March 2011

Boat House Design and Construction

Henry Oliver Moore
Worcester Polytechnic Institute

PROJECT ID: GFS 1105

Boat House Design & Construction

An Major Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science
By

Henry Moore

3/14/2011

Approved:

Guillermo Salazar, Advisor

Leonard Albano, Advisor

Abstract:
This project proposes a design for an addition to the rowing WPI facility in Shrewsbury MA. The scope of this project includes a need assessment, review of local codes and ordinances, site analysis, preliminary layout, structural design of the building foundations and building frame as well as cost estimates and construction schedule. A 3D digital model of the facility is also developed.

Capstone Design Experience

It is a requirement of the Accreditation Board for Engineering and Technology (ABET) that all Civil Engineering degrees include a Capstone Design Experience. The Capstone Design Experience must incorporate prior coursework, engineering standards, and realistic constraints, and should address some of the following concerns: environmental, sustainability, manufacturability, ethical, health and safety, social, and political. The Boat House Design and Construction MQP proposed a design for an addition to the rowing WPI facility in Shrewsbury MA. The scope of this project includes a need assessment, review of local codes and ordinances, site analysis, preliminary layout, structural design of the building foundations and building frame as well as cost estimates and construction schedule. A 3D digital model of the facility is also developed.

One consideration that this MQP addressed was the environmental aspects of the Capstone Design Experience through its adherence to restrictions by the Shoreline Protection Act. Attention was paid to building code, making sure that the proposed building meets fire code, and would be safe to occupy. This project addresses the several economic aspects. The first economic consideration was where to place the proposed facility. A new lot on the lake, tearing down the existing rowing center, or making an addition to the boat bays were all considered. It was decided that the most practical option was an addition to current facilities, for the ease and use of the athletes. The cost estimate of the facility gave a hypothetical cost for the facility. By addressing these and other concerns, this project satisfies the Capstone Design Experience as stated by ABET.

Acknowledgements

I would like to thank Larry Noble, Larry Gluckman and Kevin McDermott for their cooperation and input during the interview portion of this project. I would also like to thank Professor Salazar for his continuing advice.

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction:

Since Worcester Polytechnic Institute's varsity crew teams were formed in 1999 the team has grown to many times its original size. The original men's varsity program consisted of 8 varsity athletes and a handful of novice athletes. Now the team has almost 30 varsity athletes and over 30 novice athletes, and has sent rowers to compete at World Championships, crew's highest level. However, the crew team still uses the original exercise room it was given, a 20 x 22 ft room on the third floor of Alumni gymnasium. This room presents potential health hazards, since the large amount of dust can induce coughing fits among athletes. As the team has grown, so has the amount of equipment. The boat storage area in the boat house on Lake Quinsigamond has become over crowded, without sufficient space to store the boats. In the winter time, when temperatures are below freezing and the lake is still unfrozen, the crew team still practices outside on the lake. There is not sufficient inside space to warm up and stretch down after these winter practices at the lake. With such a large team it is difficult to lift weights at the existing WPI Fitness Center without monopolizing the weight room that is open to the entire student body and faculty of WPI. A facility specifically designed for the crew team would rectify all of these problems, as well as helping the crew team improve their performance by giving them access to more space and equipment. Currently there is a new Sports and Recreation Center being constructed at WPI. This new center will include a set of rowing tanks, which allow for simulation of an on-the-water experience, and some area for ergometers. This center will be completed in one to two years, and should help with some of the overcrowding issues in the weights area, but will not affect the amount of space the crew team has to practice, or the issue of boat storage.

This project proposes a design for an addition to the rowing WPI facility in Shrewsbury MA. The scope of this project includes a need assessment, review of local codes and ordinances, site analysis, preliminary layout, structural design of the building foundations and building frame as well as cost estimates and construction schedule. A 3D digital model of the facility is also developed.

In conducting this work there were several challenging parts of this project. The first related to the architectural design of the building. To overcome this challenge, the personal experience of the author has been used and similar facilities have been studied. Another challenge was the placement of the building on the lot, since there is limited space, and setbacks that made it even more constrained. The third challenge was related to the availability of another suitable lot in the area. There were only 18 available lots, and of those 18, only 4 are large enough. The average cost of those four lots is $650,000. Considering the final predicted cost of the new construction is approximately $870,000, the cost of a lot seems extremely high.

