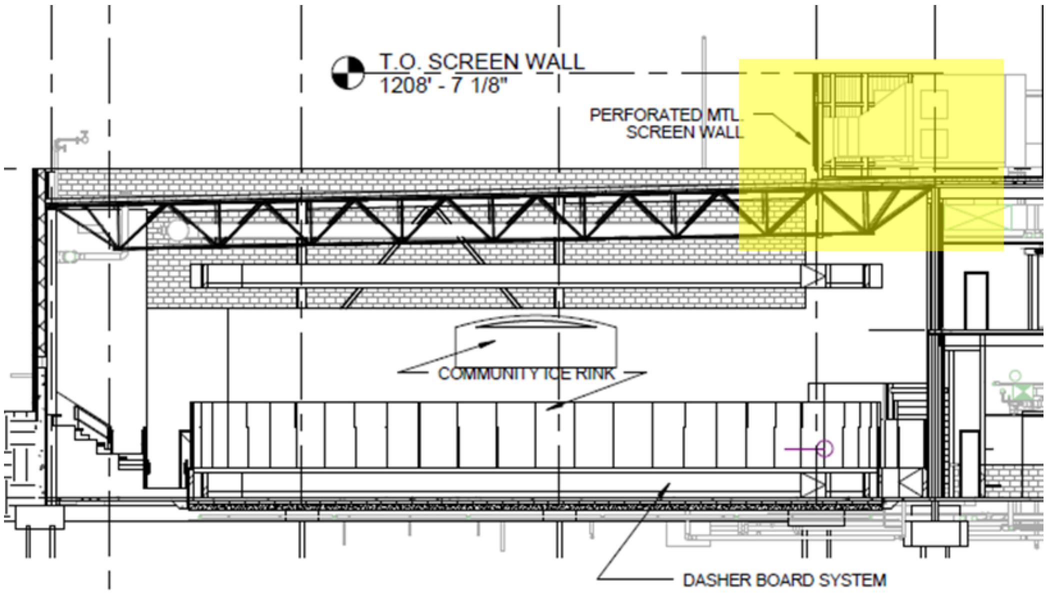


Figure 20: Community Rink Section | Courtesy of Mortenson

Therefore, in order to remove many of the structural components off the critical path of the schedule yet still pour the concrete slabs under the AHUs, it is necessary to design a different structural system which will be able to support the mechanical systems before the community rink structure is assembled.

The first step in this process was determining what type of design might be able to best support this system. This required a meeting with structural professor Kevin Parfitt. The initial design was to simply cantilever the beam off the X4 gridline, which is the gridline that transitions from the main rink roof to community rink roof, to the X3 gridline, which is where the edge of the concrete slab for the air handling units ends. If the beam started to get to large due to load sizes a rectangular HSS member could be added as a diagonal member transferring load into the column at a different angle. At the meeting Professor Parfitt suggested actually making the top girder a continuous one that connects into the column that lies on the X5 gridline. The concern was that the beam would want to rip off the X4 column or really pull it back. The design of the system can be seen in figure 21.

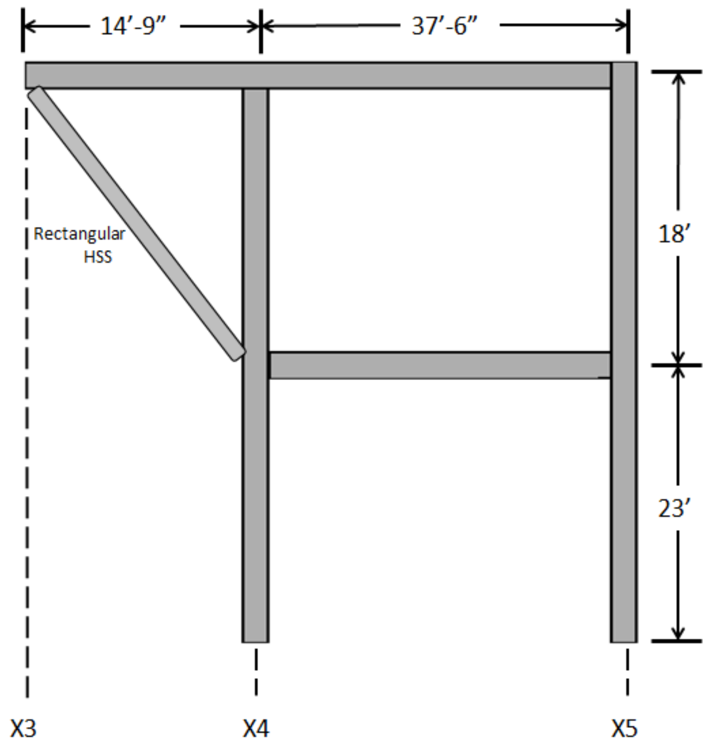


Figure 21: New Steel Design

The next step was to determine the loads on the building. There are four load groups that will put stress into this structural system. These are the community rink roof, the cantilevered section of the top girder (gridlines X3 to X4), the top girder (gridlines X4 to X5), and the bottom girder (gridlines X4 to X5). The breakdowns are below.

Community Roof

- DL = 3.6psf TPO + 5psf beam self-weight = 8.6psf
- LL = 20psf (roof load)
- SL = 30psf
- W_u = 1.2(8.6) +1.6(20) + 0.5(30) = 57.3psf
- Point Load = 57.3psf * 47.5' * 26'(worst case scenario) = 70.766kip

Cantilevered Section Top Girder (Gridlines X3 to X4)

- DL = 75psf (concrete slab) + 24psf (AHU weight) + 10psf girder self-weight = 109psf
- LL = 20psf (roof load)
- SL = 30psf
- W_u = 1.2(109) +1.6(20) + 0.5(30) = 180psf
- Distributed Load = 180psf * 26' = 4.68kip/ft

Top Girder (Gridlines X4 to X5) | Loads work out similarly to that of the cantilevered section

- DL = 75psf (concrete slab) + 24psf (AHU weight) + 10psf girder self-weight = 109psf
- LL = 20psf (roof load)
- SL = 30psf
- W_u = 1.2(109) +1.6(20) + 0.5(30) = 180psf
- Distributed Load = 180psf * 26' = 4.68kip/ft

Bottom Girder (Gridlines X4 to X5)

- DL = 75psf (concrete slab) + 10psf girder self-weight = 85psf
- LL = 100psf (corridor)
- W_u = 1.2(85) +1.6(100) = 262psf
- Distributed Load = 262psf * 27.4' (worst case scenario) = 7.183kip/ft

Appendix J has the detailed calculations.

The figure below represents these numbers.

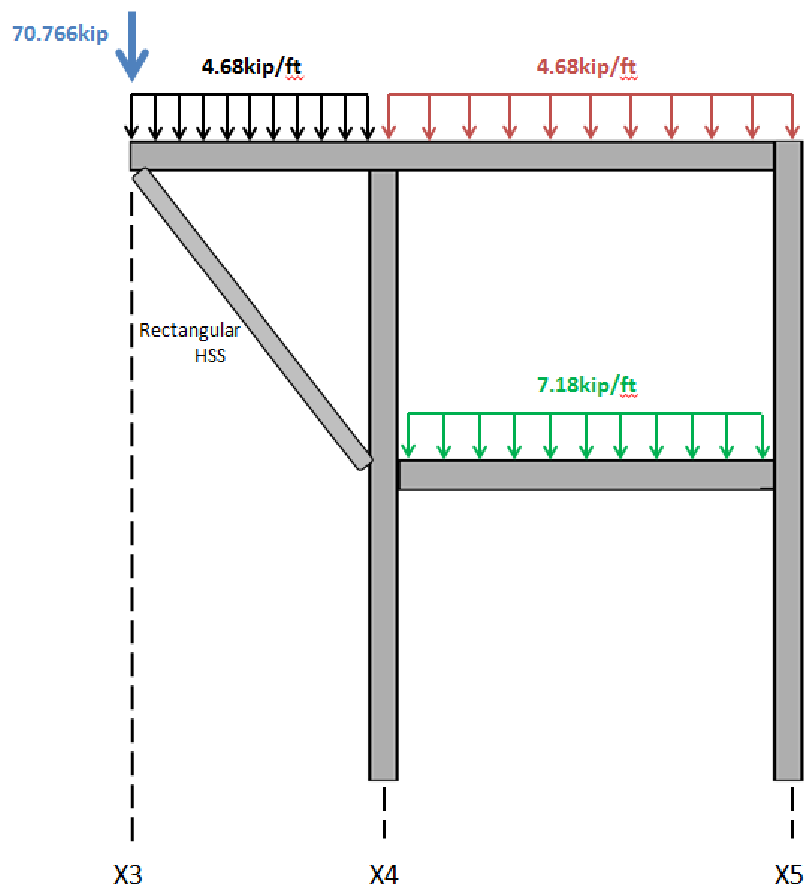


Figure 22: Steel Design with Loads

This model was then transferred into a Staad model. Originally, it was planned to exclusively use hand calculations when sizing the beam. However, since there is such a large pulling force created by the point load at the end of the cantilever, it was implied by Professor Parfitt that hand calculations would not be able to represent this information and that a Staad model would be necessary.

The first model created was done with the original column and girders with two exceptions. The first is that a rectangular HSS member was added as a compression member and that the top girder was lengthened by the 15 foot cantilever. This model can be seen below.

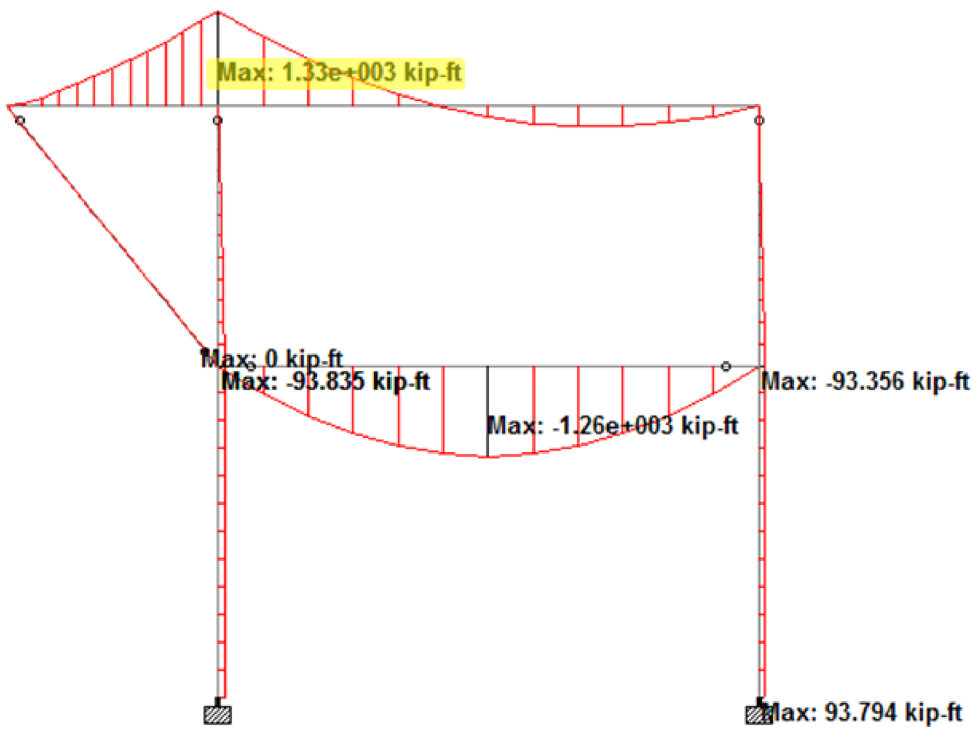


Figure 23: Staad Moment Diagram

It should be noticed that the top girder has a maximum moment of 1.33kip-ft. That member is a W30x99. This member can only withstand a maximum moment of 1.17kip-ft. Therefore, this member needed to be enlarged. A W30x116 member has an acceptable moment of 1.42kip-ft and which makes this size girder acceptable.

However, as predicted in the meeting with Professor Parfitt the structure is being pulled inward. An exaggerated version of the displacement of all members can be seen in figure 24 in green.

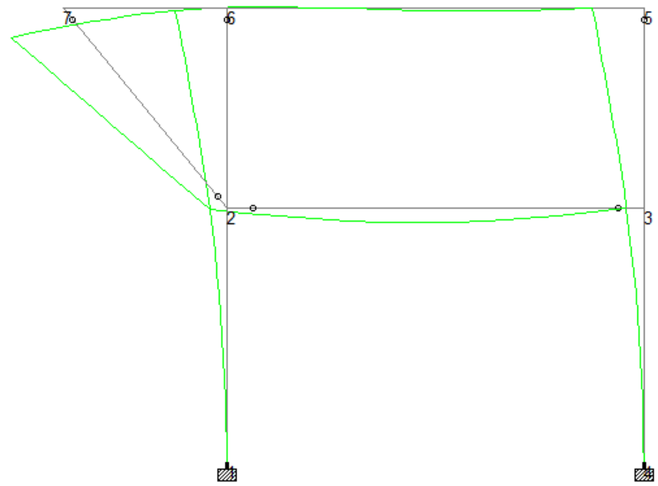


Figure 24: Staad Bending Diagram

Node 7, which can be seen in the figure above is going to be displaced the most. This node, with the new girder on top, is displaced over 5". Since this girder supports the roof structure it only needs to meet a deflection of L/180. For the cantilevered portion L = 14'-9". That makes L/180 = 0.983" which means anything that deflects less than that is an acceptable deflection.

After repeated trial and error a solution was derived. It resulted with solutions displayed in the figure below. Once again, it should be noted that structural members were originally derived via hand calculations, however, due to the unique bending forces Staad derived much larger members.

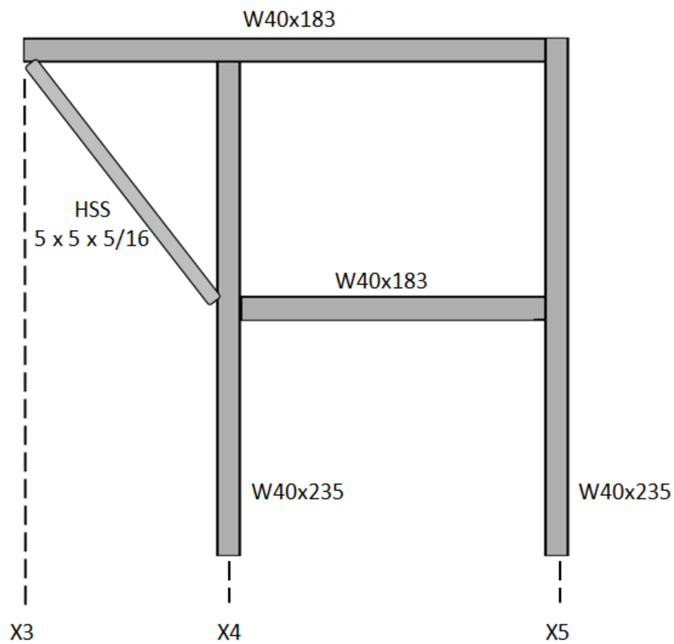


Figure 25: Steel Member Sizing

The HSS member was sized differently in the hand calculations. It was originally sized before the top girder member was changed to accommodate for deflection. It should also be noticed how large the new members are. The columns went from W14x90 to W40x235 and the top girder went from a W30x99 to a W40x183. This is a substantial increase in width and depth of the new members. There is not an overly large amount of concern with the roof girder. It may require mechanical ductwork to be lowered due to increased depth but not anything that cannot be overcome. However, the columns intersect with walkways. They are still acceptable from code standards but take up an additional two feet of depth and become awkward and an eyesore.

There is one final issue. The northwest portion of the building is where the student entrance is at. At this entrance is one of the spaces the architect designed to be wide open. The entrance is supposed to be able to house large crowds who then are funneled directly into the main arena which then opens wide up, similar to Frank Lloyd Wright's compression and expansion technique. The architect purposefully designed this space to be free of structural supports. With the newly proposed design it would require a column be added to this space. This space could still house a large amount of people but would affect the aesthetics and experience the space is supposed to express. This change can be seen in figure 26.

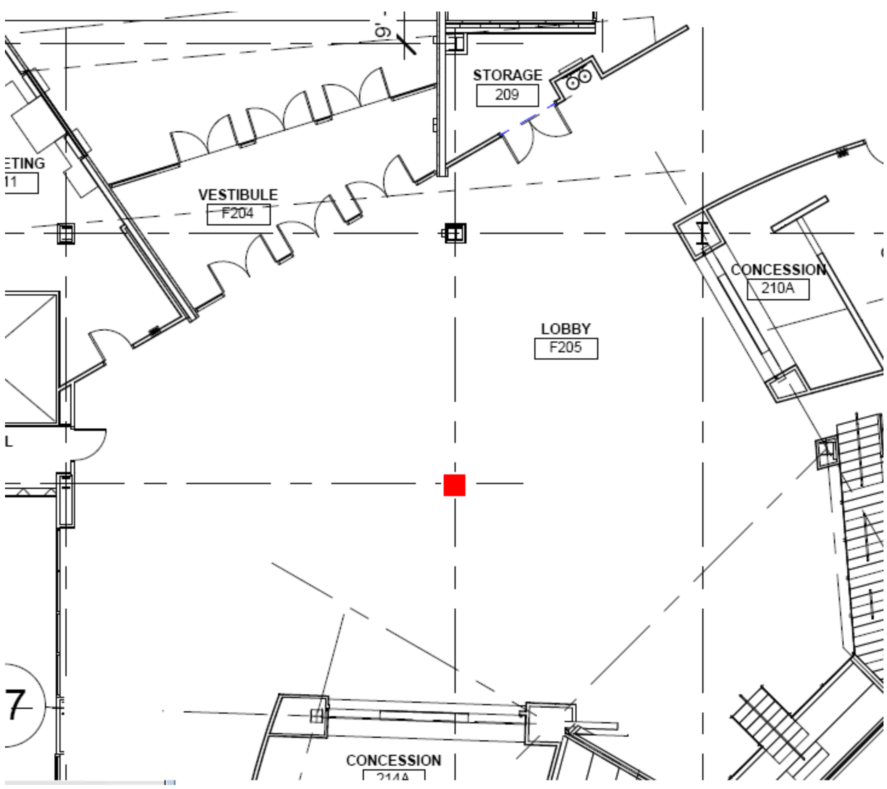


Figure 26: Student Entrance

Figure 27: 3D Steel Design

Conclusion

Below are the advantages and disadvantages of removing the community rink off the critical path.

Advantages

- Finishes can begin more quickly ahead of the current schedule which will result in the project finishing three weeks ahead of schedule.
- Allows more float on community rink activities. Specifically, mechanical room has much more time to get underground work finished.
- Decrease in general conditions
    - Employee Costs: $91,500 (Reference Appendix F)
    - Miscellaneous Costs: $8,175 (Reference Appendix F)
    - **Total Costs: $99,675**

Disadvantages

- Significant increase in size of steel columns and girders.
- **Additional cost in steel. ($361,748)**

  Appendix K contains the structural breadth estimate.
- Potential foundation upgrades.
- Minimal crane time saving.
- Significant aesthetic disruption at student entrance.

Although an additional three weeks from the schedule can be saved, it does not seem beneficial to utilize the proposed solution in removing the community rink off the critical path. Between the additional steel and general conditions there is an additional project cost of $262,073. There is also a significant architectural aspect of the building diminished. Placing a column in in the student entrance disrupts the architect's imagination for that space. Adding cost and making the occupational use of the student entrance less functional hurts the owner as well. As one can see, the proposed solution would help the construction manager, but would not help the architect or owner which is why this proposed solution does not seem beneficial.

Analysis 2 | Building Sequence

Problem Identification

This project has a finish date that must be met because this project is for Division 1 Hockey. Therefore, the building has to be ready to open by at least October 11th, 2013, the date of the home opener. The project team is moving as fast as possible but there is not going to be much extra time at the end of the project for the building facility operator to ensure all systems work as intended prior to the opening game. This all is simply stated to imply that the faster the building could be built, the better chance the building has to be properly commissioned prior to October 11th, 2013.

Background Research

It was in technical report 2 where a detailed project schedule was created and analyzed. Also, having worked over the summer it was never truly understood why the project team started the project at the location they did. As previous technical reports have stated the sequenced work all started in the center of the building along project south. In discussions with the project team in November, I was informed that part of the driving start point was the foundation wall which wraps around three sides of the building. Therefore, it was necessary for the crane to exit the building along the south side but besides that there were limited driving factors for starting work at the location they did.

The other item of research is that originally the project team had planned to remove the crane from the building using the same access point (into the main rink) the scoreboard and ice slab installers are going to use, however shortly before construction the crane exit plan was determined inadequate and there was a last second decision, to add an additional crane exit. With the schedule being a concern and the crane exit being something of an issue it seems as if something could be done to assist in these areas.

Preliminary Research and Proposed Solution

There are multiple solutions to this proposed problem. These solutions were determined organically by having meetings with the Pegula project team and by meetings with advisor Raymond Sowers. Subsequently, the research and proposed solutions are identified prior to the two parts of this analysis.

Methodology

- Retrieve the most up to date schedule from Mortenson Construction.
- Sequence the building with two crews and a new start location.
- Determine a method to allow crane and scoreboard / ice slab systems a similar access point.
- Breakdown any schedule savings.
- Perform potential cost implication analysis.

❖ Note: Relocating AHU's to expedite the student section portion of the building was analyzed in analysis 1 and proved to be implausible.

Two Crews (Part 1)

As explained in analysis 1 the inspiration behind sequencing the community rink off the critical path came from Heidi Brown, Project Manager for Mortenson. However, analysis 2 came from my own desire to determine potential ways the project could be run more quickly. Discussions were then held with advisor Raymond Sowers who confirmed that sports complexes typically do have hard timelines for completion due to home openers. The Pegula project is no exception. Mr. Sowers went onto explain that often the uniqueness of the shape of structure can also often lead to multiple ways of sequencing.

The first sequencing idea came from Raymond Sowers. He spoke of a past sports complex he worked on which utilized two crews. Essentially, these two crews started on opposite sides of one another and sequenced their work so that they would finish where the other began. This can be seen below.

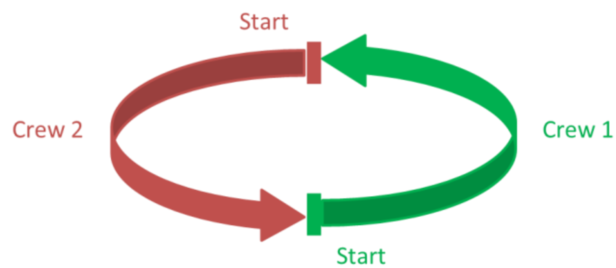


Figure 28: Two Crews Sequence

From technical report 2 a detailed schedule for the project was performed. This detailed schedule essentially broke the majority of work into four quadrants. These quadrants can be seen below.

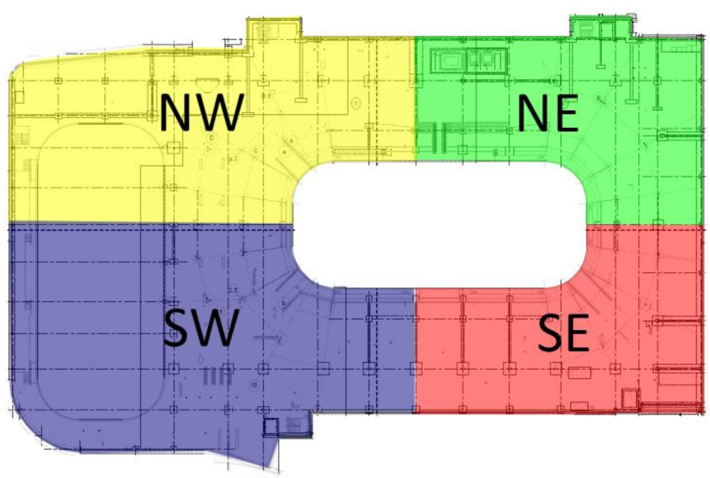


Figure 29: Building Sequence Breakdown

On this figure it appears there is significantly more work involved in the NW and SW portion of the building when compared with the NE and SW portion however, due to the limited amount of finished material there will be in the community rink the quadrants have a fairly equal amount of work. Knowing this, two crews can potentially have access to whichever quadrants they would like without fear that they will have more work than the crew working opposite of them.

This makes it possible to schedule the building without knowing the actual sequence of the building. As would be expected, the schedule is essentially cut in half. This is under the assumption that virtually every part of construction came equipped now with two crews instead of only one, with the exception of the mobilization, mass excavation, commissioning, FFE, and the setting of the main rink roof trusses. The trusses were built on tandem picks requiring two cranes anyway, therefore, the two crews could simply both support the construction of the trusses.

Appendix L contains an original schedule updated in conjunction with the most up to date schedule provided by Mortenson.

Appendix M contains the two crew summary schedule.

The breakdown of the base summary schedule vs. the two crew summary schedule can be seen in Table 6.

Table 6: Base Summary Schedule vs. Two Crew Summary Schedule

	Base Summary Schedule			Two Crews Summary Schedule		
Task Name	Duration	Start	Finish	Duration	Start	Finish
Notice to Proceed	0 days	Thu 1/26/12	Thu 1/26/12	0 days	Thu 1/26/12	Thu 1/26/12
Mobilization	6 days	Fri 1/27/12	Fri 2/3/12	6 days	Fri 1/27/12	Fri 2/3/12
Excavation - Bottom of SOG	51 days	Mon 2/13/12	Mon 4/23/12	51 days	Mon 2/13/12	Mon 4/23/12
Excavation - Foundations	82 days	Tue 3/27/12	Wed 7/18/12	41 days	Tue 3/27/12	Tue 5/22/12
Foundation Concrete	86 days	Tue 3/27/12	Tue 7/24/12	43 days	Tue 3/27/12	Thu 5/24/12
Underground MEP / SOG Concrete	120 days	Thu 4/19/12	Wed 10/3/12	60 days	Mon 4/9/12	Fri 6/29/12
Steel Erection	102 days	Tue 6/12/12	Wed 10/31/12	51 days	Mon 5/14/12	Mon 7/23/12
Roof Truss Erection	28 days	Tue 10/30/12	Thu 12/6/12	28 days	Tue 7/24/12	Thu 8/30/12
Topping Off	0 days	Thu 12/6/12	Thu 12/6/12	0 days	Thu 8/30/12	Thu 8/30/12
SOG Concrete (Crane Exit)	8 days	Fri 12/7/12	Tue 12/18/12	8 days	Fri 8/31/12	Tue 9/11/12
CFMF Panels	92 days	Mon 7/30/12	Tue 12/4/12	46 days	Wed 6/6/12	Wed 8/8/12
Roofing	97 days	Fri 8/10/12	Mon 12/24/12	49 days	Thu 6/28/12	Tue 9/4/12
Exterior CMU	37 days	Mon 10/15/12	Tue 12/4/12	19 days	Wed 8/1/12	Mon 8/27/12
Building Enclosure	0 days	Mon 12/24/12	Mon 12/24/12	0 days	Tue 9/4/12	Tue 9/4/12
MEP Rough In	112 days	Thu 8/30/12	Fri 2/1/13	56 days	Mon 7/9/12	Mon 9/24/12
Permanent Power	0 days	Fri 2/1/13	Fri 2/1/13	0 days	Mon 9/24/12	Mon 9/24/12
Drywall and Interior Finishes	189 days	Tue 10/2/12	Fri 6/21/13	95 days	Wed 7/25/12	Tue 12/4/12
Commissioning	28 days	Sat 6/22/13	Tue 7/30/13	28 days	Wed 12/5/12	Fri 1/11/13
FFE	50 days	Thu 7/18/13	Wed 9/25/13	50 days	Thu 1/3/13	Wed 3/13/13
Final Completion	0 days	Tue 9/17/13	Tue 9/17/13	0 days	Fri 3/8/13	Fri 3/8/13
1st Puck Drop - PSU vs. Army	0 days	Fri 10/11/13	Fri 10/11/13	0 days	Fri 10/11/13	Fri 10/11/13

The primary piece of information to take away from this breakdown is that the project has the potential to finish March 8th, 2013 with FFE being done shortly after that. It should be noted as a reminder from technical report 1 that FFE is being performed by Penn State which is why it is not contingent upon final completion. Final completion is contingent upon closeout items (which are not shown in the summary schedule, but stay ahead of FFE to ensure all rooms are done before furniture gets placed).

Ultimately, it was obvious from the forefront that utilizing two crew would significantly save time on schedule, however, is there any reason to do this. Essentially this stadium needs to be opened for the October home opener. That will be the first time the actual ice rink gets used for a purpose other than commissioning and testing. Therefore, having it capable of opening in the middle of March 2013 does not do much for the school. It would certainly ensure that the project would open on time even if there were difficulties throughout construction, however, at the additional cost of utilizing two crews and the potential lack of production due to congestion, two crews is not warranted for the entire project.

Therefore, it was time to look at other potential school milestones that might be worth hitting. The most obvious one seemed to be the first day of Fall semester 2013. In order to make this happen either some of the front end work, excavations and steel erection, need two crews or the rough-in and finishes need to utilize more man power. Utilizing two crews with rough-ins and finishes would not work simply because they would have no available space to go forth and work on.

Note: Having worked part time on the project and speaking with Mortenson and other subcontractors, getting more manpower is not the easiest thing in the world. Companies do not typically staff their companies with a load of excess craftsmen. Therefore, companies would have to really reach into the labor hall which is not always beneficial due to the inexperience of these people. A large number of inexperienced labor would cause significant headaches for both the subcontractors and Mortenson. Due to the lack of information and time, this was not researched as part of this analysis but certainly would cause additional problems.

With that, in order to utilize two crews and not open the project on an arbitrary date, the project will have to utilize two crews for excavation, SOG, and steel. Not only can this be done but it can hit the date perfectly without any additional tweaking of the schedule beyond using two crews for excavation and steel erection. This new schedule summary breakdown can be seen in Table 7.

Excavation, SOG, Steel Two Crews summary schedule can be seen in Appendix N.

Table 7: Base Summary Schedule vs. Excavation, SOG, and Steel Two Crews

	Base Summary Schedule			Excavation, SOG, Steel Two Crews		
Task Name	Duration	Start	Finish	Duration	Start	Finish
Notice to Proceed	0 days	Thu 1/26/12	Thu 1/26/12	0 days	Thu 1/26/12	Thu 1/26/12
Mobilization	6 days	Fri 1/27/12	Fri 2/3/12	6 days	Fri 1/27/12	Fri 2/3/12
Excavation - Bottom of SOG	51 days	Mon 2/13/12	Mon 4/23/12	51 days	Mon 2/13/12	Mon 4/23/12
Excavation - Foundations	82 days	Tue 3/27/12	Wed 7/18/12	41 days	Tue 3/27/12	Tue 5/22/12
Foundation Concrete	86 days	Tue 3/27/12	Tue 7/24/12	43 days	Tue 3/27/12	Thu 5/24/12
Underground MEP / SOG Concrete	120 days	Thu 4/19/12	Wed 10/3/12	60 days	Mon 4/9/12	Fri 6/29/12
Steel Erection	102 days	Tue 6/12/12	Wed 10/31/12	51 days	Mon 5/14/12	Mon 7/23/12
Roof Truss Erection	28 days	Tue 10/30/12	Thu 12/6/12	28 days	Tue 7/24/12	Thu 8/30/12
Topping Off	0 days	Thu 12/6/12	Thu 12/6/12	0 days	Thu 8/30/12	Thu 8/30/12
SOG Concrete (Crane Exit)	8 days	Fri 12/7/12	Tue 12/18/12	8 days	Fri 8/31/12	Tue 9/11/12
CFMF Panels	92 days	Mon 7/30/12	Tue 12/4/12	92 days	Wed 6/6/12	Thu 10/11/12
Roofing	97 days	Fri 8/10/12	Mon 12/24/12	97 days	Wed 7/18/12	Thu 11/29/12
Exterior CMU	37 days	Mon 10/15/12	Tue 12/4/12	37 days	Thu 9/20/12	Fri 11/9/12
Building Enclosure	0 days	Mon 12/24/12	Mon 12/24/12	0 days	Thu 11/29/12	Thu 11/29/12
MEP Rough In	112 days	Thu 8/30/12	Fri 2/1/13	112 days	Tue 8/7/12	Wed 1/9/13
Permanent Power	0 days	Fri 2/1/13	Fri 2/1/13	0 days	Wed 1/9/13	Wed 1/9/13
Drywall and Interior Finishes	189 days	Tue 10/2/12	Fri 6/21/13	189 days	Fri 9/7/12	Wed 5/29/13
Commissioning	28 days	Sat 6/22/13	Tue 7/30/13	28 days	Thu 5/30/13	Mon 7/8/13
FFE	50 days	Thu 7/18/13	Wed 9/25/13	50 days	Tue 6/25/13	Mon 9/2/13
Final Completion	0 days	Tue 9/17/13	Tue 9/17/13	0 days	Fri 8/23/13	Fri 8/23/13
1st Puck Drop - PSU vs. Army	0 days	Fri 10/11/13	Fri 10/11/13	0 days	Fri 10/11/13	Fri 10/11/13

From the table above it is evident that the date of final completion can occur on August 23, 2013. This is the Friday before the first day of class for Penn State students. Attempting to hit this date would benefit the overall project in three areas. It would allow tenants to be moved in and utilizing their new space at the beginning of the new school year. It would also allow students to experience the building for the first time. The community rink will primarily service as an open skate rink for students which would get students both excited about the building and the upcoming hockey season. Finally, it would benefit the project in that it would leave room in the schedule in case anything significant does put delay into the project schedule. There is now almost an additional month of schedule that can be utilized in case of an emergency.

Ultimately, this would be great to do. Naturally, it would be harder to coordinate which might make the cost of construction come at a premium, however, there is a much bigger issue than cost. Logistically this could cause nightmares for the project team. Often times sports complexes are intentionally placed in a wide open space. This is usually done so that a large amount of parking can envelop the new complex. This makes getting into the sports complex easier and also allows fans to tailgate and enjoy themselves before the game or match begins. However, due to the proximity of Beaver Stadium and the Bryce Jordan Center’s parking, the Pegula Ice Arena is in a fairly tight space with no additional parking.

Thus, mapping new site logistics plans was necessary to visually identify areas of potential hazard.

A blow up of the building perimeter can be seen below.

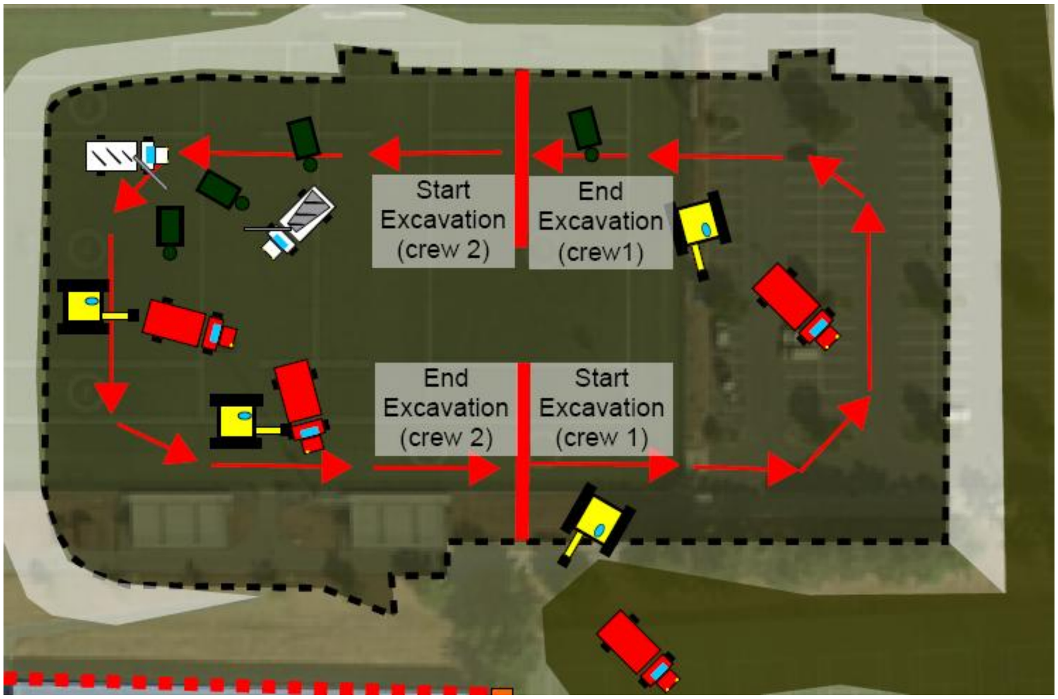


Figure 30: Excavation Site Logistics

A full Excavation Site Logistics Model for two crews can be seen in Appendix O.

There are multiple additional hazards created by using two crews during excavation. One is that there is now twice the amount of heavy equipment being used on site simultaneously. The other large issue created by using two crews during excavation is the flow of traffic pertaining to the dump trucks. Mass excavation had trucks constantly entering and leaving the site to the extent that a full time flagger was needed at the gate to ensure smooth traffic flow. If the project was to double the amount of these trucks not only could there be the possibility that lines would build up at the gate entrance but also maneuverability on site could be impeded.

The second level of site logistics pertains to the foundation wall and slab on grade seen below.

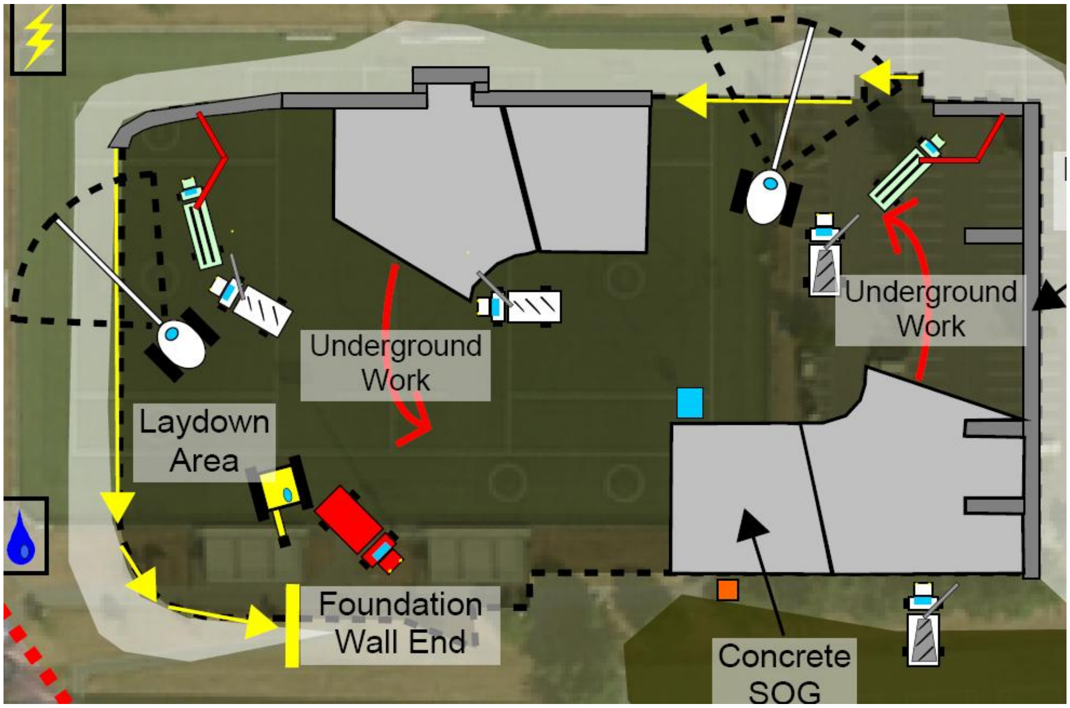


Figure 31: SOG Site Logistics

A full SOG Site Logistics Model for two crews can be seen in Appendix P

Similar to excavation, using two crews during all of this concrete work is going to get very hectic. The crews during this period have to follow each other very close behind in order to successfully make utilizing two crews time effective. At the top right of figure 31 you can see just how crowded this work area is. There is underground MEP work sandwiched between a slab on grade pour and a foundation wall pour. That means a significant amount of heavy machinery is going to be working very close to people with little protection (space or barricade) surrounding them. It should also be noted that that the foundation walls rebar is formed and tied on the ground and then lifted into place with a crane. In this logistics model there is little to no space for assembly of foundation wall reinforcement. Lastly, the underground work along the left allows for little to no access to that foundation wall at the top left. This simply shows just another workspace with little to no room.

The last two crew sequence belongs to the steel. The steel is especially interesting since an additional crane will be required on site. Before an additional logistics model was created it was essential to determine the area best suited to support a second crane. There are four potential landing spots this crane could be situated in. These places are north, west, south of the building, or inside the building. Shields Building is north of the building, the field hockey turf is to the west of the building, and Holuba Hall is to the south of the building. None of the spaces between these building and Pegula can adequately supply enough square footage for a crane and steel shakeout. Therefore, the crane would have to be located inside the structure. The only available space inside the structure is at the community rink ice slab. This can be seen in Figure 32.

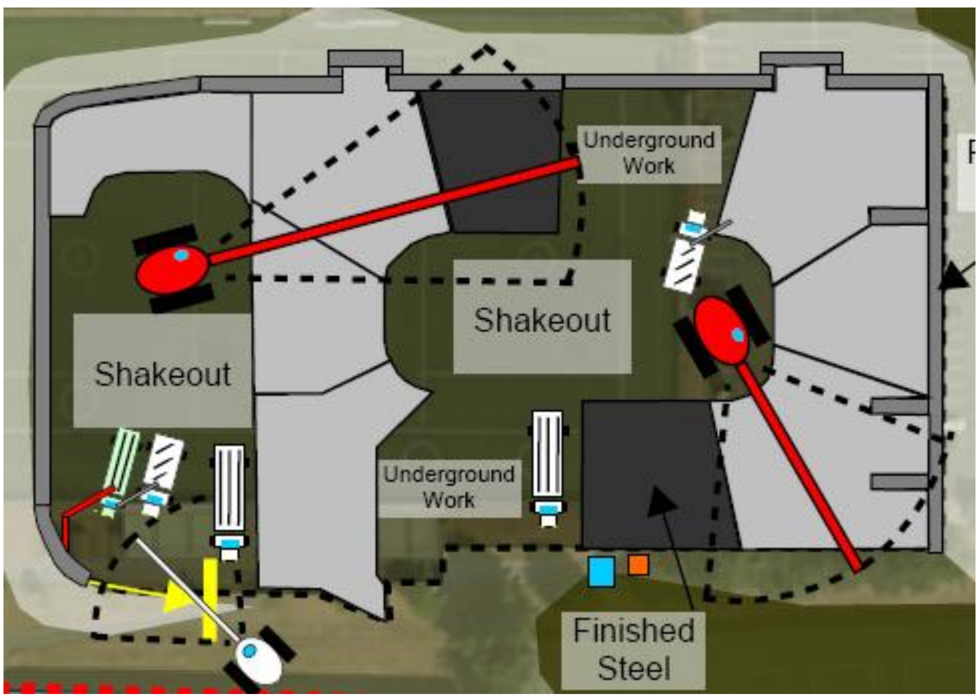


Figure 32: Steel Site Logistics

A full Steel Site Logistics Model for two crews can be seen in Appendix Q.

The use of two cranes on site causes many hazards. As one can see there is certain underground work and slab pours that now have to share access space with the crane. There is also much less access and space for steel deliveries and steel shakeout. The additional crane has to have almost 1-1/2 times longer radius than the first crane. This gives this second crane the potential to boom out over the surrounding building causing a public safety hazard. Lastly, there is the potential for the cranes to interfere with each other in this scenario.

Conclusions (Part 1)

Below are the following issues created by utilizing two crews for excavation, concrete, and steel:

- **Excavation**
  - Twice the amount of heavy machinery.
  - Traffic flow on the site and at the site entrance.

- **Foundation and SOG concrete**
  - Tight working Conditions.
  - Lack of maneuverability to working spaces.

- **Steel**
  - Tight working conditions.
  - Lack of maneuverability for steel deliveries.
  - Little to no shakeout area.
  - Second crane has potential to boom out over public buildings and pathways.
  - Cranes have potential to collide.

Potential Solutions

- Designate full time flaggers for trucks and steel deliveries at entrance and possibly on site.
- Appoint full time cleaning crew to ensure site logistics are maintained with clean paths and working conditions.
- Hire additional safety professionals to ensure work zones maintain a high level of safety.

Ultimately, there are potential solutions that might help solve some logistical challenges this project would face if two crews were utilized. However, it is believed that the level of risk and potential hazards that might develop far outweigh the potential time gained by utilizing two crews for part of the work. Not only do safety risks arise but a lack of production could occur with poor site logistics leading to additional project costs. Overall, it does not seem to be in the best interest of the project team to consider utilizing two crews for excavation, concrete, and steel.

New Start Location (Part 2)

Performing the analysis where two crews could potentially be utilized gave an insight into logistics and schedule that were not before known. After thorough review it seems that there is at least one potential schedule saving scenario based on project sequencing.

It was discovered that the foundation wall controls a significant portion of the schedule. The foundation wall is followed by additional excavation, underground MEP work, backfill, vapor barrier, FRP SOG, steel, rough-in, and finally finishes. If the foundation wall falls behind the entire project falls behind. That is one of the many reasons Mortenson decided to self-perform the concrete on site. Since they were responsible for this foundation wall they were able to drive the schedule.

However, based on project sequencing it is evident that they did not try to start the work as far behind this foundation wall as they possibly could have. Figure 33 represents how the project was sequenced.

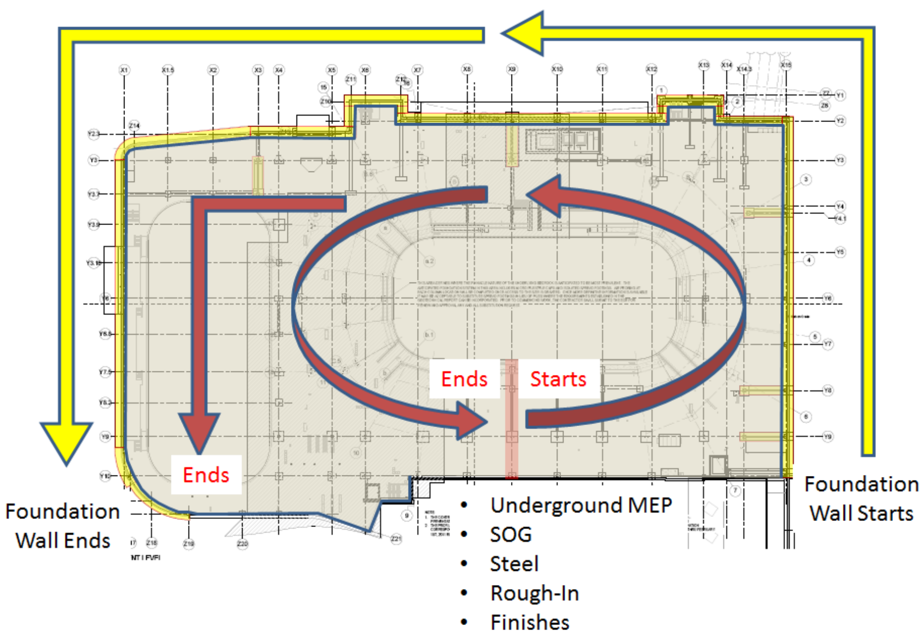


Figure 33: Project Start Sequencing

As can be seen, the foundation wall is in yellow and does begin ahead of where the rest of the project starts but the underground MEP work follows very quickly behind it. Mortenson was able to maintain this lead in the foundation wall and never allowed underground or SOG work to be slowed down. However, this project start point still seems arbitrarily placed. It seems that it could be moved back without hindering the project and should actually give the foundation wall more breathing room as well as allowing the SOG and subsequently the finish work to begin sooner which will decrease project duration.

Therefore, it was decided to try and move the project start point back around the SOG. This can be seen below.