The final proposal calls for an addition to the current boat house facility on Lake Quinsigamond. This would be most beneficial to the crew team in combining the current storage area with additional storage area and indoor exercise area. Choosing to construct in addition instead of purchasing a lot would also help to minimize costs.

Chapter 2: Background:

The WPI Men's Crew team became a Varsity Program in the fall of 1999. The team started out with only eight varsity rowers and a handful of novices recruited around campus. Over the years the team has developed into a much larger program. Currently there are 28 varsity athletes, and 31 novice athletes on the Men's Crew team. The WPI Women's Crew team has gone through a similar growth, and has almost as many team members.

Currently the WPI teams launch and store boats at the Donahue Rowing Center on Lake Quinsigamond in Worcester, MA. Below is an overhead picture of the current facilities, showing the Donahue Rowing center and the boat bays.

Figure 1: Overhead Picture of Facilities at Lake Quinsigamond

Construction began on the Donahue Rowing Center in 1992. In the first stage of construction, six bays were built, as well as the Donahue Rowing Center. The center is a facility built closer to the water, with a large viewing room, a small office, a small kitchen, and women's and men's bathrooms. The second stage of construction added four bays were added to the initial six. These facilities are shared by Shrewsbury High School, Clark University, Worcester Academy, the Bancroft School, Assumption College, Quinsigamond Rowing Association, St. John's Prep, St. Mark's School and WPI. WPI has control of a full boat bay, and shares a boat bay with the College of the Holy Cross. These boat bays need to provide storage for 8 eight person boats, 4 four person boats, 4 two person boats, and 4 one person boats. Eight person boats are approximately 65 feet long, four person boats are 35 feet long, two person boats are 25 feet long, and one person boats are 18 feet long. Boats with riggers attached are approximately 6 feet wide. The facility provides storage for extra parts, tools, eight launches, eight sets of oars (8 oars per set), miscellaneous supplies, and other exercise equipment. On campus the team has an ergometer room on the third floor of Alumni Gymnasium. Ergometers are a machine that simulates the rowing stroke and can measure the power output of each athlete. The room has space for 13 ergometers, and there are an additional five ergometers outside around the indoor track. For weight lifting facilities the crew team uses the WPI Fitness Center in downstairs Alumni.

The new Sports and Recreation center that is being constructed above Alumni field will contain some new facilities for the crew team. The building will contain a 16 person moving water rowing tanks, and there will be room for 10 ergometers in the room. There will also be a new weight room in the building. Once the new athletic facility is complete the existing Alumni Gymnasium will be renovated to offer more academic space.

There are several issues with current facilities that prompt a change to help alleviate the issues. One such issue is the lack of available space in Alumni Gymnasium. It is impossible for the Men's or Women's Crew team to hold a practice for all of its members. There is not sufficient space for all of the members. The space is also old, and some of the interior construction is rotting. There is also a large amount of dust, which has induced asthma attacks in several athletes. The weight room also does not have sufficient space for the team to hold a practice, and has limited hours. The boathouse has a limited amount of space, and it is very difficult to maneuver and store boats. Several boats have to be stored on the floor, and there is not room to work on boats inside. During inclement weather there is not room for the team to stretch, warm up, and conduct workouts at the Donahue Rowing Center. Additional space would help lighten the demands on other facilities. The new athletic facility does address some of these needs, but a loss of space in Alumni Gymnasium does not help the current situation. The options to alleviate the situation are renovating the current ergometer room, buying a lot on Lake Quinsigamond and constructing a new building, tearing down the Donahue Rowing Center and constructing a new facility, or constructing an addition to the current facilities on Lake Quinsigamond. An addition to the Lake Quinsigamond boat house would be most convenient for the athletes, and seems to be the most economical. Renovations to the current facility on campus are impractical because there is not enough room for the proposed additions, and the area is already designated for academic use. Buying a lot for new construction is not practical because the cost of a lot comes close to doubling the cost of the proposed addition. It is inadvisable to tear down the Donahue Rowing Center because it is still used by other teams who boat out of the same boat house. Therefore an addition to the current facilities seems like the most logical solution.

Chapter 3: Methodology

To develop the proposed boat house I have broken down the project into four phases. Phase 1 assessed the necessities of the building, and researched local laws and building codes for waterfront buildings. Interviews were conducted during phase 1 to better understand what comprises a facility of a comparable program, what a team needs to give the team the best chance of success, and how the current WPI facilities are used and how future facilities will be used. Phase 2 included designing the building, including placement on the lot. It was important to make sure that the building design met all requirements from the building code that was reviewed in phase 1, or else the building could not be built. Phase 3 consisted of the structural design of foundations for the building, determined by the expected loads of the building. The foundation designs were made using Allowable Stress design (ASD). Phase 4 included cost estimating, developing a building timeline, and financing considerations.

Chapter 4: Results:

Section 4.1: Information from Interviews:

Interviews were conducted with Lawrence Noble, head of WPI Rowing, Kevin McDermott, head of Trinity Rowing, and Lawrence Gluckman, former national team coach. The purpose of the interview with Lawrence Noble was to assess the current facilities available at WPI, what will become available with the construction of the new athletic facility, and ascertain what facilities would be desired in the future. The purpose of the interview with Kevin McDermott was to interview a coach at a similarly sized Division III school which has recently built a new facility and to find out pros and cons of the facility design. The purpose of the interview with Lawrence Gluckman was to find out what characteristics were needed in a facility to allow a team to become successful at the most competitive levels of the sport.

Lawrence Noble identifies the Donahue Rowing Center and the ergometer room in Alumni Gymnasium as the main areas for boat storage and training facilities for the WPI crew team. The crew team has limited access to weight lifting room in Alumni gymnasium. The new Sports and Recreation center will provide rowing tanks that allow rowers to simulate water rowing while on land, and also provide some exercising area. The construction of the new Sports and Recreation center also means renovations to Alumni Gymnasium, and the crew team will lose its ergometer room. The ergometer room in Alumni Gymnasium contains 13 ergometers that allow the athletes to practice the rowing motion. This is a training tool used by the athletes every day, but is not as similar to rowing as the rowing tanks. There are not enough ergometers for all of the athletes to use them at once, and there is not enough room for additional ergometers. The new tank room will have room for approximately ten ergometers around its perimeter.

The Trinity College Bliss Boat House was completed in 2005. The Bliss Boat House is located on the Connecticut River in Hartford, Connecticut. The Trinity College crew team is similar in size to the WPI crew team, with the men's and women's team each having between 40 and 60 athletes. The boat house provides storage for all of Trinity's boats, and provides exercise areas, meeting areas, and coaches' offices. Kevin McDermott, the Trinity head coach, listed the pros of the facility as: having boat storage and exercise facilities in the same location, available space for personal boat storage, finished space for team functions, and amount of space and equipment for team workouts. The cons of the facility were listed as: lack of parking, need of a system to hold exercise machines in place, upstairs floor surface unsuitable for weight lifting, aluminum stud walls do not allow pull up bars, insufficient free area, and lack of air conditioning upstairs.

Traits that Larry Gluckman identified as crucial to a facility are: sufficient space for whole team to exercise to encourage team unity, sufficient bathroom and locker room area, kitchen facilities for independence of athletes, sufficient boat storage area, and lounge areas for athletes.

Section 4.2: Comparison of Facilities:

Due to the similarities between the WPI Crew team and Trinity Crew team, it seems practical to make a comparison of the facilities.

Table 1: Comparison of Boating Facilities

Features	Trinity College	Current WPI Facilities	WPI Facilities w/ new athletic center	WPI Facilities w/ proposed addition and new athletic center
Sufficient Boat storage	Yes	No	No	Yes
Tanks	Yes	No	Yes	Yes
Sufficient Locker Room facilities	Yes	No	No	Yes
Ergometer Room w/ Sufficient Space	Yes	No	No	Yes
Exercise Space	Yes	No	No	Yes
Dedicated Weight lifting facility	Yes	No	No	Yes
Kitchen	Yes	Yes	Yes	Yes
Meeting Area	Yes	No	No	Yes

As is shown in the comparison, the new athletic facility does improve certain aspects of the facilities, but does not address all of the areas of concern brought up by the interviewees. These areas include boat storage, weight lifting area, ergometer area and meeting area.

Section 4.3: Alternative Facility Solutions and Locations

There are three distinct options considered for the design and potential construction of the WPI Crew facility. The options are: 1. buying land surrounding the lake and building a new facility, 2. tearing down the existing boat house and building a new facility, 3. tearing down the Donahue Rowing Center building and constructing a larger building combining the shared amenities with WPI facilities, or 4. make an addition to the current Donahue Rowing Center boathouse bays.