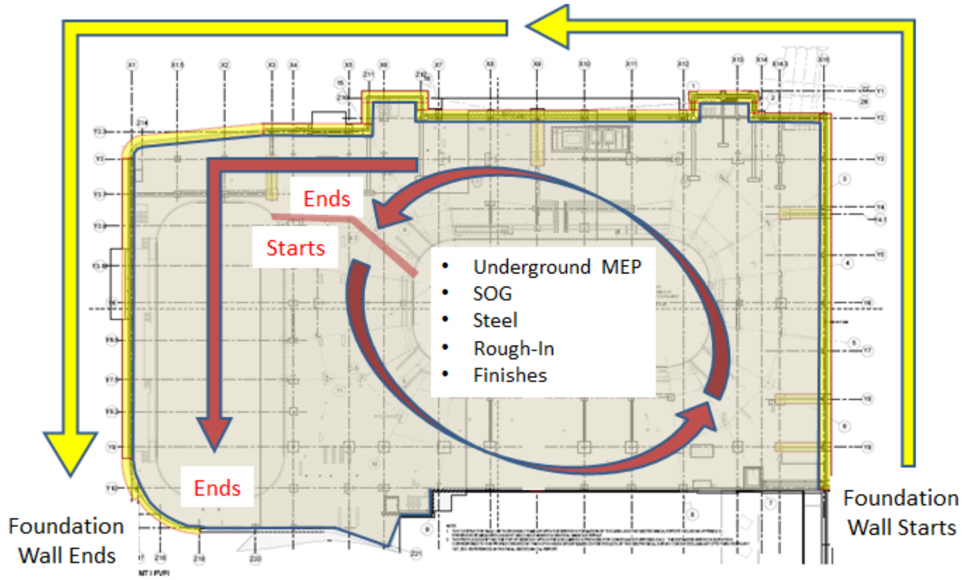


Figure 34: Potential Project Start Sequence

As can be seen the project start point will now be near the top left (northwest) of the building. When identifying this with the summary schedule there was one glaring issue. This issue is represented in Table 8.

Table 8: Different Project Start Location

	Different Project Start Point		
Task Name	**Duration**	**Start**	**Finish**
Notice to Proceed	0 days	Thu 1/26/12	Thu 1/26/12
Mobilization	6 days	Fri 1/27/12	Fri 2/3/12
Excavation - Bottom of SOG	51 days	Mon 2/13/12	Mon 4/23/12
Excavation - Foundations	41 days	Tue 3/27/12	Tue 5/22/12
Foundation Concrete	43 days	Tue 3/27/12	Thu 5/24/12
Underground MEP / SOG Concrete	60 days	Fri 3/16/12	Fri 6/29/12

It should be noticed that moving the project start location can save over a month of schedule starting with underground MEP work. This underground MEP / SOG work now starts March 16th. This comes in direct conflict with the foundation concrete work which does not start until March 27th. This made it evident that the project could not move as far back as once hoped.

Therefore it was essential to determine where the project could start which would allow the spread footers to still stay out in front of the project. Thus, it was determined the spread footers needed at least a five day head start. With this head start it was determined that the project could be started at the location represented in Figure 35.

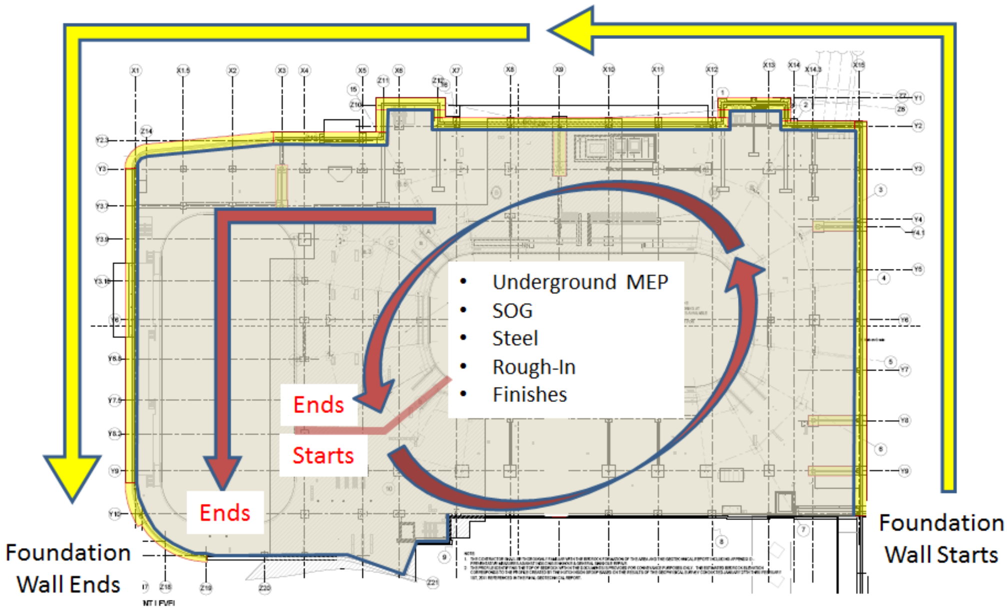


Figure 35: Proposed Project Start Location

The proposed project start location summary schedule can be seen in Appendix R (coordinates with Figure 35).

Table 9: Proposed Project Start Location

	Base Summary Schedule			Different Project Start Point (2)		
Task Name	**Duration**	**Start**	**Finish**	**Duration**	**Start**	**Finish**
Notice to Proceed	0 days	Thu 1/26/12	Thu 1/26/12	0 days	Thu 1/26/12	Thu 1/26/12
Mobilization	6 days	Fri 1/27/12	Fri 2/3/12	6 days	Fri 1/27/12	Fri 2/3/12
Excavation - Bottom of SOG	51 days	Mon 2/13/12	Mon 4/23/12	51 days	Mon 2/13/12	Mon 4/23/12
Excavation - Foundations	82 days	Tue 3/27/12	Wed 7/18/12	41 days	Tue 3/27/12	Wed 7/18/12
Foundation Concrete	86 days	Tue 3/27/12	Tue 7/24/12	43 days	Tue 3/27/12	Tue 7/24/12
Underground MEP / SOG Concrete	120 days	Thu 4/19/12	Wed 10/3/12	60 days	Tue 4/3/12	Mon 9/17/12
Steel Erection	102 days	Tue 6/12/12	Wed 10/31/12	51 days	Fri 5/25/12	Mon 10/15/12
Roof Truss Erection	28 days	Tue 10/30/12	Thu 12/6/12	28 days	Fri 10/12/12	Tue 11/20/12
Topping Off	0 days	Thu 12/6/12	Thu 12/6/12	0 days	Tue 11/20/12	Tue 11/20/12
SOG Concrete (Crane Exit)	8 days	Fri 12/7/12	Tue 12/18/12	8 days	Wed 11/21/12	Fri 11/30/12
CFMF Panels	92 days	Mon 7/30/12	Tue 12/4/12	46 days	Thu 7/12/12	Fri 11/16/12
Roofing	97 days	Fri 8/10/12	Mon 12/24/12	49 days	Wed 7/25/12	Thu 12/6/12
Exterior CMU	37 days	Mon 10/15/12	Tue 12/4/12	19 days	Thu 9/27/12	Fri 11/16/12
Building Enclosure	0 days	Mon 12/24/12	Mon 12/24/12	0 days	Thu 12/6/12	Thu 12/6/12
MEP Rough In	112 days	Thu 8/30/12	Fri 2/1/13	56 days	Tue 8/21/12	Wed 1/23/13
Permanent Power	0 days	Fri 2/1/13	Fri 2/1/13	0 days	Mon 1/21/13	Mon 1/21/13
Drywall and Interior Finishes	189 days	Tue 10/2/12	Fri 6/21/13	95 days	Wed 9/19/12	Mon 6/10/13
Commissioning	28 days	Sat 6/22/13	Tue 7/30/13	28 days	Tue 6/11/13	Thu 7/18/13
FFE	50 days	Thu 7/18/13	Wed 9/25/13	50 days	Fri 7/5/13	Thu 9/12/13
Final Completion	0 days	Tue 9/17/13	Tue 9/17/13	0 days	Wed 9/4/13	Wed 9/4/13
1st Puck Drop - PSU vs. Army	0 days	Fri 10/11/13	Fri 10/11/13	0 days	Fri 10/11/13	Fri 10/11/13

It can be seen in table 9 that the underground MEP/SOG concrete work can now begin two weeks faster. Allowing the slab on grade to start two weeks ahead of schedule allows the steel, rough-in, and finishes to also start and finish two weeks ahead of schedule. The other thing this helps with on the schedule is with the enclosure.

The enclosure became somewhat of an issue for construction. Essentially the project team had intentions of turning on temporary heat by the end of December. Unfortunately, the building was not entirely enclosed by this point.

The roofers never had enough space to work early on the project. The issue with this project is that the large majority of the roof depended on the trusses being set in order to roof the main part of the roof over the ice rink. However, there are corridors around the perimeter of the building which do not share a roof underneath the trusses. If the underground work was started earlier in the sequence it would have allowed the roofers additional roof space.

Ultimately, the roofers got "snowed out" and were not able to finish entirely enclosing the roof with their TPO system by about a weeks' worth of work. There was water prevention methods taken in order to ensure no finishes were ruined inside the building but not having roofing / insulation up allowed for an area where heat could easily escape. This did not prevent the project team from turning on temporary heat but did cause frustration. If additional roof space was proposed earlier in the project this incident could have been avoided.

Another benefit to this could be crane logistics. From technical report 1, it was shown how the crane exited the building. It enclosed itself inside the building with steel, and left out a SOG pour which would allow the crane to disassemble and walk itself out of the building. The primary issue this creates is that now rework has to be done to finish off this crane exit slab. It disrupts the flow and logistics of work. One potential solution to this might have presented itself by starting the project in that south west quadrant. It is possible for the steel to be erected in the shape of a horseshoe, followed by hanging the trusses, and then finishing the center west portion of steel and community rink. This can be seen in Figure 36. It should be noted that the purple sequence 2 represents roof trusses.

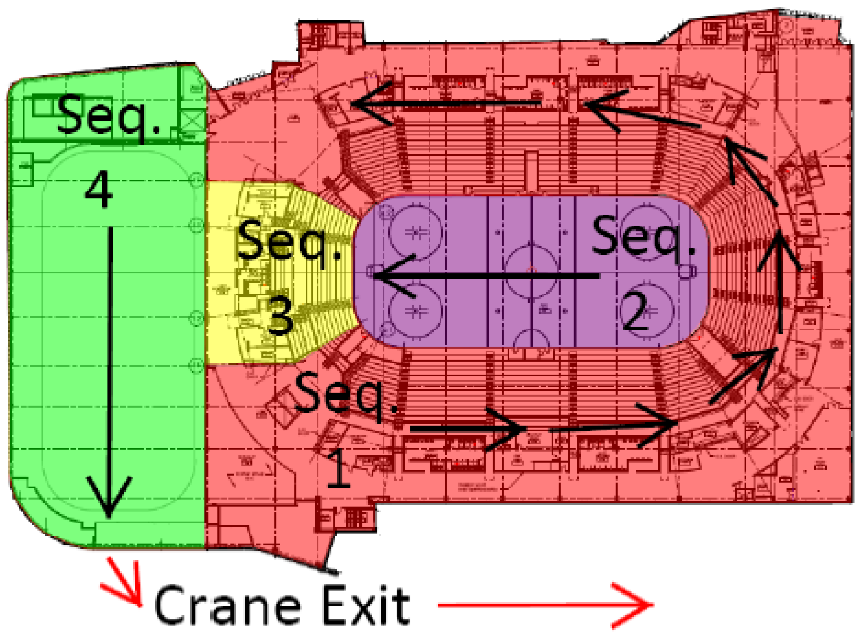


Figure 36: Proposed Project Sequence

It should be noted that there is one potential downfall of this crane exit. Sequence 3 requires by far the most work for the crane. It is part of the student section and the only portion of the building where precast extends from the event level up through the club level. Since the amount of work is so large in this portion of the building, setting the precast from behind the steel instead of in front of it would be extremely difficult. The crane operator would essentially be blind for the most work intensive portion of the building. There would also be two cranes on site for this since a final truss would have to be set on top of sequence 3. In order to utilize both of these cranes on site it costs over $6,000 a day. Both of those cranes could be utilized but there would certainly be lost time due to increased congestion.

Conclusion (Part 2)

Advantages

- Rough-in and Finishes can begin more quickly
- Roof enclosure has less chance to be "snowed out."
- Two weeks of schedule reduction.
- Potential alternative crane logistics.
- Potential for no SOG comeback pours which originally was left out as crane exit.

Disadvantages

- Most difficult sequence of steel / precast stadia work done installed "blind."
- Potential for increased crane time adding additional cost.

As can be seen there are a considerable amount of advantages when compared to disadvantages. The disadvantages that do occur are a result of attempting to utilize a different crane exit. Therefore, it seems most beneficial to utilize a similar crane exit plan as that with which Mortenson utilized. However, it could have been beneficial for the project to move the start of the project to that of which is represented in Figure 35. Ultimately, this saves two weeks of schedule and would have allowed for the roof to be properly enclosed before temporary heat was switched on. It has these benefits with no glaring disadvantages.

Analysis 3 | Building Enclosure

Problem Identification

This project is utilizing a metal studded wall panel system which incorporates sheathing, vapor barrier, and insulation that extend the length of the wall vertically. Part of the reason these wall panels were utilized was to help the building become enclosed before winter. The purpose of the building being enclosed before winter is to ensure temporary heat can be utilized to allow finish work to be installed inside the building

With some of the injuries incurred on site and the schedule being as tight as it, it could be advantageous to try and remove as many hazards and possibly give some breathing room for the schedule.

Background Research

In technical report 3 a value engineering analysis was done. Located in technical report 3 is a section detailing metal studded wall panel system. As stated above, these panels can extend the height of the building. They are around ten feet wide and were largely value engineered to ensure the building could be enclosed to help support finish work.

Later in discussions with the project team, Heidi Brown, project manager, relayed a similar message as the one above. When asked if there was ever consideration to attach brick to the panels it was implied that attaching brick to metal studs is not done, or at least that she has never seen it done. This was part of the interest in exploring this topic; to see if a brick façade could be attached, all as one system, to the metal studded wall panels.

After this meeting the PACE Roundtable was attended, where prefabrication was a topic of interest. There were breakout sessions attended. The first, Assistant Director of Design and Construction of Penn State's Office of Physical Plant, John Bechtel, discussed his continued interest in using prefabricated systems as part of Penn State's design approach. The other breakout session attended was with Jeffrey Angstadt, of Foreman Program and Construction Managers, who discussed possible contacts that could be of value in regards to prefabricated facades.

Preliminary Research and Proposed Solution

The two types of systems to analyze are a panel system that utilizes metal studs and a concrete system. The concrete system proved more effective. It was capable of providing a better R value, raised no concern for metal corrosion, has a reputable erection plan, and is a proven system utilized in today's industry.

There was a system found that utilized metal studs to back the system. This system is called Slenderwall. Slenderwall is a system that utilizes 16 gauge metal studs, filled with foam insulation with concrete ties, that get molded into 2" poured concrete. The one massive benefit to utilizing a system such as this is its weight. It is approximately 35 lbs/sf as compared to the concrete system which is approximately 80 lbs/sf. However, it does not offer a ton of flexibility in terms of insulation thickness, it is fairly flimsy which can result in cracking during erection, and concrete curing can causing metal stud erosion. This and the multiple benefits resulted in the selection of utilizing a concrete precast system with thin inlaid brick.

Methodology

- Get in touch with Mr. Angstadt and any possible contacts he may have.
- Engineer a brick façade that is embedded into concrete that is to be hung in similar fashion to the metal wall panels.
- Perform a cost comparison of original solution as compared to new system.
- Determine schedule impacts.
- Determine logistical challenges in moving and hanging each of these systems.
- Perform breadth analysis for architectural joints.

Proposed Wall System

Mr. Angstadt spoke of a potential contact he had and was willing to share at the PACE meeting. Unfortunately, the contact he had no longer worked for the company, but he still recommended that I get in touch with High Concrete, LLC.

High Concrete, LLC is a precast concrete manufacturer that specializes in enclosure systems among other things. Their projects range from structural precast concrete systems to architectural precast concrete systems. In review of the High Concrete website a system was found that could be utilized for the Pegula Ice Arena. This system is called CarbonCast Insulated Architectural Cladding. The thickness of the system can vary but essentially what it entails is two layers of concrete on the inside and outside and a panel of insulation sandwiched between the concrete. This description can be seen in the image below.

Figure 37: CarbonCast Insulated Architectural Cladding | Image courtesy of High Concrete, LLC

This system will be the basis of design for the architectural breadth required for the project.

Architectural Breadth

The first step necessary in designing the system was meeting with architectural advisor Professor Holland. At this meeting the main point of emphasis was the less aesthetic design, the better. Professor Holland went in depth in explaining how oftentimes general contractors will come to architects and propose alternative systems that require significantly new design concepts. He emphasized that when this arises there is very rarely the time or money to actually change the design. This can create a hostile work environment that can lead to constant bickering between the architect and general contractor.

Subsequently, it was decided that instead of changing the aesthetics of the building an alteration to the system would be designed and detailed. Professor Holland pointed to the waterproofing and thermal performance of the wall being of particular importance.

The next resource that was utilized was Mortenson Construction. Conversations were held with Senior Superintendent, Jason Brown, and Senior Project Manager, Steve Laurila. Sequencing conversations were held with Jason while Steve provided great insight into a similar system he used on a previous job. He worked for Hunt Construction on Lucas Oil Field, home of the Indianapolis Colts. He worked directly with Gate Precast on a sandwiched insulated panel system that was installed at this stadium. He explained that the system went concrete – insulation – concrete. This led to a great deal of confusion on why there was no vapor barrier.

After this conversation with Steve was held, High Concrete, LLC was contacted. Tom Holmes, Vice President of Sales and Marketing, was very helpful in this process. He provided information and a power point which helped explain why no vapor barrier is required in this system. He and the power point helped explain that as long as the wall temperature stays above the dew point temperature all the way through the system, no vapor barrier is required. Essentially, if the wall temperature stays above the dew point temperature no water will ever condense through the system.

Knowing all of this, the wall could start being designed. At least three inches of concrete were needed on each side of the insulation in order to ensure enough reinforcement could be added. The next step was determining if any thickness needed added to the system and how thick the extruded polystyrene insulation (recommended by Tom Holmes) should be sandwiched in the middle. This required calculations to be done as to ensure a proper R value was acquired as well as no water would condense through the system. With the help of other Architectural Engineering students in AE 542, Building Enclosure Science and Design, these calculations were able to be performed.

The full breakdown with calculations can be seen in Appendix S.

The calculations were done under two extremes. The same system was tested against a summer day (97° F | 85% RH) to a winter day (5° F | 10% RH). Simplified breakdowns of Appendix Blank can be seen in the figures below.

*As long as the relative humidity never surpasses 100% the water will never condense.

Table 10: Summer Thermal and Moisture Resistance

Layer material	temp (t)	Saturated Vapor Pressure (Pw,sat)	Vapor Pressure (Pw)	Relative Humidity (RH)
Units	[°C]	[Pa]	[Pa]	(%)
Interior Temp	23.89	2949.60	1179.84	40.00
Interior film				
	24.36	3033.45	1183.49	39.01
Drywall				
	24.67	3091.17	1211.98	39.21
Air Space				
	25.33	3215.02	1219.81	37.94
Concrete				
	25.49	3246.03	2041.66	62.90
Insulation XPS				
	35.83	5858.78	4233.26	72.25
Concrete				
	36.00	5910.97	5055.11	85.52
Exterior film				
Exterior Temp	36.11	5948.05	5055.84	85.00

Interior temperature of 23.89° C (75° F) and 40% relative humidity for summer performance.

Table 11: Winter Thermal and Moisture Resistance

Layer material	temp (t)	Saturated Vapor Pressure (Pw,sat)	Vapor Pressure (Pw)	Relative Humidity (RH)
Units	[°C]	[Pa]	[Pa]	(%)
Interior Temp	18.33	2096.38	838.55	40.00
Interior film				
	16.98	1925.79	837.75	43.50
Drywall				
	16.08	1817.74	831.51	45.74
Air Space				
	14.18	1608.71	829.79	51.58
Concrete				
	13.71	1560.81	649.65	41.62
Insulation XPS				
	-14.21	202.96	199.31	98.20
Concrete				
	-14.67	195.35	19.17	9.81
Exterior film				
Exterior Temp	-15.00	190.13	19.01	10.00

Interior temperature of 18.33^{o} C (65^{o} F) and 40% relative humidity for winter performance.

The drywall will be fastened to hat channels that will be installed after the precast enclosure system is erected.

After a wall system was determined, it was essential that panel sizes be chosen. On the south side of the building, windows span every 11 feet. Therefore, a span of 11ft in width for each panel was chosen for the south side. It is the same on the north side of the building but instead windows only span 8 ft. Finally, it was decided to span the wall panels the entire length of the wall. This minimizes the amount of joints and subsequently allows for no horizontal joints between systems. This makes it less likely for condensed water to form inside the joints. Figures diagraming this can be seen below.

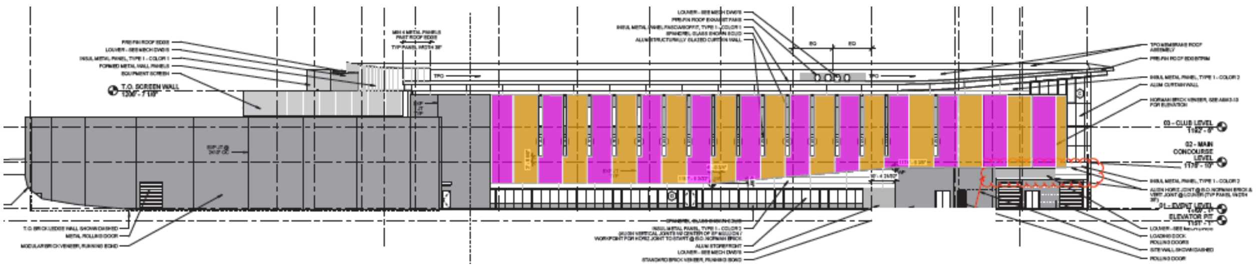


Figure 38: South Facade Panel Layout

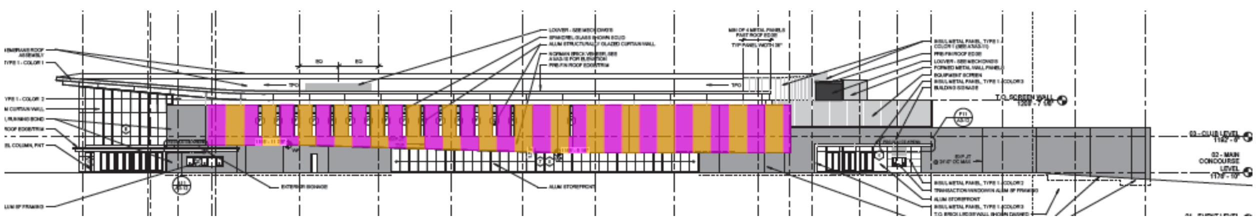


Figure 39: North Facade Panel Layout

It should be noted that the reason the panels are only located at places that are colored is because these locations are where the majority of the metal studded system was utilized to expedite enclosure. Also the largest panel is located on the south side and spans 11 ft x 39 ft. The smallest panel size resides on the north size and spans 8 ft x 18 ft.

The old joint pattern as compared to the new joint pattern can be seen on the following two pages.

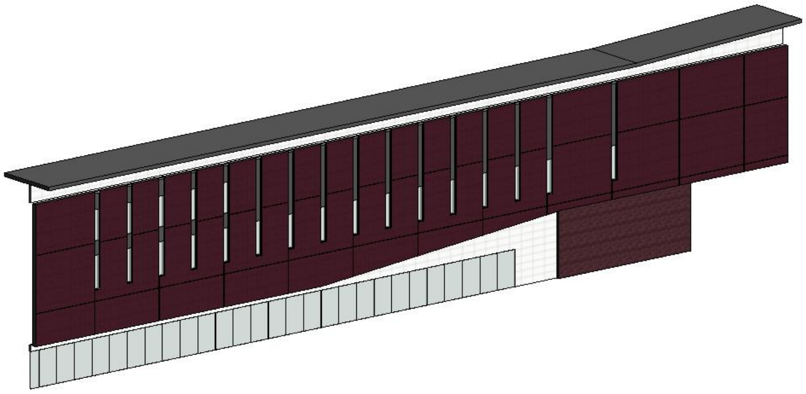


Figure 40: Original South Facade with Expansion Joints and Brick Angles

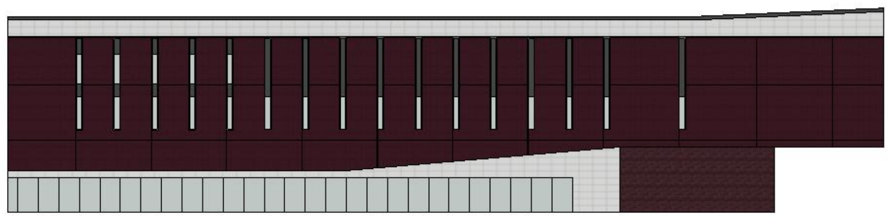


Figure 41: Original South Facade with Expansion Joints and Brick Angles (2)

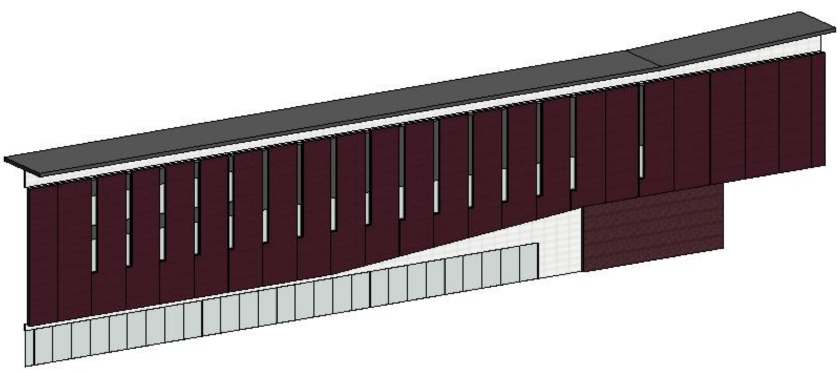


Figure 42: Proposed South Facade with Expansion Joints

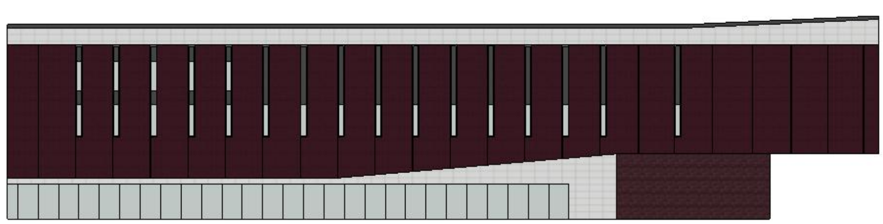


Figure 43: Proposed South Facade and Expansion Joints

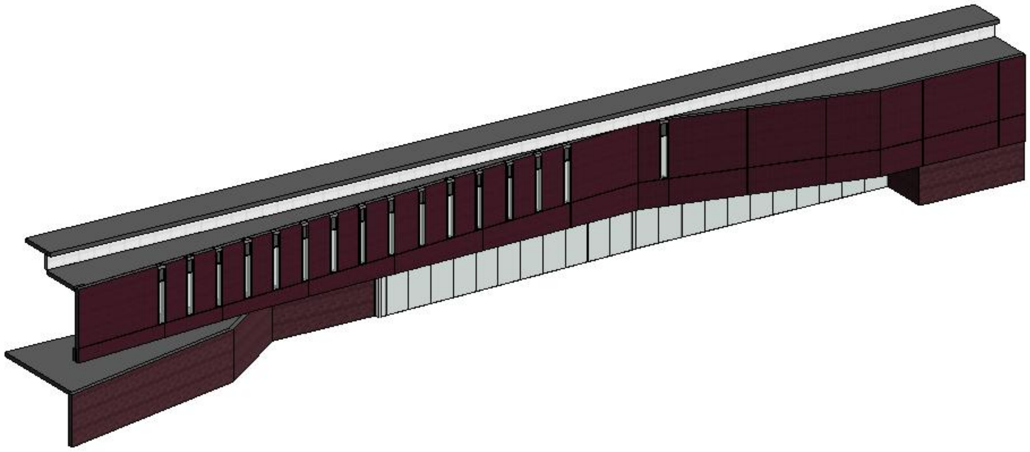


Figure 44: Original North Facade with Expansion Joints and Brick Angles

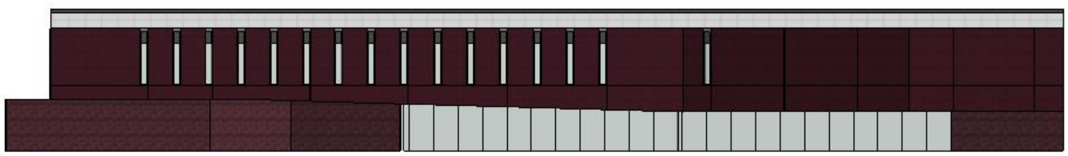


Figure 45: Original North Facade with Expansion Joints and Brick Angles (2)

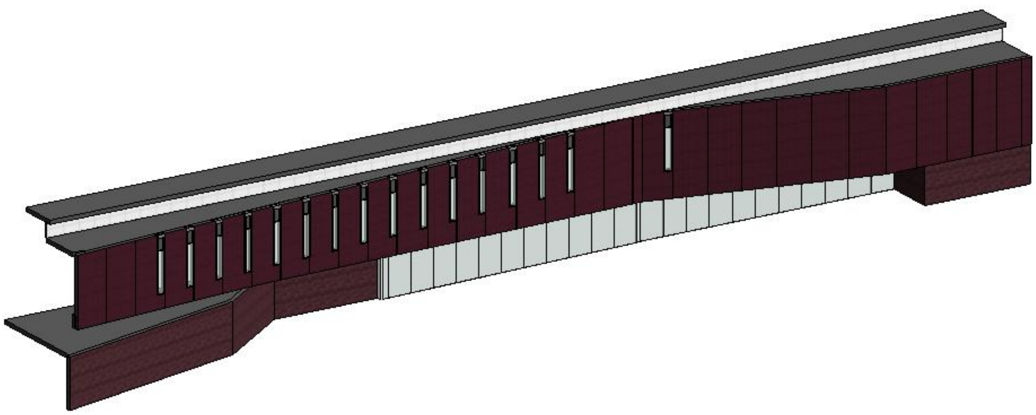


Figure 46: Proposed North Facade and Expansion Joints

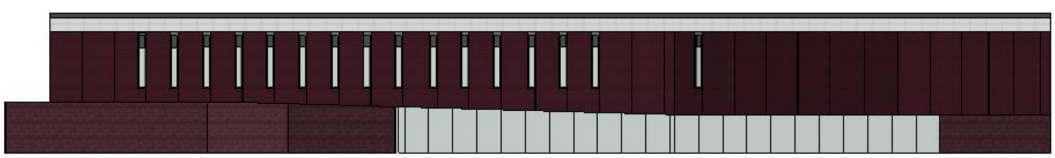


Figure 47: Proposed North Facade and Expansion Joints (2)

Figures 48 through 55 represent the new architectural system details created by the insulated sandwich wall panel system.

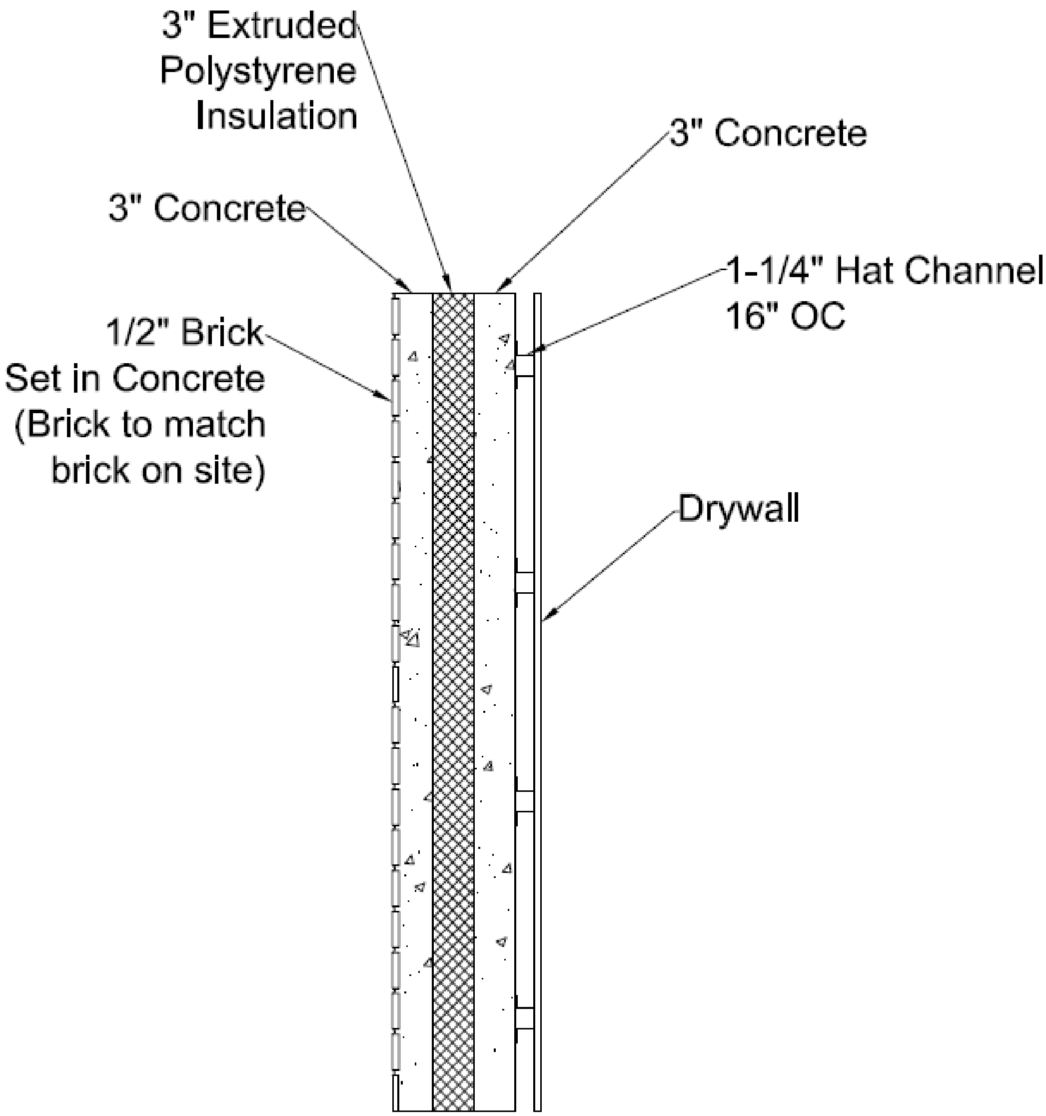


Figure 48: Wall Section

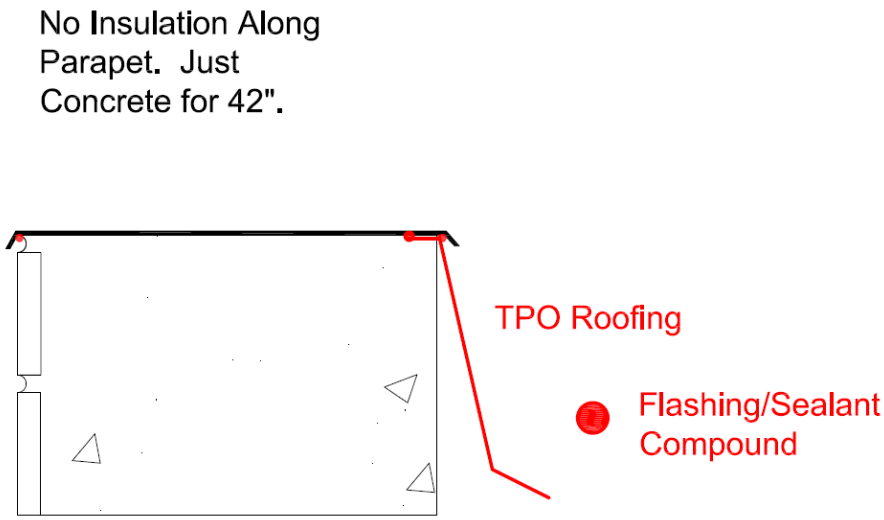


Figure 49: Top of Wall / Roof Detail

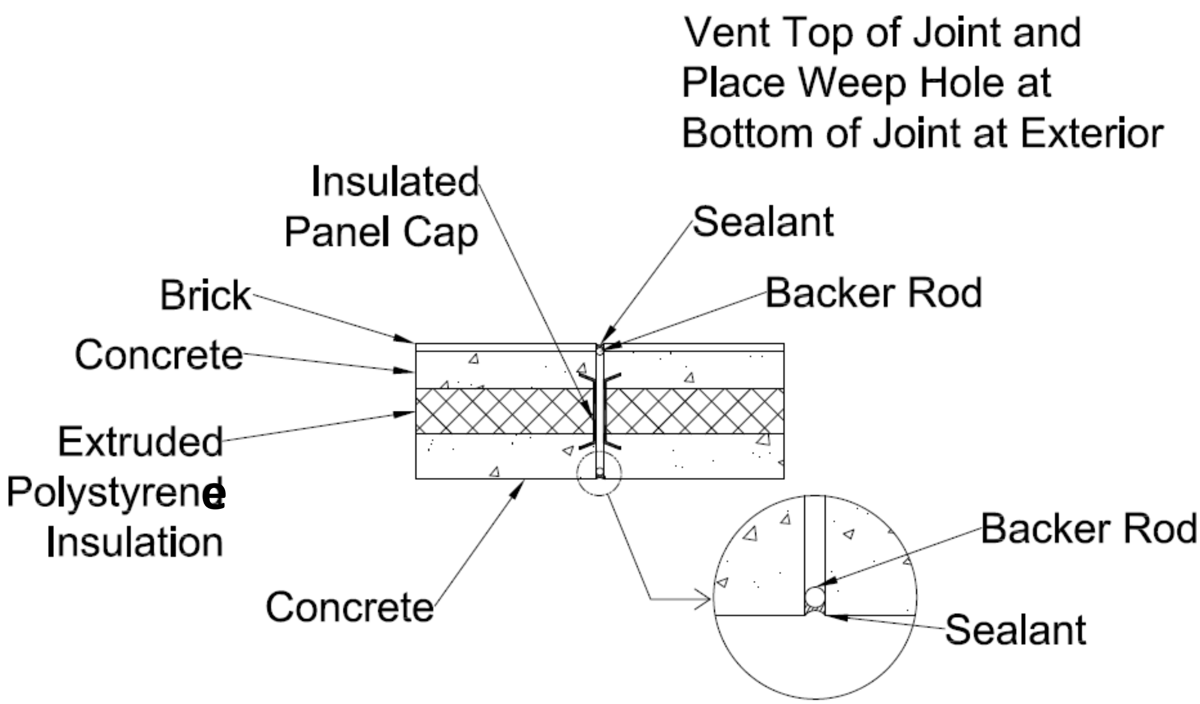


Figure 50: Vertical Joint

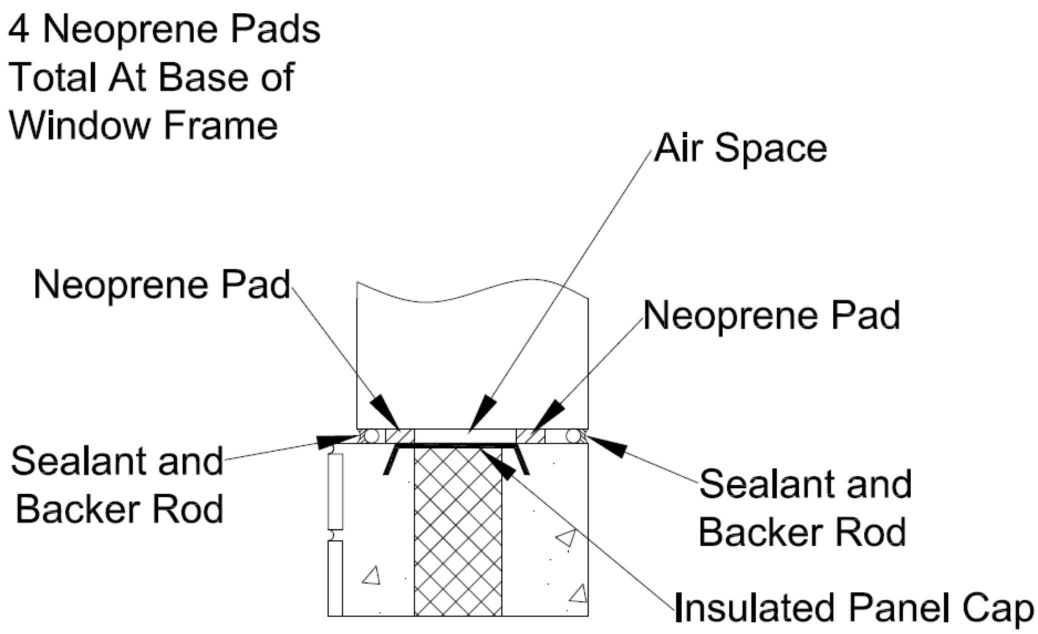


Figure 51: Window Section

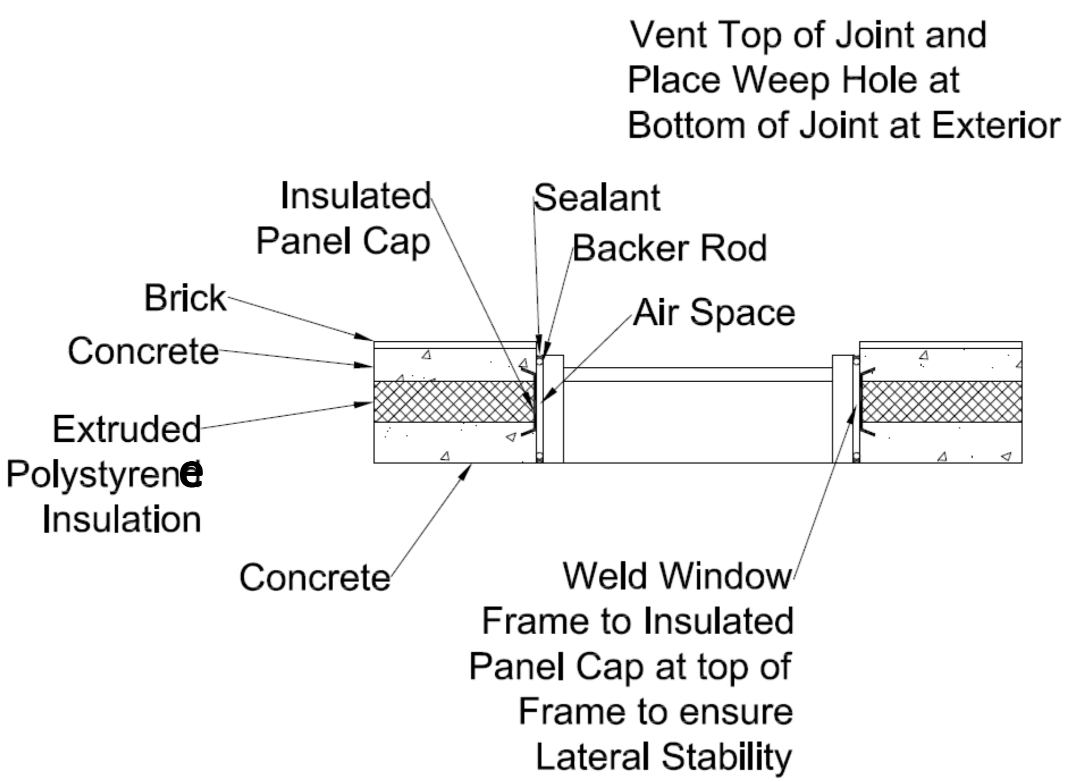


Figure 52: Window Top Down

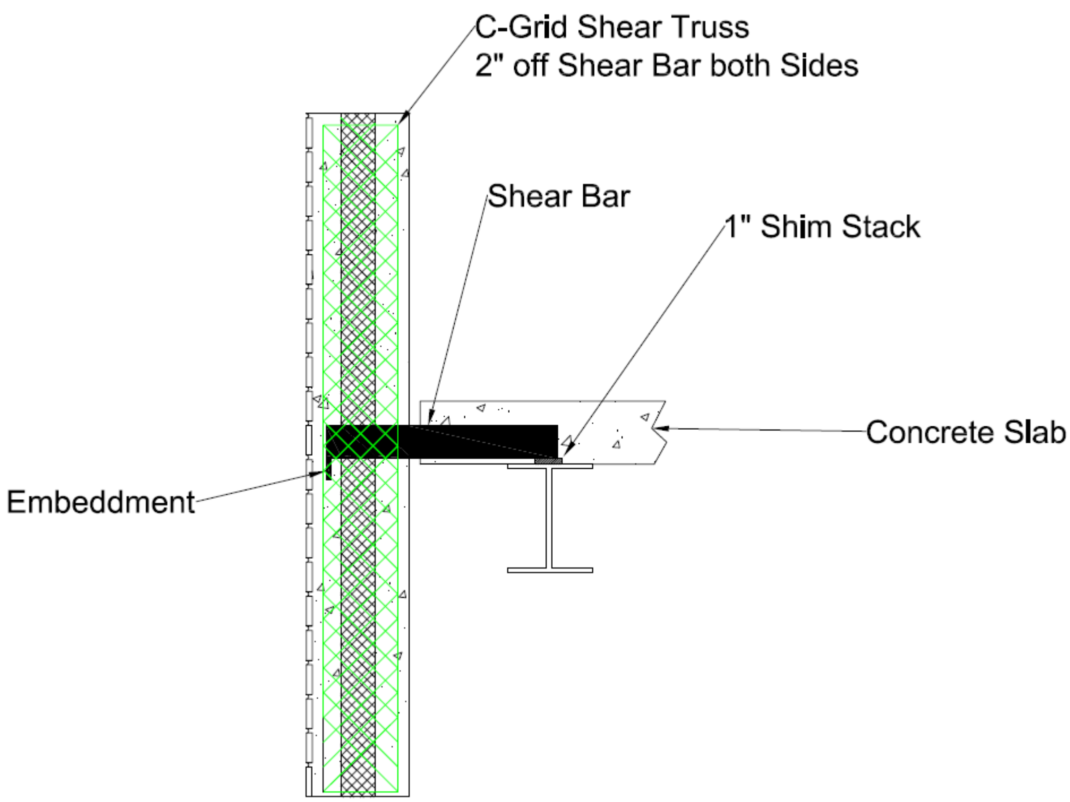


Figure 53: Structural Bearing Section

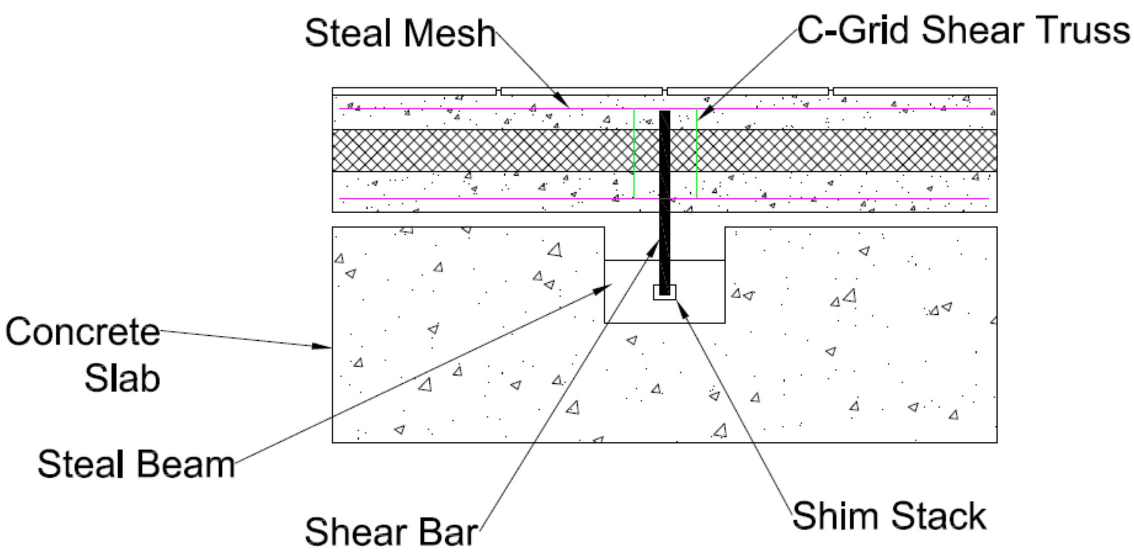


Figure 54: Structural Bearing Top Down

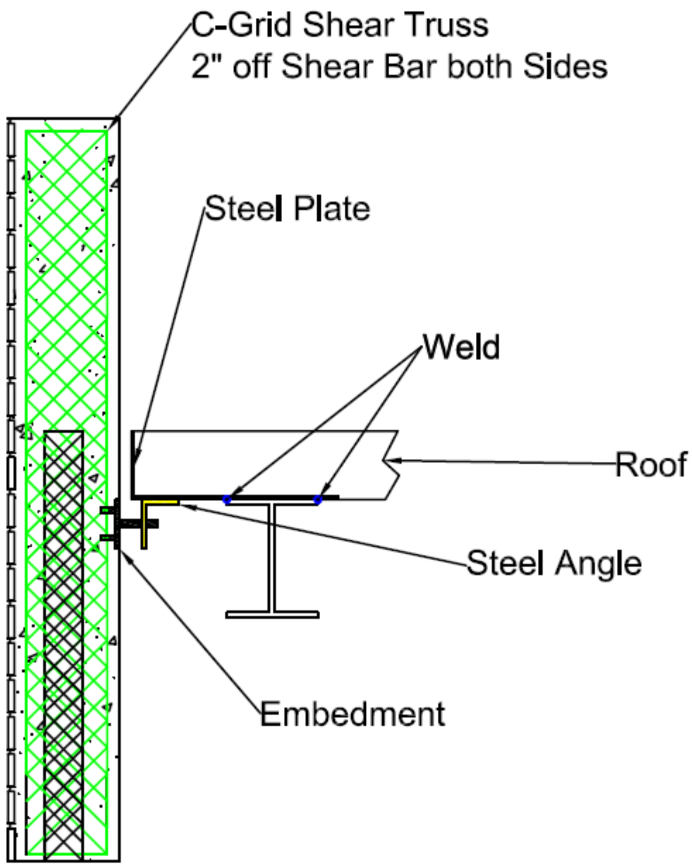


Figure 55: Lateral Bracing

Final Architectural Notes

- Panel bearing will be done in main concourse slab along south and club slab along north.
- Pour backs will be needed at every bearing detail location.
- Lateral bracing will be at club and roof along south and just at roof along north.
- Tom Holmes of High Concrete, LLC stated that water is negligible at joints. However, occasionally vents and weeps are added as security blanket.
- Reinforcement design steel standards to align with High Concrete, LLC product CarbonCast Insulated Architectural Cladding
- Concrete Strength: 5,000 - 7,000 psi
- Water-cement ratio: </= 0.38
- Structural attachments were made in coordination with High Concrete, LLC recommended connections.

Construction Concerns

Weight

Original System

- Panels (Studs, sheathing, Vapor Barrier) = 8 psf
- Insulation = 5 psf
- Brick = 42 psf
- **Total =55 psf**

New System

- 6" Concrete and Thin Brick = 75 psf
- Insulation = 5 psf
- **Total = 80 psf**

Schedule

Original Masonry (For Panel Portion Only)

- 54 Working Days
- Start Date: December 2012
- Finish Date: February 2013

New Masonry (For Panel Portion Only)

- Per RS Means, based on average square foot, 3 panels can be erected per day. There are 57 panels total
- 57/3 = 19 Working Days
- Start Date: August 2012
- Finish Date: September 2012

Masonry activities are expedited; however, overall schedule duration does not change since finishes cannot begin any earlier.

Cost

<u>Original</u>

- Panels (Studs, Sheathing, Vapor Barrier, Insulation) = $495,000
- Scaffold Temporary Heating = $30,000
- Brick = $9.00 sf x 12,973 sf = $116,757
- **Total = $641,757 | $49.47 sf**

<u>New</u>

- 6" Precast Concrete = $44.84 sf x 12,973 sf = $581,709
- Insulation Panel (3") = $1.60 sf x 12,973 sf = $20,757
- Thin Brick façade, modular, red, add = $8.75 sf x 12,973 = $113,514
- Cost increase of crane = $50,000
- Adjustment Factor (admixtures, large panels/shipping, additional structural support to accommodate additional weight from system) = 1.1
- **Total = $842,578 | $64.95 sf**

Note: Numbers for cost were primarily obtained through RS Means. Some outside numbers were acquired but for consistency sake, RS Means was primarily utilized.

Conclusions

The cost of the newly proposed system is a significant cost increase. The total difference in cost is $200,821. This is a fairly significant increase in cost considering this system does not include even half of the total wall enclosure system.

The obvious benefit in the system comes in the form of its quick on-site installation. Since it is able to begin when the metal studded panel system originally went up it allows for all masonry work to be finished well before the end of December. It also would remove the majority of scaffolding from the project which would remove a serious safety concern from the project.

As important as safety is, the newly proposed system does not save any overall schedule duration and is a significant increase in cost. Subsequently, this proposed alternative system would not be recommended.

Analysis 4 | Geotechnical Investigation

Problem Identification

Before construction began, a geotechnical investigation was performed. This report was performed using a combination of boring samples as well as ground penetrating radar. The areas of the site that utilized the bore samples proved fairly true. However, the areas of the site where ground penetrating radar was used came out very misleading. This led the project team to believe one thing which became untrue once construction began. Therefore, it is of interest to research different types of geotechnical analysis and determine which one is the best and most efficient.

Background Research

This was not researched as part of any of the technical reports. However, it was something that the Pegula project team has discussed multiple times and would be of great interest to explore further. Essentially, the eastern portion of the building, along University Drive, was analyzed using boring samples. There was however, an existing lacrosse field located on site before construction that Penn State wanted to maintain for as long as possible. Therefore, they utilized ground penetrating radar over this location as to not destroy the artificial turf.

A geotechnical survey of the Pegula Ice Arena Site can be seen in Appendix T.

Once construction began the areas in which boring was done proved fairly accurate, whereas, the areas which utilized ground penetrating radar proved extremely misleading. Ultimately, the micropiles needed to be deeper than expected and where strip footers rested, massive amounts of lean fill was required. At face value, it appears as if ground penetrating radar is entirely a waste of money and that companies should always bore. However, it is my intention to research the different types of geotechnical analysis equipment and determine which of them is best.

Preliminary Research and Proposed Solution

This will function as the industry related issue to be analyzed. Similar to what is mentioned above. The analysis will compare boring and ground penetrating radar. The advantages and disadvantages will be determined of both systems and finalized with a summary of the two systems and a recommendation for the superior system.

Methodology

- Obtain the geotechnical report from Mortenson Construction.
- Obtain any additional information that supports the ground conditions.

- Perform an accuracy analysis of the geotechnical systems.
- Perform a cost analysis of the different systems.
- Determine which method is the best.

❖ Note: Proposed comparison of original concrete vs. additional concrete required for the Pegula Ice Arena project was not performed due to its limited benefit in proving the benefits of either system from an industry wide perspective.

Boring

Professional Service Industries, Inc. states that, "Geotechnical drilling, engineering, and laboratory testing is a vital predecessor to the design and construction of a project." This sentiment is believed by many others including owners, engineers, and contractors.

Boring is the most accurate, and consistent way to analyze subsurface conditions prior to the start of construction. It has the precision in determining what medium it drills through very precisely. It can help determine where the expected water table is on a project. This can often be a bigger issue than the soil type. For example, most large cities are built around some body of water. This can be a river, lake, or ocean but usually this surrounding water can make the subsurface extremely wet and the water table unusually high. By boring, engineers are usually able to find very accurate water tables on site. This helps construction managers determine potential spots for dewatering and the potential associated costs that could be a result of removing the water from a project site.

However, in most places the soil type is usually the larger concern. The soil type helps determine what challenges the contractor and structural engineer are going to face. In an ideal world the contractor would be able to excavate down to the required elevation of structural foundations and then hit a solid bed of rock. *This rarely happens.* Depending on location a varying degree of soil types can be encountered. For example, at the Pegula Ice Arena, primarily two soil types were discovered; They were silty clay, and rock. Strangely enough, what was so interesting was the configuration of these soils. A portion of the site had rock on top of clay. This made it necessary for Mortenson Construction to blast the rock and then provide additional structural bearing techniques (lean fill) for the foundations. The use of borings made it possible to understand and plan for future construction activities. Having an understanding of the soil type also allowed the structural engineer to adequately design the foundation and their sizes. This unfortunately became a problem where ground penetrating radar was utilized (GPR) which will be discussed in the next section.

There are issues with geotechnical investigations. These issues are and stem from cost related problems. A geotechnical report that utilizes boring with samples is extremely expensive. Utilizing the geotechnical report and RS Means, an estimate was done for the cost of the geotechnical report for the Pegula Ice Arena, not including the section where GPR was used (Reference Appendix T boring locations). This estimate can be seen in Table 12.

Table 12: Boring Estimate

Geotechnical Estimate (Boring)								
System	Amount	Unit	Material	Labor	Equipment	Total	Total Incl O and P	Cost
Borings, initial field stake out & determination of elevations	1	Day		705	78.5	783.5	1150	$1,150
Drawings showing boring details	1	Day		310		310	390	$390
Report and recommendations from P.E.	1	Day		720		720	900	$900
Mobilization and demobilization	1	Day		209	246	455	590	$590
Borings in earth, with samples, 2-1/2" diameter	567	L.F.	22	15.05	17.7	54.75	66.5	$37,706

Total: $ 40,736

Spending over $40,000 for a report that accepts no level of responsibility for inaccurate findings is a large amount of money. It can be noticed that the bulk amount of the cost came directly from the on-site drilling that needs done. This cost was nearly $38,000 for 33 holes averaging 17.2 feet deep. Not all projects will utilize this many bores but in order to ensure accuracy, the more samples the better. Also, it is not at all uncommon to drill 17 feet or more per hole, which approximates to $1,140 per hole.

Final Thoughts

Advantages

- Accurate, Proven, Consistent
- Reliable in identifying soil type.
- Reliable in identifying ground water.

Disadvantages

- Expensive
- Identifies material and water only through destruction *(turf example)*

Ground Penetrating Radar

Ground penetrating radar has gained vast popularity due to the inexpensiveness of the system. Take for example, the geotechnical investigation using borings for the Pegula Ice Arena cost over $40,000. GPR services are considerably cheaper. The cost of equipment alone for GPR is less than $40,000. In discussions with Maggie Beird, geophysicist of THG Geophysics, she explained a site the size of Pegula would cost approximately $1,000 to $2,000. There are also no running costs of GPR, compared to boring which requires oil and new drill bits constantly. The lack of oil makes it particularly more environmentally friendly than boring. The system not only does not disrupt the earth but there is also no chance of harmful liquids entering into the ground.

Photo 2: GPR | Courtesy of Mala

Another large benefit to ground penetrating radar is how noninvasive it is. Take the Pegula Ice Arena as an example. Penn State did not want to remove the lacrosse field on site until they had to, which is why they utilized GPR. They were able to walk directly over the turf and not damage anything. This can also be applied to other construction related work. GPR can detect reinforcement in concrete or can detect underground utilities. This can really help owners ensure they know what is in concrete or underground instead of utilizing old, potentially unreliable, as-built drawings. Also, according to Maggie Beird, if leaks occur in underground utility lines, GPR can accurately locate said leaks.

It should be noticed that everything the GPR does well is basically the exact opposite of what boring does poorly. This same principle can basically be applied to what the GPR does not do well. Ground Penetrating Radar is not as accurate as boring at detecting subsurface material. Specifically, GPR is especially poor in soils that include clay. The signal sent through the ground does not properly reflect upwards from the clay which gives an inaccurate reading. Results are more accurate with sands, rocks, and glacial soils.

Maggie Beird emphasized these points and went on to explain depths. She said that in clay type soils accurate readings of only 5 feet can be guaranteed. Whereas sands can accurately record results up to 8 to 10 feet. The water table is also something hard for the GPR to detect. It can detect pools of water but cannot detect where wet soil exists.

Information above was provided by Maggie Beird of THG Geophysics and from information provided from the Trenchless Technology website.

Final Thoughts

Advantages

- Fast and instant
- Inexpensive
- Environmentally friendly
- Noninvasive
- Can detect utility lines
- Can be used inside (reinforcement in slabs)

Disadvantages

- Not efficient and accurate
- Does not penetrate well through clay
- Cannot reach great depths
- Cannot detect a water table

Conclusion

Ground penetrating radar is a very valuable tool. It has the ability to locate utility lines and is very effective in determining conditions for highway construction. Depending on the area and subsurface conditions GPR can be valuable. However, due to some of the inaccuracies it records it should not be the sole source of geotechnical equipment utilized.

Boring is still the more powerful tool in determining subsurface conditions. However, since it is so expensive it could potentially be beneficial to combine the two operations. If the ground condition is known not to be clay, boring holes could be spaced out more and followed with GPR. This would ensure the accuracy with boring but would help maintain low costs. If discrepancies were found additional boring holes could be drilled to ensure accurate results. Also, combining these two systems allows for the water table to be discovered.

It should not be utilized the way it was at Pegula. A separate portion of the building was analyzed at this location even though this area is known for its large concentration of clay like material.

Conclusion and Recommendations

This senior thesis final report proved extremely valuable. It gave insight into a number of construction related issues that a project team may go through during the construction of a building.

Analysis 1 | Community Rink Sequence off Critical Path

As beneficial to the construction management team sequencing the community rink off the critical path would be due to the cost increase and architectural defects created it would not be beneficial to the owner or architect. The bulk of the proposed cost increases and architectural defects came from the structural design that was done as part of this analysis.

Analysis 2 | Building Sequence

There is a beneficial way to increase the schedule at little to no cost. This could have been done by changing the starting location. If the project start point moved further back from the foundation wall the underground MEP could have begun sooner than it did ultimately resulting in two weeks of schedule reduction.

Analysis 3 | Building Enclosure

A newly proposed façade design was also done as part of a construction depth and architectural breadth. Changing this façade system would cause a significant additional cost to the project. Although, it would positively impact safety the disadvantages seem to far outweigh the advantages.

Analysis 4 | Geotechnical Investigation

Finally, a geotechnical analysis of boring and ground penetrating radar was done to determine the advantages and disadvantages of each. As expected, boring proved much more accurate but much more expensive. Interestingly enough, GPR proved less beneficial in certain areas, one of which included locations with clay type soils which State College features much of.

These four analyses gave great insight into scheduling, enclosure systems, and geotechnical research. These lessons learned will be transferred and utilized throughout my professional career.

Resources & References

Microsoft Excel

Microsoft Powerpoint

Microsoft Project

Microsoft Word

Bluebeam Revu CAD

Adobe Dreamweaver

Revit Architecture

Staad Space Frame

"Geotechnical Engineering." , *Contamination of Soil or Groundwater, Drilling Services*. N.p., n.d. Web. 22 Mar. 2013. <http://www.psiusa.com/services/geo.aspx>.

"Ground Penetrating Radar:." *Ground Penetrating Radar:*. N.p., n.d. Web. 22 Mar. 2013. <http://www.trenchlessonline.com/index/webapp-stories-action?id=1268>.

"MALÃ… Ground-Penetrating Radar Global Vendor Network." *Ground Penetrating Radar (GPR/georadar) Equipment Manufacturer, Sales, Training and Service*. N.p., n.d. Web. 22 Mar. 2013. <http://www.malags.com/home>.

"Precast Concrete from High Concrete Group." *Architectural Precast Concrete*. N.p., n.d. Web. 22 Mar. 2013. <http://www.highconcrete.com/>.

"Slender Wall Architectural Cladding Wall System." *SlenderWall Precast Concrete Panels Homepage*. N.p., n.d. Web. 22 Mar. 2013. <http://www.slenderwall.com/>.

Waier, Phillip R. *RSMeans Building Construction Cost Data 2013*. Kingston, MA: R.S. Means, 2013. Print.

Angstadt, Jeffrey (VP of Operations) | Foreman Program and Construction Managers

Holmes, Tom (VP of Sales) | High Concrete Group LLC

Beird, Maggie (Geophysicist) | THG Geophysics

Brown, Heidi (Project Manager) | Mortenson Construction

Brown, Jason (Senior Superintendent) | Mortenson Construction

Laurila, Steve (Senior Project Manager) | Mortenson Construction

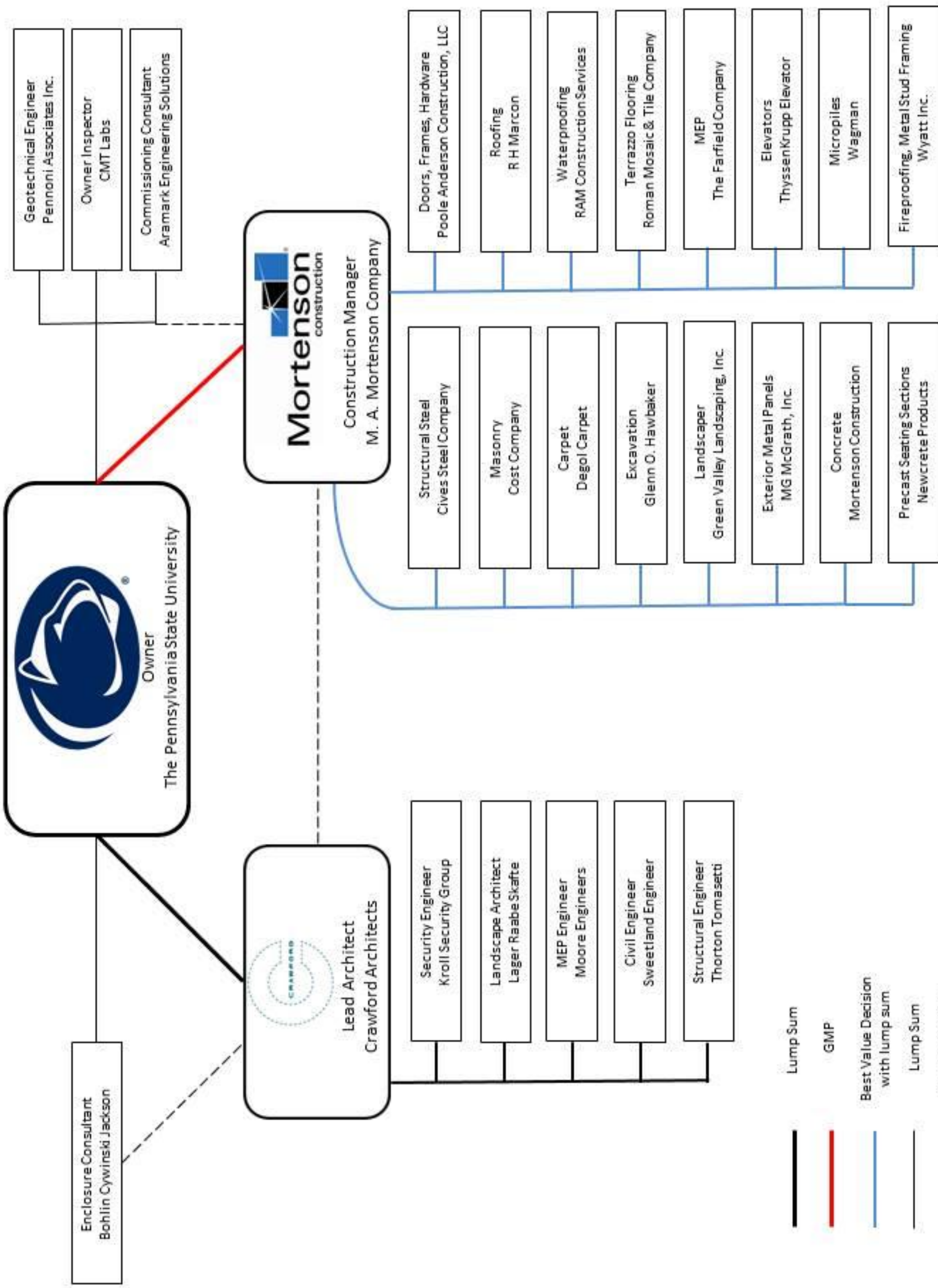
Holland, Robert (Architectural Advisor) | Pennsylvania State University

Parfitt, Kevin (Structural Advisor) | Pennsylvania State University

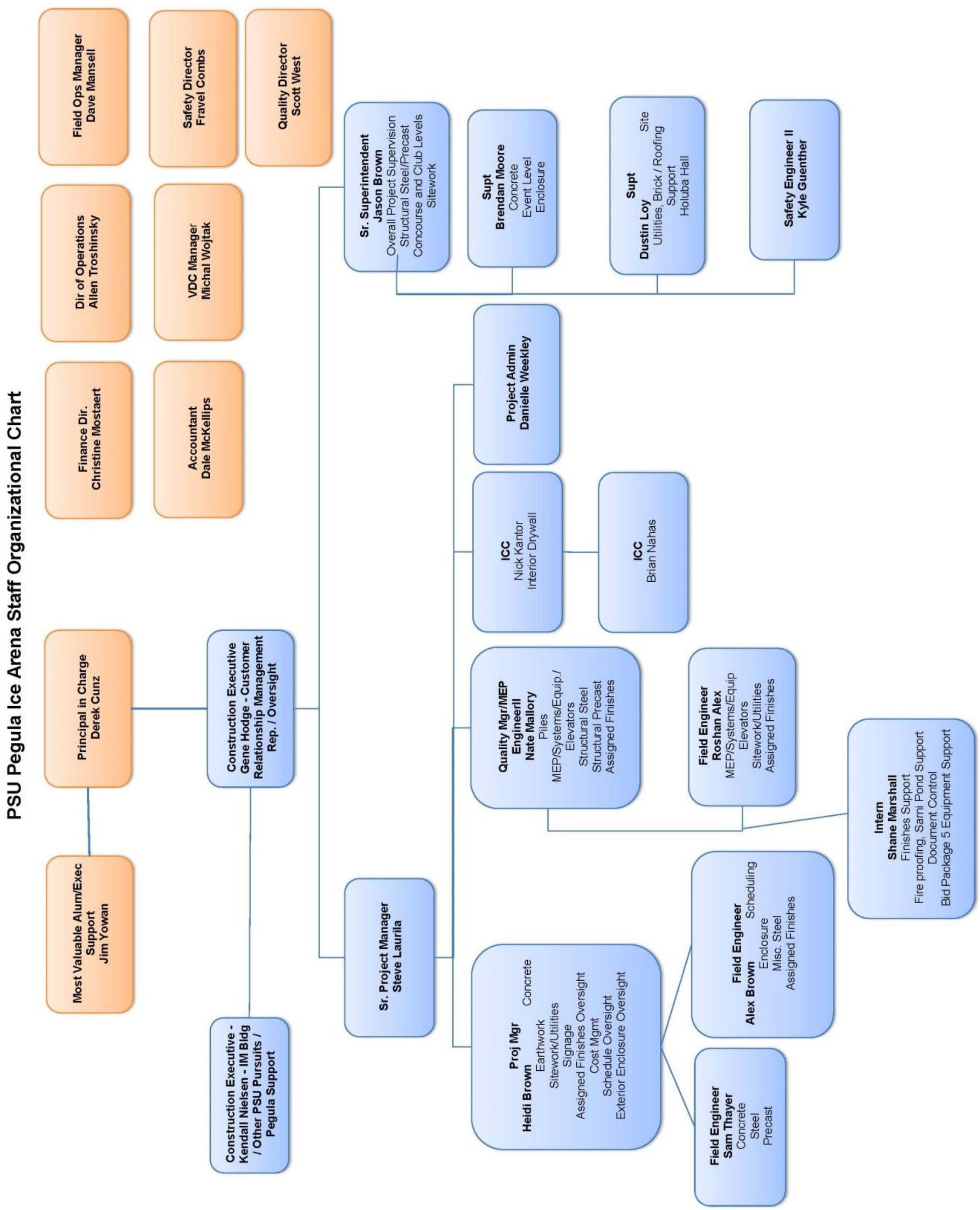
Sowers, Raymond (Thesis Advisor) | Pennsylvania State University

Appendix U has RS MEANS pages that were utilized.

Appendix A: Project Organizational Chart

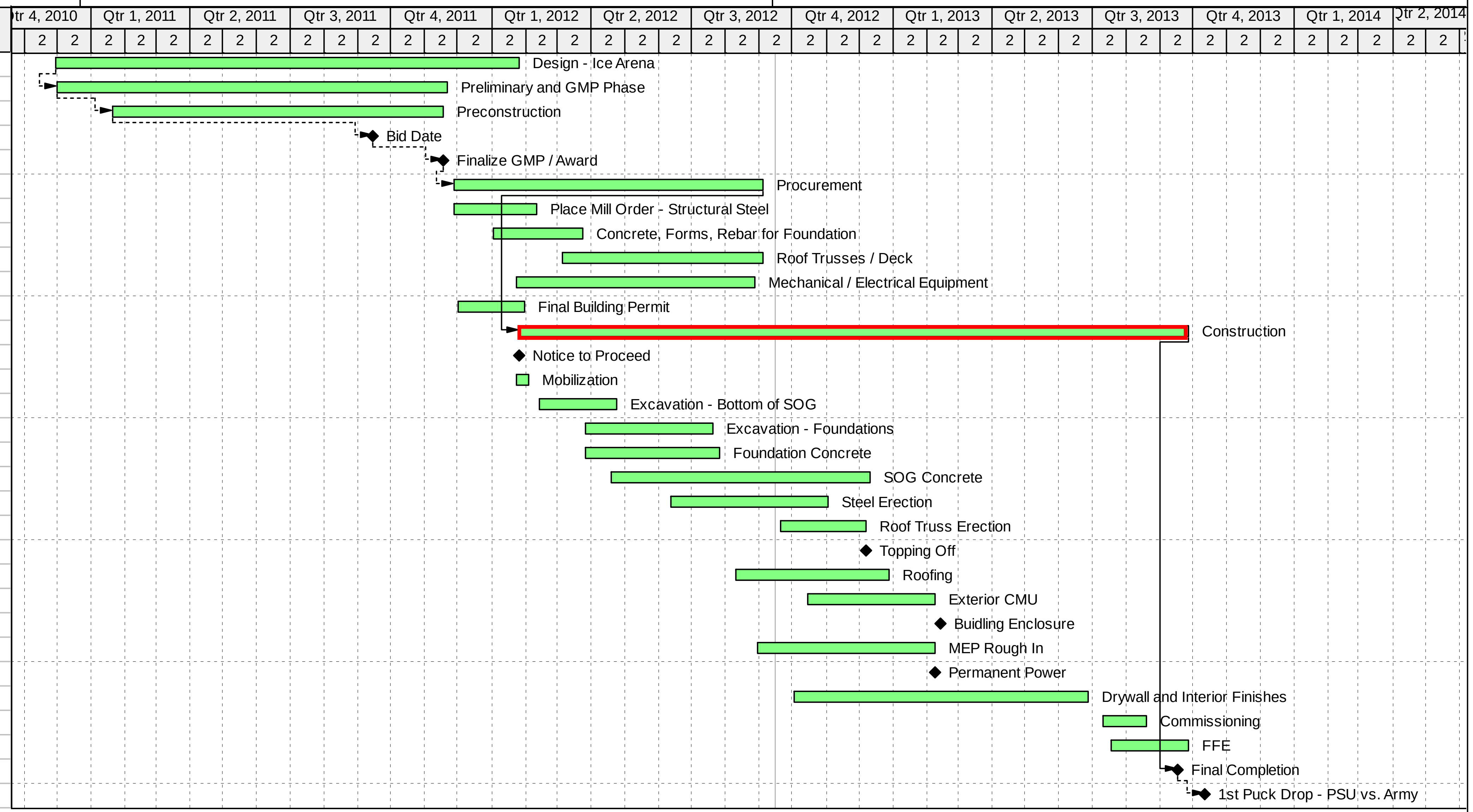

Owner
The Pennsylvania State University
Construction Manager
M. A. Mortenson Company
Lead Architect
Crawford Architects
Geotechnical Engineer
Pennoni Associates Inc.
Owner Inspector
CMT Labs
Commissioning Consultant
Aramark Engineering Solutions
Enclosure Consultant
Bohlin Cywinski Jackson
Doors, Frames, Hardware
Poole Anderson Construction, LLC
Roofing
R H Marcon
Waterproofing
RAM Construction Services
Terrazzo Flooring
Roman Mosaic & Tile Company
MEP
The Farfield Company
Elevators
ThyssenKrupp Elevator
Micropiles
Wagman
Fireproofing, Metal Stud Framing
Wyatt Inc.
Structural Steel
Cives Steel Company
Masonry
Cost Company
Carpet
Degol Carpet
Excavation
Glenn O. Hawbaker
Landscaper
Green Valley Landscaping, Inc.
Exterior Metal Panels
MG McGrath, Inc.
Concrete
Mortenson Construction
Precast Seating Sections
Newcrete Products
Security Engineer
Kroll Security Group
Landscape Architect
Lager Raabe Skafte
MEP Engineer
Moore Engineers
Civil Engineer
Sweetland Engineer
Structural Engineer
Thorton Tomasetti
Lump Sum
GMP
Best Value Decision with lump sum
Lump Sum
Communication Line

Appendix B: Staff Organizational Chart


PSU Pegula Ice Arena Staff Organizational Chart
Most Valuable Alum/Exec Support
Jim Yowan
Principal in Charge
Derek Cunz
Finance Dir.
Christine Mostaert
Dir of Operations
Allen Troshinsky
Field Ops Manager
Dave Mansell
Accountant
Dale McKellips
VDC Manager
Michal Wojtak
Safety Director
Fravel Combs
Quality Director
Scott West
Construction Executive - Kendall Nielsen - IM Bldg / Other PSU Pursuits / Pegula Support
Construction Executive
Gene Hodge - Customer Relationship Management Rep. / Oversight
Sr. Project Manager
Steve Laurila
Sr. Superintendent
Jason Brown
Overall Project Supervision
Structural Steel/Precast
Concourse and Club Levels
Sitework
Supt
Brendan Moore
Concrete
Event Level
Enclosure
Supt
Dustin Loy
Site
Utilities, Brick / Roofing
Support
Holuba Hall
Safety Engineer II
Kyle Guenther
Project Admin
Danielle Weekley
ICC
Nick Kantor
Interior Drywall
ICC
Brian Nahas
Quality Mgr/MEP Engineerll
Nate Mallory
Piles
MEP/Systems/Equip./
Elevators
Structural Steel
Structural Precast
Assigned Finishes
Field Engineer
Roshan Alex
MEP/Systems/Equip
Elevators
Sitework/Utilities
Assigned Finishes
Intern
Shane Marshall
Finishes Support
Fire proofing, Sarni Pond Support
Document Control
Bid Package 5 Equipment Support
Proj Mgr
Heidi Brown
Concrete
Earthwork
Sitework/Utilities
Signage
Assigned Finishes Oversight
Cost Mgmt
Schedule Oversight
Exterior Enclosure Oversight
Field Engineer
Alex Brown
Scheduling
Enclosure
Misc. Steel
Assigned Finishes
Field Engineer
Sam Thayer
Concrete
Steel
Precast

Appendix C: Project Schedule Summary

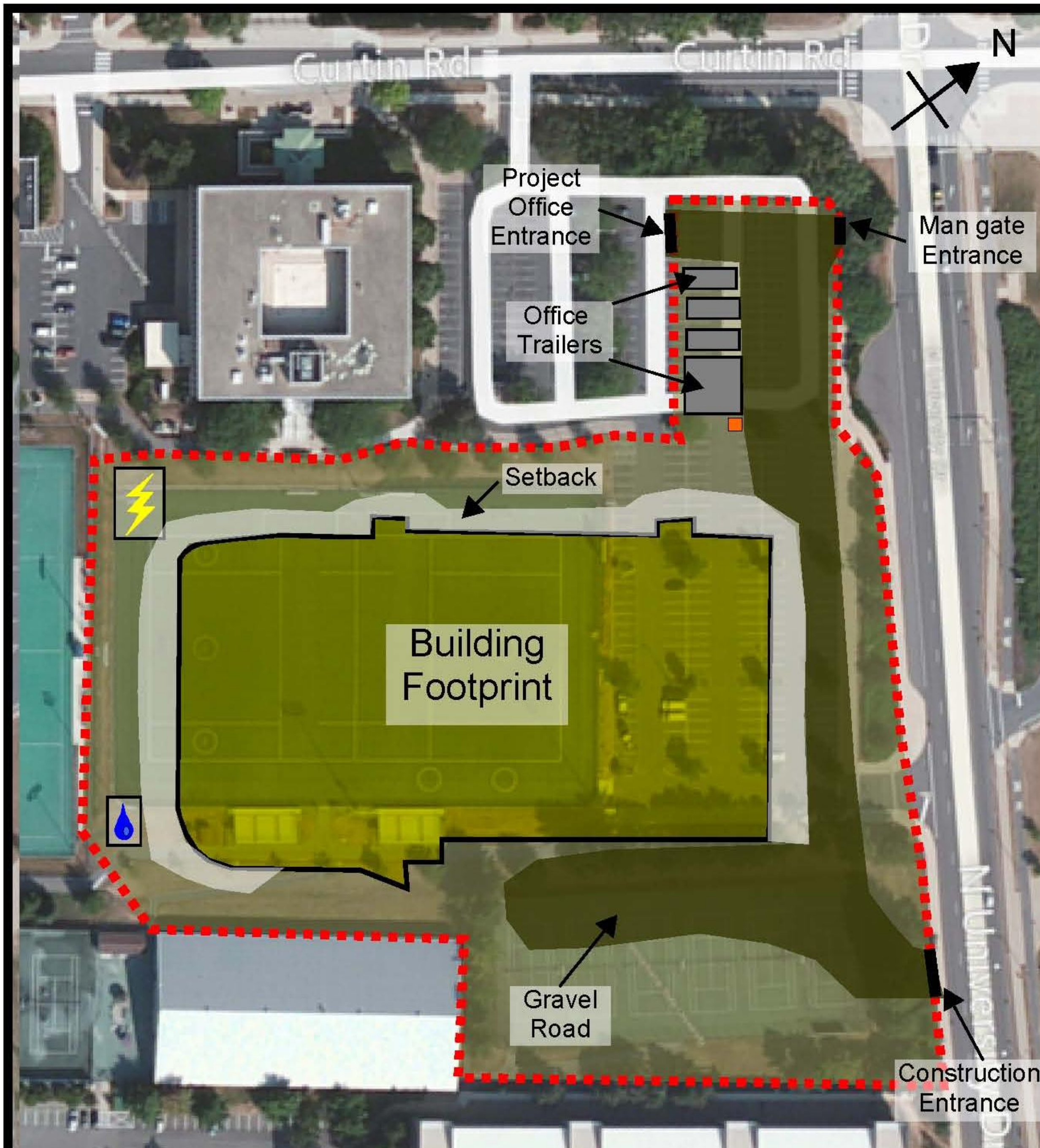
Activity ID	Activity Name	Original Duration	Start	Finish
A1000	Design - Ice Arena	295	30-Nov-10	26-Jan-12
A1010	Preliminary and GMP Phase	249	01-Dec-10	21-Nov-11
A1020	Preconstruction	214	20-Jan-11	18-Nov-11
A1030	Bid Date	0	15-Sep-11	
A1040	Finalize GMP / Award	0		18-Nov-11
A1050	Procurement	197	28-Nov-11	04-Sep-12
A1060	Place Mill Order - Structural Steel	53	28-Nov-11	10-Feb-12
A1070	Concrete, Forms, Rebar for Foundation	59	03-Jan-12	23-Mar-12
A1080	Roof Trusses / Deck	129	05-Mar-12	04-Sep-12
A1090	Mechanical / Electrical Equipment	155	23-Jan-12	28-Aug-12
A1100	Final Building Permit	41	01-Dec-11	30-Jan-12
A1110	Construction	427	26-Jan-12	26-Sep-13
A1120	Notice to Proceed	0	26-Jan-12	
A1130	Mobilization	10	23-Jan-12	03-Feb-12
A1140	Excavation - Bottom of SOG	51	13-Feb-12	23-Apr-12
A1150	Excavation - Foundations	82	27-Mar-12	20-Jul-12
A1160	Foundation Concrete	86	27-Mar-12	26-Jul-12
A1170	SOG Concrete	164	19-Apr-12	10-Dec-12
A1180	Steel Erection	102	12-Jun-12	02-Nov-12
A1190	Roof Truss Erection	56	20-Sep-12	07-Dec-12
A1200	Topping Off	0		07-Dec-12
A1210	Roofing	98	10-Aug-12	28-Dec-12
A1210.1	Exterior CMU	82	15-Oct-12	08-Feb-13
A1220	Buidling Enclosure	0		13-Feb-13
A1230	MEP Rough In	112	30-Aug-12	07-Feb-13
A1240	Permanent Power	0		07-Feb-13
A1250	Drywall and Interior Finishes	189	02-Oct-12	27-Jun-13
A1260	Commissioning	28	11-Jul-13	19-Aug-13
A1270	FFE	50	18-Jul-13	26-Sep-13
A1280	Final Completion	0		17-Sep-13
A1290	1st Puck Drop - PSU vs. Army	0	11-Oct-13	



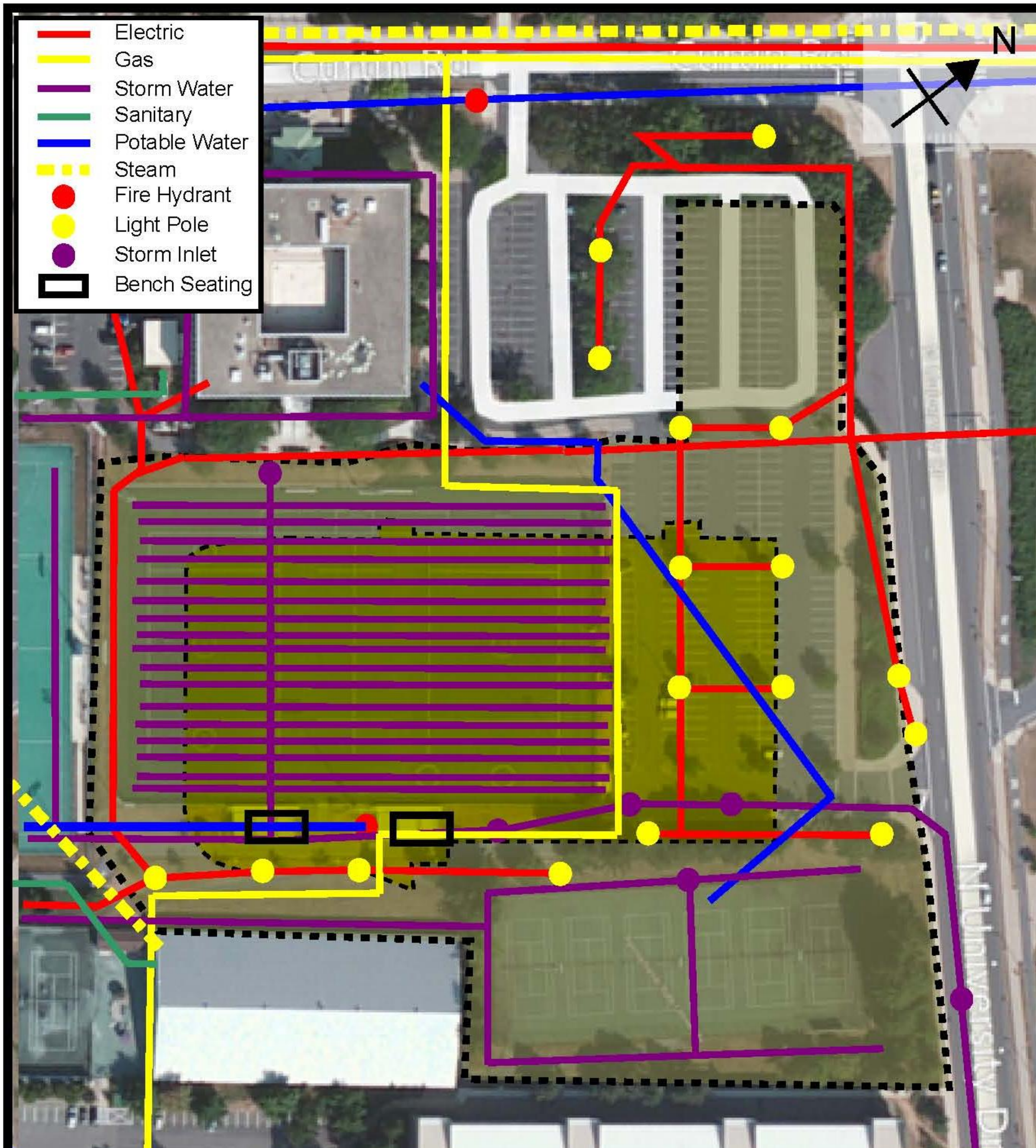
Construction Summary
Work

TASK filter: All Activities

Appendix D: Existing Conditions



Shane Marshall	The Pegula Ice Arena University Park, PA	
Construction Management	Technical Report1	*Site Layout Plan* *Start: NA* *End: NA*



Shane Marshall

Construction Management

The Pegula Ice Arena

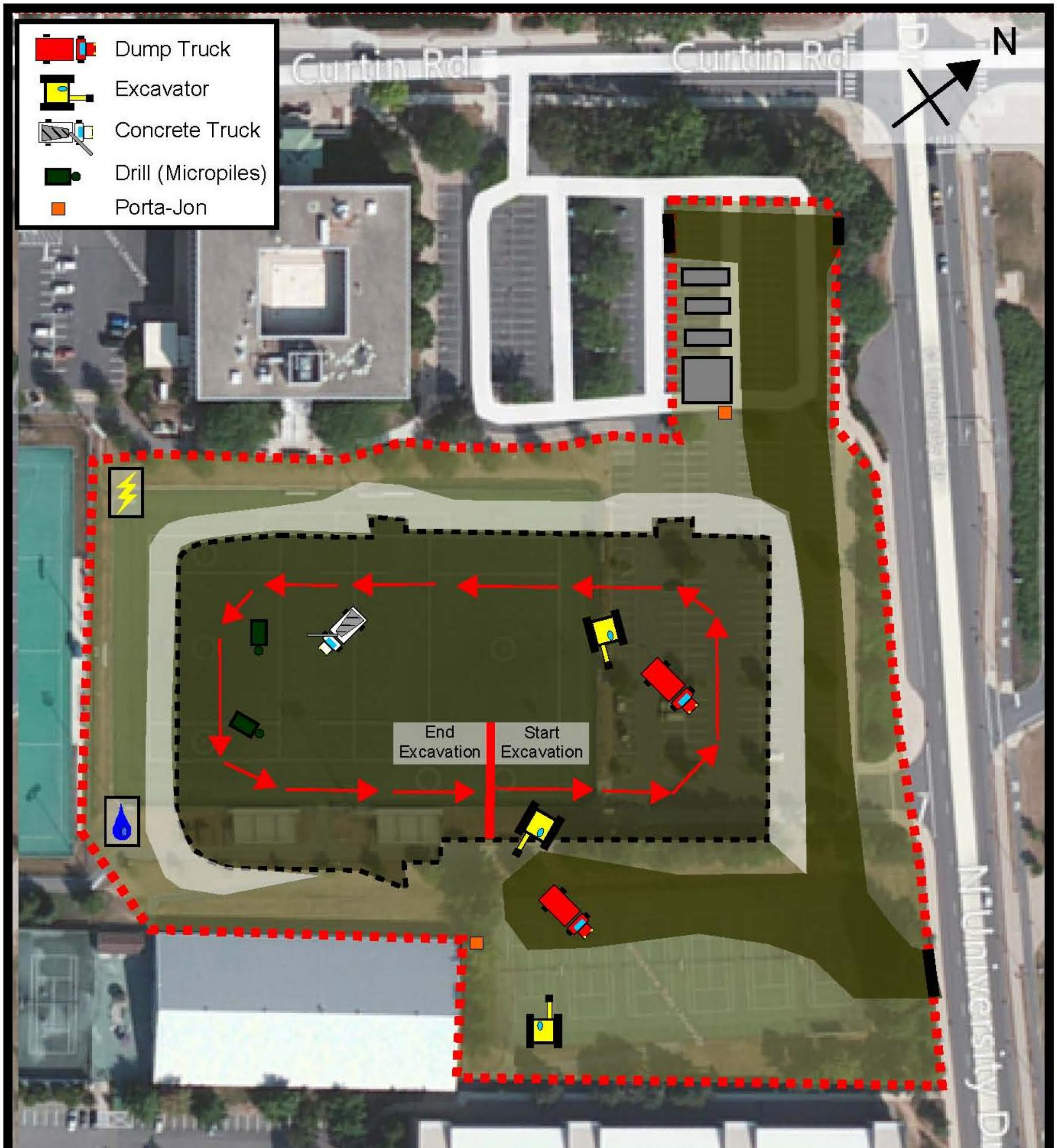
University Park, PA

Technical Report1

Existing Utilities

Start: NA *End: NA*

Appendix E: Site Layout



Shane Marshall

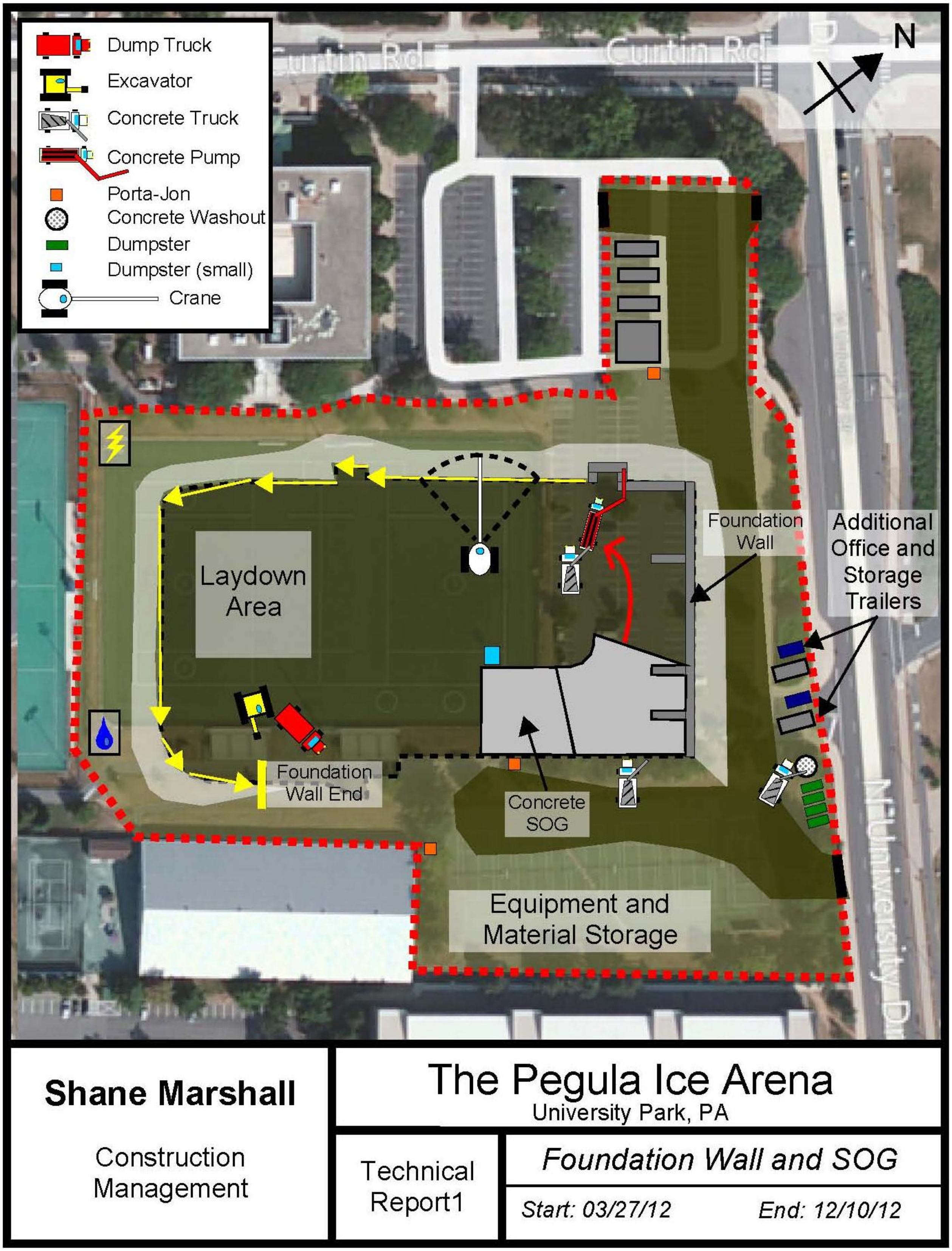
Construction Management

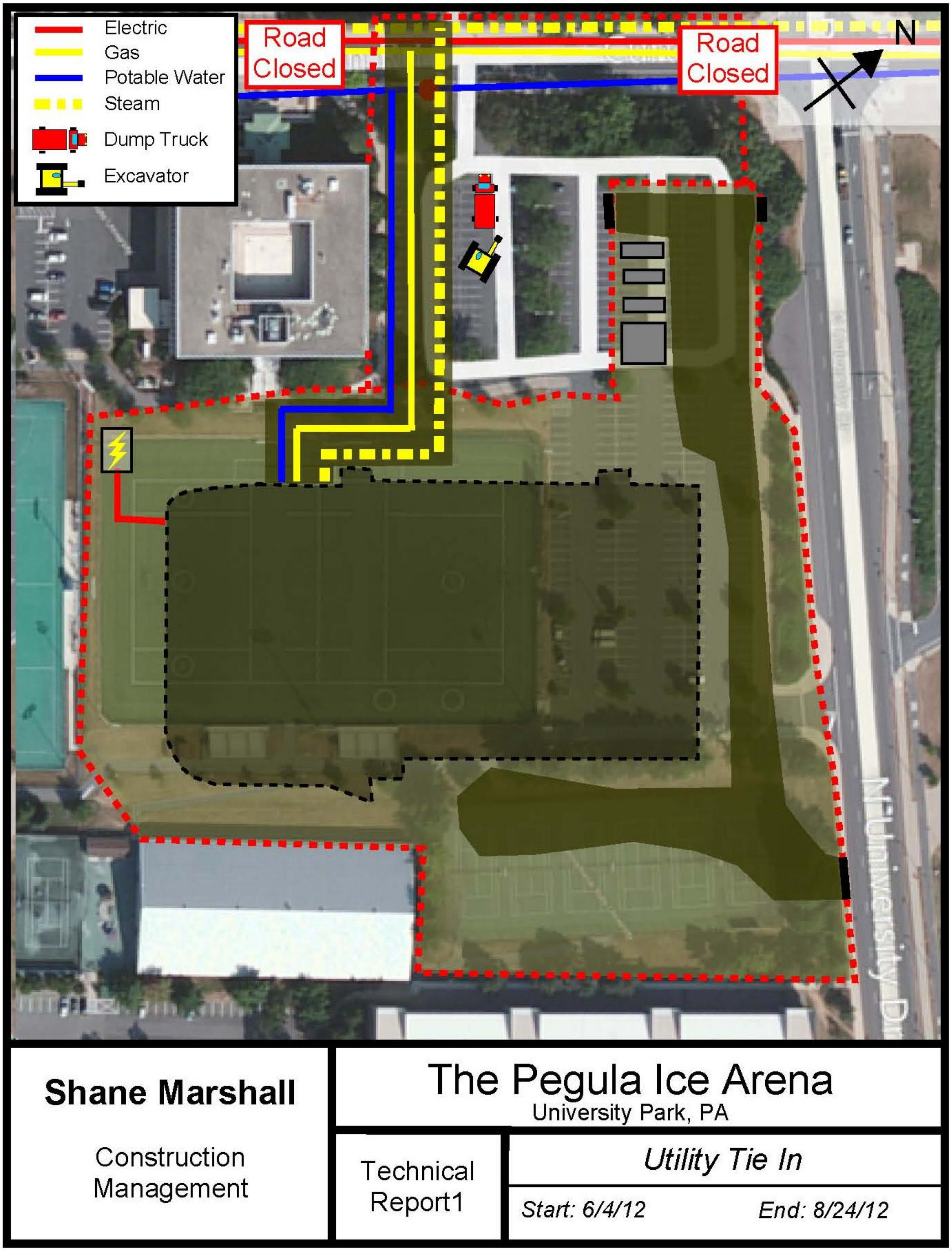
The Pegula Ice Arena
University Park, PA

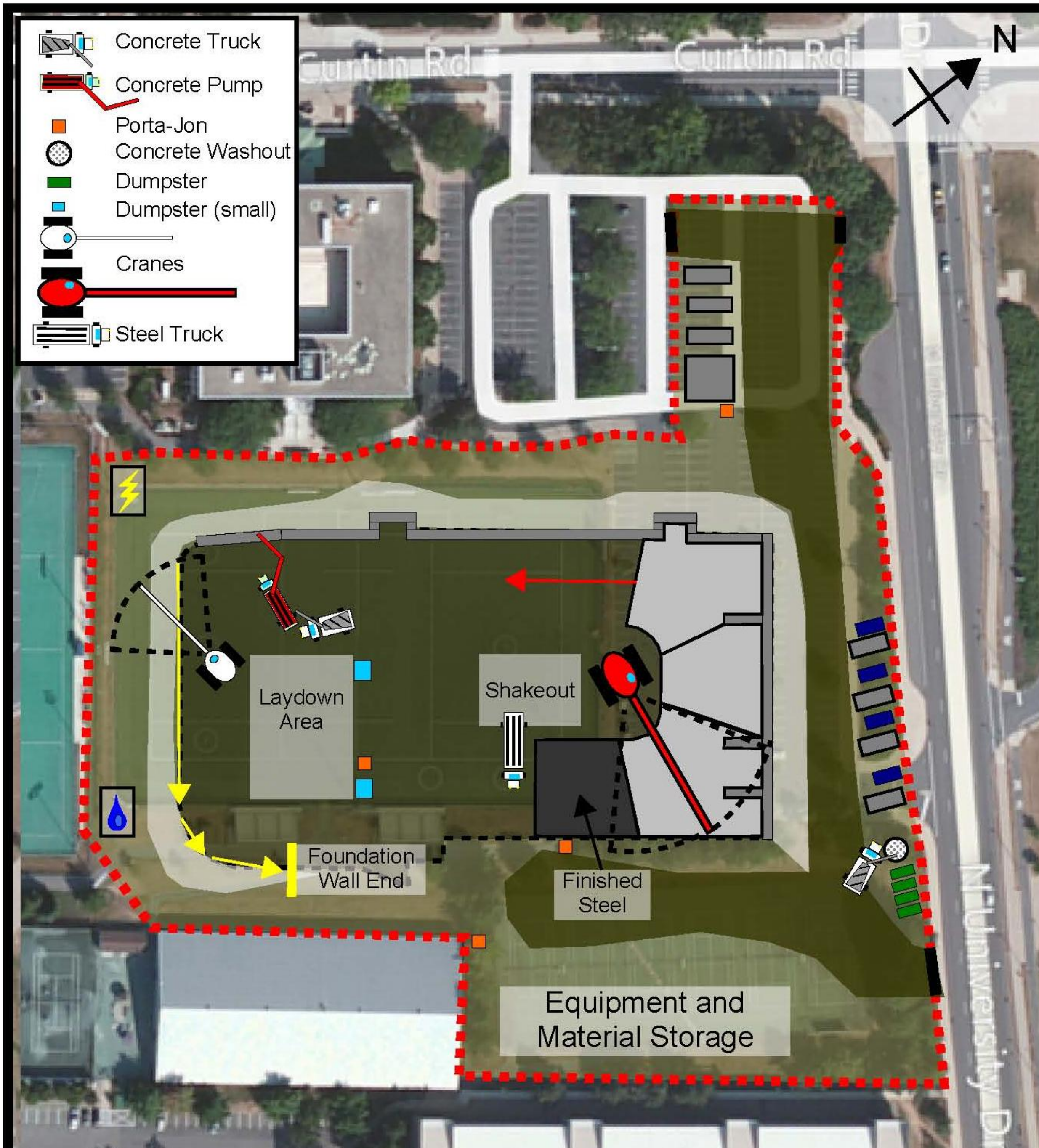
Technical Report1

Excavation

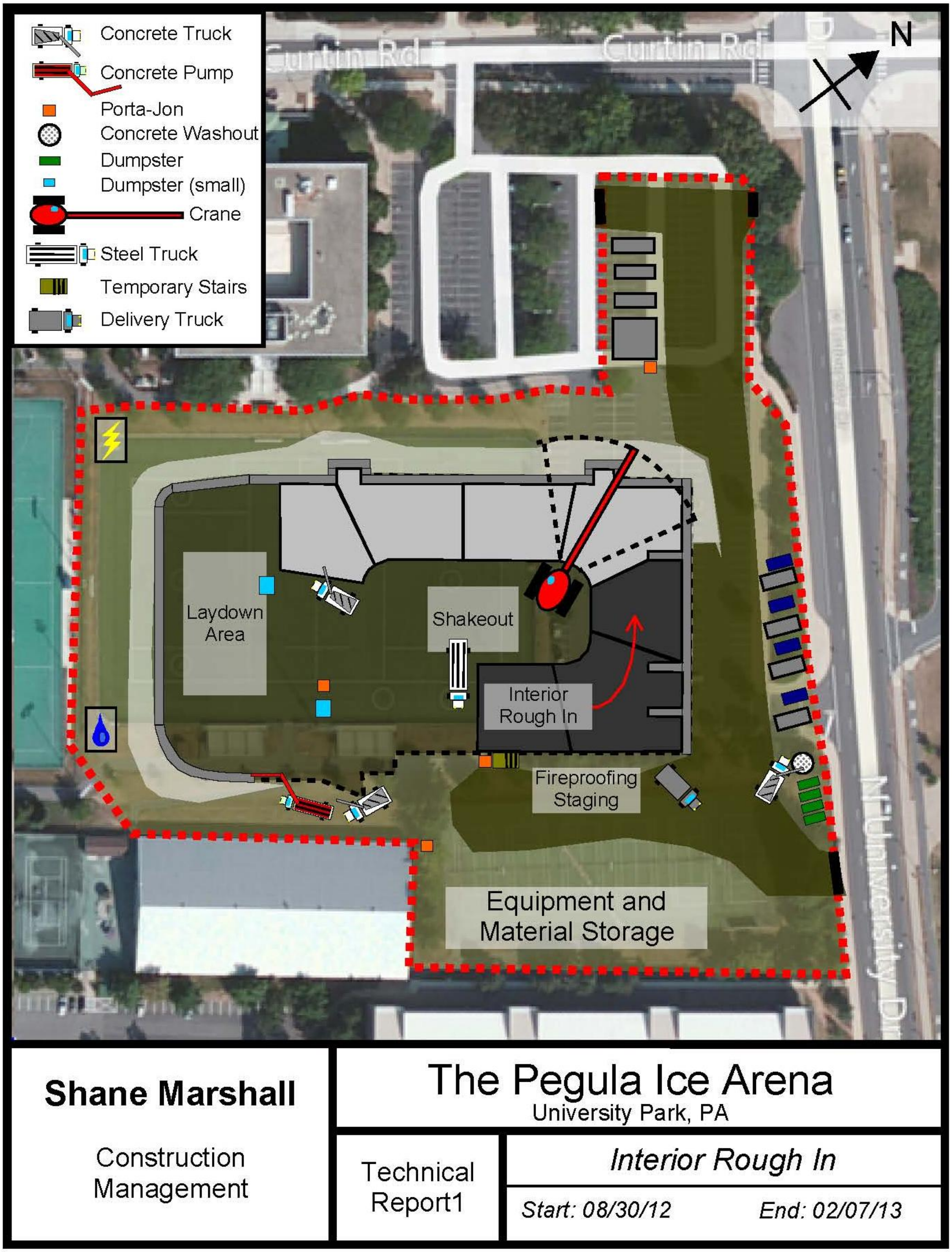
Start: 02/12/12 *End: 07/20/12*

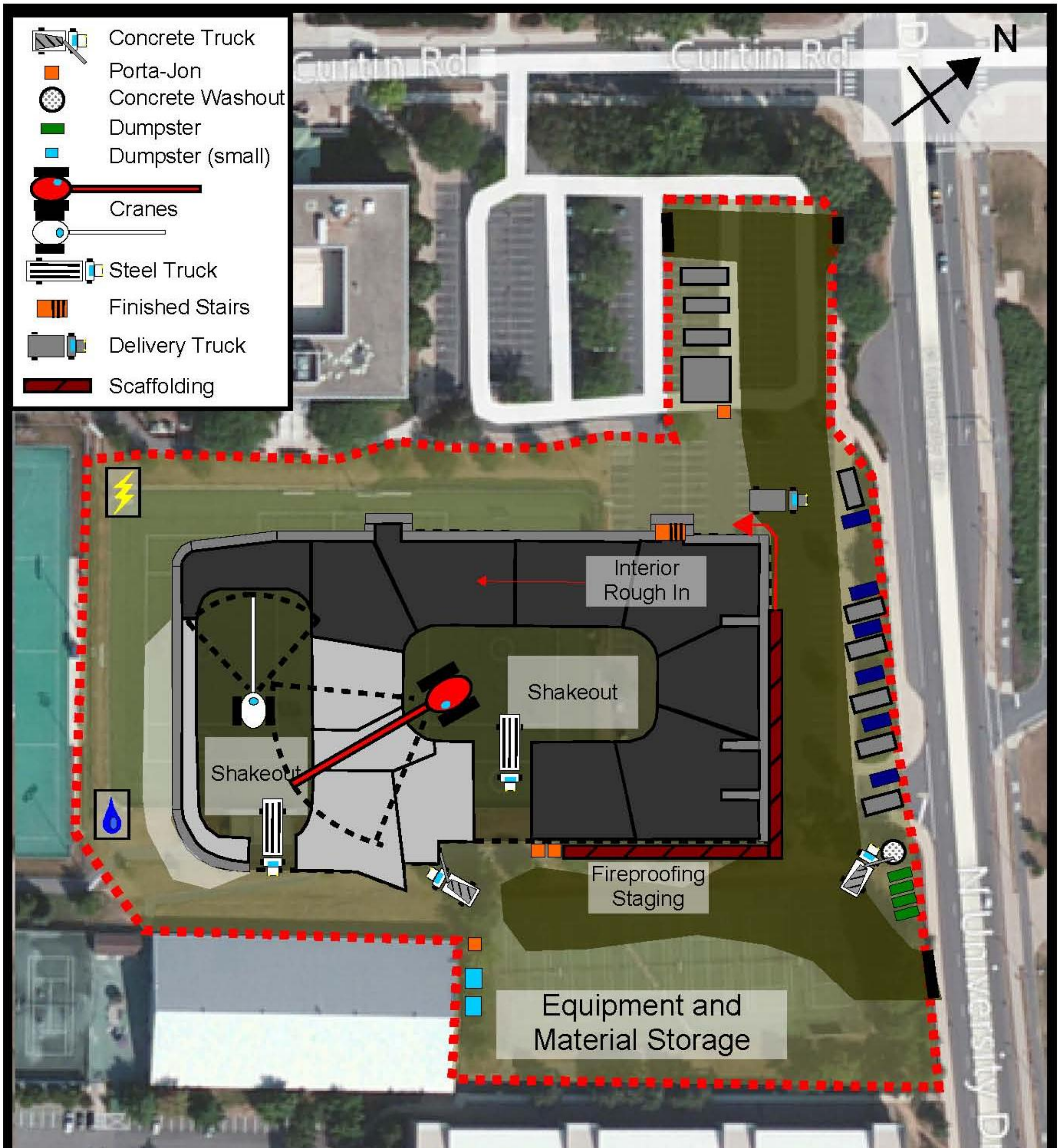

Dump Truck
Excavator
Concrete Truck
Concrete Pump
Porta-Jon
Concrete Washout
Dumpster
Dumpster (small)
Crane
N
Curtin Rd
Laydown Area
Foundation Wall
Additional Office and Storage Trailers
Foundation Wall End
Concrete SOG
Equipment and Material Storage
N University Dr
Shane Marshall
Construction Management
The Pegula Ice Arena
University Park, PA
Technical Report1
Foundation Wall and SOG
Start: 03/27/12
End: 12/10/12


Electric
Gas
Potable Water
Steam
Dump Truck
Excavator
Road Closed
Road Closed
N
Shane Marshall
Construction Management
The Pegula Ice Arena
University Park, PA
Technical Report1
Utility Tie In
Start: 6/4/12
End: 8/24/12



Shane Marshall Construction Management	The Pegula Ice Arena University Park, PA	
	Technical Report1	*Steel* *Start: 6/12/12* *End: 12/07/12*


Concrete Truck
Concrete Pump
Porta-Jon
Concrete Washout
Dumpster
Dumpster (small)
Crane
Steel Truck
Temporary Stairs
Delivery Truck
Curtin Rd
Curtin Rd
N
Laydown Area
Shakeout
Interior Rough In
Fireproofing Staging
Equipment and Material Storage
N University Dr
Shane Marshall
Construction Management
The Pegula Ice Arena
University Park, PA
Technical Report1
Interior Rough In
Start: 08/30/12
End: 02/07/13



Shane Marshall	The Pegula Ice Arena University Park, PA	
Construction Management	Technical Report1	*Exterior Enclosure* *Start: 10/15/12* *End: 02/08/13*

Appendix F: General Conditions Estimate

Staffing Plan	Month	Rate/Month	Cost	Personnel
Construction Executive	11	$ 19,750	**$ 217,250**	Hodge
Senior Project Manager	18	$ 18,000	**$ 324,000**	Laurila
Project Manager	20	$ 16,000	**$ 320,000**	Brown
Senior Superintendent	20	$ 14,250	**$ 285,000**	Brown
Superintendent	18	$ 12,500	**$ 225,000**	Moore
Superintendent	14	$ 12,500	**$ 175,000**	Loy
Quality Manager	20	$ 11,500	**$ 230,000**	Mallory
Integrated Construction Coordinator II	19	$ 11,000	**$ 209,000**	Kantor
Integrated Construction Coordinator I	6	$ 10,000	**$ 60,000**	Nahas
Safetey Engineer	18	$ 10,500	**$ 189,000**	Guenther
MEP Engineer	18	$ 10,000	**$ 180,000**	Alex
Field Engineer	18	$ 10,000	**$ 180,000**	Brown
Field Engineer	17	$ 10,000	**$ 170,000**	Thayor
Office Administrator	16	$ 8,250	**$ 132,000**	Weekley
Intern	12	$ 1,000	**$ 12,000**	Nahas/Marshall
		Total	**$ 2,908,250**	

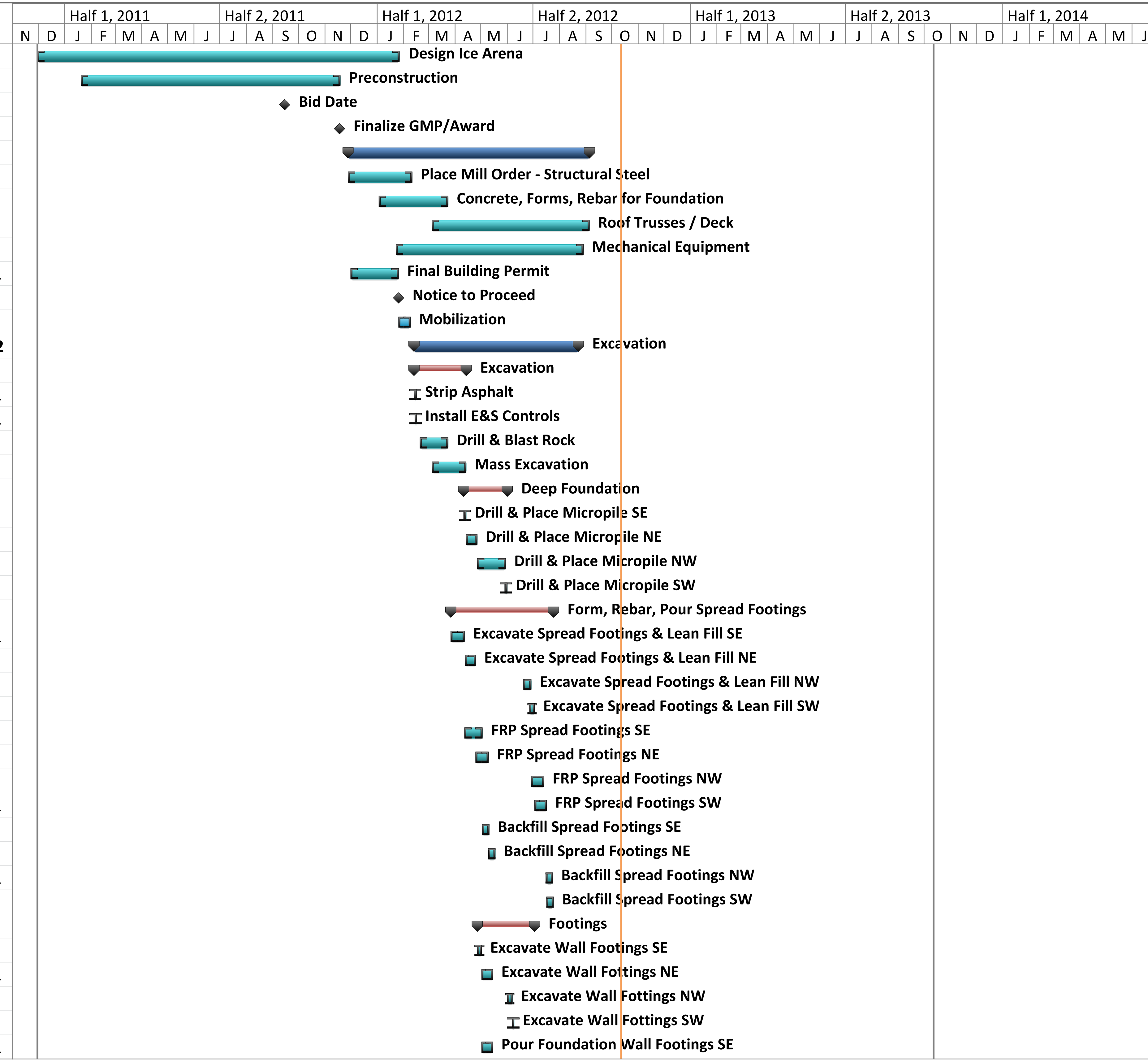
Insurance and Bonds	Quantity	Unit	Rate	Total
Builder's Risk Insurance				Owner
Automobile Insurance	2	Year	$ 4,000	**$ 8,000**
Liability Insurance	0.75	%	$ 68,000,000	**$ 510,000**
Payment & Performance Bonds	0.70	%	$ 68,000,000	**$ 476,000**
			Total	**$ 994,000**

General Services	Quantity	Unit	Rate	Total
Site Vehicle				
Senior Project Manager	18	Month	$ 500	**$ 9,000**
Senior Superintendent	20	Month	$ 400	**$ 8,000**
Superintendent	18	Month	$ 400	**$ 7,200**
Superintendent	13	Month	$ 400	**$ 5,200**
Telephone	16	Ea	$ 75	**$ 1,200**
Mobile Phone Monthly Bill	20	Month	$ 800	**$ 16,000**
Handheld Transciever	20	Month	$ 50	**$ 1,000**
IT				
Server	20	Month	$ 100	**$ 2,000**
Router/Wireless	1	Ea	$ 100	**$ 100**
Terminal Computer	10	Ea	$ 800	**$ 8,000**
Tablet Computer	6	Ea	$ 1,200	**$ 7,200**
Plan Room Computer	1	Ea	$ 2,000	**$ 2,000**
Projecter/Computer	1	Ea	$ 3,000	**$ 3,000**
Printer	1	Ea	$ 300	**$ 300**
Printer/Faxer/Scanner	1	Ea	$ 1,000	**$ 1,000**
Camera	5	Ea	$ 70	**$ 350**
Office Supplies/Paper	1	LS	$ 10,000	**$ 10,000**
Shipping Expenses	20	Month	$ 100	**$ 2,000**
Office Clean	20	Month	$ 400	**$ 8,000**
Aerial Photos	12	Month	$ 250	**$ 3,000**
			Total	**$ 94,550**

Temporary Facilities & Utilities	Quantity	Unit	Rate	Total
Trailer Rental	20	Month	$ 2,000	**$ 40,000**
Trailer Setup & Removal	1	LS	$ 30,000	**$ 30,000**
Site Fence	1	LS	$ 5,000	**$ 5,000**
Tools/Gang Box	1	LS	$ 10,000	**$ 10,000**
Signage	1	LS	$ 25,000	**$ 25,000**
Dumpsters	15	Month	$ 4,000	**$ 60,000**
IT/Network Setup	1	LS	$ 300	**$ 300**
Monthly Internet Bill	20	Month	$ 500	**$ 10,000**
Telephone Setup	1	LS	$ 300	**$ 300**
Monthly Phone Bill	20	Month	$ 400	**$ 8,000**
Electric Installation	1	LS	$ 1,000	**$ 1,000**
Monthly Electric Bill	20	Month	$ 500	**$ 10,000**
Water Setup	1	LS	$ 500	**$ 500**
Monthly Water Bill	20	Month	$ 500	**$ 10,000**
Temporary Toilets	15	LS	$ 5,000	**$ 75,000**
			Total	**$ 285,100**

Appendix G: Detailed Project Schedule

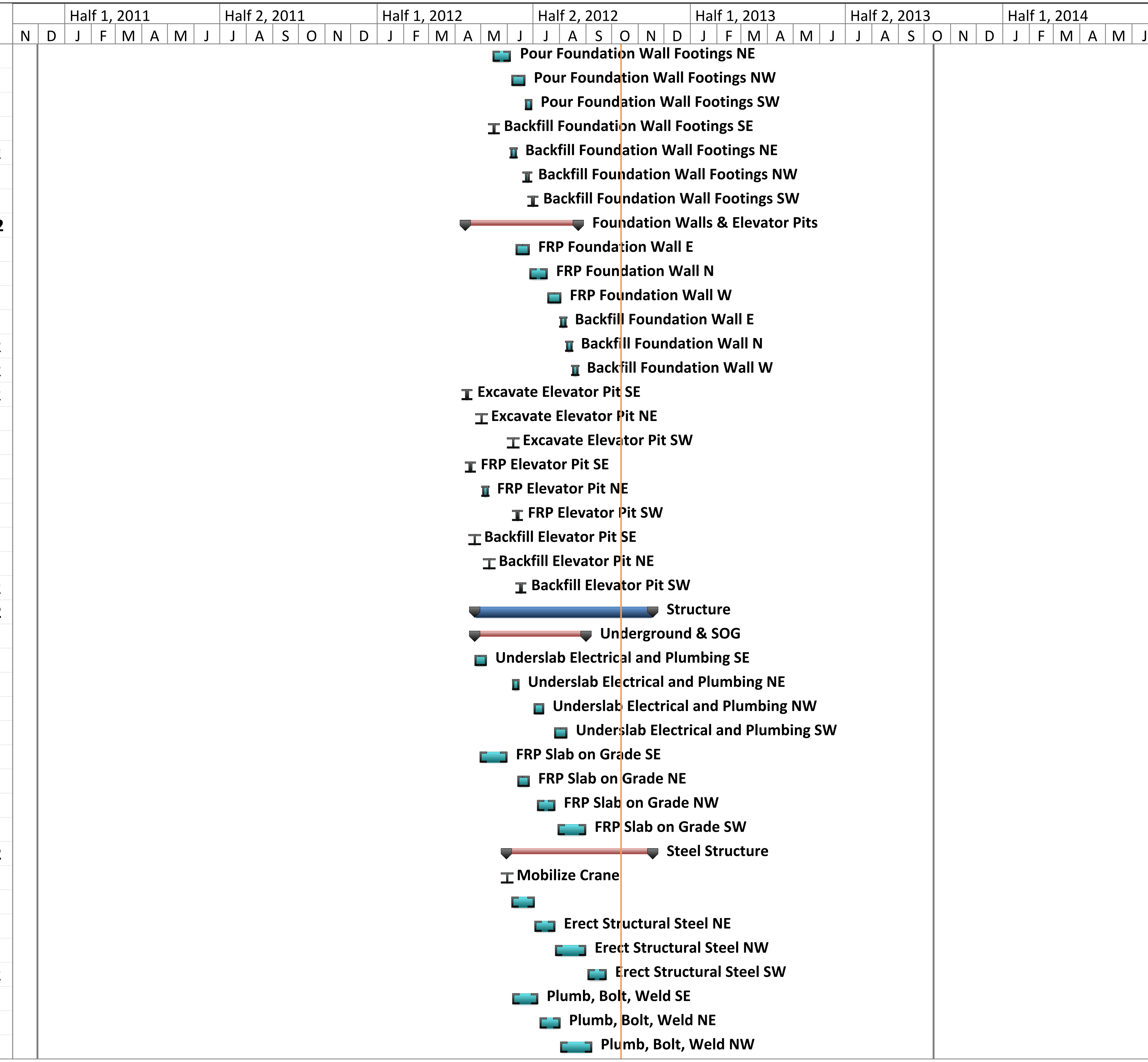
ID	Task Name	Duration	Start	Finish
1	Design Ice Arena	303 days	Tue 11/30/10	Thu 1/26/12
2	Preconstruction	217 days	Thu 1/20/11	Fri 11/18/11
3	Bid Date	0 days	Thu 9/15/11	Thu 9/15/11
4	Finalize GMP/Award	0 days	Fri 11/18/11	Fri 11/18/11
5	**Procurement**	**202 days**	**Mon 11/28/11**	**Tue 9/4/12**
6	Place Mill Order - Structural Steel	55 days	Mon 11/28/11	Fri 2/10/12
7	Concrete, Forms, Rebar for Foundation	59 days	Tue 1/3/12	Fri 3/23/12
8	Roof Trusses / Deck	132 days	Mon 3/5/12	Tue 9/4/12
9	Mechanical Equipment	157 days	Mon 1/23/12	Tue 8/28/12
10	Final Building Permit	40 days	Thu 12/1/11	Wed 1/25/12
11	Notice to Proceed	0 days	Thu 1/26/12	Thu 1/26/12
12	Mobilization	10 days	Thu 1/26/12	Wed 2/8/12
13	**Excavation**	**138 days**	**Mon 2/13/12**	**Wed 8/22/12**
14	**Excavation**	**45 days**	**Mon 2/13/12**	**Fri 4/13/12**
15	Strip Asphalt	3 days	Mon 2/13/12	Wed 2/15/12
16	Install E&S Controls	2 days	Tue 2/14/12	Wed 2/15/12
17	Drill & Blast Rock	25 days	Mon 2/20/12	Fri 3/23/12
18	Mass Excavation	30 days	Mon 3/5/12	Fri 4/13/12
19	**Deep Foundation**	**37 days**	**Wed 4/11/12**	**Thu 5/31/12**
20	Drill & Place Micropile SE	3 days	Wed 4/11/12	Fri 4/13/12
21	Drill & Place Micropile NE	10 days	Sat 4/14/12	Thu 4/26/12
22	Drill & Place Micropile NW	23 days	Fri 4/27/12	Tue 5/29/12
23	Drill & Place Micropile SW	3 days	Tue 5/29/12	Thu 5/31/12
24	**Form, Rebar, Pour Spread Footings**	**86 days**	**Tue 3/27/12**	**Tue 7/24/12**
25	Excavate Spread Footings & Lean Fill SE	12 days	Tue 3/27/12	Wed 4/11/12
26	Excavate Spread Footings & Lean Fill NE	8 days	Fri 4/13/12	Tue 4/24/12
27	Excavate Spread Footings & Lean Fill NW	7 days	Wed 6/20/12	Thu 6/28/12
28	Excavate Spread Footings & Lean Fill SW	4 days	Wed 6/27/12	Mon 7/2/12
29	FRP Spread Footings SE	15 days	Thu 4/12/12	Wed 5/2/12
30	FRP Spread Footings NE	11 days	Wed 4/25/12	Wed 5/9/12
31	FRP Spread Footings NW	11 days	Fri 6/29/12	Fri 7/13/12
32	FRP Spread Footings SW	10 days	Tue 7/3/12	Mon 7/16/12
33	Backfill Spread Footings SE	6 days	Thu 5/3/12	Thu 5/10/12
34	Backfill Spread Footings NE	6 days	Thu 5/10/12	Thu 5/17/12
35	Backfill Spread Footings NW	6 days	Mon 7/16/12	Mon 7/23/12
36	Backfill Spread Footings SW	6 days	Tue 7/17/12	Tue 7/24/12
37	**Footings**	**47 days**	**Fri 4/27/12**	**Mon 7/2/12**
38	Excavate Wall Footings SE	3 days	Fri 4/27/12	Tue 5/1/12
39	Excavate Wall Fottings NE	9 days	Wed 5/2/12	Mon 5/14/12
40	Excavate Wall Fottings NW	4 days	Fri 6/1/12	Wed 6/6/12
41	Excavate Wall Fottings SW	2 days	Thu 6/7/12	Fri 6/8/12
42	Pour Foundation Wall Footings SE	9 days	Wed 5/2/12	Mon 5/14/12



Project: The Pegula Ice Arena
Date: 10/10/12

Milestone ◆ Summary Task

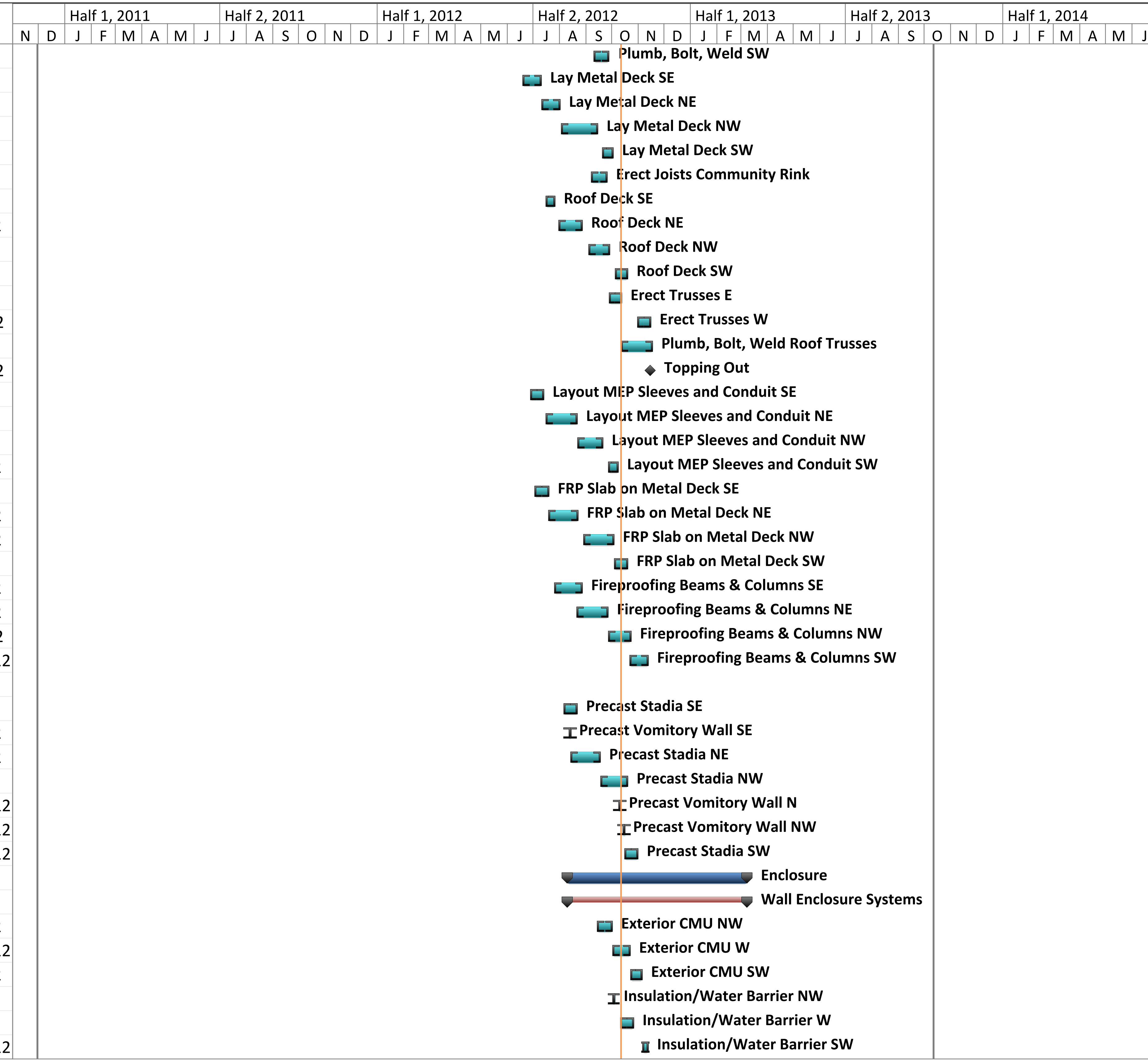
ID	Task Name	Duration	Start	Finish
43	Pour Foundation Wall Footings NE	15 days	Tue 5/15/12	Mon 6/4/12
44	Pour Foundation Wall Footings NW	12 days	Wed 6/6/12	Thu 6/21/12
45	Pour Foundation Wall Footings SW	6 days	Fri 6/22/12	Fri 6/29/12
46	Backfill Foundation Wall Footings SE	3 days	Tue 5/15/12	Thu 5/17/12
47	Backfill Foundation Wall Footings NE	5 days	Tue 6/5/12	Mon 6/11/12
48	Backfill Foundation Wall Footings NW	3 days	Fri 6/22/12	Tue 6/26/12
49	Backfill Foundation Wall Footings SW	2 days	Fri 6/29/12	Mon 7/2/12
50	**Foundation Walls & Elevator Pits**	**94 days**	**Fri 4/13/12**	**Wed 8/22/12**
51	FRP Foundation Wall E	12 days	Mon 6/11/12	Tue 6/26/12
52	FRP Foundation Wall N	15 days	Wed 6/27/12	Tue 7/17/12
53	FRP Foundation Wall W	12 days	Wed 7/18/12	Thu 8/2/12
54	Backfill Foundation Wall E	5 days	Thu 8/2/12	Wed 8/8/12
55	Backfill Foundation Wall N	5 days	Thu 8/9/12	Wed 8/15/12
56	Backfill Foundation Wall W	5 days	Thu 8/16/12	Wed 8/22/12
57	Excavate Elevator Pit SE	2 days	Fri 4/13/12	Mon 4/16/12
58	Excavate Elevator Pit NE	2 days	Tue 5/1/12	Wed 5/2/12
59	Excavate Elevator Pit SW	2 days	Thu 6/7/12	Fri 6/8/12
60	FRP Elevator Pit SE	4 days	Tue 4/17/12	Fri 4/20/12
61	FRP Elevator Pit NE	5 days	Thu 5/3/12	Wed 5/9/12
62	FRP Elevator Pit SW	4 days	Mon 6/11/12	Thu 6/14/12
63	Backfill Elevator Pit SE	2 days	Mon 4/23/12	Tue 4/24/12
64	Backfill Elevator Pit NE	2 days	Thu 5/10/12	Fri 5/11/12
65	Backfill Elevator Pit SW	2 days	Fri 6/15/12	Mon 6/18/12
66	**Structure**	**149 days**	**Tue 4/24/12**	**Sat 11/17/12**
67	**Underground & SOG**	**94 days**	**Tue 4/24/12**	**Fri 8/31/12**
68	Underslab Electrical and Plumbing SE	10 days	Tue 4/24/12	Mon 5/7/12
69	Underslab Electrical and Plumbing NE	6 days	Thu 6/7/12	Thu 6/14/12
70	Underslab Electrical and Plumbing NW	10 days	Mon 7/2/12	Fri 7/13/12
71	Underslab Electrical and Plumbing SW	11 days	Thu 7/26/12	Thu 8/9/12
72	FRP Slab on Grade SE	24 days	Mon 4/30/12	Thu 5/31/12
73	FRP Slab on Grade NE	10 days	Wed 6/13/12	Tue 6/26/12
74	FRP Slab on Grade NW	15 days	Fri 7/6/12	Thu 7/26/12
75	FRP Slab on Grade SW	25 days	Mon 7/30/12	Fri 8/31/12
76	**Steel Structure**	**122 days**	**Thu 5/31/12**	**Sat 11/17/12**
77	Mobilize Crane	2 days	Thu 5/31/12	Fri 6/1/12
78	Erect Structural Steel SE	19 days	Wed 6/6/12	Mon 7/2/12
79	Erect Structural Steel NE	18 days	Tue 7/3/12	Thu 7/26/12
80	Erect Structural Steel NW	26 days	Fri 7/27/12	Fri 8/31/12
81	Erect Structural Steel SW	16 days	Mon 9/3/12	Mon 9/24/12
82	Plumb, Bolt, Weld SE	22 days	Thu 6/7/12	Fri 7/6/12
83	Plumb, Bolt, Weld NE	18 days	Mon 7/9/12	Wed 8/1/12
84	Plumb, Bolt, Weld NW	27 days	Thu 8/2/12	Fri 9/7/12



Project: The Pegula Ice Arena
Date: 10/10/12

Milestone ◆ Summary Task

ID	Task Name	Duration	Start	Finish
85	Plumb, Bolt, Weld SW	14 days	Mon 9/10/12	Thu 9/27/12
86	Lay Metal Deck SE	16 days	Tue 6/19/12	Tue 7/10/12
87	Lay Metal Deck NE	16 days	Wed 7/11/12	Wed 8/1/12
88	Lay Metal Deck NW	31 days	Fri 8/3/12	Fri 9/14/12
89	Lay Metal Deck SW	9 days	Thu 9/20/12	Tue 10/2/12
90	Erect Joists Community Rink	13 days	Fri 9/7/12	Tue 9/25/12
91	Roof Deck SE	9 days	Mon 7/16/12	Thu 7/26/12
92	Roof Deck NE	20 days	Tue 7/31/12	Mon 8/27/12
93	Roof Deck NW	19 days	Tue 9/4/12	Fri 9/28/12
94	Roof Deck SW	11 days	Fri 10/5/12	Fri 10/19/12
95	Erect Trusses E	11 days	Fri 9/28/12	Fri 10/12/12
96	Erect Trusses W	12 days	Wed 10/31/12	Thu 11/15/12
97	Plumb, Bolt, Weld Roof Trusses	27 days	Fri 10/12/12	Sat 11/17/12
98	Topping Out	0 days	Thu 11/15/12	Thu 11/15/12
99	Layout MEP Sleeves and Conduit SE	12 days	Thu 6/28/12	Fri 7/13/12
100	Layout MEP Sleeves and Conduit NE	27 days	Mon 7/16/12	Tue 8/21/12
101	Layout MEP Sleeves and Conduit NW	22 days	Wed 8/22/12	Thu 9/20/12
102	Layout MEP Sleeves and Conduit SW	8 days	Thu 9/27/12	Mon 10/8/12
103	FRP Slab on Metal Deck SE	13 days	Tue 7/3/12	Thu 7/19/12
104	FRP Slab on Metal Deck NE	25 days	Thu 7/19/12	Wed 8/22/12
105	FRP Slab on Metal Deck NW	26 days	Wed 8/29/12	Wed 10/3/12
106	FRP Slab on Metal Deck SW	12 days	Thu 10/4/12	Fri 10/19/12
107	Fireproofing Beams & Columns SE	23 days	Thu 7/26/12	Mon 8/27/12
108	Fireproofing Beams & Columns NE	27 days	Tue 8/21/12	Wed 9/26/12
109	Fireproofing Beams & Columns NW	19 days	Thu 9/27/12	Tue 10/23/12
110	Fireproofing Beams & Columns SW	16 days	Mon 10/22/12	Mon 11/12/12
111	**Precast**	**64 days**	**Mon 8/6/12**	**Thu 11/1/12**
112	Precast Stadia SE	12 days	Mon 8/6/12	Tue 8/21/12
113	Precast Vomitory Wall SE	1 day	Mon 8/13/12	Mon 8/13/12
114	Precast Stadia NE	25 days	Tue 8/14/12	Mon 9/17/12
115	Precast Stadia NW	24 days	Tue 9/18/12	Fri 10/19/12
116	Precast Vomitory Wall N	1 day	Wed 10/10/12	Wed 10/10/12
117	Precast Vomitory Wall NW	1 day	Mon 10/15/12	Mon 10/15/12
118	Precast Stadia SW	12 days	Tue 10/16/12	Wed 10/31/12
119	**Enclosure**	**150 days**	**Fri 8/10/12**	**Thu 3/7/13**
120	**Wall Enclosure Systems**	**150 days**	**Fri 8/10/12**	**Thu 3/7/13**
121	Exterior CMU NW	12 days	Fri 9/14/12	Mon 10/1/12
122	Exterior CMU W	15 days	Tue 10/2/12	Mon 10/22/12
123	Exterior CMU SW	10 days	Tue 10/23/12	Mon 11/5/12
124	Insulation/Water Barrier NW	3 days	Tue 10/2/12	Thu 10/4/12
125	Insulation/Water Barrier W	12 days	Thu 10/11/12	Fri 10/26/12
126	Insulation/Water Barrier SW	5 days	Tue 11/6/12	Mon 11/12/12



Project: The Pegula Ice Arena
Date: 10/10/12

Milestone ◆ Summary Task

ID	Task Name	Duration	Start	Finish
127	Erect Prefab CFMF Wall Panel System SE	35 days	Fri 8/10/12	Thu 9/27/12
128	Erect Prefab CFMF Wall Panel System NE	27 days	Tue 10/2/12	Wed 11/7/12
129	Erect Prefab CFMF Wall Panel System NW	16 days	Fri 11/9/12	Fri 11/30/12
130	Erect Prefab CFMF Wall Panel System SW	14 days	Mon 12/3/12	Thu 12/20/12
131	Install Brick Ties SE	9 days	Mon 10/1/12	Thu 10/11/12
132	Install Brick Ties NE	29 days	Fri 10/12/12	Wed 11/21/12
133	Install Brick Ties NW	18 days	Mon 11/26/12	Wed 12/19/12
134	Install Brick Ties SW	2 days	Thu 12/27/12	Fri 12/28/12
135	Face Brick SE	15 days	Wed 11/21/12	Tue 12/11/12
136	Face Brick NE	24 days	Mon 11/26/12	Thu 12/27/12
137	Face Brick SW	8 days	Wed 1/2/13	Fri 1/11/13
138	Building Enclosure	0 days	Fri 1/11/13	Fri 1/11/13
139	Install Metal Panel Soffit/Fascia SE	8 days	Mon 12/24/12	Wed 1/2/13
140	Install Metal Panel Soffit/Fascia NE	10 days	Wed 1/9/13	Tue 1/22/13
141	Install Metal Panel Soffit/Fascia NW	16 days	Wed 1/23/13	Wed 2/13/13
142	Install Metal Panel Soffit/Fascia SW	16 days	Thu 2/14/13	Thu 3/7/13
143	**Glazing Systems**	**35 days**	**Thu 12/6/12**	**Wed 1/23/13**
144	Curtain Wall Framing & Glazing SE	16 days	Thu 12/6/12	Thu 12/27/12
145	Curtain Wall Framing & Glazing NE	19 days	Fri 12/28/12	Wed 1/23/13
146	**Roof Systems**	**66 days**	**Tue 9/25/12**	**Tue 12/25/12**
147	Install Roof Blocking	22 days	Tue 9/25/12	Wed 10/24/12
148	Membrane Roof SE	8 days	Mon 10/1/12	Wed 10/10/12
149	Membrane Roof NE	9 days	Wed 10/10/12	Mon 10/22/12
150	Membrane Roof NW	23 days	Tue 10/23/12	Thu 11/22/12
151	Membrane Roof SW	23 days	Fri 11/23/12	Tue 12/25/12
152	**Conveying Systems**	**81 days**	**Mon 10/8/12**	**Mon 1/28/13**
153	**Elevators**	**81 days**	**Mon 10/8/12**	**Mon 1/28/13**
154	Install Elevator SE	37 days	Mon 10/8/12	Tue 11/27/12
155	Install Elevator NE	28 days	Tue 11/13/12	Thu 12/20/12
156	Install Elevator SW	27 days	Fri 12/21/12	Mon 1/28/13
157	Temporary Use of SE Elevator	0 days	Fri 11/30/12	Fri 11/30/12
158	**Interior Rough-In**	**174 days**	**Fri 7/20/12**	**Wed 3/20/13**
159	**Hangers**	**69 days**	**Mon 7/23/12**	**Thu 10/25/12**
160	Install Hangers SE	13 days	Mon 7/23/12	Wed 8/8/12
161	Install Hangers NE	27 days	Fri 8/17/12	Mon 9/24/12
162	Install Hangers NW	11 days	Thu 9/27/12	Thu 10/11/12
163	Install Hangers SW	9 days	Mon 10/15/12	Thu 10/25/12
164	**Steel Stairs**	**67 days**	**Tue 7/24/12**	**Wed 10/24/12**
165	Erect Steel Stairs NE	7 days	Tue 7/24/12	Wed 8/1/12
166	Erect Steel Stairs Grand Stair	3 days	Mon 8/27/12	Wed 8/29/12
167	Erect Steel Stairs NW	37 days	Tue 9/4/12	Wed 10/24/12
168	Erect Steel Stairs SW	6 days	Mon 10/1/12	Mon 10/8/12

Project: The Pegula Ice Arena
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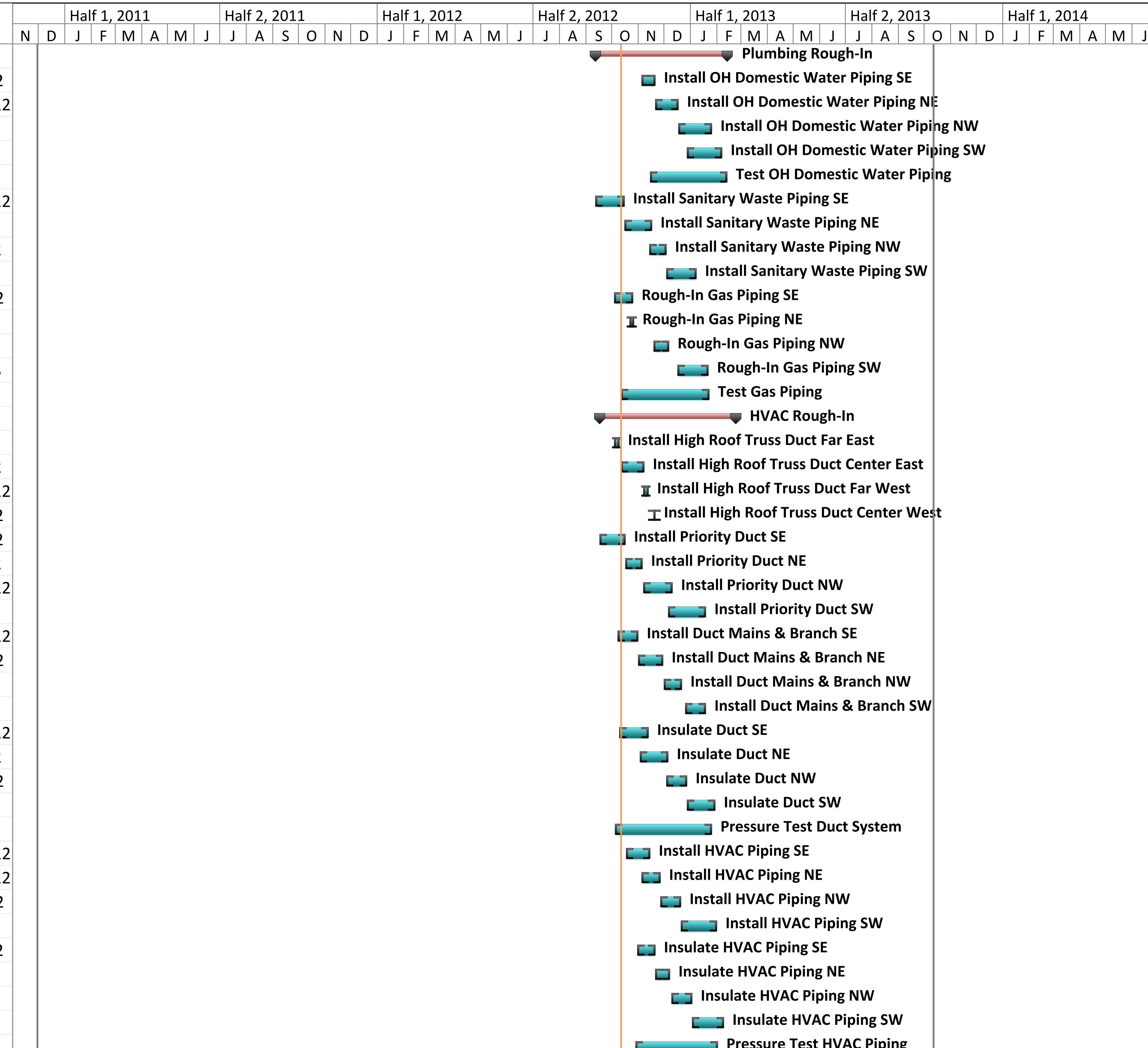
Milestone ◆ Summary Task

ID	Task Name	Duration	Start	Finish
169	**Plumbing Rough-In**	**110 days**	**Wed 9/12/12**	**Tue 2/12/13**
170	Install OH Domestic Water Piping SE	12 days	Mon 11/5/12	Tue 11/20/12
171	Install OH Domestic Water Piping NE	19 days	Wed 11/21/12	Mon 12/17/12
172	Install OH Domestic Water Piping NW	29 days	Tue 12/18/12	Fri 1/25/13
173	Install OH Domestic Water Piping SW	29 days	Fri 12/28/12	Wed 2/6/13
174	Test OH Domestic Water Piping	64 days	Thu 11/15/12	Tue 2/12/13
175	Install Sanitary Waste Piping SE	24 days	Wed 9/12/12	Mon 10/15/12
176	Install Sanitary Waste Piping NE	24 days	Tue 10/16/12	Fri 11/16/12
177	Install Sanitary Waste Piping NW	14 days	Wed 11/14/12	Mon 12/3/12
178	Install Sanitary Waste Piping SW	25 days	Tue 12/4/12	Mon 1/7/13
179	Rough-In Gas Piping SE	16 days	Thu 10/4/12	Thu 10/25/12
180	Rough-In Gas Piping NE	5 days	Mon 10/22/12	Fri 10/26/12
181	Rough-In Gas Piping NW	14 days	Mon 11/19/12	Thu 12/6/12
182	Rough-In Gas Piping SW	26 days	Mon 12/17/12	Mon 1/21/13
183	Test Gas Piping	73 days	Fri 10/12/12	Tue 1/22/13
184	**HVAC Rough-In**	**115 days**	**Mon 9/17/12**	**Fri 2/22/13**
185	Install High Roof Truss Duct Far East	4 days	Thu 10/4/12	Tue 10/9/12
186	Install High Roof Truss Duct Center East	19 days	Fri 10/12/12	Wed 11/7/12
187	Install High Roof Truss Duct Far West	4 days	Wed 11/7/12	Mon 11/12/12
188	Install High Roof Truss Duct Center West	2 days	Mon 11/19/12	Tue 11/20/12
189	Install Priority Duct SE	22 days	Mon 9/17/12	Tue 10/16/12
190	Install Priority Duct NE	14 days	Wed 10/17/12	Mon 11/5/12
191	Install Priority Duct NW	24 days	Wed 11/7/12	Mon 12/10/12
192	Install Priority Duct SW	32 days	Thu 12/6/12	Fri 1/18/13
193	Install Duct Mains & Branch SE	18 days	Mon 10/8/12	Wed 10/31/12
194	Install Duct Mains & Branch NE	21 days	Thu 11/1/12	Thu 11/29/12
195	Install Duct Mains & Branch NW	16 days	Sat 12/1/12	Fri 12/21/12
196	Install Duct Mains & Branch SW	18 days	Wed 12/26/12	Fri 1/18/13
197	Insulate Duct SE	24 days	Wed 10/10/12	Mon 11/12/12
198	Insulate Duct NE	24 days	Sat 11/3/12	Wed 12/5/12
199	Insulate Duct NW	18 days	Tue 12/4/12	Thu 12/27/12
200	Insulate Duct SW	23 days	Fri 12/28/12	Tue 1/29/13
201	Pressure Test Duct System	81 days	Fri 10/5/12	Fri 1/25/13
202	Install HVAC Piping SE	20 days	Thu 10/18/12	Wed 11/14/12
203	Install HVAC Piping NE	16 days	Mon 11/5/12	Mon 11/26/12
204	Install HVAC Piping NW	18 days	Tue 11/27/12	Thu 12/20/12
205	Install HVAC Piping SW	30 days	Fri 12/21/12	Thu 1/31/13
206	Insulate HVAC Piping SE	15 days	Wed 10/31/12	Tue 11/20/12
207	Insulate HVAC Piping NE	13 days	Wed 11/21/12	Fri 12/7/12
208	Insulate HVAC Piping NW	18 days	Mon 12/10/12	Wed 1/2/13
209	Insulate HVAC Piping SW	27 days	Thu 1/3/13	Fri 2/8/13
210	Pressure Test HVAC Piping	70 days	Mon 10/29/12	Fri 2/1/13



Project: The Pegula Ice Arena
Date: 10/10/12

Milestone ◆ Summary Task

ID	Task Name	Duration	Start	Finish
211	Install Fire Sprinkler SE	19 days	Wed 11/21/12	Mon 12/17/12
212	Install Fire Sprinkler NE	9 days	Tue 12/18/12	Fri 12/28/12
213	Install Fire Sprinkler NW	18 days	Mon 12/31/12	Wed 1/23/13
214	Install Fire Sprinkler SW	22 days	Thu 1/24/13	Fri 2/22/13
215	**Electrical Rough-In**	**118 days**	**Mon 10/8/12**	**Wed 3/20/13**
216	Install OH Branch/Feeder Conduit SE	14 days	Thu 10/18/12	Tue 11/6/12
217	Install OH Branch/Feeder Conduit NE	14 days	Wed 11/7/12	Mon 11/26/12
218	Install OH Branch/Feeder Conduit NW	17 days	Wed 11/28/12	Thu 12/20/12
219	Install OH Branch/Feeder Conduit SW	32 days	Fri 12/21/12	Mon 2/4/13
220	Pull Feeder Cable SE	15 days	Fri 10/26/12	Thu 11/15/12
221	Pull Feeder Cable NE	12 days	Fri 11/16/12	Mon 12/3/12
222	Pull Feeder Cable NW	15 days	Tue 12/4/12	Mon 12/24/12
223	Pull Feeder Cable SW	32 days	Fri 12/28/12	Mon 2/11/13
224	Install In-Wall Electrical Rough-In SE	16 days	Tue 10/23/12	Tue 11/13/12
225	Install In-Wall Electrical Rough-In NE	20 days	Wed 11/14/12	Tue 12/11/12
226	Install In-Wall Electrical Rough-In NW	13 days	Thu 12/13/12	Mon 12/31/12
227	Install In-Wall Electrical Rough-In SW	24 days	Tue 1/1/13	Fri 2/1/13
228	Pull Branch Wire Arena Catwalk Lights and Scoreboard	17 days	Thu 12/20/12	Fri 1/11/13
229	Pull Branch Wire SE	18 days	Fri 12/21/12	Tue 1/15/13
230	Pull Branch Wire NE	16 days	Wed 1/16/13	Wed 2/6/13
231	Pull Branch Wire NW	18 days	Thu 2/7/13	Mon 3/4/13
232	Pull Branch Wire SW	9 days	Tue 3/5/13	Fri 3/15/13
233	Install Electrical Panels/Equipment SE	16 days	Mon 10/8/12	Mon 10/29/12
234	Install Electrical Panels/Equipment NE	14 days	Mon 10/15/12	Thu 11/1/12
235	Install Electrical Panels/Equipment NW	28 days	Tue 10/30/12	Thu 12/6/12
236	Install Electrical Panels/Equipment SW	16 days	Wed 12/12/12	Wed 1/2/13
237	Electric Testing	58 days	Mon 12/31/12	Wed 3/20/13
238	Permanent Power	0 days	Wed 3/20/13	Wed 3/20/13
239	**Architectural Rough-In**	**163 days**	**Fri 7/20/12**	**Tue 3/5/13**
240	Layout & Install Top Track SE	48 days	Fri 7/20/12	Tue 9/25/12
241	Layout & Install Top Track NE	13 days	Wed 9/12/12	Fri 9/28/12
242	Layout & Install Top Track NW	7 days	Mon 10/1/12	Tue 10/9/12
243	Layout & Install Top Track SW	9 days	Thu 10/11/12	Tue 10/23/12
244	Interior Masonry SE	13 days	Tue 8/21/12	Thu 9/6/12
245	Interior Masonry NE	5 days	Fri 9/7/12	Thu 9/13/12
246	Interior Masonry NW	11 days	Mon 9/24/12	Mon 10/8/12
247	Interior Masonry SW	35 days	Fri 10/12/12	Thu 11/29/12
248	Erect Metal Studs SE	33 days	Tue 9/4/12	Thu 10/18/12
249	Erect Metal Studs NE	34 days	Tue 9/18/12	Fri 11/2/12
250	Erect Metal Studs NW	27 days	Wed 10/24/12	Thu 11/29/12
251	Erect Metal Studs SW	25 days	Mon 11/26/12	Fri 12/28/12

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Milestone ◆ Summary Task

ID	Task Name	Duration	Start	Finish
252	Install Backing/Blocking SE	5 days	Mon 9/24/12	Fri 9/28/12
253	Install Backing/Blocking NE	12 days	Mon 10/1/12	Tue 10/16/12
254	Install Backing/Blocking NW	25 days	Mon 10/29/12	Fri 11/30/12
255	Install Backing/Blocking SW	25 days	Thu 11/29/12	Wed 1/2/13
256	Install Door Frames SE	17 days	Tue 9/25/12	Wed 10/17/12
257	Install Door Frames NE	15 days	Tue 10/2/12	Mon 10/22/12
258	Install Door Frames NW	23 days	Mon 10/29/12	Wed 11/28/12
259	Install Door Frames SW	28 days	Thu 11/29/12	Mon 1/7/13
260	Erect Ceiling/Soffit Studs SE	17 days	Fri 11/30/12	Mon 12/24/12
261	Erect Ceiling/Soffit Studs NE	15 days	Thu 12/27/12	Wed 1/16/13
262	Erect Ceiling/Soffit Studs NW	14 days	Thu 1/17/13	Tue 2/5/13
263	Erect Ceiling/Soffit Studs SW	20 days	Wed 2/6/13	Tue 3/5/13
264	Building Controls SE	20 days	Thu 10/25/12	Wed 11/21/12
265	Building Controls NE	22 days	Thu 11/22/12	Fri 12/21/12
266	Building Controls NW	15 days	Wed 12/26/12	Tue 1/15/13
267	Building Controls SW	23 days	Thu 1/17/13	Mon 2/18/13
268	**Equipment**	**144 days**	**Thu 10/4/12**	**Tue 4/23/13**
269	**Mechanical Equipment**	**90 days**	**Thu 10/4/12**	**Wed 2/6/13**
270	Set AHUs NW	7 days	Thu 10/18/12	Fri 10/26/12
271	Set & Install AHUs SW	5 days	Mon 10/29/12	Fri 11/2/12
272	Set Pumps, Heat Exchangers, Tanks, & VFDs Mech. Court	19 days	Tue 11/20/12	Fri 12/14/12
273	Install Accessories for Mechanical Equipment	36 days	Mon 12/17/12	Mon 2/4/13
274	Install and Connect HVAC Equipment Connections SE	24 days	Thu 10/4/12	Tue 11/6/12
275	Install and Connect HVAC Equipment Connections NE	26 days	Fri 10/26/12	Fri 11/30/12
276	Install and Connect HVAC Equipment Connections NW	19 days	Mon 11/19/12	Thu 12/13/12
277	Install and Connect HVAC Equipment Connections SW	38 days	Mon 12/17/12	Wed 2/6/13
278	**Electrical Equipment**	**7 days**	**Fri 11/16/12**	**Mon 11/26/12**
279	Set Switchgear	7 days	Fri 11/16/12	Mon 11/26/12
280	**Specialty Equipment**	**102 days**	**Mon 12/3/12**	**Tue 4/23/13**
281	Install FS Counter & Set FS Equipment SE	26 days	Fri 1/18/13	Fri 2/22/13
282	Install FS Counter & Set FS Equipment NE	36 days	Mon 2/11/13	Mon 4/1/13
283	Install FS Counter & Set FS Equipment NW	25 days	Tue 3/12/13	Mon 4/15/13
284	Install FS Counter & Set FS Equipment SW	13 days	Fri 3/29/13	Tue 4/16/13
285	Mech./Elec. Conn @ FS Equipment SE	14 days	Tue 2/12/13	Fri 3/1/13
286	Mech./Elec. Conn @ FS Equipment NE	21 days	Thu 3/7/13	Thu 4/4/13
287	Mech./Elec. Conn @ FS Equipment NW	21 days	Fri 3/22/13	Fri 4/19/13
288	Mech./Elec. Conn @ FS Equipment SW	11 days	Tue 4/9/13	Tue 4/23/13

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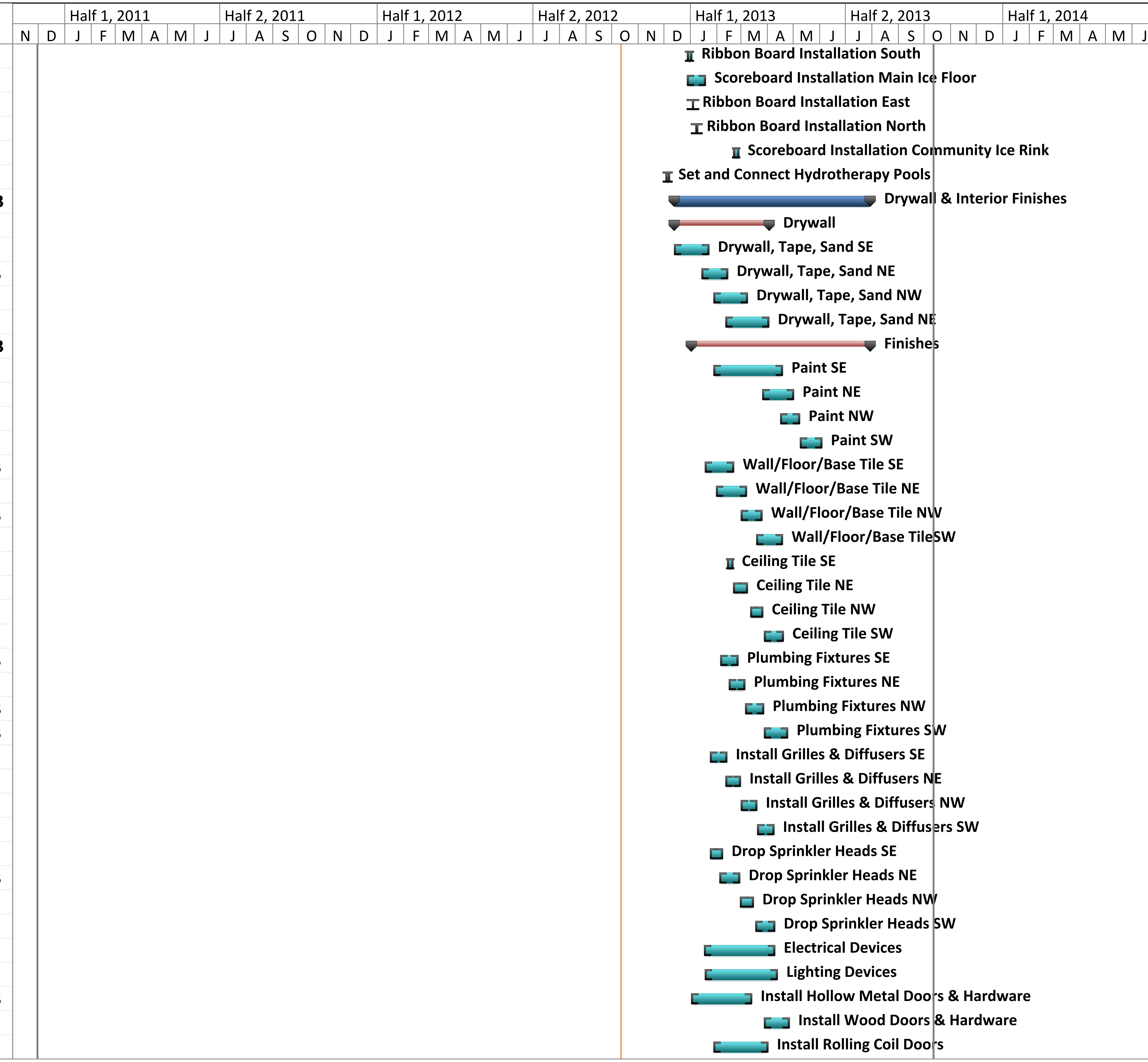
Milestone ◆ Summary Task

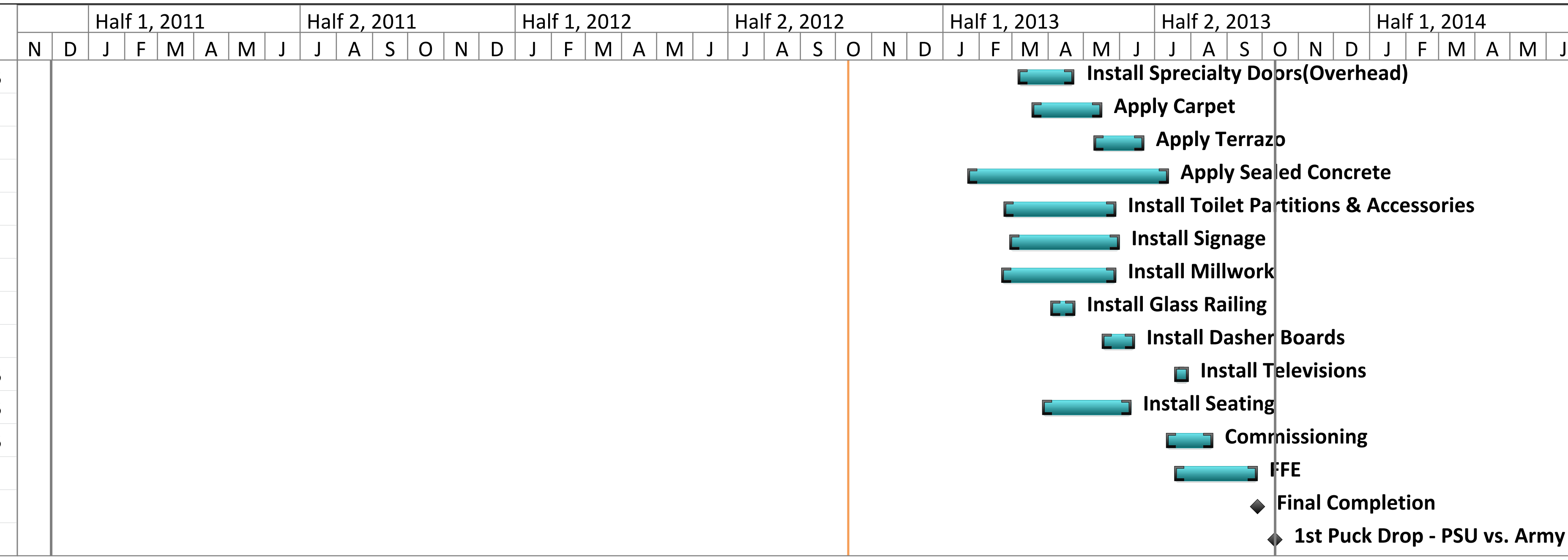
ID	Task Name	Duration	Start	Finish
289	Ribbon Board Installation South	4 days	Fri 12/28/12	Wed 1/2/13
290	Scoreboard Installation Main Ice Floor	16 days	Fri 12/28/12	Fri 1/18/13
291	Ribbon Board Installation East	2 days	Thu 1/3/13	Fri 1/4/13
292	Ribbon Board Installation North	3 days	Mon 1/7/13	Wed 1/9/13
293	Scoreboard Installation Community Ice Rink	5 days	Wed 2/20/13	Tue 2/26/13
294	Set and Connect Hydrotherapy Pools	5 days	Mon 12/3/12	Fri 12/7/12
295	**Drywall & Interior Finishes**	**163 days**	**Thu 12/13/12**	**Mon 7/29/13**
296	**Drywall**	**79 days**	**Thu 12/13/12**	**Tue 4/2/13**
297	Drywall, Tape, Sand SE	29 days	Thu 12/13/12	Tue 1/22/13
298	Drywall, Tape, Sand NE	23 days	Mon 1/14/13	Wed 2/13/13
299	Drywall, Tape, Sand NW	30 days	Mon 1/28/13	Fri 3/8/13
300	Drywall, Tape, Sand NE	37 days	Mon 2/11/13	Tue 4/2/13
301	**Finishes**	**149 days**	**Wed 1/2/13**	**Mon 7/29/13**
302	Paint SE	59 days	Mon 1/28/13	Thu 4/18/13
303	Paint NE	27 days	Tue 3/26/13	Wed 5/1/13
304	Paint NW	17 days	Tue 4/16/13	Wed 5/8/13
305	Paint SW	18 days	Thu 5/9/13	Mon 6/3/13
306	Wall/Floor/Base Tile SE	24 days	Fri 1/18/13	Wed 2/20/13
307	Wall/Floor/Base Tile NE	26 days	Thu 1/31/13	Thu 3/7/13
308	Wall/Floor/Base Tile NW	17 days	Fri 3/1/13	Mon 3/25/13
309	Wall/Floor/Base TileSW	23 days	Tue 3/19/13	Thu 4/18/13
310	Ceiling Tile SE	5 days	Wed 2/13/13	Tue 2/19/13
311	Ceiling Tile NE	13 days	Wed 2/20/13	Fri 3/8/13
312	Ceiling Tile NW	11 days	Tue 3/12/13	Tue 3/26/13
313	Ceiling Tile SW	17 days	Thu 3/28/13	Fri 4/19/13
314	Plumbing Fixtures SE	15 days	Tue 2/5/13	Mon 2/25/13
315	Plumbing Fixtures NE	13 days	Fri 2/15/13	Tue 3/5/13
316	Plumbing Fixtures NW	16 days	Wed 3/6/13	Wed 3/27/13
317	Plumbing Fixtures SW	20 days	Thu 3/28/13	Wed 4/24/13
318	Install Grilles & Diffusers SE	14 days	Thu 1/24/13	Tue 2/12/13
319	Install Grilles & Diffusers NE	14 days	Mon 2/11/13	Thu 2/28/13
320	Install Grilles & Diffusers NW	13 days	Fri 3/1/13	Tue 3/19/13
321	Install Grilles & Diffusers SW	14 days	Wed 3/20/13	Mon 4/8/13
322	Drop Sprinkler Heads SE	11 days	Thu 1/24/13	Thu 2/7/13
323	Drop Sprinkler Heads NE	18 days	Mon 2/4/13	Wed 2/27/13
324	Drop Sprinkler Heads NW	12 days	Thu 2/28/13	Fri 3/15/13
325	Drop Sprinkler Heads SW	17 days	Mon 3/18/13	Tue 4/9/13
326	Electrical Devices	59 days	Thu 1/17/13	Tue 4/9/13
327	Lighting Devices	61 days	Fri 1/18/13	Fri 4/12/13
328	Install Hollow Metal Doors & Hardware	51 days	Wed 1/2/13	Wed 3/13/13
329	Install Wood Doors & Hardware	22 days	Thu 3/28/13	Fri 4/26/13
330	Install Rolling Coil Doors	46 days	Mon 1/28/13	Mon 4/1/13



Project: The Pegula Ice Arena
Date: 10/10/12

Milestone ◆ Summary Task

ID	Task Name	Duration	Start	Finish
331	Install Sprecialty Doors(Overhead)	34 days	Wed 3/6/13	Mon 4/22/13
332	Apply Carpet	44 days	Mon 3/18/13	Thu 5/16/13
333	Apply Terrazo	31 days	Fri 5/10/13	Fri 6/21/13
334	Apply Sealed Concrete	124 days	Tue 1/22/13	Fri 7/12/13
335	Install Toilet Partitions & Accessories	68 days	Fri 2/22/13	Tue 5/28/13
336	Install Signage	68 days	Wed 2/27/13	Fri 5/31/13
337	Install Millwork	70 days	Wed 2/20/13	Tue 5/28/13
338	Install Glass Railing	15 days	Wed 4/3/13	Tue 4/23/13
339	Install Dasher Boards	20 days	Fri 5/17/13	Thu 6/13/13
340	Install Televisions	8 days	Thu 7/18/13	Mon 7/29/13
341	Install Seating	54 days	Wed 3/27/13	Mon 6/10/13
342	Commissioning	28 days	Thu 7/11/13	Mon 8/19/13
343	FFE	51 days	Thu 7/18/13	Thu 9/26/13
344	Final Completion	0 days	Thu 9/26/13	Thu 9/26/13
345	1st Puck Drop - PSU vs. Army	0 days	Fri 10/11/13	Fri 10/11/13

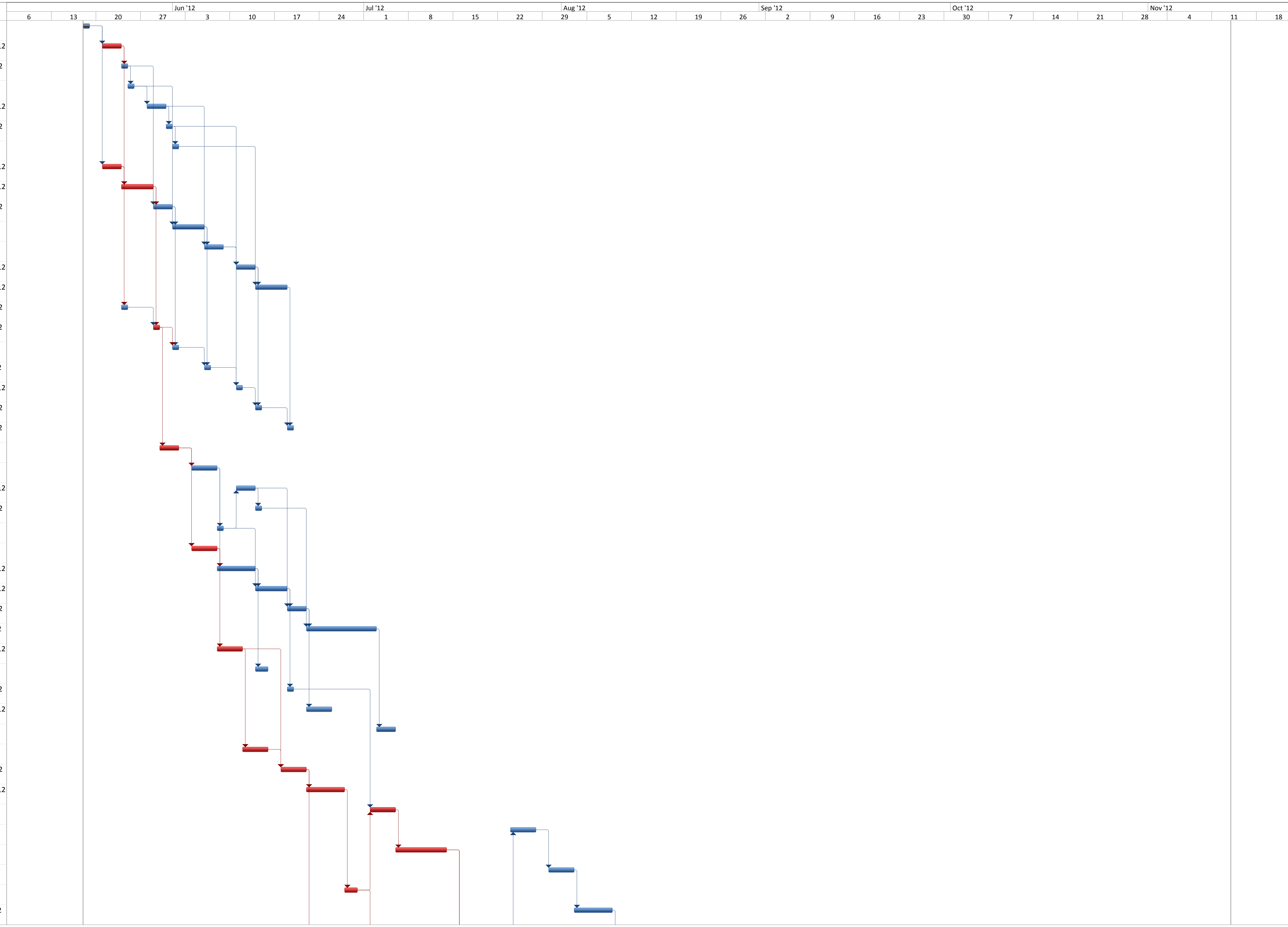


Project: The Pegula Ice Arena
Date: 10/10/12

Milestone ◆ Summary Task

Appendix H: Analysis 1| Original Community Rink Detailed Schedule

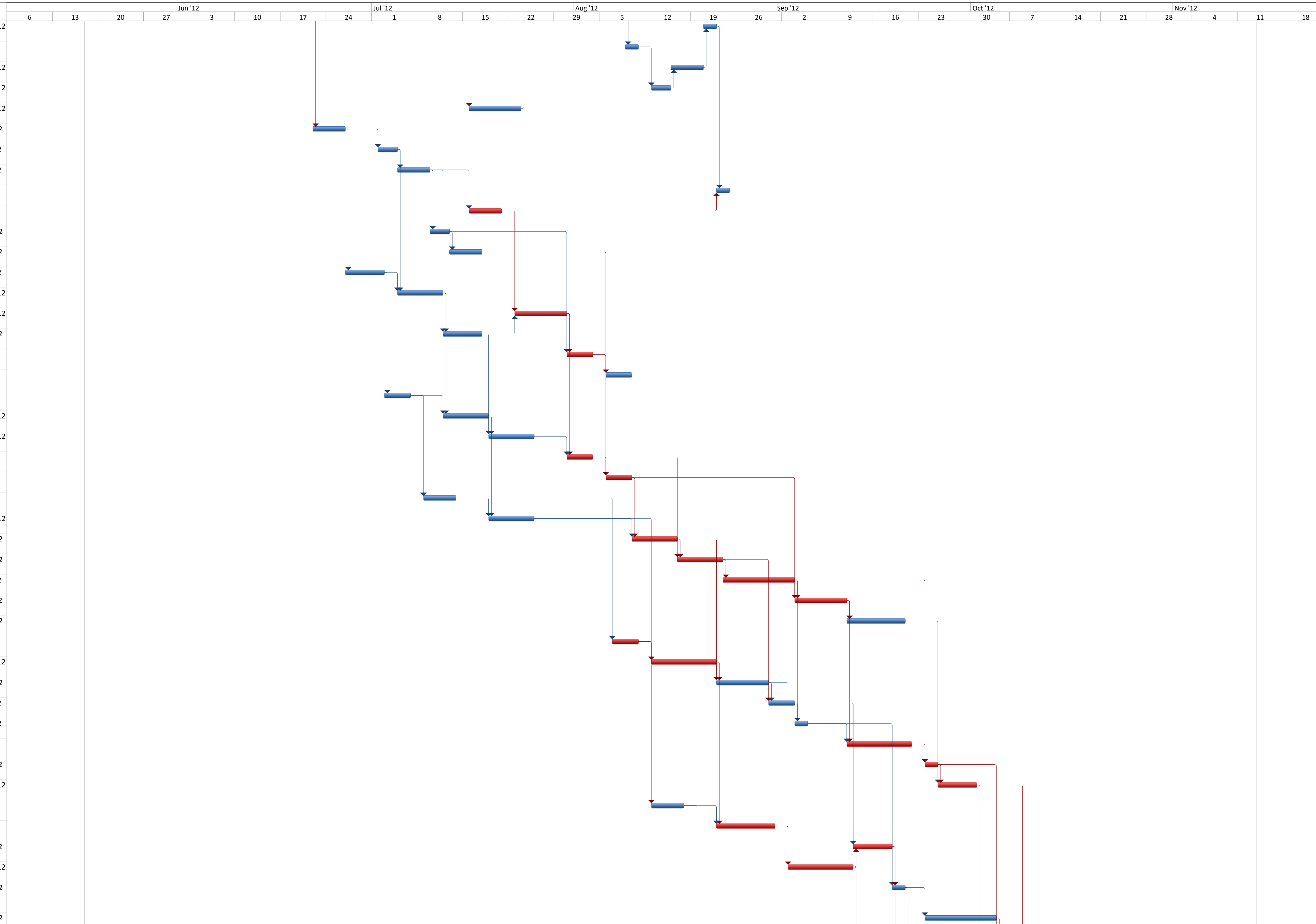
ID	Task Name	Duration	Start	Finish
1	Excavate Fdn Wall Footings - Arena Foundation Lvl NE #8 - 6D	1 day	Fri 5/18/12	Fri 5/18/12
2	Excavate Fdn Wall Footings - Arena Foundation Lvl NE #9	3 days	Mon 5/21/12	Wed 5/23/12
3	Excavate Fdn Wall Footings - Arena Foundation Lvl NE #10	1 day	Thu 5/24/12	Thu 5/24/12
4	Excavate Fdn Wall Footings - Arena Foundation Lvl NW #11	1 day	Fri 5/25/12	Fri 5/25/12
5	Excavate Fdn Wall Footings - Arena Foundation Lvl NW #12	3 days	Mon 5/28/12	Wed 5/30/12
6	Excavate Fdn Wall Footings - Arena Foundation Lvl SW #13	1 day	Thu 5/31/12	Thu 5/31/12
7	Excavate Fdn Wall Footings - Arena Foundation Lvl SW #14	1 day	Fri 6/1/12	Fri 6/1/12
8	FRP Fdn Wall Footings - Arena Foundat ion Lvl NE #8	3 days	Mon 5/21/12	Wed 5/23/12
9	FRP Fdn Wall Footings - Arena Foundat ion Lvl NW #9 - 6D	3 days	Thu 5/24/12	Mon 5/28/12
10	FRP Fdn Wall Footings - Arena Foundat ion Lvl NW #10	3 days	Tue 5/29/12	Thu 5/31/12
11	FRP Fdn Wall Footings - Arena Foundat ion Lvl NW #12	3 days	Fri 6/1/12	Tue 6/5/12
12	FRP Fdn Wall Footings - Arena Foundat ion Lvl NW #11	3 days	Wed 6/6/12	Fri 6/8/12
13	FRP Fdn Wall Footings - Arena Foundat ion Lvl SW #13 - 6D	3 days	Mon 6/11/12	Wed 6/13/12
14	FRP Fdn Wall Footings - Arena Foundat ion Lvl SW #14	3 days	Thu 6/14/12	Mon 6/18/12
15	Backfill Fdn Wall Footings - Arena Foundation Lvl NE #8	1 day	Thu 5/24/12	Thu 5/24/12
16	Backfill Fdn Wall Footings - Arena Foundation Lvl NW #9	1 day	Tue 5/29/12	Tue 5/29/12
17	Backfill Fdn Wall Footings - Arena Foundation Lvl NW #10	1 day	Fri 6/1/12	Fri 6/1/12
18	Backfill Fdn Wall Footings - Arena Foundation Lvl NW #11	1 day	Wed 6/6/12	Wed 6/6/12
19	Backfill Fdn Wall Footings - Arena Foundation Lvl NW #12	1 day	Mon 6/11/12	Mon 6/11/12
20	Backfill Fdn Wall Footings - Arena Foundation Lvl SW #13	1 day	Thu 6/14/12	Thu 6/14/12
21	Backfill Fdn Wall Footings - Arena Foundation Lvl SW #14	1 day	Tue 6/19/12	Tue 6/19/12
22	Excavate Spread Footings - Arena Foundation Lvl NW #7	3 days	Wed 5/30/12	Fri 6/1/12
23	Excavate Spread Footings - Arena Foundation Lvl NW #8	4 days	Mon 6/4/12	Thu 6/7/12
24	Excavate Spread Footings - Arena Foundation Lvl SW #10	3 days	Mon 6/11/12	Wed 6/13/12
25	Excavate Spread Footings - Arena Foundation Lvl SW #11	1 day	Thu 6/14/12	Thu 6/14/12
26	Excavate Spread Footings - Arena Foundation Lvl NW #9	1 day	Fri 6/8/12	Fri 6/8/12
27	FRP Spread Footings - Arena Foundation Lvl NW #7 - 6D	4 days	Mon 6/4/12	Thu 6/7/12
28	FRP Spread Footings - Arena Foundation Lvl NW #8	4 days	Fri 6/8/12	Wed 6/13/12
29	FRP Spread Footings - Arena Foundation Lvl NW #9	3 days	Thu 6/14/12	Mon 6/18/12
30	FRP Spread Footings - Arena Foundation Lvl SW #10	3 days	Tue 6/19/12	Thu 6/21/12
31	FRP Spread Footings - Arena Foundation Lvl SW #11	7 days	Fri 6/22/12	Mon 7/2/12
32	Backfill Spread Footings - Arena Foundation Lvl NW #7	2 days	Fri 6/8/12	Mon 6/11/12
33	Backfill Spread Footings - Arena Foundation Lvl NW #8	2 days	Thu 6/14/12	Fri 6/15/12
34	Backfill Spread Footings - Arena Foundation Lvl NW #9	1 day	Tue 6/19/12	Tue 6/19/12
35	Backfill Spread Footings - Arena Foundation Lvl SW #10	2 days	Fri 6/22/12	Mon 6/25/12
36	Backfill Spread Footings - Arena Foundation Lvl SW #11	3 days	Tue 7/3/12	Thu 7/5/12
37	FRP Fdn Wall - Ar ena Foundation Lvl NW #11 - 6D	4 days	Tue 6/12/12	Fri 6/15/12
38	FRP Fdn Wall - Ar ena Foundation Lvl NW #12 - 6D	4 days	Mon 6/18/12	Thu 6/21/12
39	FRP Fdn Wall - Ar ena Foundation Lvl NW #13	4 days	Fri 6/22/12	Wed 6/27/12
40	FRP Fdn Wall - Ar ena Foundation Lvl NW #14	4 days	Mon 7/2/12	Thu 7/5/12
41	FRP Fdn Wall - Ar ena Foundation Lvl NW #16	4 days	Tue 7/24/12	Fri 7/27/12
42	FRP Fdn Wall - Ar ena Foundation Lvl NW #15	6 days	Fri 7/6/12	Fri 7/13/12
43	FRP Fdn Wall - Ar ena Foundation Lvl SW #17	4 days	Mon 7/30/12	Thu 8/2/12
44	FRP Fdn Wall - Ar ena Foundation Lvl NW #13a	2 days	Thu 6/28/12	Fri 6/29/12
45	FRP Fdn Wall - Ar ena Foundation Lvl SW #18	4 days	Fri 8/3/12	Wed 8/8/12



Comm Rink Sched
Date: Sat 3/16/13

Task — Milestone ◆ — Critical

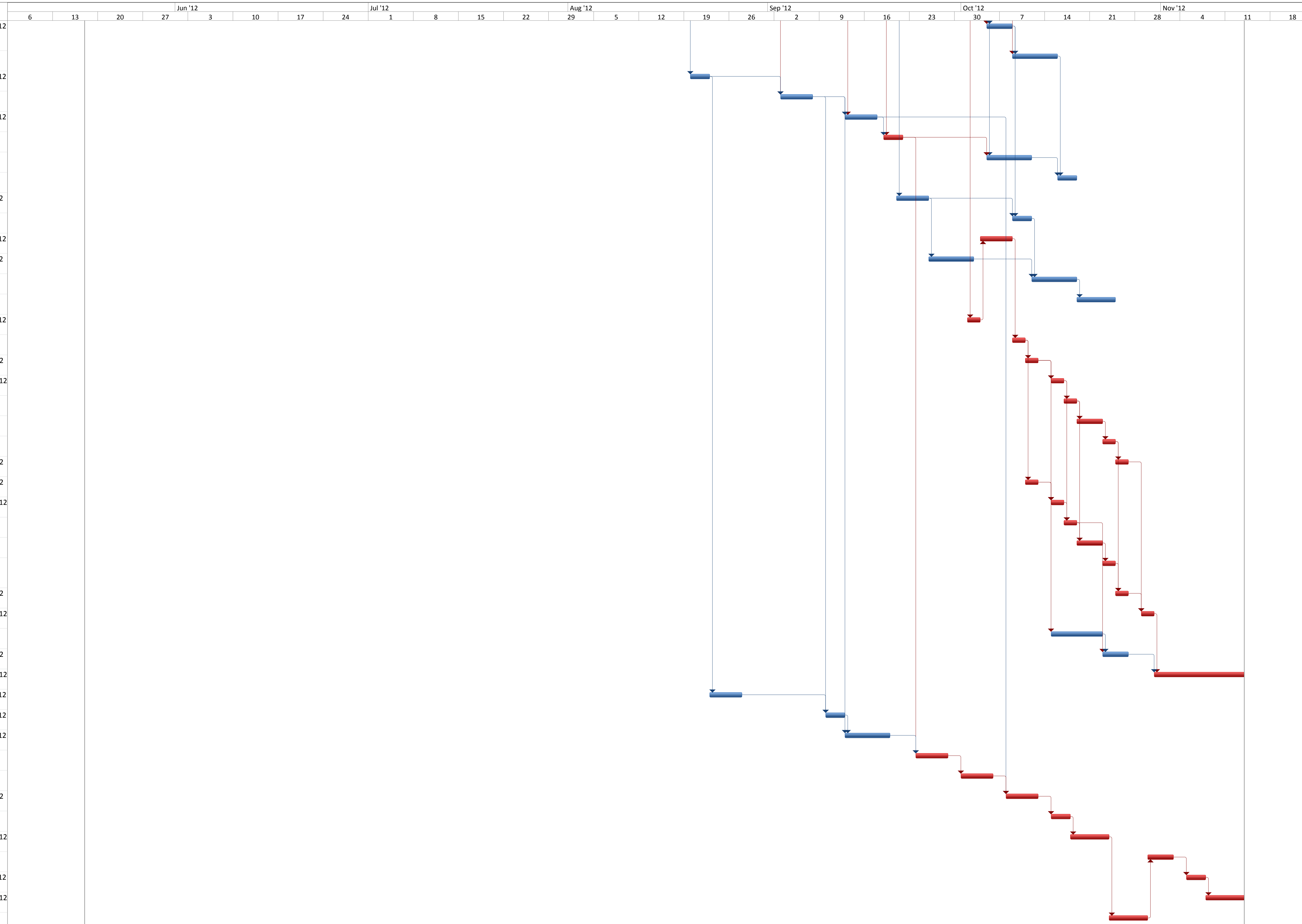
ID	Task Name	Duratio	Start	Finish
46	FRP Fdn Wall - Ar ena Foundation Lvl SW #22	2 days	Tue 8/21/12	Wed 8/22/12
47	FRP Fdn Wall - Ar ena Foundation Lvl SW #19	2 days	Thu 8/9/12	Fri 8/10/12
48	FRP Fdn Wall - Ar ena Foundation Lvl SW #21	3 days	Thu 8/16/12	Mon 8/20/12
49	FRP Fdn Wall - Ar ena Foundation Lvl SW #20	3 days	Mon 8/13/12	Wed 8/15/12
50	FRP Fdn Wall - Ar ena Foundation Lvl NW #15 Radius	6 days	Mon 7/16/12	Mon 7/23/12
51	Underslab Electrical - Arena Event Lvl NW #6	3 days	Fri 6/22/12	Tue 6/26/12
52	Underslab Electrical - Arena Event Lvl NW #7	3 days	Mon 7/2/12	Wed 7/4/12
53	Underslab Electrical - Arena Event Lvl SW #9	3 days	Thu 7/5/12	Mon 7/9/12
54	Underslab Electrical - Arena Event Lvl SW #12	2 days	Thu 8/23/12	Fri 8/24/12
55	Underslab Electrical - Arena Event Lvl NW #8	5 days	Mon 7/16/12	Fri 7/20/12
56	Underslab Electrical - Arena Event Lvl SW #10	3 days	Tue 7/10/12	Thu 7/12/12
57	Underslab Electrical - Arena Event Lvl SW #11	3 days	Fri 7/13/12	Tue 7/17/12
58	Underslab Mech / Plumbing - Arena Event Lvl NW #6	4 days	Wed 6/27/12	Mon 7/2/12
59	Underslab Mech / Plumbing - Arena Event Lvl NW #7	5 days	Thu 7/5/12	Wed 7/11/12
60	Underslab Mech / Plumbing - Arena Event Lvl NW #8	6 days	Mon 7/23/12	Mon 7/30/12
61	Underslab Mech / Plumbing - Arena Event Lvl SW #9	4 days	Thu 7/12/12	Tue 7/17/12
62	Underslab Mech / Plumbing - Arena Event Lvl SW #10	4 days	Tue 7/31/12	Fri 8/3/12
63	Underslab Mech / Plumbing - Arena Event Lvl SW #11	4 days	Mon 8/6/12	Thu 8/9/12
64	Underslab Glycol Lines - Arena Event Lvl NW #5	4 days	Tue 7/3/12	Fri 7/6/12
65	Underslab Glycol Lines - Arena Event Lvl NW #6	5 days	Thu 7/12/12	Wed 7/18/12
66	Underslab Glycol Lines - Arena Event Lvl NW #7	5 days	Thu 7/19/12	Wed 7/25/12
67	Underslab Glycol Lines - Arena Event Lvl NW #8	4 days	Tue 7/31/12	Fri 8/3/12
68	Underslab Glycol Lines - Arena Event Lvl SW #9	4 days	Mon 8/6/12	Thu 8/9/12
69	FRP Slab on Grade - Arena Event Lvl NW #6	5 days	Mon 7/9/12	Fri 7/13/12
70	FRP Slab on Grade - Arena Event Lvl NW #7	5 days	Thu 7/19/12	Wed 7/25/12
71	FRP Slab on Grade - Arena Event Lvl SW #9	5 days	Fri 8/10/12	Thu 8/16/12
72	FRP Slab on Grade - Arena Event Lvl NW #8	5 days	Fri 8/17/12	Thu 8/23/12
73	FRP Slab on Grade - Arena Event Lvl SW #12	7 days	Fri 8/24/12	Mon 9/3/12
74	FRP Slab on Grade - Arena Event Lvl SW #10	6 days	Tue 9/4/12	Tue 9/11/12
75	FRP Slab on Grade - Arena Event Lvl SW #11	7 days	Wed 9/12/12	Thu 9/20/12
76	Erect Structural Steel - Arena All Levels NW #6	4 days	Tue 8/7/12	Fri 8/10/12
77	Erect Structural Steel - Arena All Levels NW #7	8 days	Mon 8/13/12	Wed 8/22/12
78	Erect Structural Steel - Arena All Levels NW #8	6 days	Thu 8/23/12	Thu 8/30/12
79	Erect Structural Steel - Arena Mech Court NW #11	2 days	Fri 8/31/12	Mon 9/3/12
80	Erect Structural Steel - Arena All Levels Community Rink #12	2 days	Tue 9/4/12	Wed 9/5/12
81	Erect Structural Steel - Arena All Levels SW #9	8 days	Wed 9/12/12	Fri 9/21/12
82	Erect Structural Steel - Arena All Levels Community Rink #13	2 days	Mon 9/24/12	Tue 9/25/12
83	Erect Structural Steel - Arena All Levels SW #10	4 days	Wed 9/26/12	Mon 10/1/12
84	Plumb/Bolt/Weld Structural Steel - Arena All Levels NW #6	5 days	Mon 8/13/12	Fri 8/17/12
85	Plumb/Bolt/Weld Structural Steel - Arena All Levels NW #7	7 days	Thu 8/23/12	Fri 8/31/12
86	Plumb/Bolt/Weld Structural Steel - Arena Mech Court NW #11	4 days	Thu 9/13/12	Tue 9/18/12
87	Plumb/Bolt/Weld Structural Steel - Arena All Levels NW #8	8 days	Mon 9/3/12	Wed 9/12/12
88	Plumb/Bolt/Weld Structural Steel - Arena All Levels Community Ice Rink #12	2 days	Wed 9/19/12	Thu 9/20/12
89	Plumb/Bolt/Weld Structural Steel - Arena All Levels SW #9	9 days	Mon 9/24/12	Thu 10/4/12



Comm Rink Sched
Date: Sat 3/16/13

Task | Milestone ◆ | Critical

ID	Task Name	Duration	Start	Finish
90	Plumb/Bolt/Weld Structural Steel - Arena All Levels Community Ice Rink #13	2 days	Fri 10/5/12	Mon 10/8/12
91	Plumb/Bolt/Weld Structural Steel - Arena All Levels SW #10	5 days	Tue 10/9/12	Mon 10/15/12
92	Lay Metal Deck - Arena All Levels NW #6	3 days	Mon 8/20/12	Wed 8/22/12
93	Lay Metal Deck - Arena All Levels NW #7	5 days	Mon 9/3/12	Fri 9/7/12
94	Lay Metal Deck - Arena All Levels NW #8	3 days	Thu 9/13/12	Mon 9/17/12
95	Lay Metal Deck - Arena Mech Court NW #11	3 days	Wed 9/19/12	Fri 9/21/12
96	Lay Metal Deck - Arena All Levels SW #9	5 days	Fri 10/5/12	Thu 10/11/12
97	Lay Metal Deck - Arena All Levels SW #10	3 days	Tue 10/16/12	Thu 10/18/12
98	Erect Steel / Bar Joists - Arena Roof Community Ice Rink #12	3 days	Fri 9/21/12	Tue 9/25/12
99	Erect Steel / Bar Joists - Arena Roof Community Ice Rink #13	3 days	Tue 10/9/12	Thu 10/11/12
100	Erect Steel & Bar Joists - Arena East Roof Seq #15 & #16	3 days	Thu 10/4/12	Mon 10/8/12
101	Lay Roof Deck - Arena Roof Community Ice Rink #12	5 days	Wed 9/26/12	Tue 10/2/12
102	Lay Roof Deck - Arena Roof Community Ice Rink #13	5 days	Fri 10/12/12	Thu 10/18/12
103	Complete Roof Deck - Arena Roof Community Ice Rink	4 days	Fri 10/19/12	Wed 10/24/12
104	Erect Roof Trusses - Arena High Roof Truss Seq #14	2 days	Tue 10/2/12	Wed 10/3/12
105	Erect Roof Trusses - Arena High Roof Truss Seq #17	2 days	Tue 10/9/12	Wed 10/10/12
106	Erect Roof Trusses - Arena High Roof Truss Seq #23	2 days	Thu 10/11/12	Fri 10/12/12
107	Erect Roof Trusses - Arena High Roof Truss Seq #24	2 days	Mon 10/15/12	Tue 10/16/12
108	Erect Roof Trusses - Arena High Roof Truss Seq #25	2 days	Wed 10/17/12	Thu 10/18/12
109	Erect Roof Trusses - Arena High Roof Truss Seq #18	2 days	Fri 10/19/12	Mon 10/22/12
110	Erect Roof Trusses - Arena High Roof Truss Seq #21	2 days	Tue 10/23/12	Wed 10/24/12
111	Erect Roof Trusses - Arena High Roof Truss Seq #22	2 days	Thu 10/25/12	Fri 10/26/12
112	Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #17	2 days	Thu 10/11/12	Fri 10/12/12
113	Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #23	2 days	Mon 10/15/12	Tue 10/16/12
114	Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #24	2 days	Wed 10/17/12	Thu 10/18/12
115	Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #25	2 days	Fri 10/19/12	Mon 10/22/12
116	Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #19 & #20	2 days	Tue 10/23/12	Wed 10/24/12
117	Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #21	2 days	Thu 10/25/12	Fri 10/26/12
118	Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #22	2 days	Mon 10/29/12	Tue 10/30/12
119	Lay Roof Truss Metal Deck - Arena High Roof East (GL x15-x12)	6 days	Mon 10/15/12	Mon 10/22/12
120	Lay Roof Truss Metal Deck - Arena High Roof East (GL x12-x10)	4 days	Tue 10/23/12	Fri 10/26/12
121	Lay Roof Truss Metal Deck - Arena High Roof West (GL x10- x4.5)	10 days	Wed 10/31/12	Tue 11/13/12
122	FRP Slab on Metal Deck - Arena Main Conc NW #6	3 days	Thu 8/23/12	Mon 8/27/12
123	FRP Slab on Metal Deck - Arena Main Conc NW #7A (Lower)	3 days	Mon 9/10/12	Wed 9/12/12
124	FRP Slab on Metal Deck - Arena Main Conc NW #7	5 days	Thu 9/13/12	Wed 9/19/12
125	FRP Slab on Metal Deck - Arena Mech Court NW	5 days	Mon 9/24/12	Fri 9/28/12
126	FRP Slab on Metal Deck - Arena Club Lbl NW #6	5 days	Mon 10/1/12	Fri 10/5/12
127	FRP Slab on Metal Deck - Arena Main Conc SW #8	5 days	Mon 10/8/12	Fri 10/12/12
128	FRP Slab on Metal Deck - Arena Club Lvl NW #7	3 days	Mon 10/15/12	Wed 10/17/12
129	FRP Slab on Metal Deck - Arena Main Conc SW #9	4 days	Thu 10/18/12	Tue 10/23/12
130	FRP Slab on Metal Deck - Arena Club Lbl SW #8	4 days	Tue 10/30/12	Fri 11/2/12
131	FRP Slab on Metal Deck - Arena Main Conc SW #10	3 days	Mon 11/5/12	Wed 11/7/12
132	FRP Slab on Metal Deck - Arena Club Lvl SW #9	4 days	Thu 11/8/12	Tue 11/13/12
133	FRP Slab on Metal Deck - Arena Club Lvl SW #10	4 days	Wed 10/24/12	Mon 10/29/12

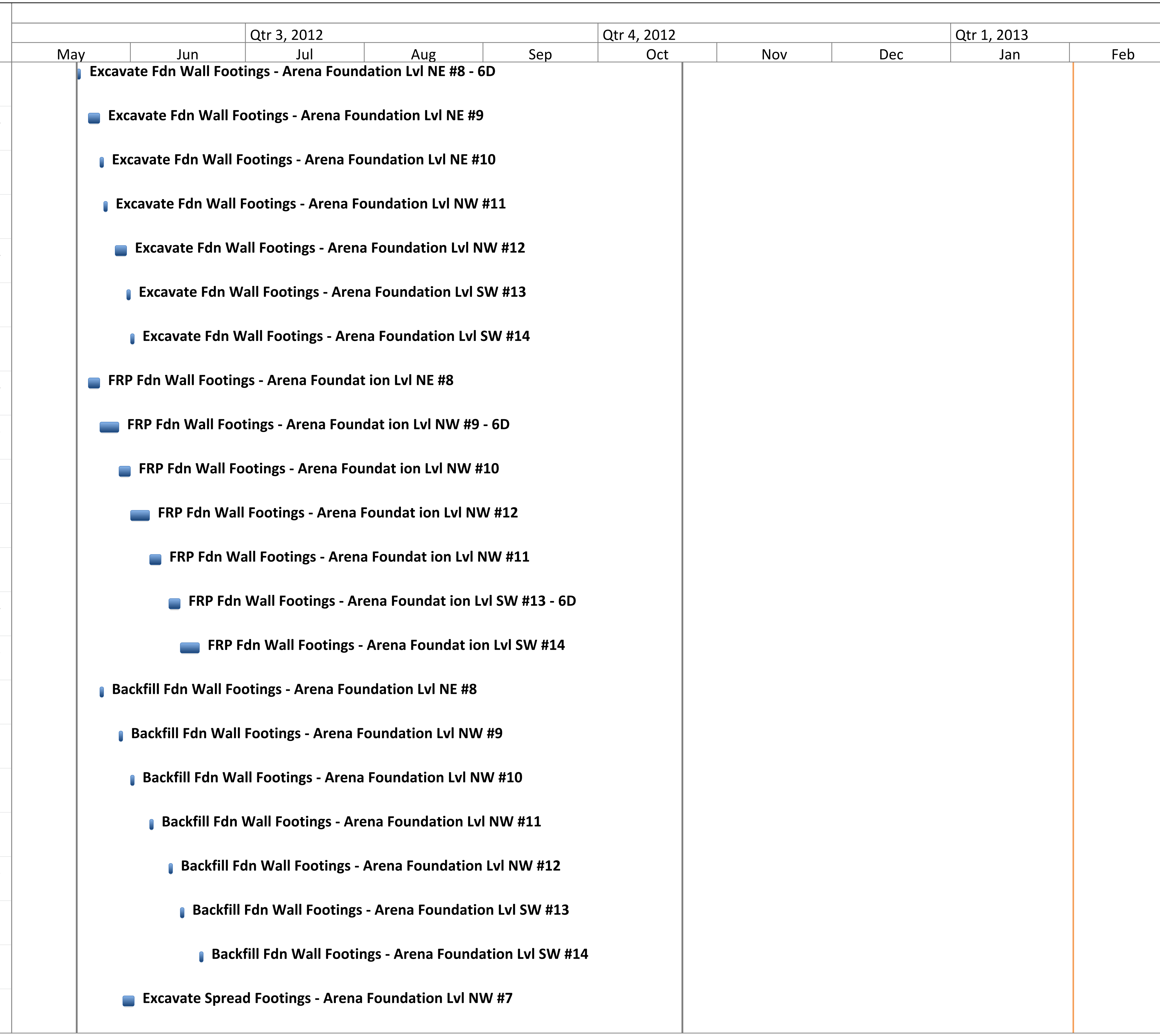


Comm Rink Sched
Date: Sat 3/16/13

Task — Milestone ◆ — Critical

Appendix I: Analysis 1| New Community Rink Detailed Schedule

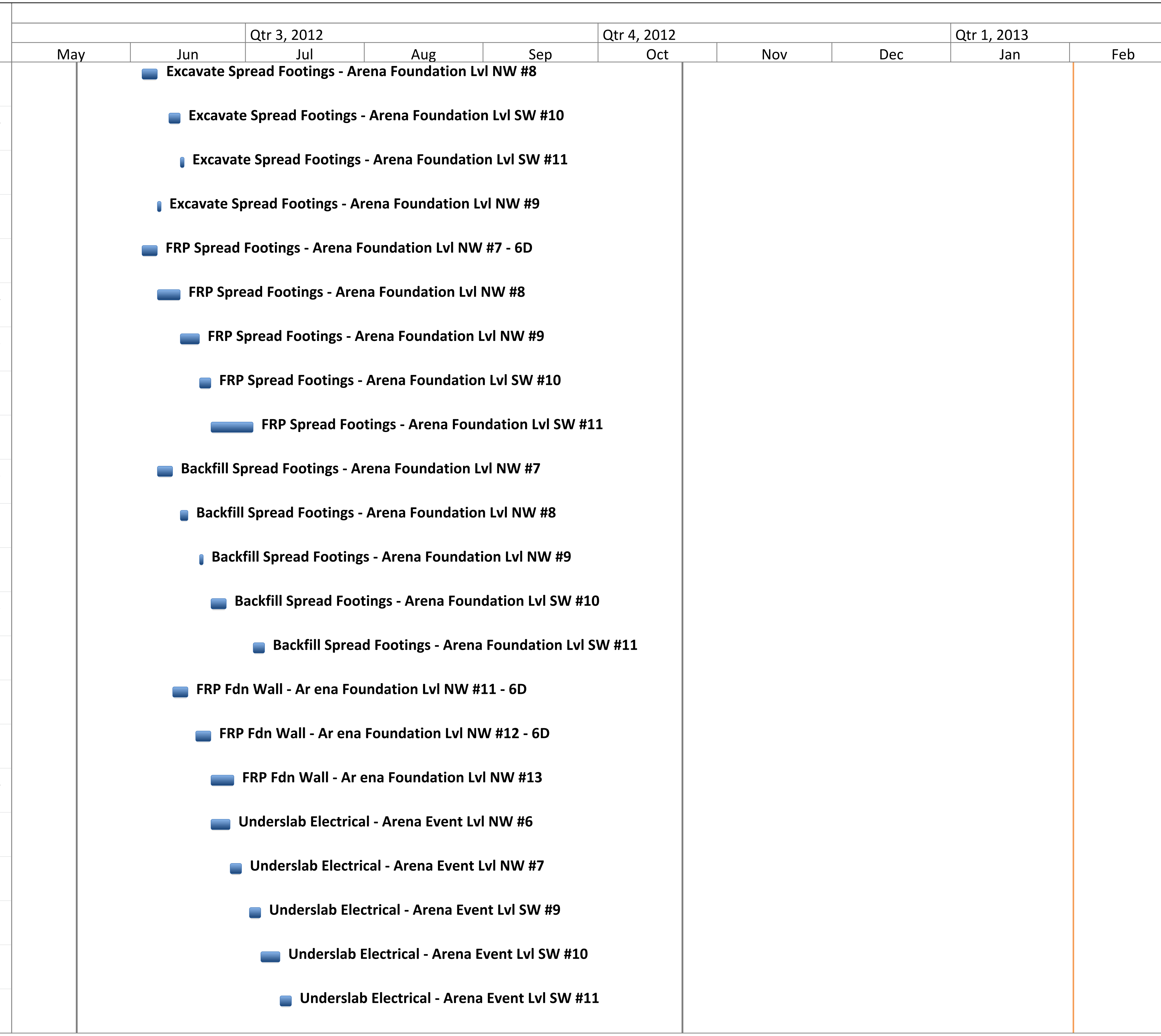
ID		Task Name	Duration	Start	Finish
1	✓	Excavate Fdn Wall Footings - Arena Foundation Lvl NE #8 - 6D	1 day	Fri 5/18/12	Fri 5/18/12
2		Excavate Fdn Wall Footings - Arena Foundation Lvl NE #9	3 days	Mon 5/21/12	Wed 5/23/12
3		Excavate Fdn Wall Footings - Arena Foundation Lvl NE #10	1 day	Thu 5/24/12	Thu 5/24/12
4		Excavate Fdn Wall Footings - Arena Foundation Lvl NW #11	1 day	Fri 5/25/12	Fri 5/25/12
5		Excavate Fdn Wall Footings - Arena Foundation Lvl NW #12	3 days	Mon 5/28/12	Wed 5/30/12
6		Excavate Fdn Wall Footings - Arena Foundation Lvl SW #13	1 day	Thu 5/31/12	Thu 5/31/12
7		Excavate Fdn Wall Footings - Arena Foundation Lvl SW #14	1 day	Fri 6/1/12	Fri 6/1/12
8		FRP Fdn Wall Footings - Arena Foundat ion Lvl NE #8	3 days	Mon 5/21/12	Wed 5/23/12
9		FRP Fdn Wall Footings - Arena Foundat ion Lvl NW #9 - 6D	3 days	Thu 5/24/12	Mon 5/28/12
10		FRP Fdn Wall Footings - Arena Foundat ion Lvl NW #10	3 days	Tue 5/29/12	Thu 5/31/12
11		FRP Fdn Wall Footings - Arena Foundat ion Lvl NW #12	3 days	Fri 6/1/12	Tue 6/5/12
12		FRP Fdn Wall Footings - Arena Foundat ion Lvl NW #11	3 days	Wed 6/6/12	Fri 6/8/12
13		FRP Fdn Wall Footings - Arena Foundat ion Lvl SW #13 - 6D	3 days	Mon 6/11/12	Wed 6/13/12
14		FRP Fdn Wall Footings - Arena Foundat ion Lvl SW #14	3 days	Thu 6/14/12	Mon 6/18/12
15		Backfill Fdn Wall Footings - Arena Foundation Lvl NE #8	1 day	Thu 5/24/12	Thu 5/24/12
16		Backfill Fdn Wall Footings - Arena Foundation Lvl NW #9	1 day	Tue 5/29/12	Tue 5/29/12
17		Backfill Fdn Wall Footings - Arena Foundation Lvl NW #10	1 day	Fri 6/1/12	Fri 6/1/12
18		Backfill Fdn Wall Footings - Arena Foundation Lvl NW #11	1 day	Wed 6/6/12	Wed 6/6/12
19		Backfill Fdn Wall Footings - Arena Foundation Lvl NW #12	1 day	Mon 6/11/12	Mon 6/11/12
20		Backfill Fdn Wall Footings - Arena Foundation Lvl SW #13	1 day	Thu 6/14/12	Thu 6/14/12
21		Backfill Fdn Wall Footings - Arena Foundation Lvl SW #14	1 day	Tue 6/19/12	Tue 6/19/12
22		Excavate Spread Footings - Arena Foundation Lvl NW #7	3 days	Wed 5/30/12	Fri 6/1/12



Project: Pegula Ice Arena (Community Rink)
Date: February 2nd, 2013

Task	(bar)	Crane Driven Activities	Community Rink Activities After Main Crane Finishes
Milestone	◆	Community Rink Activities Before Crane Required	

ID		Task Name	Duration	Start	Finish
23		Excavate Spread Footings - Arena Foundation Lvl NW #8	4 days	Mon 6/4/12	Thu 6/7/12
24		Excavate Spread Footings - Arena Foundation Lvl SW #10	3 days	Mon 6/11/12	Wed 6/13/12
25		Excavate Spread Footings - Arena Foundation Lvl SW #11	1 day	Thu 6/14/12	Thu 6/14/12
26		Excavate Spread Footings - Arena Foundation Lvl NW #9	1 day	Fri 6/8/12	Fri 6/8/12
27		FRP Spread Footings - Arena Foundation Lvl NW #7 - 6D	4 days	Mon 6/4/12	Thu 6/7/12
28		FRP Spread Footings - Arena Foundation Lvl NW #8	4 days	Fri 6/8/12	Wed 6/13/12
29		FRP Spread Footings - Arena Foundation Lvl NW #9	3 days	Thu 6/14/12	Mon 6/18/12
30		FRP Spread Footings - Arena Foundation Lvl SW #10	3 days	Tue 6/19/12	Thu 6/21/12
31		FRP Spread Footings - Arena Foundation Lvl SW #11	7 days	Fri 6/22/12	Mon 7/2/12
32		Backfill Spread Footings - Arena Foundation Lvl NW #7	2 days	Fri 6/8/12	Mon 6/11/12
33		Backfill Spread Footings - Arena Foundation Lvl NW #8	2 days	Thu 6/14/12	Fri 6/15/12
34		Backfill Spread Footings - Arena Foundation Lvl NW #9	1 day	Tue 6/19/12	Tue 6/19/12
35		Backfill Spread Footings - Arena Foundation Lvl SW #10	2 days	Fri 6/22/12	Mon 6/25/12
36		Backfill Spread Footings - Arena Foundation Lvl SW #11	3 days	Tue 7/3/12	Thu 7/5/12
37		FRP Fdn Wall - Ar ena Foundation Lvl NW #11 - 6D	4 days	Tue 6/12/12	Fri 6/15/12
38		FRP Fdn Wall - Ar ena Foundation Lvl NW #12 - 6D	4 days	Mon 6/18/12	Thu 6/21/12
39		FRP Fdn Wall - Ar ena Foundation Lvl NW #13	4 days	Fri 6/22/12	Wed 6/27/12
40		Underslab Electrical - Arena Event Lvl NW #6	3 days	Fri 6/22/12	Tue 6/26/12
41		Underslab Electrical - Arena Event Lvl NW #7	3 days	Wed 6/27/12	Fri 6/29/12
42		Underslab Electrical - Arena Event Lvl SW #9	3 days	Mon 7/2/12	Wed 7/4/12
43		Underslab Electrical - Arena Event Lvl SW #10	3 days	Thu 7/5/12	Mon 7/9/12
44		Underslab Electrical - Arena Event Lvl SW #11	3 days	Tue 7/10/12	Thu 7/12/12

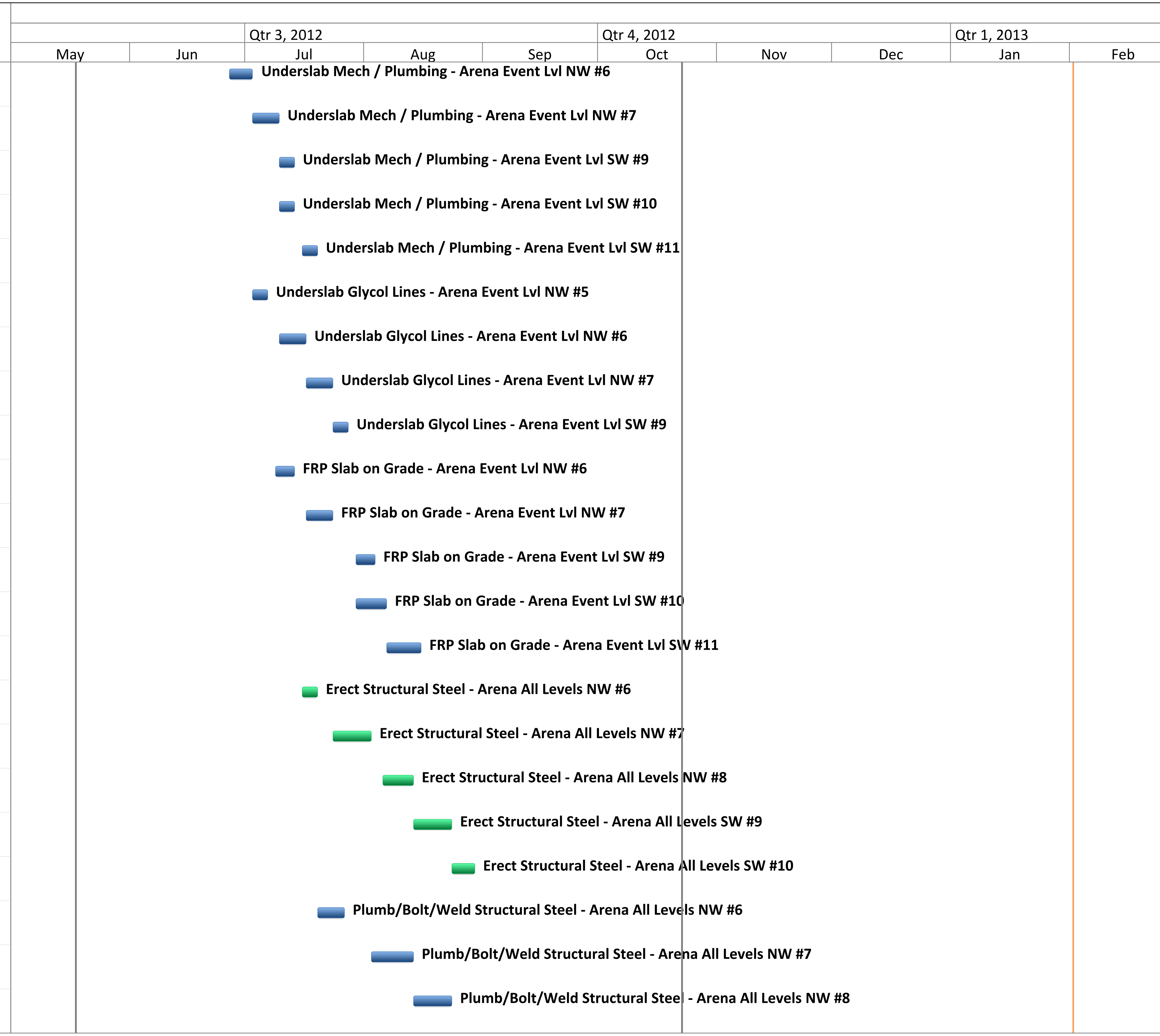


Project: Pegula Ice Arena
(Community Rink)
Date: February 2nd, 2013

Task — Crane Driven Activities — Community Rink Activities After Main Crane Finishes

Milestone — Community Rink Activities Before Crane Required

ID		Task Name	Duration	Start	Finish
45		Underslab Mech / Plumbing - Arena Event Lvl NW #6	4 days	Wed 6/27/12	Mon 7/2/12
46		Underslab Mech / Plumbing - Arena Event Lvl NW #7	5 days	Tue 7/3/12	Mon 7/9/12
47		Underslab Mech / Plumbing - Arena Event Lvl SW #9	4 days	Tue 7/10/12	Fri 7/13/12
48		Underslab Mech / Plumbing - Arena Event Lvl SW #10	4 days	Tue 7/10/12	Fri 7/13/12
49		Underslab Mech / Plumbing - Arena Event Lvl SW #11	4 days	Mon 7/16/12	Thu 7/19/12
50		Underslab Glycol Lines - Arena Event Lvl NW #5	4 days	Tue 7/3/12	Fri 7/6/12
51		Underslab Glycol Lines - Arena Event Lvl NW #6	5 days	Tue 7/10/12	Mon 7/16/12
52		Underslab Glycol Lines - Arena Event Lvl NW #7	5 days	Tue 7/17/12	Mon 7/23/12
53		Underslab Glycol Lines - Arena Event Lvl SW #9	4 days	Tue 7/24/12	Fri 7/27/12
54		FRP Slab on Grade - Arena Event Lvl NW #6	5 days	Mon 7/9/12	Fri 7/13/12
55		FRP Slab on Grade - Arena Event Lvl NW #7	5 days	Tue 7/17/12	Mon 7/23/12
56		FRP Slab on Grade - Arena Event Lvl SW #9	5 days	Mon 7/30/12	Fri 8/3/12
57		FRP Slab on Grade - Arena Event Lvl SW #10	6 days	Mon 7/30/12	Mon 8/6/12
58		FRP Slab on Grade - Arena Event Lvl SW #11	7 days	Tue 8/7/12	Wed 8/15/12
59		Erect Structural Steel - Arena All Levels NW #6	4 days	Mon 7/16/12	Thu 7/19/12
60		Erect Structural Steel - Arena All Levels NW #7	8 days	Tue 7/24/12	Thu 8/2/12
61		Erect Structural Steel - Arena All Levels NW #8	6 days	Mon 8/6/12	Mon 8/13/12
62		Erect Structural Steel - Arena All Levels SW #9	8 days	Tue 8/14/12	Thu 8/23/12
63		Erect Structural Steel - Arena All Levels SW #10	4 days	Fri 8/24/12	Wed 8/29/12
64		Plumb/Bolt/Weld Structural Steel - Arena All Levels NW #6	5 days	Fri 7/20/12	Thu 7/26/12
65		Plumb/Bolt/Weld Structural Steel - Arena All Levels NW #7	7 days	Fri 8/3/12	Mon 8/13/12
66		Plumb/Bolt/Weld Structural Steel - Arena All Levels NW #8	8 days	Tue 8/14/12	Thu 8/23/12

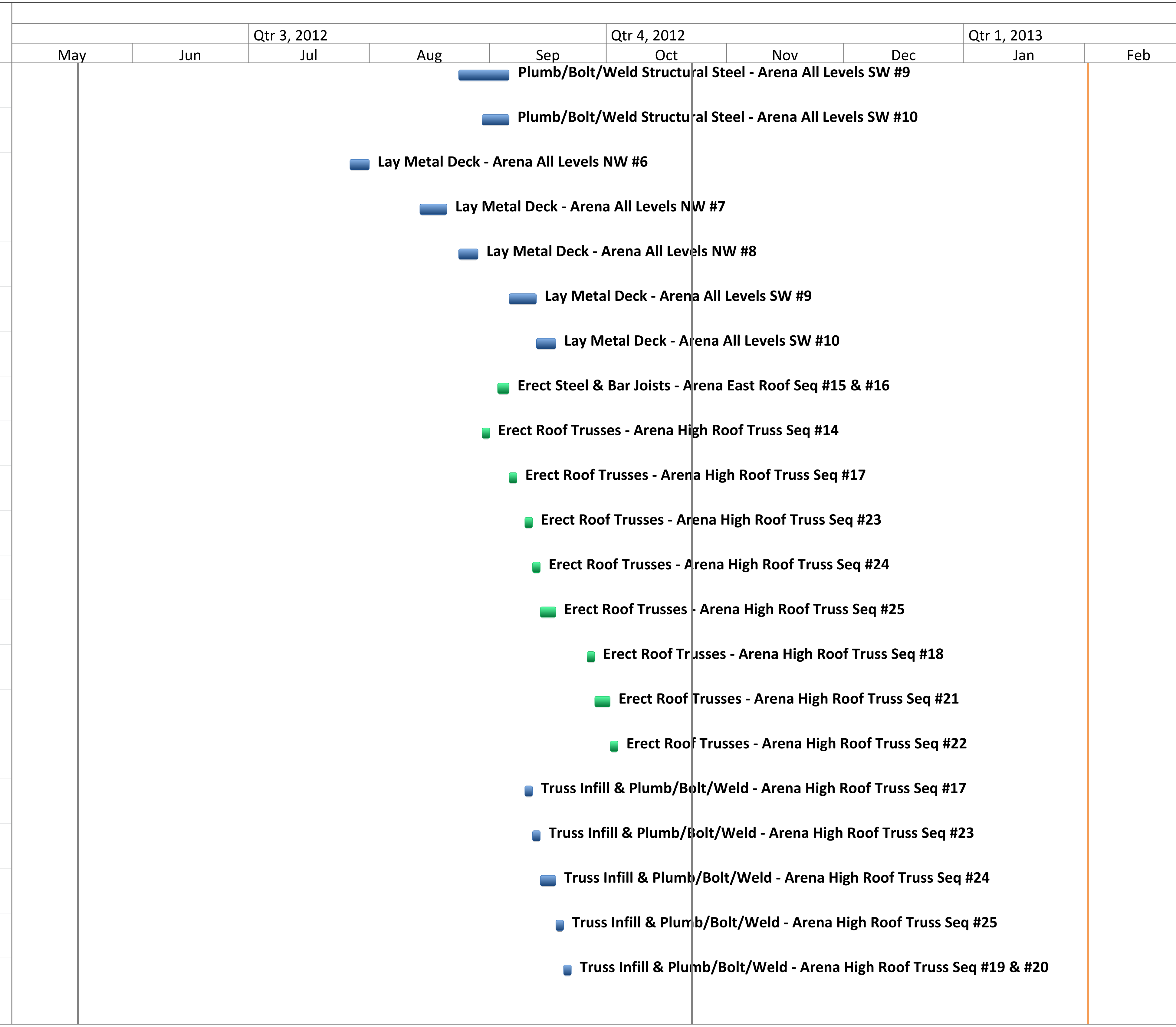


Project: Pegula Ice Arena (Community Rink)
Date: February 2nd, 2013

Task		Crane Driven Activities	
Milestone	◆	Community Rink Activities Before Crane Required	

Community Rink Activities After Main Crane Finishes

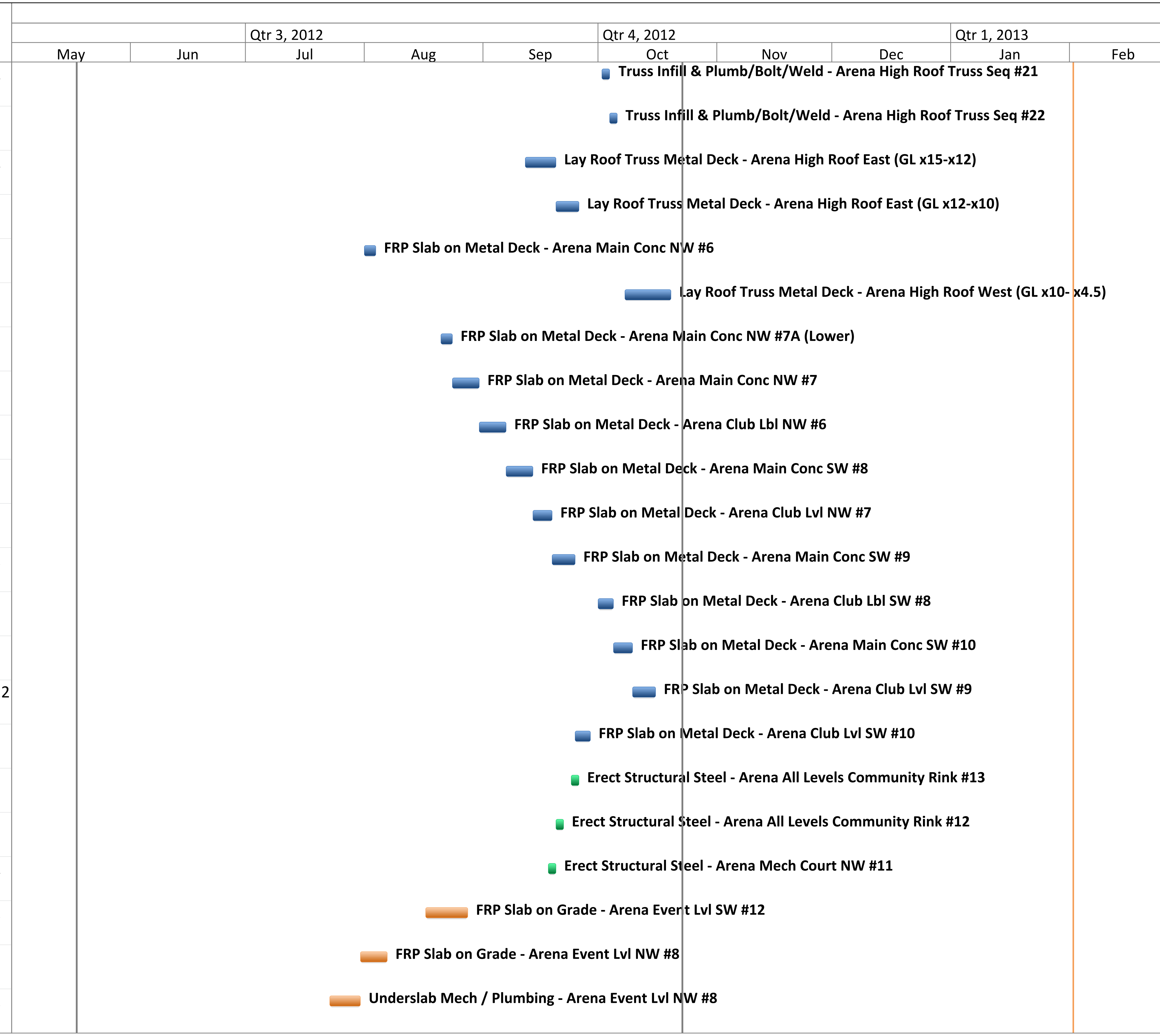
ID		Task Name	Duration	Start	Finish
67		Plumb/Bolt/Weld Structural Steel - Arena All Levels SW #9	9 days	Fri 8/24/12	Wed 9/5/12
68		Plumb/Bolt/Weld Structural Steel - Arena All Levels SW #10	5 days	Thu 8/30/12	Wed 9/5/12
69		Lay Metal Deck - Arena All Levels NW #6	3 days	Fri 7/27/12	Tue 7/31/12
70		Lay Metal Deck - Arena All Levels NW #7	5 days	Tue 8/14/12	Mon 8/20/12
71		Lay Metal Deck - Arena All Levels NW #8	3 days	Fri 8/24/12	Tue 8/28/12
72		Lay Metal Deck - Arena All Levels SW #9	5 days	Thu 9/6/12	Wed 9/12/12
73		Lay Metal Deck - Arena All Levels SW #10	3 days	Thu 9/13/12	Mon 9/17/12
74		Erect Steel & Bar Joists - Arena East Roof Seq #15 & #16	3 days	Mon 9/3/12	Wed 9/5/12
75		Erect Roof Trusses - Arena High Roof Truss Seq #14	2 days	Thu 8/30/12	Fri 8/31/12
76		Erect Roof Trusses - Arena High Roof Truss Seq #17	2 days	Thu 9/6/12	Fri 9/7/12
77		Erect Roof Trusses - Arena High Roof Truss Seq #23	2 days	Mon 9/10/12	Tue 9/11/12
78		Erect Roof Trusses - Arena High Roof Truss Seq #24	2 days	Wed 9/12/12	Thu 9/13/12
79		Erect Roof Trusses - Arena High Roof Truss Seq #25	2 days	Fri 9/14/12	Mon 9/17/12
80		Erect Roof Trusses - Arena High Roof Truss Seq #18	2 days	Wed 9/26/12	Thu 9/27/12
81		Erect Roof Trusses - Arena High Roof Truss Seq #21	2 days	Fri 9/28/12	Mon 10/1/12
82		Erect Roof Trusses - Arena High Roof Truss Seq #22	2 days	Tue 10/2/12	Wed 10/3/12
83		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #17	2 days	Mon 9/10/12	Tue 9/11/12
84		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #23	2 days	Wed 9/12/12	Thu 9/13/12
85		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #24	2 days	Fri 9/14/12	Mon 9/17/12
86		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #25	2 days	Tue 9/18/12	Wed 9/19/12
87		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #19 & #20	2 days	Thu 9/20/12	Fri 9/21/12



Project: Pegula Ice Arena
(Community Rink)
Date: February 2nd, 2013

Task | Crane Driven Activities | Community Rink Activities After Main Crane Finishes
Milestone | Community Rink Activities Before Crane Required

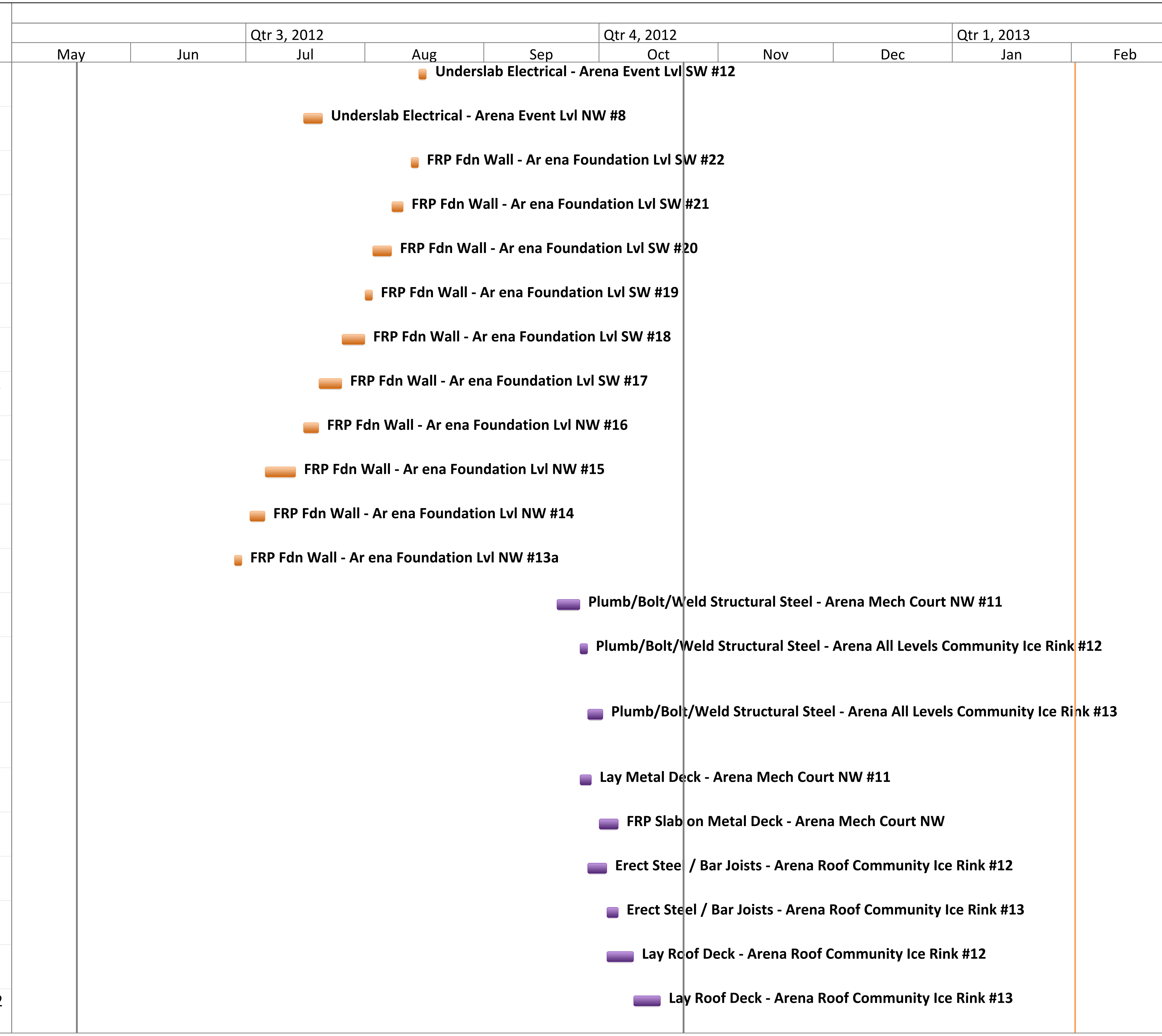
ID		Task Name	Duration	Start	Finish
88		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #21	2 days	Tue 10/2/12	Wed 10/3/12
89		Truss Infill & Plumb/Bolt/Weld - Arena High Roof Truss Seq #22	2 days	Thu 10/4/12	Fri 10/5/12
90		Lay Roof Truss Metal Deck - Arena High Roof East (GL x15-x12)	6 days	Wed 9/12/12	Wed 9/19/12
91		Lay Roof Truss Metal Deck - Arena High Roof East (GL x12-x10)	4 days	Thu 9/20/12	Tue 9/25/12
92		FRP Slab on Metal Deck - Arena Main Conc NW #6	3 days	Wed 8/1/12	Fri 8/3/12
93		Lay Roof Truss Metal Deck - Arena High Roof West (GL x10- x4.5)	10 days	Mon 10/8/12	Fri 10/19/12
94		FRP Slab on Metal Deck - Arena Main Conc NW #7A (Lower)	3 days	Tue 8/21/12	Thu 8/23/12
95		FRP Slab on Metal Deck - Arena Main Conc NW #7	5 days	Fri 8/24/12	Thu 8/30/12
96		FRP Slab on Metal Deck - Arena Club Lbl NW #6	5 days	Fri 8/31/12	Thu 9/6/12
97		FRP Slab on Metal Deck - Arena Main Conc SW #8	5 days	Fri 9/7/12	Thu 9/13/12
98		FRP Slab on Metal Deck - Arena Club Lvl NW #7	3 days	Fri 9/14/12	Tue 9/18/12
99		FRP Slab on Metal Deck - Arena Main Conc SW #9	4 days	Wed 9/19/12	Mon 9/24/12
100		FRP Slab on Metal Deck - Arena Club Lbl SW #8	4 days	Mon 10/1/12	Thu 10/4/12
101		FRP Slab on Metal Deck - Arena Main Conc SW #10	3 days	Fri 10/5/12	Tue 10/9/12
102		FRP Slab on Metal Deck - Arena Club Lvl SW #9	4 days	Wed 10/10/12	Mon 10/15/12
103		FRP Slab on Metal Deck - Arena Club Lvl SW #10	4 days	Tue 9/25/12	Fri 9/28/12
104		Erect Structural Steel - Arena All Levels Community Rink #13	2 days	Mon 9/24/12	Tue 9/25/12
105		Erect Structural Steel - Arena All Levels Community Rink #12	2 days	Thu 9/20/12	Fri 9/21/12
106		Erect Structural Steel - Arena Mech Court NW #11	2 days	Tue 9/18/12	Wed 9/19/12
107		FRP Slab on Grade - Arena Event Lvl SW #12	7 days	Fri 8/17/12	Mon 8/27/12
108		FRP Slab on Grade - Arena Event Lvl NW #8	5 days	Tue 7/31/12	Mon 8/6/12
109		Underslab Mech / Plumbing - Arena Event Lvl NW #8	6 days	Mon 7/23/12	Mon 7/30/12



Project: Pegula Ice Arena
(Community Rink)
Date: February 2nd, 2013

Task — Crane Driven Activities — Community Rink Activities After Main Crane Finishes
Milestone — Community Rink Activities Before Crane Required

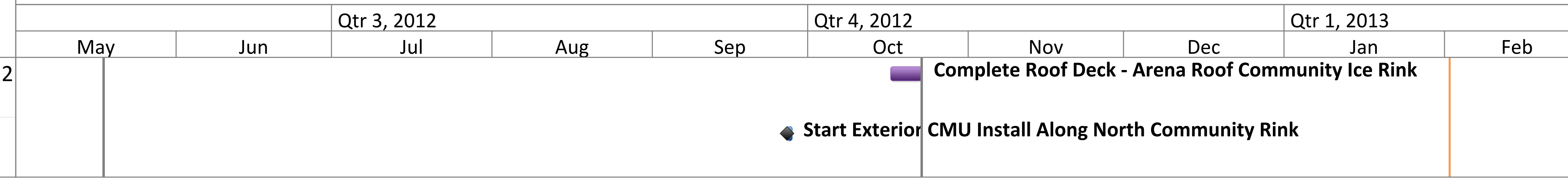
ID	Task Name	Duration	Start	Finish
110	Underslab Electrical - Arena Event Lvl SW #12	2 days	Wed 8/15/12	Thu 8/16/12
111	Underslab Electrical - Arena Event Lvl NW #8	5 days	Mon 7/16/12	Fri 7/20/12
112	FRP Fdn Wall - Ar ena Foundation Lvl SW #22	2 days	Mon 8/13/12	Tue 8/14/12
113	FRP Fdn Wall - Ar ena Foundation Lvl SW #21	3 days	Wed 8/8/12	Fri 8/10/12
114	FRP Fdn Wall - Ar ena Foundation Lvl SW #20	3 days	Fri 8/3/12	Tue 8/7/12
115	FRP Fdn Wall - Ar ena Foundation Lvl SW #19	2 days	Wed 8/1/12	Thu 8/2/12
116	FRP Fdn Wall - Ar ena Foundation Lvl SW #18	4 days	Thu 7/26/12	Tue 7/31/12
117	FRP Fdn Wall - Ar ena Foundation Lvl SW #17	4 days	Fri 7/20/12	Wed 7/25/12
118	FRP Fdn Wall - Ar ena Foundation Lvl NW #16	4 days	Mon 7/16/12	Thu 7/19/12
119	FRP Fdn Wall - Ar ena Foundation Lvl NW #15	6 days	Fri 7/6/12	Fri 7/13/12
120	FRP Fdn Wall - Ar ena Foundation Lvl NW #14	4 days	Mon 7/2/12	Thu 7/5/12
121	FRP Fdn Wall - Ar ena Foundation Lvl NW #13a	2 days	Thu 6/28/12	Fri 6/29/12
122	Plumb/Bolt/Weld Structural Steel - Arena Mech Court NW #11	4 days	Thu 9/20/12	Tue 9/25/12
123	Plumb/Bolt/Weld Structural Steel - Arena All Levels Community Ice Rink #12	2 days	Wed 9/26/12	Thu 9/27/12
124	Plumb/Bolt/Weld Structural Steel - Arena All Levels Community Ice Rink #13	2 days	Fri 9/28/12	Mon 10/1/12
125	Lay Metal Deck - Arena Mech Court NW #11	3 days	Wed 9/26/12	Fri 9/28/12
126	FRP Slab on Metal Deck - Arena Mech Court NW	5 days	Mon 10/1/12	Fri 10/5/12
127	Erect Steel / Bar Joists - Arena Roof Community Ice Rink #12	3 days	Fri 9/28/12	Tue 10/2/12
128	Erect Steel / Bar Joists - Arena Roof Community Ice Rink #13	3 days	Wed 10/3/12	Fri 10/5/12
129	Lay Roof Deck - Arena Roof Community Ice Rink #12	5 days	Wed 10/3/12	Tue 10/9/12
130	Lay Roof Deck - Arena Roof Community Ice Rink #13	5 days	Wed 10/10/12	Tue 10/16/12



Project: Pegula Ice Arena (Community Rink)
Date: February 2nd, 2013

Task — Crane Driven Activities — Community Rink Activities After Main Crane Finishes
Milestone — Community Rink Activities Before Crane Required

ID		Task Name	Duration	Start	Finish
131		Complete Roof Deck - Arena Roof Community Ice Rink	4 days	Wed 10/17/12	Mon 10/22/12
132		Start Exterior CMU Install Along North Community Rink	1 day	Thu 9/27/12	Thu 9/27/12

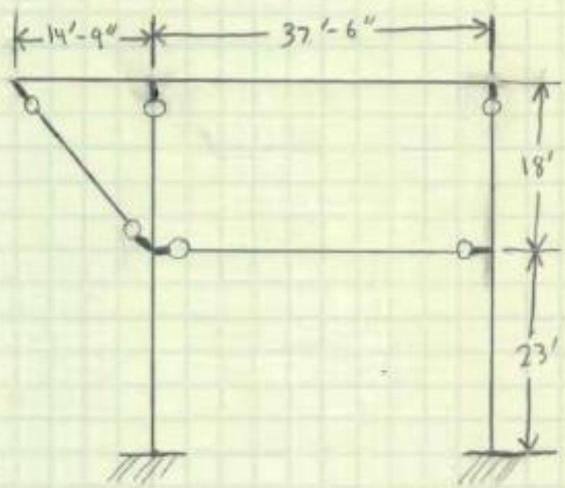


Project: Pegula Ice Arena
(Community Rink)
Date: February 2nd, 2013

Task — Crane Driven Activities — Community Rink Activities After Main Crane Finishes
Milestone ◆ — Community Rink Activities Before Crane Required

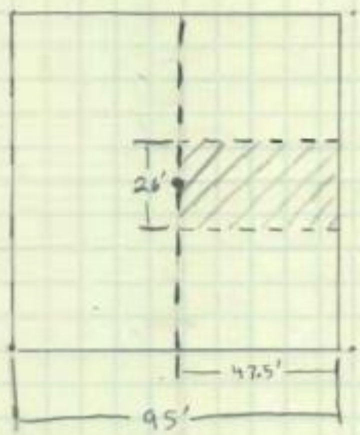
Appendix J: Structural Breadth Calculations

Model in Staad



Community Rink Roof

Insulation = 2 pcf ≈ 5" insul. ≈ 0.83 lb/ft²
TPO = 0.256 lb/ft²
3VLI19 roof deck = 2.5 psf
} 3.6 psf



DL = 3.6 psf + 5 psf (beam self weight) = 8.6 psf

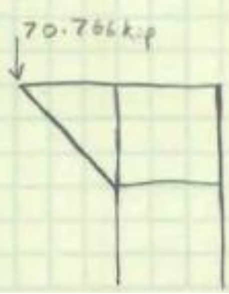
LL = 20 psf (roof)

SL = 30 psf

$w_u = 1.2DL + 1.6LL + 0.5SL$

$w_u = 1.2(8.6) + 1.6(20) + 0.5(30) = 57.3$ psf

Point Load = 57.3 psf × (47.5 ft × 26 ft) = 70.766 kip



Mechanical Units & Concrete Deck (Cantilevered Section)

Mechanical Unit Weight = 18,500 lbs

Concrete Deck & Slab (3VLI19: Sheet Attached) = 75psf

DL =

Mechanical Units cover two spans : 18,500/2 = 9,250 lbs (cont.)

9,250 lbs / (14'-9" x 26') = 24.2psf

Beam Self weight = 10psf

SDMD (3VLI19) = 75psf

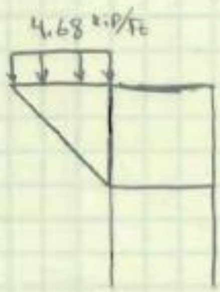
LL = 20 psf (roof)

SL = 30 psf

$w_u = 1.2D + 1.6L + 0.5S$

$w_u = 1.2(24.2 + 10 + 75) + 1.6(20) + 0.5(30) = 180psf$

180psf x 26' = 4.68 kip/ft



Mechanical Units + Concrete Deck (east half)

* Much information similar to cantilevered section.

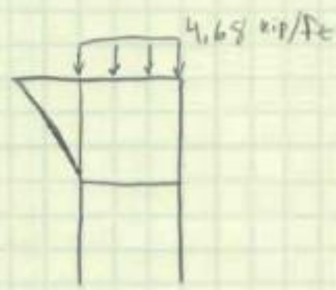
DL = 24.2 psf (Mechanical Units)
75 psf (3VLI19)
10 psf (beam self weight)

LL = 20 psf (roof)

SL = 30 psf

$w_u = 1.2(24.2 + 75 + 10) + 1.6(20) + 0.5(30) = 180 psf$

$180 psf \times 26' = 4.68 kip/ft$



Corridor Loads (Main Concourse)

DL = 75 psf (SOMD)

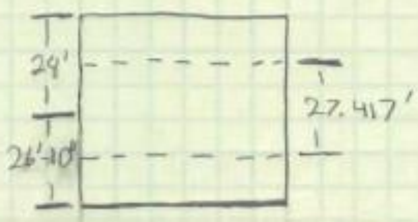
10 psf (beam self weight)

LL = 100 psf (corridor)

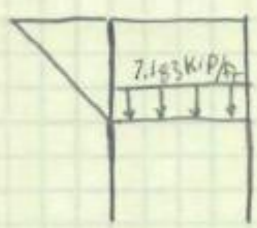
$w_u = 1.2DL + 1.6LL$

$w_u = 1.2(75 + 10) + 1.6(100) = 262$ psf

Worst case scenario



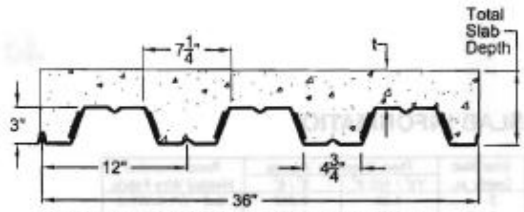
262 psf × 27.417' = 7.183 kip/ft



VULCRAFT

3 VLI

Maximum Sheet Length 42'-0
Extra Charge for Lengths Under 6'-0
ICBO Approved (No. 3415)



Interlocking side lap is not drawn to show actual detail.

STEEL SECTION PROPERTIES

Deck Type	Design Thickness in	Deck Weight psf	Section Properties I_p in^4/ft	S_p in^3/ft	I_n in^4/ft	S_n in^3/ft	V_a lbs/ft	F_y ksi
3VLI22	0.0295	1.77	0.730	0.414	0.729	0.426	1528	50
3VLI20	0.0358	2.14	0.920	0.534	0.919	0.551	2698	50
3VLI19	0.0418	2.50	1.104	0.654	1.102	0.676	3678	50
3VLI18	0.0474	2.84	1.254	0.770	1.252	0.797	4729	50
3VLI16	0.0598	3.58	1.580	1.013	1.580	1.013	5309	40

(N=9.35) NORMAL WEIGHT CONCRETE (145 PCF)

TOTAL SLAB DEPTH	DECK TYPE	SDI Max. Unshored Clear Span 1 SPAN	2 SPAN	3 SPAN	Superimposed Live Load, PSF Clear Span (ft.-in.) 7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0	12'-6	13'-0	13'-6	14'-0
	3VLI22	9'-2	10'-7	11'-8	216	195	176	161	148	109	99	90	83	76	70	64	59	54	50
5.00	3VLI20	10'-8	12'-11	13'-4	241	216	196	178	163	150	139	129	93	85	78	72	66	61	57
(t=2.00)	3VLI19	12'-0	14'-4	14'-7	265	237	214	194	178	163	151	140	131	122	115	79	73	67	62
45 PSF	3VLI18	12'-10	15'-1	15'-1	289	261	238	218	201	186	173	161	151	142	134	127	92	86	80
	3VLI16	13'-5	15'-7	15'-11	327	294	267	243	223	206	191	178	167	156	147	139	132	96	89
	3VLI22	8'-9	9'-8	10'-11	247	222	201	184	137	124	113	103	94	87	80	73	67	62	57
5.50	3VLI20	10'-1	12'-4	12'-9	275	247	223	203	186	171	159	116	106	97	89	82	76	70	65
(t=2.50)	3VLI19	11'-4	13'-8	14'-2	302	270	244	222	203	186	172	160	149	107	98	90	83	77	71
51 PSF	3VLI18	12'-5	14'-7	14'-7	330	298	271	248	229	212	197	184	173	162	153	112	105	98	92
	3VLI16	12'-9	14'-11	15'-6	373	336	304	277	255	235	218	203	190	178	168	159	117	109	102
	3VLI22	8'-4	8'-10	10'-1	277	249	226	171	154	140	127	116	106	97	89	82	76	70	65
6.00	3VLI20	9'-8	11'-10	12'-3	309	277	250	228	209	193	143	130	119	109	100	92	85	79	73
(t=3.00)	3VLI19	10'-10	13'-2	13'-7	339	304	274	249	227	209	193	179	131	120	110	102	94	87	80
57 PSF	3VLI18	11'-10	14'-2	14'-2	370	334	304	279	257	238	221	207	194	182	136	126	118	110	103
	3VLI16	12'-2	14'-4	14'-10	400	376	341	311	286	264	245	228	213	200	189	141	132	123	115
	3VLI22	8'-0	8'-3	9'-4	307	277	251	190	171	155	141	129	118	108	99	91	84	78	72
6.50	3VLI20	9'-3	11'-5	11'-9	343	307	278	253	232	174	158	144	132	121	111	103	95	87	81
(t=3.50)	3VLI19	10'-4	12'-8	13'-1	377	337	304	276	252	232	214	159	146	134	123	113	104	96	89
63 PSF	3VLI18	11'-4	13'-9	13'-10	400	371	338	309	285	264	246	229	215	162	151	140	131	122	115
	3VLI16	11'-7	13'-10	14'-3	400	400	378	345	317	293	272	253	237	222	169	157	146	136	128
	3VLI22	7'-9	7'-8	8'-8	338	304	233	209	188	171	155	142	130	119	109	101	93	86	79
7.00	3VLI20	9'-0	10'-11	11'-4	377	338	305	278	255	192	174	159	145	133	122	113	104	96	89
(t=4.00)	3VLI19	10'-1	12'-3	12'-7	400	370	334	303	277	255	236	175	160	147	135	124	115	106	98
69 PSF	3VLI18	11'-0	13'-3	13'-6	400	400	371	340	313	290	270	252	236	178	166	154	144	135	126
	3VLI16	11'-4	13'-4	13'-9	400	400	400	379	348	322	298	278	260	200	186	172	161	150	140
	3VLI22	7'-7	7'-2	8'-2	368	331	254	228	205	186	169	154	141	130	119	110	101	93	86
7.50	3VLI20	8'-9	10'-2	11'-0	400	368	333	303	231	209	190	173	158	145	134	123	113	105	97
(t=4.50)	3VLI19	9'-10	11'-10	12'-2	400	400	364	331	302	278	209	191	175	160	147	136	125	116	107
75 PSF	3VLI18	10'-9	12'-10	13'-3	400	400	400	370	341	316	294	275	210	195	181	168	157	147	138
	3VLI16	11'-0	12'-11	13'-4	400	400	400	400	380	351	325	303	283	218	202	188	175	164	153

COMPOSITE

Notes: 1. Minimum exterior bearing length required is 2.50 inches. Minimum interior bearing length required is 5.00 inches. If these minimum lengths are not provided, web crippling must be checked.
2. Always contact Vulcraft when using loads in excess of 200 psf. Such loads often result from concentrated, dynamic, or long term load cases for which reductions due to bond breakage, concrete creep, etc. should be evaluated.
3. All fire rated assemblies are subject to an upper live load limit of 250 psf.

Table 4-1 Minimum Uniformly Distributed Live Loads, L_o, and Minimum Concentrated Live Loads

Occupancy or Use	Uniform psf (kN/m²)	Conc. lb (kN)
Apartments (see Residential)		
Access floor systems		
Office use	50 (2.4)	2,000 (8.9)
Computer use	100 (4.79)	2,000 (8.9)
Armories and drill rooms	150 (7.18)[a]	
Assembly areas and theaters		
Fixed seats (fastened to floor)	60 (2.87)[a]	
Lobbies	100 (4.79)[a]	
Movable seats	100 (4.79)[a]	
Platforms (assembly)	100 (4.79)[a]	
Stage floors	150 (7.18)[a]	
Balconies and decks	1.5 times the live load for the occupancy served. Not required to exceed 100 psf (4.79 kN/m²)	
Catwalks for maintenance access	40 (1.92)	300 (1.33)
Corridors		
First floor	100 (4.79)	
Other floors, same as occupancy served except as indicated		
Dining rooms and restaurants	100 (4.79)[a]	
Dwellings (see Residential)		
Elevator machine room grating (on area of 2 in. by 2 in. (50 mm by 50 mm))		300 (1.33)
Finish light floor plate construction (on area of 1 in. by 1 in. (25 mm by 25 mm))		200 (0.89)
Fire escapes	100 (4.79)	
On single-family dwellings only	40 (1.92)	
Fixed ladders	See Section 4.5	
Garages		
Passenger vehicles only	40 (1.92)[a,b,c]	
Trucks and buses		
Handrails, guardrails, and grab bars	See Section 4.5	
Helipads	60 (2.87)[d,e] Nonreducible	[e,f,g]
Hospitals		
Operating rooms, laboratories	60 (2.87)	1,000 (4.45)
Patient rooms	40 (1.92)	1,000 (4.45)
Corridors above first floor	80 (3.83)	1,000 (4.45)
Hotels (see Residential)		
Libraries		
Reading rooms	60 (2.87)	1,000 (4.45)
Stack rooms	150 (7.18)[a,h]	1,000 (4.45)
Corridors above first floor	80 (3.83)	1,000 (4.45)
Manufacturing		
Light	125 (6.00)[a]	2,000 (8.90)
Heavy	250 (11.97)[a]	3,000 (13.40)

Continued

Table 4-1 *(Continued)*

Occupancy or Use	Uniform psf (kN/m²)	Conc. lb (kN)
Office buildings		
File and computer rooms shall be designed for heavier loads based on anticipated occupancy		
Lobbies and first-floor corridors	100 (4.79)	2,000 (8.90)
Offices	50 (2.40)	2,000 (8.90)
Corridors above first floor	80 (3.83)	2,000 (8.90)
Penal institutions		
Cell blocks	40 (1.92)	
Corridors	100 (4.79)	
Recreational uses		
Bowling alleys, poolrooms, and similar uses	75 (3.59)[a]	
Dance halls and ballrooms	100 (4.79)[a]	
Gymnasiums	100 (4.79)[a]	
Reviewing stands, grandstands, and bleachers	100 (4.79)[a,k]	
Stadiums and arenas with fixed seats (fastened to the floor)	60 (2.87)[a,k]	
Residential		
One- and two-family dwellings		
Uninhabitable attics without storage	10 (0.48)[l]	
Uninhabitable attics with storage	20 (0.96)[m]	
Habitable attics and sleeping areas	30 (1.44)	
All other areas except stairs	40 (1.92)	
All other residential occupancies		
Private rooms and corridors serving them	40 (1.92)	
Public rooms[a] and corridors serving them	100 (4.79)	
Roofs		
Ordinary flat, pitched, and curved roofs	20 (0.96)[n]	
Roofs used for roof gardens	100 (4.79)	
Roofs used for assembly purposes	Same as occupancy served	
Roofs used for other occupancies	[o]	[a]
Awnings and canopies		
Fabric construction supported by a skeleton structure	5 (0.24) nonreducible	300 (1.33) applied to skeleton structure
Screen enclosure support frame	5 (0.24) nonreducible and applied to the roof frame members only, not the screen	200 (0.89) applied to supporting roof frame members only
All other construction	20 (0.96)	
Primary roof members, exposed to a work floor		
Single panel point of lower chord of roof trusses or any point along primary structural members supporting roofs over manufacturing, storage warehouses, and repair garages		2,000 (8.9)
All other primary roof members		300 (1.33)
All roof surfaces subject to maintenance workers		300 (1.33)
Schools		
Classrooms	40 (1.92)	1,000 (4.45)
Corridors above first floor	80 (3.83)	1,000 (4.45)
First-floor corridors	100 (4.79)	1,000 (4.45)
Scuttles, skylight ribs, and accessible ceilings		200 (0.89)
Sidewalks, vehicular driveways, and yards subject to trucking	250 (11.97)[a,p]	8,000 (35.60)[q]
Stairs and exit ways	100 (4.79)	300[r]
One- and two-family dwellings only	40 (1.92)	300[r]

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Appendix K: Structural Breadth Estimates

Original Structural System Estimate

System	Amount	Unit	Material	Labor	Equipment	Total	Total Incl O and P	Cost
W18x35	96	LF	50	4.13	1.74	55.87	64	$ **6,144**
W24x55	86	LF	78.5	3.57	1.5	83.57	94.5	$ **8,127**
W24x84	49	LF	120	3.67	1.55	125.22	140	$ **6,860**
W30x99	74	LF	142	3.3	1.39	146.69	163	$ **12,062**
W35x150	37	LF	193	3.39	1.43	197.82	219	$ **8,103**
W14x90	656	LF	129	3.71	2.06	134.77	151	$ **99,056**

Total: $ 140,352

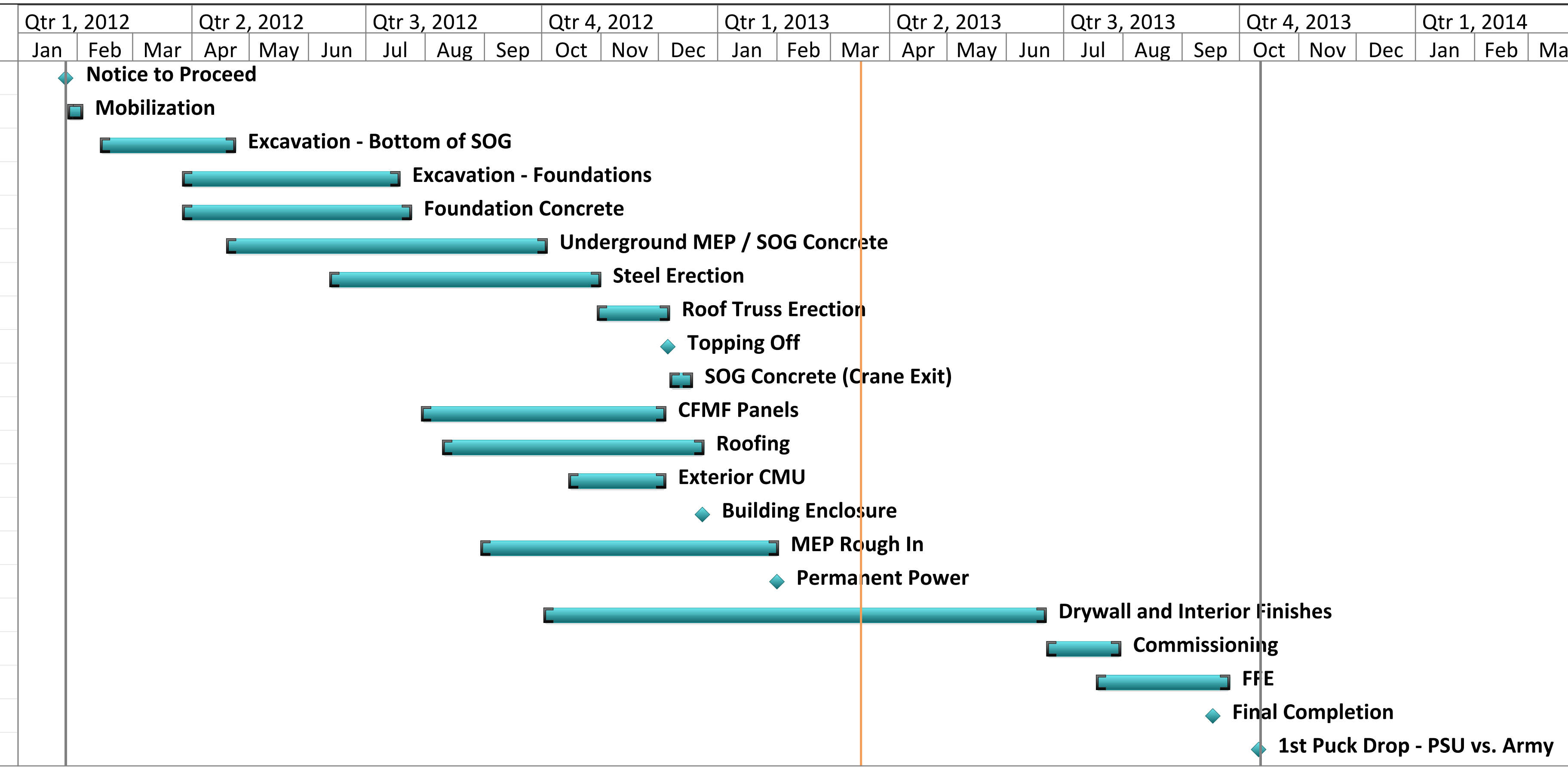
New Structural System Estimate

System	Amount	Unit	Material	Labor	Equipment	Total	Total Incl O and P	Cost
W40x183	597	LF	277	3.52	1.48	282	315	$ **188,055**
W40x235	738	LF	375	3.83	1.61	380.44	420	$ **309,960**
HSS 5x5x5/16	210	LF	29.17	4.25	2.33	35.75	42	$ **8,820**
Additional Connection Beam								
W18x35	190	LF	50	4.13	1.74	55.87	64	$ **12,160**
Deduction for Decreased Joist Length								
68DSHSP	310	LF	-46	-1.8	-0.82	-48.37	-54.5	$ **(16,895)**

Total: $ 502,100

Appendix L: Original Summary Schedule Updated in Conjunction with the most up to date Schedule Provided by Mortenson

ID	Task Name	Duration	Start	Finish	Predecessors
1	Notice to Proceed	0 days	Thu 1/26/12	Thu 1/26/12	
2	Mobilization	6 days	Fri 1/27/12	Fri 2/3/12	
3	Excavation - Bottom of SOG	51 days	Mon 2/13/12	Mon 4/23/12	
4	Excavation - Foundations	82 days	Tue 3/27/12	Wed 7/18/12	
5	Foundation Concrete	86 days	Tue 3/27/12	Tue 7/24/12	
6	Underground MEP / SOG Concrete	120 days	Thu 4/19/12	Wed 10/3/12	
7	Steel Erection	102 days	Tue 6/12/12	Wed 10/31/12	
8	Roof Truss Erection	28 days	Tue 10/30/12	Thu 12/6/12	
9	Topping Off	0 days	Thu 12/6/12	Thu 12/6/12	
10	SOG Concrete (Crane Exit)	8 days	Fri 12/7/12	Tue 12/18/12	
11	CFMF Panels	92 days	Mon 7/30/12	Tue 12/4/12	
12	Roofing	97 days	Fri 8/10/12	Mon 12/24/12	
13	Exterior CMU	37 days	Mon 10/15/12	Tue 12/4/12	
14	Building Enclosure	0 days	Mon 12/24/12	Mon 12/24/12	
15	MEP Rough In	112 days	Thu 8/30/12	Fri 2/1/13	
16	Permanent Power	0 days	Fri 2/1/13	Fri 2/1/13	
17	Drywall and Interior Finishes	189 days	Tue 10/2/12	Fri 6/21/13	
18	Commissioning	28 days	Sat 6/22/13	Tue 7/30/13	
19	FFE	50 days	Thu 7/18/13	Wed 9/25/13	
20	Final Completion	0 days	Tue 9/17/13	Tue 9/17/13	
21	1st Puck Drop - PSU vs. Army	0 days	Fri 10/11/13	Fri 10/11/13	

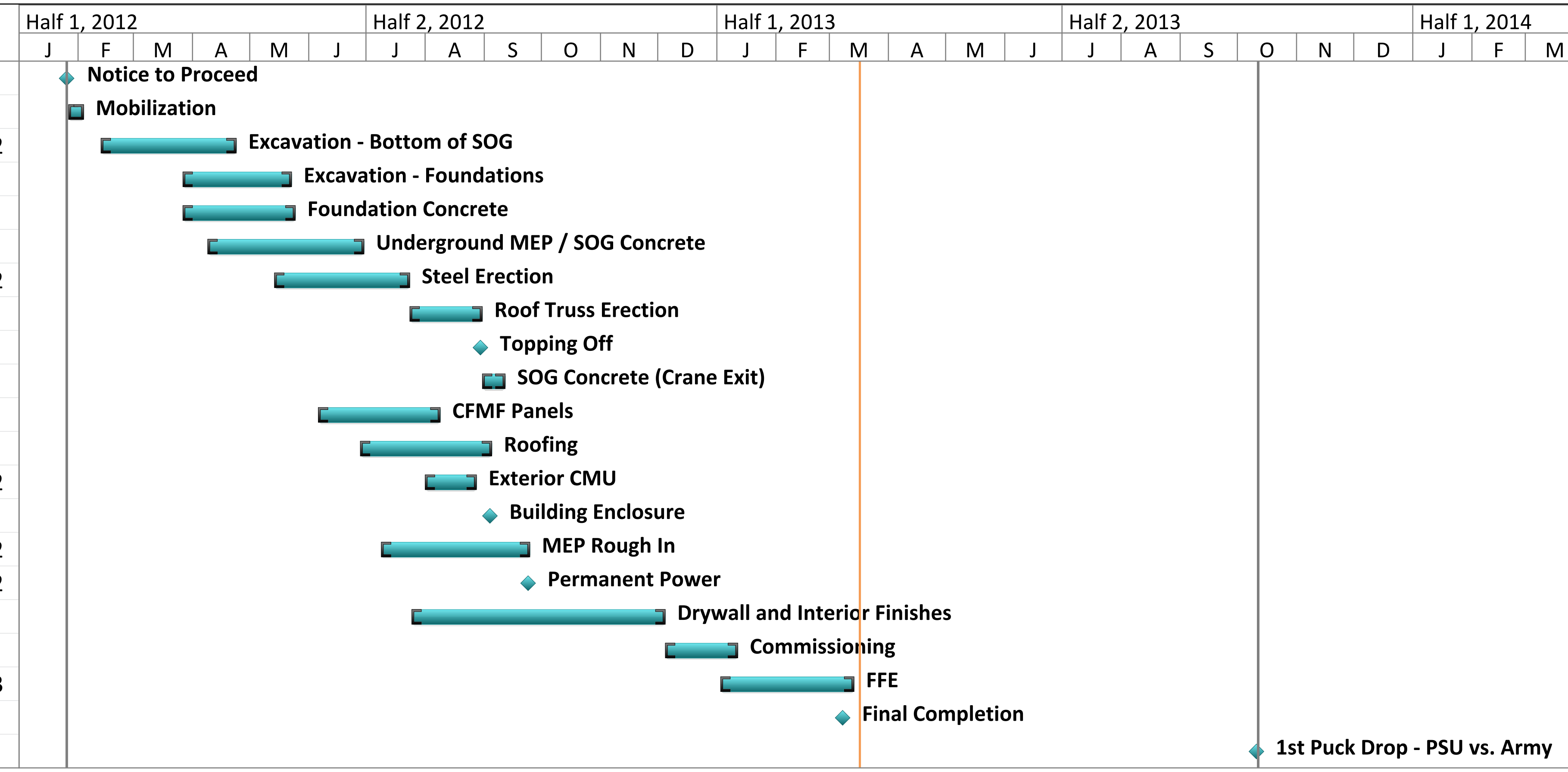


Project: Base
Date: Sun 3/17/13

Milestone ◆ Manual Task

Appendix M: Two Crew Summary Schedule

ID		Task Mode	Task Name	Duration	Start	Finish
1			Notice to Proceed	0 days	Thu 1/26/12	Thu 1/26/12
2			Mobilization	6 days	Fri 1/27/12	Fri 2/3/12
3			Excavation - Bottom of SOG	51 days	Mon 2/13/12	Mon 4/23/12
4			Excavation - Foundations	41 days	Tue 3/27/12	Tue 5/22/12
5			Foundation Concrete	43 days	Tue 3/27/12	Thu 5/24/12
6			Underground MEP / SOG Concrete	60 days	Mon 4/9/12	Fri 6/29/12
7			Steel Erection	51 days	Mon 5/14/12	Mon 7/23/12
8			Roof Truss Erection	28 days	Tue 7/24/12	Thu 8/30/12
9			Topping Off	0 days	Thu 8/30/12	Thu 8/30/12
10			SOG Concrete (Crane Exit)	8 days	Fri 8/31/12	Tue 9/11/12
11			CFMF Panels	46 days	Wed 6/6/12	Wed 8/8/12
12			Roofing	49 days	Thu 6/28/12	Tue 9/4/12
13			Exterior CMU	19 days	Wed 8/1/12	Mon 8/27/12
14			Building Enclosure	0 days	Tue 9/4/12	Tue 9/4/12
15			MEP Rough In	56 days	Mon 7/9/12	Mon 9/24/12
16			Permanent Power	0 days	Mon 9/24/12	Mon 9/24/12
17			Drywall and Interior Finishes	95 days	Wed 7/25/12	Tue 12/4/12
18			Commissioning	28 days	Wed 12/5/12	Fri 1/11/13
19			FFE	50 days	Thu 1/3/13	Wed 3/13/13
20			Final Completion	0 days	Fri 3/8/13	Fri 3/8/13
21			1st Puck Drop - PSU vs. Army	0 days	Fri 10/11/13	Fri 10/11/13

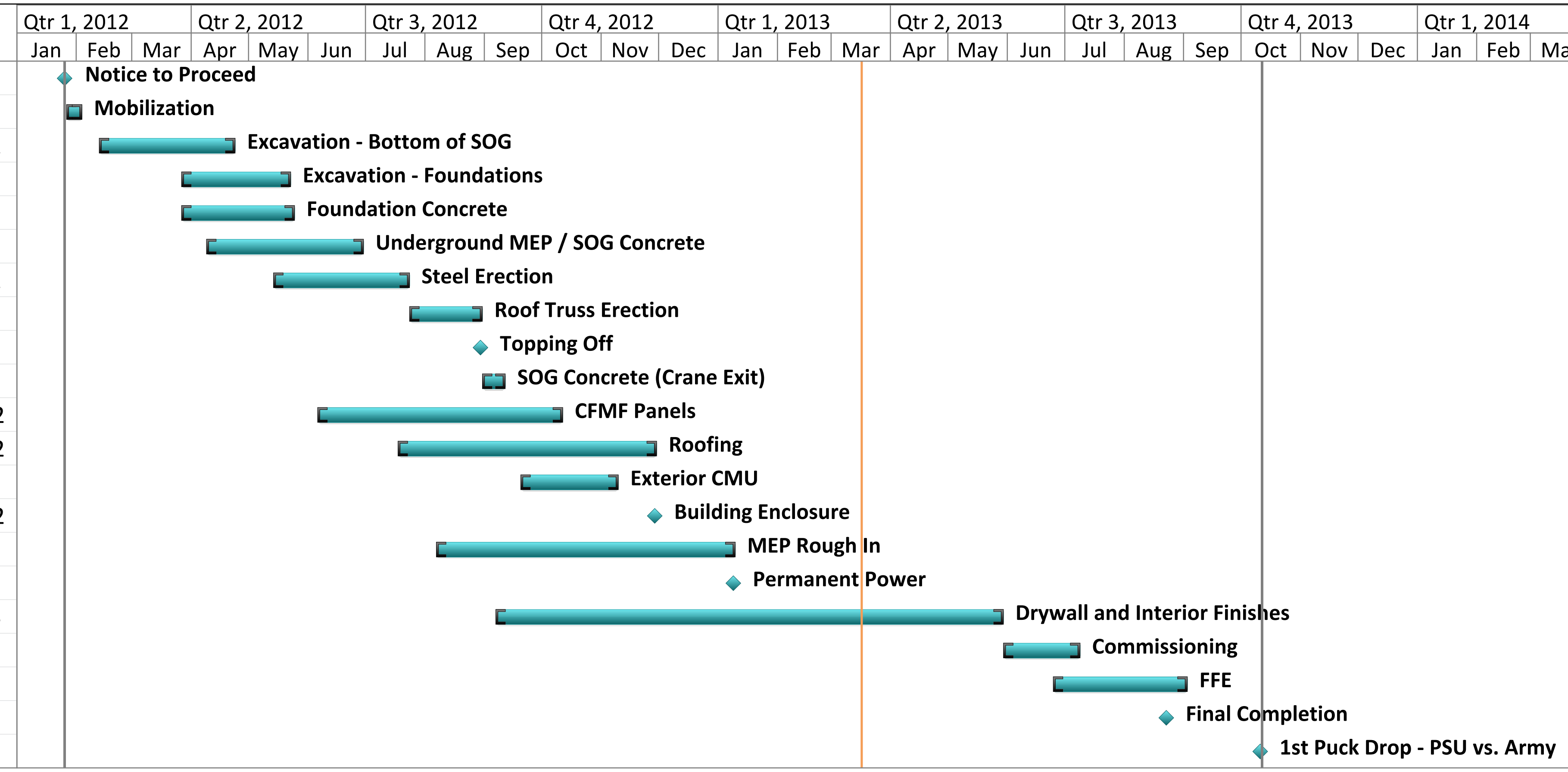


Project: halfworkshouldbedoneal
Date: Sun 3/17/13

Milestone ◆ Manual Task

Appendix N: Excavation, SOG, Steel Two Crew Summary Schedule

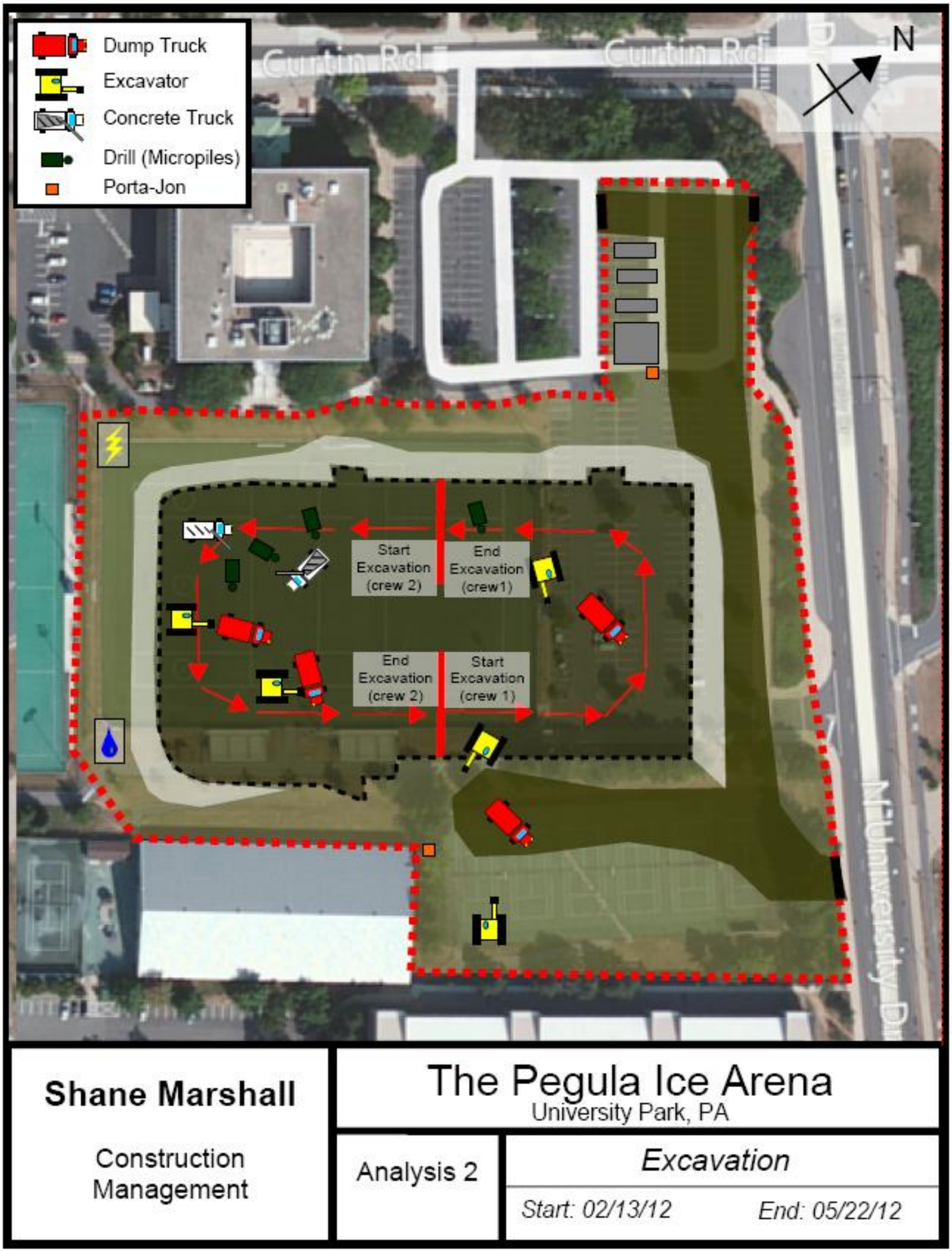
ID	Task Mode	Task Name	Duration	Start	Finish
1		Notice to Proceed	0 days	Thu 1/26/12	Thu 1/26/12
2		Mobilization	6 days	Fri 1/27/12	Fri 2/3/12
3		Excavation - Bottom of SOG	51 days	Mon 2/13/12	Mon 4/23/12
4		Excavation - Foundations	41 days	Tue 3/27/12	Tue 5/22/12
5		Foundation Concrete	43 days	Tue 3/27/12	Thu 5/24/12
6		Underground MEP / SOG Concrete	60 days	Mon 4/9/12	Fri 6/29/12
7		Steel Erection	51 days	Mon 5/14/12	Mon 7/23/12
8		Roof Truss Erection	28 days	Tue 7/24/12	Thu 8/30/12
9		Topping Off	0 days	Thu 8/30/12	Thu 8/30/12
10		SOG Concrete (Crane Exit)	8 days	Fri 8/31/12	Tue 9/11/12
11		CFMF Panels	92 days	Wed 6/6/12	Thu 10/11/12
12		Roofing	97 days	Wed 7/18/12	Thu 11/29/12
13		Exterior CMU	37 days	Thu 9/20/12	Fri 11/9/12
14		Building Enclosure	0 days	Thu 11/29/12	Thu 11/29/12
15		MEP Rough In	112 days	Tue 8/7/12	Wed 1/9/13
16		Permanent Power	0 days	Wed 1/9/13	Wed 1/9/13
17		Drywall and Interior Finishes	189 days	Fri 9/7/12	Wed 5/29/13
18		Commissioning	28 days	Thu 5/30/13	Mon 7/8/13
19		FFE	50 days	Tue 6/25/13	Mon 9/2/13
20		Final Completion	0 days	Fri 8/23/13	Fri 8/23/13
21		1st Puck Drop - PSU vs. Army	0 days	Fri 10/11/13	Fri 10/11/13



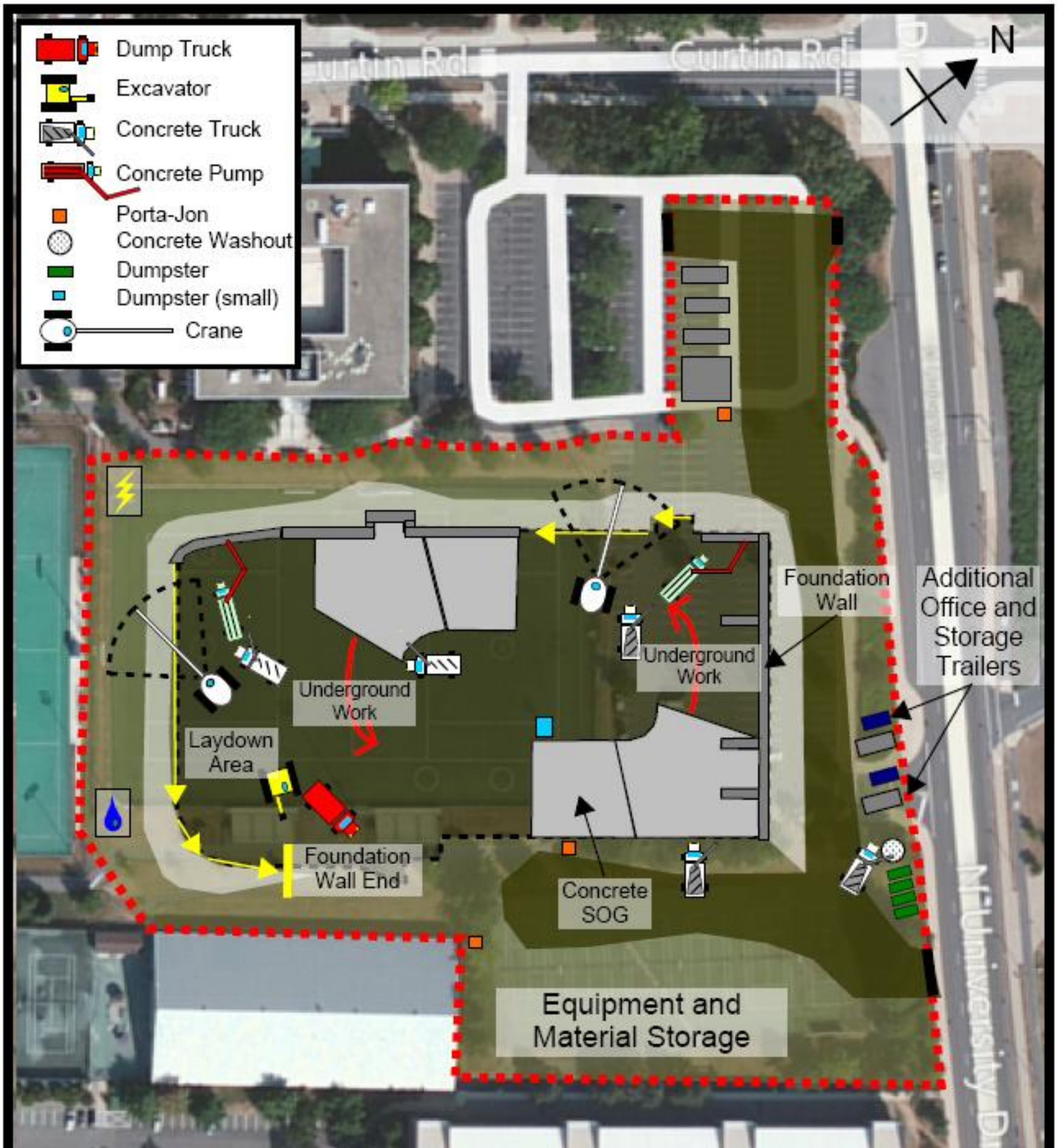
Project: Excavation, SOG, Steel Tw
Date: Sun 3/17/13

Milestone ◆ Manual Task

Appendix O: Two Crew Excavation Site Logistics


Dump Truck
Excavator
Concrete Truck
Drill (Micropiles)
Porta-Jon
Curtin Rd
Curtin Rd
N
Start Excavation (crew 2)
End Excavation (crew1)
End Excavation (crew 2)
Start Excavation (crew 1)
N University Dr
Shane Marshall
Construction Management
The Pegula Ice Arena
University Park, PA
Analysis 2
Excavation
Start: 02/13/12
End: 05/22/12

Appendix P: Two Crew SOG Site Logistics



Shane Marshall

Construction Management

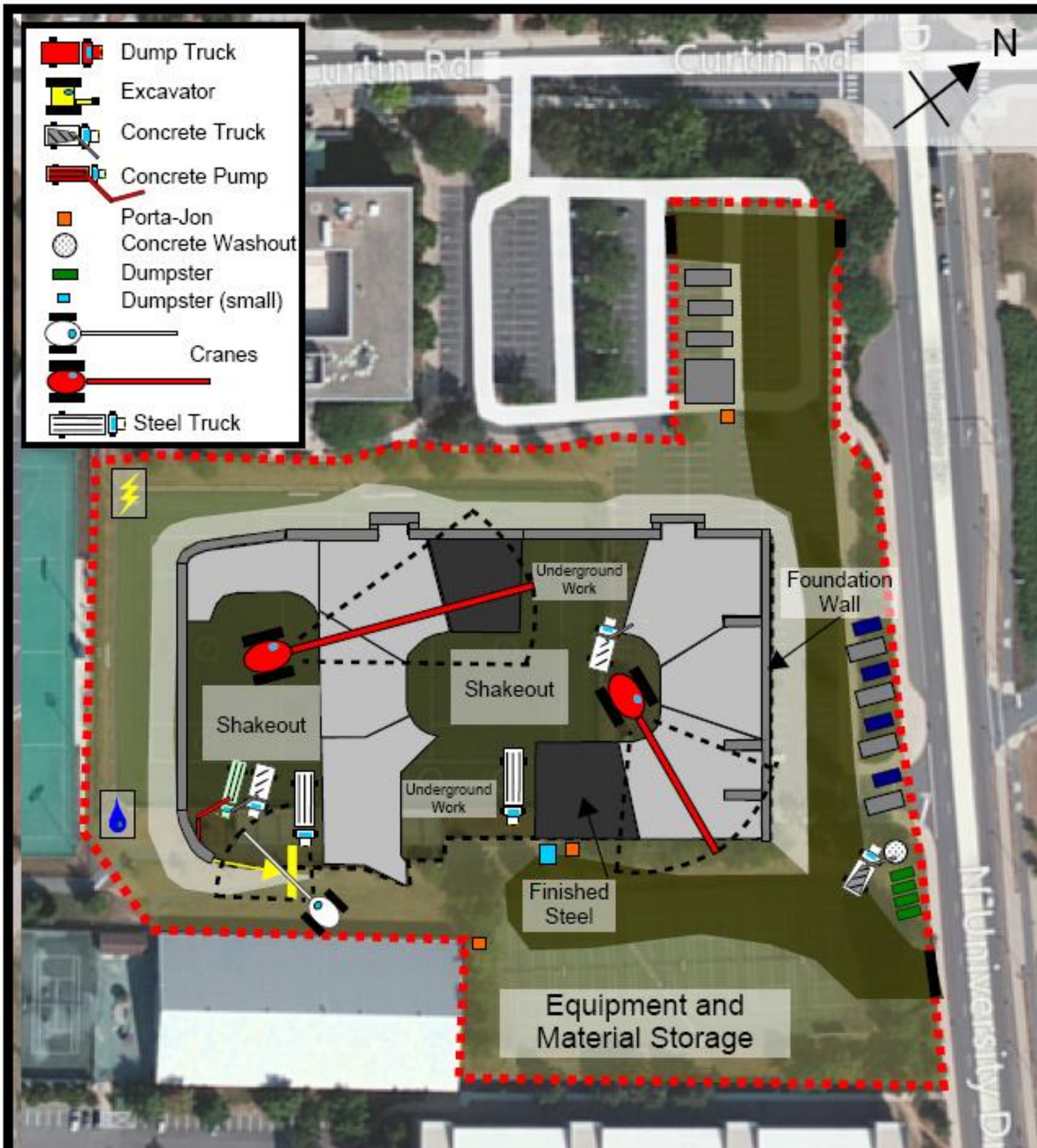
The Pegula Ice Arena
University Park, PA

Analysis 2

Foundation Wall and SOG

Start: 03/27/12 *End: 09/11/12*

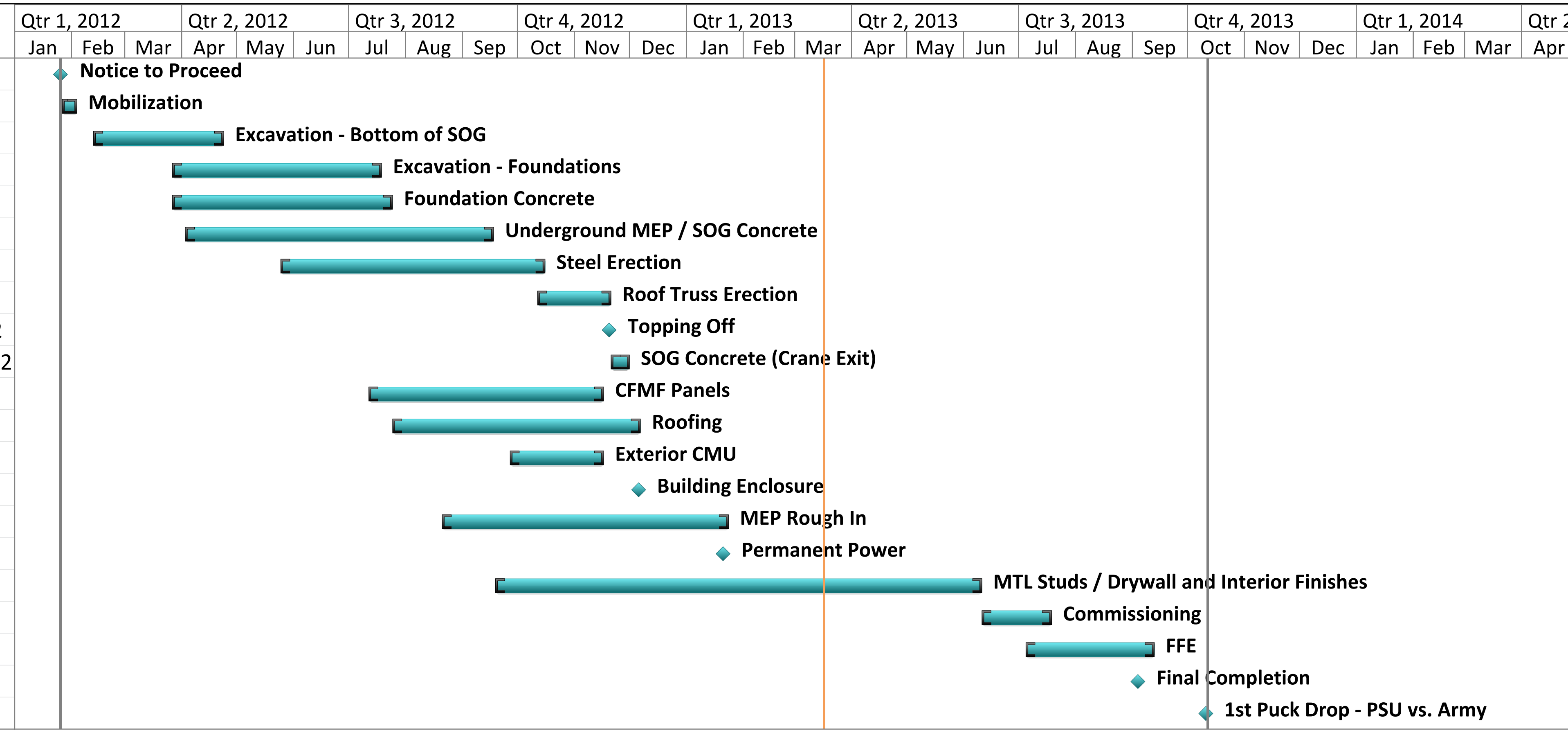
Appendix Q: Two Crew Steel Site Logistics



Shane Marshall	The Pegula Ice Arena University Park, PA	
Construction Management	Analysis 2	*Steel (incl. Trusses)* *Start: 05/14/12* *End: 08/30/12*

Appendix R: Potential Project Start Location Summary Schedule

ID	Task Mode	Task Name	Duration	Start
1		Notice to Proceed	0 days	Thu 1/26/12
2		Mobilization	6 days	Fri 1/27/12
3		Excavation - Bottom of SOG	51 days	Mon 2/13/12
4		Excavation - Foundations	82 days	Tue 3/27/12
5		Foundation Concrete	86 days	Tue 3/27/12
6		Underground MEP / SOG Concrete	120 days	Tue 4/3/12
7		Steel Erection	102 days	Fri 5/25/12
8		Roof Truss Erection	28 days	Fri 10/12/12
9		Topping Off	0 days	Tue 11/20/12
10		SOG Concrete (Crane Exit)	8 days	Wed 11/21/12
11		CFMF Panels	92 days	Thu 7/12/12
12		Roofing	97 days	Wed 7/25/12
13		Exterior CMU	37 days	Thu 9/27/12
14		Building Enclosure	0 days	Thu 12/6/12
15		MEP Rough In	112 days	Tue 8/21/12
16		Permanent Power	0 days	Mon 1/21/13
17		MTL Studs / Drywall and Interior Finishes	189 days	Wed 9/19/12
18		Commissioning	28 days	Tue 6/11/13
19		FFE	50 days	Fri 7/5/13
20		Final Completion	0 days	Wed 9/4/13
21		1st Puck Drop - PSU vs. Army	0 days	Fri 10/11/13



Project: Proposed Project Start Lo
Date: Sun 3/17/13

Milestone ◆ Manual Task

Appendix S: Thermal & Moisture Resistance

	Conductivity values are found in lecture notes 6 of AE 542 (pg 58-61)					$\Delta T_i = \frac{R_i}{\sum R_i}(T_{int} - T_{ext})$		Permeability values are found in Straube and Brunett, 2005			$\Delta P_w = \frac{R_{vi}}{\sum R_{vi}}(P_{int} - P_{ext})$			
	k=Ct	Given	C=k/t	R=5.678R_{SI}	R_{SI}=1/C			Material Property	M=μ/t	R_v=1/M				RH=P_w/P_{ws}*100
Layer material	Conductivity (k)	Thickness (t)	Conductance (C)	Resistance (R)	Resistance (R_{SI})	Δtemp (Δt)	temp (t)	Permeability (μ)	Vapor Permeance (M)	Vapor Resistance (R_v)	ΔVapor Pressure (ΔP_w)	Vapor Pressure (P_w)	Saturated Vapor Pressure (Pw,sat)	Relative Humidity (RH)
Units	[W/m*K]	[m]	[W/m²*K]		[m2*K/W]	[°C]	[°C]	[ng/Pa*s*m]	[ng/Pa*s*m²]	[Pa*s*m²/ng]	[Pa]	[Pa]	[Pa]	(%)
Interior Temp							23.89					1179.84	2949.60	40.00
Interior film	N/A	N/A	8.30	0.68	0.12	-0.47		N/A	15000.00	0.000067	-3.65			
							24.36					1183.49	3033.45	39.01
Drywall	0.16	0.01	12.31	0.46	0.08	-0.32		25.00	1923.08	0.000520	-28.49			
							24.67					1211.98	3091.17	39.21
Air Space	N/A	0.03	N/A	0.97	0.17	-0.66		175.00	7000.00	0.000143	-7.83			
							25.33					1219.81	3215.02	37.94
Concrete	1.80	0.08	24.00	0.24	0.04	-0.16		5.00	66.67	0.015000	-821.85			
							25.49					2041.66	3246.03	62.90
Insulation XPS	0.03	0.08	0.38	15.14	2.67	-10.34		2.00	25.00	0.040000	-2191.60			
							35.83					4233.26	5858.78	72.25
Concrete	1.80	0.08	24.00	0.24	0.04	-0.16		5.00	66.67	0.015000	-821.85			
							36.00					5055.11	5910.97	85.52
Exterior film	N/A	N/A	34.00	0.17	0.03	-0.11		N/A	75000.00	0.000013	-0.73			
Exterior Temp							36.11					5055.84	5948.05	85.00
		R_{SI} Total			3.15				R_v Total	0.07				
		R Total		17.89						ΔP_w Total	-3876.00			
	U=1/R	Overall co-eff. Of heat (U)			**0.32**									

Summer

Interior

T=23.89°C=301K RH= 40 percent

$$P_{WS} = 1000 * e^{[52.58 - \frac{6790.5}{T} - 5.028\ln(T)]}$$

P_{ws}= 2949.600858

$$P_W = RH * P_{WS}$$

P_w= 1179.840343

Exterior

T=36.11°C=258K RH= 85 percent

$$P_{WS} = 1000 * e^{[52.58 - \frac{6790.5}{T} - 5.028\ln(T)]}$$

P_{ws}= 5948.045099

$$P_W = RH * P_{WS}$$

P_w= 5055.838334

	Conductivity values are found in lecture notes 6 of AE 542 (pg 58-61)					$\Delta T_i = \frac{R_i}{\sum R_i}(T_{int} - T_{ext})$		Permeability values are found in Straube and Brunett, 2005			$\Delta P_w = \frac{R_{vi}}{\sum R_{vi}}(P_{int} - P_{ext})$			
	k=Ct	Given	C=k/t	R=5.678R_{SI}	R_{SI}=1/C			Material Property	M=μ/t	R_v=1/M				RH=P_w/P_{ws}*100
Layer material	Conductivity (k)	Thickness (t)	Conductance (C)	Resistance (R)	Resistance (R_{SI})	Δtemp (Δt)	temp (t)	Permeability (μ)	Vapor Permeance (M)	Vapor Resistance (R_v)	ΔVapor Pressure (ΔP_w)	Vapor Pressure (P_w)	Saturated Vapor Pressure (Pw,sat)	Relative Humidity (RH)
Units	[W/m*K]	[m]	[W/m^2*K]		[m2*K/W]	[°C]	[°C]	[ng/Pa*s*m]	[ng/Pa*s*m^2]	[Pa*s*m^2/ng]	[Pa]	[Pa]	[Pa]	(%)
Interior Temp							18.33					838.55	2096.38	40.00
Interior film	N/A	N/A	8.30	0.68	0.12	1.35		N/A	15000.00	0.000067	0.80			
							16.98					837.75	1925.79	43.50
Drywall	0.16	0.01	12.31	0.46	0.08	0.91		25.00	1923.08	0.000520	6.24			
							16.08					831.51	1817.74	45.74
Air Space	N/A	0.03	N/A	0.97	0.17	1.90		175.00	7000.00	0.000143	1.72			
							14.18					829.79	1608.71	51.58
Concrete	1.80	0.08	24.00	0.24	0.04	0.47		5.00	66.67	0.015000	180.14			
							13.71					649.65	1560.81	41.62
Insulation XPS	0.03	0.08	0.40	14.20	2.50	27.92		2.00	26.67	0.037500	450.34			
							-14.21					199.31	202.96	98.20
Concrete	1.80	0.08	24.00	0.24	0.04	0.47		5.00	66.67	0.015000	180.14			
							-14.67					19.17	195.35	9.81
Exterior film	N/A	N/A	34.00	0.17	0.03	0.33		N/A	75000.00	0.000013	0.16			
Exterior Temp							-15.00					19.01	190.13	10.00
		R_{SI} Total			2.98				R_v Total	0.07				
		R Total		16.95						ΔP_w Total	819.54			
	U=1/R	Overall co-eff. Of heat (U)			**0.34**									

Winter

Interior

T=18.33°C=301K RH= 40 percent

$$P_{WS} = 1000 * e^{[52.58 - \frac{6790.5}{T} - 5.028\ln(T)]}$$

P_{ws}= 2096.381778

$$P_W = RH * P_{WS}$$

P_w= 838.5527112

Exterior

T=-15°C=258K RH= 10 percent

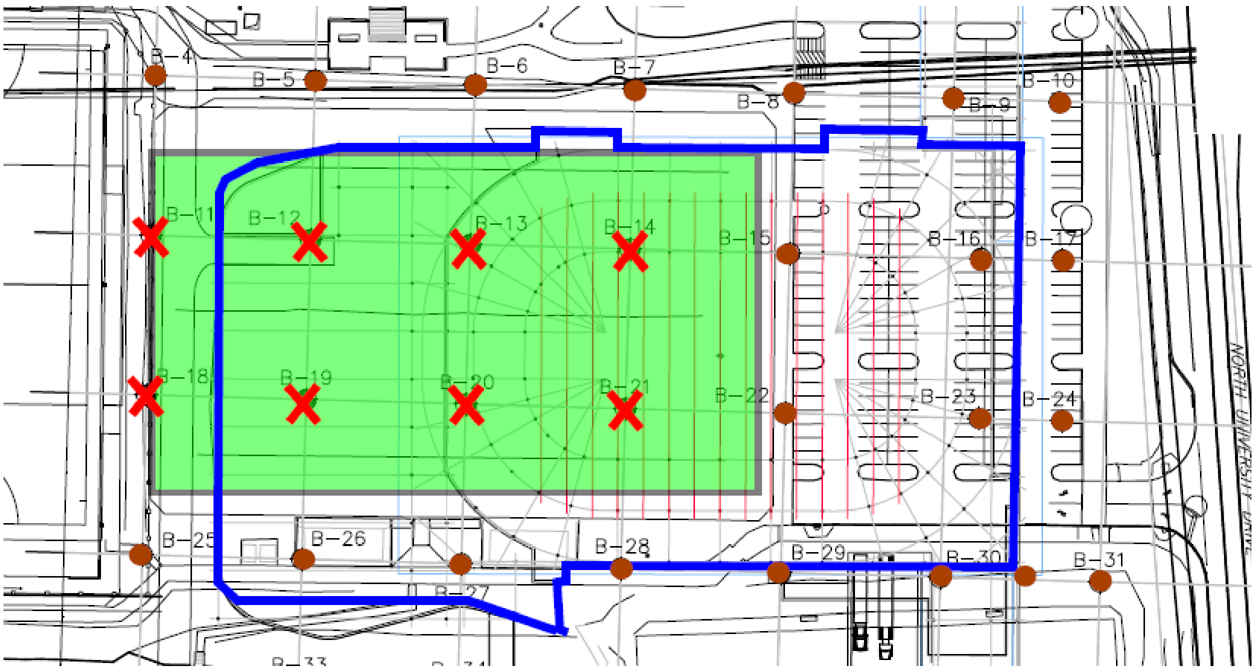
$$P_{WS} = 1000 * e^{[52.58 - \frac{6790.5}{T} - 5.028\ln(T)]}$$

P_{ws}= 190.129809

$$P_W = RH * P_{WS}$$

P_w= 19.0129809

Appendix T: Geotechnical Survey



Boring Holes Penn State Denied

Boring Holes

Lacrosse Field (GPR)

Building Outline

Appendix U: RS Means Cost Data

05 12 Structural Steel Framing

05 12 23 – Structural Steel for Buildings

05 12 23.60 Pipe Support Framing

05 12 23.60 Pipe Support Framing			Crew	Daily Output	Labor-Hours	Unit	2013 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
0010	PIPE SUPPORT FRAMING										
0020	Under 10#/L.F., shop fabricated	G	E-4	3900	.008	Lb.	1.74	.42	.04	2.20	2.70
0200	10.1 to 15#/L.F.	G		4300	.007		1.72	.38	.03	2.13	2.60
0400	15.1 to 20#/L.F.	G		4800	.007		1.69	.34	.03	2.06	2.49
0600	Over 20#/L.F.	G		5400	.006		1.66	.30	.03	1.99	2.39

05 12 23.65 Plates

Code	Description		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	PLATES R051223-80										
0015	*Made from recycled materials*	G									
0020	For connections & stiffener plates, shop fabricated										
0050	1/8" thick (5.1 lb./S.F.)	G				S.F.	6.65			6.65	7.30
0100	1/4" thick (10.2 lb./S.F.)	G					13.25			13.25	14.60
0300	3/8" thick (15.3 lb./S.F.)	G					19.90			19.90	22
0400	1/2" thick (20.4 lb./S.F.)	G					26.50			26.50	29
0450	3/4" thick (30.6 lb./S.F.)	G					40			40	44
0500	1" thick (40.8 lb./S.F.)	G					53			53	58.50
2000	Steel plate, warehouse prices, no shop fabrication										
2100	1/4" thick (10.2 lb./S.F.)	G				S.F.	8.50			8.50	9.30

23.70 Stressed Skin Steel Roof and Ceiling System

Code	Description		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	STRESSED SKIN STEEL ROOF & CEILING SYSTEM										
0020	Double panel flat roof, spans to 100'	G	E-2	1150	.049	S.F.	10.40	2.39	1.33	14.12	17
0100	Double panel convex roof, spans to 200'	G		960	.058		16.90	2.86	1.59	21.35	25.50
[illegible]	Double panel arched roof, spans to 300'	G		760	.074		26	3.61	2.01	31.62	37

05 12 23.75 Structural Steel Members

Code	Description		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	STRUCTURAL STEEL MEMBERS R051223-10										
0015	*Made from recycled materials*	G									
0020	Shop fab'd for 100-ton, 1-2 story project, bolted connections										
0100	Beam or girder, W 6 x 9	G	E-2	600	.093	L.F.	12.85	4.58	2.54	19.97	25
0120	x 15	G		600	.093		21.50	4.58	2.54	28.62	34
0140	x 20	G		600	.093		28.50	4.58	2.54	35.62	42
0300	W 8 x 10	G		600	.093		14.30	4.58	2.54	21.42	26.50
0320	x 15	G		600	.093		21.50	4.58	2.54	28.62	34
0350	x 21	G		600	.093		30	4.58	2.54	37.12	43.50
0360	x 24	G		550	.102		34.50	4.99	2.77	42.26	49.50
0370	x 28	G		550	.102		40	4.99	2.77	47.76	55.50
0500	x 31	G		550	.102		44.50	4.99	2.77	52.26	60.50
0520	x 35	G		550	.102		50	4.99	2.77	57.76	66.50
0540	x 48	G		550	.102		68.50	4.99	2.77	76.26	87
0600	W 10 x 12	G		600	.093		17.15	4.58	2.54	24.27	29.50
0620	x 15	G		600	.093		21.50	4.58	2.54	28.62	34
0700	x 22	G		600	.093		31.50	4.58	2.54	38.62	45
0720	x 26	G		600	.093		37	4.58	2.54	44.12	51.50
0740	x 33	G		550	.102		47	4.99	2.77	54.76	63.50
0900	x 49	G		550	.102		70	4.99	2.77	77.76	88.50
1100	W 12 x 16	G		880	.064		23	3.12	1.73	27.85	32.50
1300	x 22	G		880	.064		31.50	3.12	1.73	36.35	42
1500	x 26	G		880	.064		37	3.12	1.73	41.85	48.50
1520	x 35	G		810	.069		50	3.39	1.88	55.27	63
1560	x 50	G		750	.075		71.50	3.66	2.03	77.19	87
1580	x 58	G		750	.075		83	3.66	2.03	88.69	99.50
1700	x 72	G		640	.088		103	4.29	2.38	109.67	123
1740	x 87	G		640	.088		124	4.29	2.38	130.67	147

05 12 Structural Steel Framing

05 12 23 – Structural Steel for Buildings

05 12 23.75 Structural Steel Members			Crew	Daily Output	Labor-Hours	Unit	Material	2013 Bare Costs Labor	Equipment	Total	Total Incl O&P
1900	W 14 x 26	G	E-2	990	.057	L.F.	37	2.77	1.54	41.31	47.5
2100	x 30	G		900	.062		43	3.05	1.69	47.74	54
2300	x 34	G		810	.069		48.50	3.39	1.88	53.77	61.5
2320	x 43	G		810	.069		61.50	3.39	1.88	66.77	75.5
2340	x 53	G		800	.070		76	3.43	1.91	81.34	91.5
2360	x 74	G		760	.074		106	3.61	2.01	111.62	124
2380	x 90	G		740	.076		129	3.71	2.06	134.77	151
2500	x 120	G		720	.078		172	3.81	2.12	177.93	198
2700	W 16 x 26	G		1000	.056		37	2.75	1.52	41.27	47.5
2900	x 31	G		900	.062		44.50	3.05	1.69	49.24	56
3100	x 40	G		800	.070		57	3.43	1.91	62.34	71
3120	x 50	G		800	.070		71.50	3.43	1.91	76.84	86.5
3140	x 67	G		760	.074		96	3.61	2.01	101.62	113
3300	W 18 x 35	G	E-5	960	.083		50	4.13	1.74	55.87	64
3500	x 40	G		960	.083		57	4.13	1.74	62.87	72
3520	x 46	G		960	.083		66	4.13	1.74	71.87	81.5
3700	x 50	G		912	.088		71.50	4.35	1.83	77.68	88
3900	x 55	G		912	.088		78.50	4.35	1.83	84.68	96
3920	x 65	G		900	.089		93	4.40	1.85	99.25	112
3940	x 76	G		900	.089		109	4.40	1.85	115.25	130
3960	x 86	G		900	.089		123	4.40	1.85	129.25	145
3980	x 106	G		900	.089		152	4.40	1.85	158.25	177
4100	W 21 x 44	G		1064	.075		63	3.73	1.57	68.30	77
4300	x 50	G		1064	.075		71.50	3.73	1.57	76.80	86.5
4500	x 62	G		1036	.077		88.50	3.83	1.61	93.94	[illegible]
4700	x 68	G		1036	.077		97	3.83	1.61	102.44	115
4720	x 83	G		1000	.080		119	3.96	1.67	124.63	140
4740	x 93	G		1000	.080		133	3.96	1.67	138.63	155
4760	x 101	G		1000	.080		144	3.96	1.67	149.63	168
4780	x 122	G		1000	.080		174	3.96	1.67	179.63	201
4900	W 24 x 55	G		1110	.072		78.50	3.57	1.50	83.57	94.5
5100	x 62	G		1110	.072		88.50	3.57	1.50	93.57	105
5300	x 68	G		1110	.072		97	3.57	1.50	102.07	115
5500	x 76	G		1110	.072		109	3.57	1.50	114.07	128
5700	x 84	G		1080	.074		120	3.67	1.55	125.22	140
5720	x 94	G		1080	.074		134	3.67	1.55	139.22	156
5740	x 104	G		1050	.076		149	3.78	1.59	154.37	172
5760	x 117	G		1050	.076		167	3.78	1.59	172.37	192
5780	x 146	G		1050	.076		209	3.78	1.59	214.37	238
5800	W 27 x 84	G		1190	.067		120	3.33	1.40	124.73	139
5900	x 94	G		1190	.067		134	3.33	1.40	138.73	155
5920	x 114	G		1150	.070		163	3.45	1.45	167.90	187
5940	x 146	G		1150	.070		209	3.45	1.45	213.90	238
5960	x 161	G		1150	.070		230	3.45	1.45	234.90	261
6100	W 30 x 99	G		1200	.067		142	3.30	1.39	146.69	163
6300	x 108	G		1200	.067		154	3.30	1.39	158.69	177
6500	x 116	G		1160	.069		166	3.42	1.44	170.86	190
6520	x 132	G		1160	.069		189	3.42	1.44	193.86	216
6540	x 148	G		1160	.069		212	3.42	1.44	216.86	241
6560	x 173	G		1120	.071		247	3.54	1.49	252.03	280
6580	x 191	G		1120	.071		273	3.54	1.49	278.03	310
6700	W 33 x 118	G		1176	.068		169	3.37	1.42	173.79	193
6900	x 130	G		1134	.071		186	3.50	1.47	190.97	212

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7100 7120 7140 7300 7500 7600 7700 7900 7920 8100 8490 8492 8494 8496 8498 8499

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0010 0015 0020 0200 0300 0400 0500 0700 0800 0900 1000 1100 1300 1400 1500 1510 1600 1700 1900 2000 2200 2300 2800 2900 2950 3000 3040 3070 3100 3200 3210 3220 3400 3500 3700

05 12 Structural Steel Framing

05 12 23 – Structural Steel for Buildings

05 12 23.75 Structural Steel Members			Crew	Daily Output	Labor-Hours	Unit	Material	2013 Bare Costs Labor	Equipment	Total	Total Incl O&P
7100	x 141	G	E-5	1134	.071	L.F.	202	3.50	1.47	206.97	230
7120	x 169	G		1100	.073		242	3.60	1.52	247.12	274
7140	x 201	G		1100	.073		287	3.60	1.52	292.12	325
7300	W 36 x 135	G		1170	.068		193	3.39	1.43	197.82	219
7500	x 150	G		1170	.068		215	3.39	1.43	219.82	243
7600	x 170	G		1150	.070		243	3.45	1.45	247.90	275
7700	x 194	G		1125	.071		277	3.52	1.48	282	315
7900	x 231	G		1125	.071		330	3.52	1.48	335	375
7920	x 262	G		1035	.077		375	3.83	1.61	380.44	420
8100	x 302	G		1035	.077		430	3.83	1.61	435.44	485
8490	For projects 75 to 99 tons, add						10%				
8492	50 to 74 tons, add						20%				
8494	25 to 49 tons, add						30%	10%			
8496	10 to 24 tons, add						50%	25%			
8498	2 to 9 tons, add						75%	50%			
8499	Less than 2 tons, add						100%	100%			

05 12 23.77 Structural Steel Projects			Crew	Daily Output	Labor-Hours	Unit	Material	2013 Bare Costs Labor	Equipment	Total	Total Incl O&P
0010	**STRUCTURAL STEEL PROJECTS** R050516-30										
0015	Made from recycled materials	G									
0020	Shop fab'd for 100-ton, 1-2 story project, bolted connections										
0200	Apartments, nursing homes, etc., 1 to 2 stories R050523-10	G	E-5	10.30	7.767	Ton	2,600	385	162	3,147	3,700
0300	3 to 6 stories	G	"	10.10	7.921		2,650	390	165	3,205	3,775
0400	7 to 15 stories R051223-10	G	E-6	14.20	9.014		2,700	445	131	3,276	3,900
0500	Over 15 stories	G	"	13.90	9.209		2,800	455	134	3,389	4,050
0700	Offices, hospitals, etc., steel bearing, 1 to 2 stories R051223-20	G	E-5	10.30	7.767		2,600	385	162	3,147	3,700
0800	3 to 6 stories	G	E-6	14.40	8.889		2,650	440	129	3,219	3,825
0900	7 to 15 stories R051223-25	G		14.20	9.014		2,700	445	131	3,276	3,900
1000	Over 15 stories	G		13.90	9.209		2,800	455	134	3,389	4,050
1100	For multi-story masonry wall bearing construction, add R051223-30							30%			
1300	Industrial bldgs., 1 story, beams & girders, steel bearing	G	E-5	12.90	6.202		2,600	305	129	3,034	3,525
1400	Masonry bearing	G	"	10	8		2,600	395	167	3,162	3,725
1500	Industrial bldgs., 1 story, under 10 tons,										
1510	steel from warehouse, trucked	G	E-2	7.50	7.467	Ton	3,125	365	203	3,693	4,275
1600	1 story with roof trusses, steel bearing	G	E-5	10.60	7.547		3,075	375	157	3,607	4,200
1700	Masonry bearing	G	"	8.30	9.639		3,075	480	201	3,756	4,425
1900	Monumental structures, banks, stores, etc., minimum	G	E-6	13	9.846		2,600	490	143	3,233	3,850
2000	Maximum	G	"	9	14.222		4,325	705	207	5,237	6,200
2200	Churches, minimum	G	E-5	11.60	6.897		2,425	340	144	2,909	3,400
2300	Maximum	G	"	5.20	15.385		3,225	760	320	4,305	5,225
2800	Power stations, fossil fuels, minimum	G	E-6	11	11.636		2,600	575	169	3,344	4,025
2900	Maximum	G		5.70	22.456		3,900	1,125	325	5,350	6,575
2950	Nuclear fuels, non-safety steel, minimum	G		7	18.286		2,600	905	266	3,771	4,725
3000	Maximum	G		5.50	23.273		3,900	1,150	340	5,390	6,675
3040	Safety steel, minimum	G		2.50	51.200		3,800	2,550	745	7,095	9,400
3070	Maximum	G		1.50	85.333		5,000	4,225	1,250	10,475	14,200
3100	Roof trusses, minimum	G	E-5	13	6.154		3,650	305	128	4,083	4,675
3200	Maximum	G		8.30	9.639		4,425	480	201	5,106	5,900
3210	Schools, minimum	G		14.50	5.517		2,600	273	115	2,988	3,450
3220	Maximum	G		8.30	9.639		3,800	480	201	4,481	5,225
3400	Welded construction, simple commercial bldgs., 1 to 2 stories	G	E-7	7.60	10.526		2,650	520	239	3,409	4,100
3500	7 to 15 stories	G	E-9	8.30	15.422		3,075	765	271	4,111	5,000
3700	Welded rigid frame, 1 story, minimum	G	E-7	15.80	5.063		2,700	251	115	3,066	3,525

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05 15 Wire Rope Assemblies

05 15 16 – Steel Wire Rope Assemblies

05 15 16.50 Steel Wire Rope			Crew	Daily Output	Labor-Hours	Unit	Material	Labor (2013 Bare Costs)	Equipment (2013 Bare Costs)	Total (2013 Bare Costs)	Total Incl O&P
0720	2" diameter	G	E-18	200	.200	L.F.	21	10	4.79	35.79	45.50
0730	2-1/4" diameter	G		160	.250		27.50	12.50	6	46	58.50
0800	6 x 19 & 6 x 37, swaged, 1/2" diameter	G	E-17	1220	.013		2.31	.67		2.98	3.73
0810	9/16" diameter	G		1120	.014		2.69	.73		3.42	4.26
0820	5/8" diameter	G		930	.017		3.19	.88		4.07	5.10
0830	3/4" diameter	G		640	.025		4.06	1.28		5.34	6.75
0840	7/8" diameter	G		480	.033		5.15	1.70		6.85	8.70
0850	1" diameter	G		350	.046		6.25	2.33		8.58	11.05
0860	1-1/8" diameter	G		288	.056		7.70	2.84		10.54	13.50
0870	1-1/4" diameter	G		230	.070		9.30	3.55		12.85	16.60
0880	1-3/8" diameter	G		192	.083		10.75	4.25		15	19.45
0890	1-1/2" diameter	G	E-18	300	.133		13.05	6.65	3.19	22.89	[illegible]

05 15 16.60 Galvanized Steel Wire Rope and Accessories			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**GALVANIZED STEEL WIRE ROPE & ACCESSORIES**										
0015	*Made from recycled materials*	G									
3000	Aircraft cable, galvanized, 7 x 7 x 1/8"	G	E-17	5000	.003	L.F.	.20	.16		.36	.51
3100	Clamps, 1/8"	G	"	125	.128	Ea.	1.86	6.55		8.41	13.70

05 15 16.70 Temporary Cable Safety Railing			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**TEMPORARY CABLE SAFETY RAILING**, Each 100' strand incl.										
0020	2 eyebolts, 1 turnbuckle, 100' cable, 2 thimbles, 6 clips										
0025	Made from recycled materials	G									
0100	One strand using 1/4" cable & accessories	G	2 Sswk	4	4	C.L.F.	201	200		401	575
0200	1/2" cable & accessories	G	"	2	8	"	425	400		825	1,175

05 21 Steel Joist Framing

05 21 13 – Deep Longspan Steel Joist Framing

05 21 13.50 Deep Longspan Joists			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**DEEP LONGSPAN JOISTS**										
3010	DLH series, 40-ton job lots, bolted cross bridging, shop primer										
3015	*Made from recycled materials*	G									
3040	Spans to 144' (shipped in 2 pieces)	G	E-7	13	6.154	Ton	1,875	305	139	2,319	2,725
3200	52DLH11, 26 lb./L.F.	G		2000	.040	L.F.	23.50	1.98	.91	26.39	33
3220	52DLH16, 45 lb./L.F.	G		2000	.040		42	1.98	.91	44.89	51
3240	56DLH11, 26 lb./L.F.	G		2000	.040		24.50	1.98	.91	27.39	31.50
3260	56DLH16, 46 lb./L.F.	G		2000	.040		43	1.98	.91	45.89	52
3280	60DLH12, 29 lb./L.F.	G		2000	.040		27	1.98	.91	29.89	34.50
3300	60DLH17, 52 lb./L.F.	G		2000	.040		48.50	1.98	.91	51.39	58
3320	64DLH12, 31 lb./L.F.	G		2200	.036		29	1.80	.82	31.62	36
3340	64DLH17, 52 lb./L.F.	G		2200	.036		48.50	1.80	.82	51.12	57.50
3360	68DLH13, 37 lb./L.F.	G		2200	.036		34.50	1.80	.82	37.12	42
3380	68DLH18, 61 lb./L.F.	G		2200	.036		57	1.80	.82	59.62	67
3400	72DLH14, 41 lb./L.F.	G		2200	.036		38.50	1.80	.82	41.12	46
3420	72DLH19, 70 lb./L.F.	G		2200	.036		65.50	1.80	.82	68.12	76
3500	For less than 40-ton job lots										
3502	For 30 to 39 tons, add						10%				
3504	20 to 29 tons, add						20%				
3506	10 to 19 tons, add						30%				
3507	5 to 9 tons, add						50%	25%			
3508	1 to 4 tons, add						75%	50%			
3509	Less than 1 ton, add						100%	100%			

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05 12 Structural Steel Framing

05 12 23 – Structural Steel for Buildings

05 12 23.10 Ceiling Supports			Crew	Daily Output	Labor-Hours	Unit	2013 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
1250	Two coats primer paint instead of galv.	G	E-4	267	.120	L.F.	15.40	6.05	.54	21.99	28.50
1400	Monitor support, ceiling hung, expansion bolted	G		4	8	Ea.	410	405	36	851	1,225
1450	Hung from pre-set inserts	G		6	5.333		445	270	24	739	995
1600	Motor supports for overhead doors	G		4	8		210	405	36	651	990
1700	Partition support for heavy folding partitions, without pocket	G		24	1.333	L.F.	59	67.50	6	132.50	192
1750	Supports at pocket only	G		12	2.667		118	135	12	265	385
2000	Rolling grilles & fire door supports	G		34	.941		50.50	47.50	4.24	102.24	146
2100	Spider-leg light supports, expansion bolted to ceiling slab	G		8	4	Ea.	169	202	18	389	565
2150	Hung from pre-set inserts	G		12	2.667	"	182	135	12	329	455
2400	Toilet partition support	G		36	.889	L.F.	59	45	4	108	149
2500	X-ray travel gantry support	G		12	2.667	"	203	135	12	350	475

05 12 23.15 Columns, Lightweight			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**COLUMNS, LIGHTWEIGHT**										
1000	Lightweight units (lally), 3-1/2" diameter		E-2	780	.072	L.F.	7.50	3.52	1.95	12.97	16.45
1050	4" diameter		"	900	.062	"	9	3.05	1.69	13.74	16.95
5800	Adjustable jack post, 8' maximum height, 2-3/4" diameter	G				Ea.	44			44	48.50
5850	4" diameter	G				"	70.50			70.50	77.50

05 12 23.17 Columns, Structural			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**COLUMNS, STRUCTURAL** R051223-10										
0015	Made from recycled materials	G									
0020	Shop fab'd for 100-ton, 1-2 story project, bolted connections										
0800	Steel, concrete filled, extra strong pipe, 3-1/2" diameter		E-2	660	.085	L.F.	43	4.16	2.31	49.47	56.50
0830	4" diameter			780	.072		48	3.52	1.95	53.47	60.50
0890	5" diameter			1020	.055		57	2.69	1.49	61.18	69
0930	6" diameter			1200	.047		75.50	2.29	1.27	79.06	88.50
0940	8" diameter			1100	.051		75.50	2.50	1.39	79.39	89
1100	For galvanizing, add					Lb.	.25			.25	.28
1300	For web ties, angles, etc., add per added lb.		1 Sswk	945	.008		1.30	.42		1.72	2.19
1500	Steel pipe, extra strong, no concrete, 3" to 5" diameter	G	E-2	16000	.004		1.30	.17	.10	1.57	1.82
1600	6" to 12" diameter	G		14000	.004		1.30	.20	.11	1.61	1.89
1700	Steel pipe, extra strong, no concrete, 3" diameter x 12'-0"	G		60	.933	Ea.	160	46	25.50	231.50	283
1750	4" diameter x 12'-0"	G		58	.966		234	47.50	26.50	308	365
1800	6" diameter x 12'-0"	G		54	1.037		445	51	28	524	610
1850	8" diameter x 14'-0"	G		50	1.120		790	55	30.50	875.50	1,000
1900	10" diameter x 16'-0"	G		48	1.167		1,150	57	32	1,239	1,375
1950	12" diameter x 18'-0"	G		45	1.244		1,525	61	34	1,620	1,825
3300	Structural tubing, square, A500GrB, 4" to 6" square, light section	G		11270	.005	Lb.	1.30	.24	.14	1.68	2
3600	Heavy section	G		32000	.002	"	1.30	.09	.05	1.44	1.63
4000	Concrete filled, add					L.F.	4.14			4.14	4.56
4500	Structural tubing, square, 4" x 4" x 1/4" x 12'-0"	G	E-2	58	.966	Ea.	215	47.50	26.50	289	345
4550	6" x 6" x 1/4" x 12'-0"	G		54	1.037		350	51	28	429	505
4600	8" x 8" x 3/8" x 14'-0"	G		50	1.120		760	55	30.50	845.50	965
4650	10" x 10" x 1/2" x 16'-0"	G		48	1.167		1,400	57	32	1,489	1,675
5100	Structural tubing, rect., 5" to 6" wide, light section	G		8000	.007	Lb.	1.30	.34	.19	1.83	2.23
5200	Heavy section	G		12000	.005		1.30	.23	.13	1.66	1.96
5300	7" to 10" wide, light section	G		15000	.004		1.30	.18	.10	1.58	1.85
5400	Heavy section	G		18000	.003		1.30	.15	.08	1.53	1.78
5500	Structural tubing, rect., 5" x 3" x 1/4" x 12'-0"	G		58	.966	Ea.	208	47.50	26.50	282	340
5550	6" x 4" x 5/16" x 12'-0"	G		54	1.037		325	51	28	404	480
5600	8" x 4" x 3/8" x 12'-0"	G		54	1.037		475	51	28	554	640
5650	10" x 6" x 3/8" x 14'-0"	G		50	1.120		760	55	30.50	845.50	965
5700	12" x 8" x 1/2" x 16'-0"	G		48	1.167		1,400	57	32	1,489	1,675

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03 41 Precast Structural Concrete

03 41 33 – Precast Structural Pretensioned Concrete

03 41 33.60 Tees		Crew	Daily Output	Labor-Hours	Unit	2012 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
1200	32" x 10' wide, 60' span	C-11	16	4.500	Ea.	5,200	218	114	5,532	6,225
1250	Standard weight, 12" x 8' wide, 20' span		22	3.273		1,250	159	83	1,492	1,750
1300	16" x 8' wide, 25' span		20	3.600		1,575	175	91.50	1,841.50	2,125
1350	18" x 8' wide, 30' span		20	3.600		1,900	175	91.50	2,166.50	2,475
1400	20" x 8' wide, 45' span		18	4		2,825	194	102	3,121	3,575
1450	24" x 8' wide, 50' span		16	4.500		3,150	218	114	3,482	3,975
1500	32" x 10' wide, 60' span		14	5.143		4,725	249	131	5,105	5,775
2000	Roof members									
2050	Lightweight, 20" x 8' wide, 40' span	C-11	20	3.600	Ea.	2,775	175	91.50	3,041.50	3,450
2100	24" x 8' wide, 50' span		18	4		3,475	194	102	3,771	4,275
2150	32" x 10' wide, 60' span		16	4.500		5,200	218	114	5,532	6,225
2200	Standard weight, 12" x 8' wide, 30' span		22	3.273		1,900	159	83	2,142	2,450
2250	16" x 8' wide, 30' span		20	3.600		1,975	175	91.50	2,241.50	2,575
2300	18" x 8' wide, 30' span		20	3.600		2,075	175	91.50	2,341.50	2,700
2350	20" x 8' wide, 40' span		18	4		2,525	194	102	2,821	3,225
2400	24" x 8' wide, 50' span		16	4.500		3,150	218	114	3,482	3,975
2450	32" x 10' wide, 60' span		14	5.143		4,725	249	131	5,105	5,775

03 41 36 – Precast Structural Post-Tensioned Concrete

03 41 36.50 Post-Tensioned Jobs		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	POST-TENSIONED JOBS R034105-30									
0100	Post-tensioned in place, small job R034136-90	C-17B	8.50	9.647	C.Y.	1,150	440	47	1,637	2,000
0200	Large job	"	10	8.200	"	870	375	40	1,285	1,575

03 45 Precast Architectural Concrete

03 45 13 – Faced Architectural Precast Concrete

03 45 13.50 Precast Wall Panels		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	PRECAST WALL PANELS R034513-10									
0050	Uninsulated 4" thick, smooth gray									
0150	Low rise, 4' x 8' x 4" thick	C-11	320	.225	S.F.	21.50	10.90	5.70	38.10	48.50
0210	8' x 8', 4" thick		576	.125		21	6.05	3.18	30.23	37.50
0250	8' x 16' x 4" thick		1024	.070		21	3.41	1.79	26.20	31
0600	High rise, 4' x 8' x 4" thick		288	.250		21.50	12.15	6.35	40	51.50
0650	8' x 8' x 4" thick		512	.141		21	6.80	3.57	31.37	39
0700	8' x 16' x 4" thick		768	.094		21	4.55	2.38	27.93	33.50
0750	20' x 10', 6" thick, smooth gray		1400	.051		35.50	2.49	1.31	39.30	45
0800	Insulated panel, 2" polystyrene, add					1			1	1.10
0850	2" urethane, add					.78			.78	.86
1200	Finishes, white, add					2.87			2.87	3.15
1250	Exposed aggregate, add					1.88			1.88	2.07
1300	Granite faced, domestic, add					29.50			29.50	32.50
1350	Brick faced, modular, red, add					8.75			8.75	9.65
2200	Fiberglass reinforced cement with urethane core									
2210	R20, 8' x 8', minimum	E-2	750	.075	S.F.	22	3.60	2	27.60	32.50
2220	Maximum	"	600	.093	"	33	4.50	2.49	39.99	46.50

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02 21 Surveys

02 21 13 – Site Surveys

02 21 13.09 Topographical Surveys		Crew	Daily Output	Labor-Hours	Unit	Material	2012 Bare Costs Labor	Equipment	Total	Total Incl O&P
0010	**TOPOGRAPHICAL SURVEYS**									
0020	Topographical surveying, conventional, minimum	A-7	3.30	7.273	Acre	18.90	350	24	392.90	590
0100	Maximum	A-8	.60	53.333	″	58	2,500	131	2,689	4,025
02 21 13.13 Boundary and Survey Markers										
0010	**BOUNDARY AND SURVEY MARKERS**									
0300	Lot location and lines, large quantities, minimum	A-7	2	12	Acre	33.50	580	39.50	653	970
0320	Average	″	1.25	19.200		53.50	925	63	1,041.50	1,550
0400	Small quantities, maximum	A-8	1	32		71.50	1,500	78.50	1,650	2,475
0600	Monuments, 3′ long	A-7	10	2.400	Ea.	31.50	116	7.85	155.35	221
0800	Property lines, perimeter, cleared land	″	1000	.024	L.F.	.04	1.16	.08	1.28	1.91
0900	Wooded land	A-8	875	.037	″	.06	1.71	.09	1.86	2.79
02 21 13.16 Aerial Surveys										
0010	**AERIAL SURVEYS**									
1500	Aerial surveying, including ground control, minimum fee, 10 acres				Total					4,400
1510	100 acres									8,800
1550	From existing photography, deduct									1,500
1600	2′ contours, 10 acres				Acre					160
1650	20 acres									80
1800	50 acres									35
1850	100 acres									28
2000	1000 acres									28
2050	10,000 acres									28
2150	For 1′ contours and									
2160	dense urban areas, add to above				Acre					20%
3000	Inertial guidance system for									
3010	locating coordinates, rent per day				Ea.					4,400

02 32 Geotechnical Investigations

02 32 13 – Subsurface Drilling and Sampling

02 32 13.10 Boring and Exploratory Drilling		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**BORING AND EXPLORATORY DRILLING**									
0020	Borings, initial field stake out & determination of elevations	A-6	1	16	Day		705	78.50	783.50	1,150
0100	Drawings showing boring details				Total		310		310	390
0200	Report and recommendations from P.E.						720		720	900
0300	Mobilization and demobilization	B-55	4	6			209	246	455	590
0350	For over 100 miles, per added mile		450	.053	Mile		1.86	2.18	4.04	5.25
0600	Auger holes in earth, no samples, 2-1/2″ diameter		78.60	.305	L.F.		10.65	12.50	23.15	30
0650	4″ diameter		67.50	.356			12.40	14.55	26.95	35
0800	Cased borings in earth, with samples, 2-1/2″ diameter		55.50	.432		22	15.05	17.70	54.75	66.50
0850	4″ diameter		32.60	.736		34.50	25.50	30	90	111
1000	Drilling in rock, "BX" core, no sampling	B-56	34.90	.458			18.30	40.50	58.80	72.50
1050	With casing & sampling		31.70	.505		22	20	45	87	104
1200	"NX" core, no sampling		25.92	.617			24.50	55	79.50	98
1250	With casing and sampling		25	.640		26.50	25.50	57	109	131
1400	Borings, earth, drill rig and crew with truck mounted auger	B-55	1	24	Day		835	985	1,820	2,350
1450	Rock using crawler type drill	B-56	1	16	″		640	1,425	2,065	2,525
1500	For inner city borings add, minimum									10%
1510	Maximum									20%

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