Section 4.3.1: Land Purchase

When considering purchasing land around Lake Quinsigamond several problems became apparent. There are very few lots available that are large enough to accommodate a facility and provide sufficient parking. Out of 18 available lots, only four were large enough for the proposed facility (the list of lots can be found in Appendix A). These lots are also very expensive. The average price of those four lots is $650,000. Since the cost of the proposed facility is $870,000, the additional cost of a lot would increase the cost of the project by 75%. Three out of four of the acceptable lots have existing structures. Demolition costs come mostly from the waste disposal part of the project, and there could also be issues with some of the older structures which contain lead paint and asbestos. Being so near to a body of water demolition is very strictly regulated, and hazardous materials could make this a very difficult process.

Section 4.3.2: Demolition of the Donahue Rowing Center

Tearing down the existing Donahue Rowing Center building is also very impractical. The building is one of the only portions of the site that is open to the public, and since the facility to be constructed is primarily for WPI Crew it is not practical to eliminate public space. The loss of the use of the rowing center during construction would affect not only WPI, but the other schools who use the center. Since there are races during the fall, spring and summer, there is no advantageous time for construction.

From a financial standpoint, it is very unreasonable to consider building anywhere besides the current lot. Any lot would have the cost of the proposed building, but building on another lot would include the cost of the lot, and any demolition costs. The average cost of an available lot on Lake Quinsigamond is $525,475 (see Appendix A for table of lot prices and sizes). This amount itself is substantial, but of all of these lots, only four are large enough for the proposed facility, observing the setbacks necessary in the Shoreline Protection Act. Of those four the average cost is $650,000. Adding approximately $15,000 to this cost for the demolition of the current structure, and the cost prior to construction of the facility is over $665,000. When adding this cost to the $870,000 cost of the proposed facility, the total cost comes to $1.535 million.

After considering the project it seems that the best option is to build an addition to the Donahue Rowing Center boathouse bays. This is based on price, continuing availability of the facilities during construction, and use in conjunction with the current boat bays. There is already plentiful parking, it is in close proximity to the other existing WPI boat bays and can be used in conjunction with it. There is an overhead picture of the boat bays and Donahue Rowing Center in Appendix B. There is a parking lot behind the existing boat bays with approximately 50 spots and there is an adjacent town parking lot with approximately 120 additional slots. There is a precedent for Shrewsbury allowing privately funded construction on town owned property. The current boat house facilities were funded by the Donahue family, and the land they on which this facility was built was and still is owned by the town. Since the town owns the lot it is very reasonable to think that the town would be amenable to making an addition to their current facility.

Section 4.4: Architectural Design

Section 4.4.1: Design Requirements

When designing the boat house facility, there are certain aspects of the International Building Code that needed to be observed. Examples are:

- 25’ Setback from shoreline
- 60’ setback from other properties
- Building is classified as A-3 so must comply with following guidelines
- Maximum height 40’
- Unlimited area
- Must have automated sprinkler system
- Maximum occupancy determined by 50 ft^2 per person, so 200 people
- Walls minimum fire rating of 1 hour
- Must be reasonable continuity to points of egress
- No more than 7” height difference out of point of egress
- Door width must be greater than 32”
- Distance to nearest point of egress be no more than 250’

All of these requirements were considered and met by the proposed design.

Section 4.4.2: Facility Floor Plan

The major areas of the facility are the entrance lobby, coaching office, two locker rooms, exercise area, meeting room, and boat storage area. These can be seen in photos and plans below, and more details can be seen in Appendix B. The main entrance to the facility would be through the lobby. From the lobby you can enter into the boat bay, coaches' office, or exercise area. From the exercise area it is possible to enter either of the two locker rooms, or the meeting area. The locker rooms occupy the end of the building farthest from the lake, since their lack of windows would not provide a view. The coaches' office allows a view of the access to the boat bay, but also features windows viewing the exercise room, to better supervise the athletes. The meeting room features windows viewing onto the lake and access to the exercise room and boat bay. All of these features allow for athletes to progress from one part of the facility to another, and also for coaches to supervise multiple areas of the facility at once. The gross square footage of the building is 10,080 ft^2. All of the plan, elevation, and interior views shown below are taken from a Revit Architectural model created to help show the design of the facility.

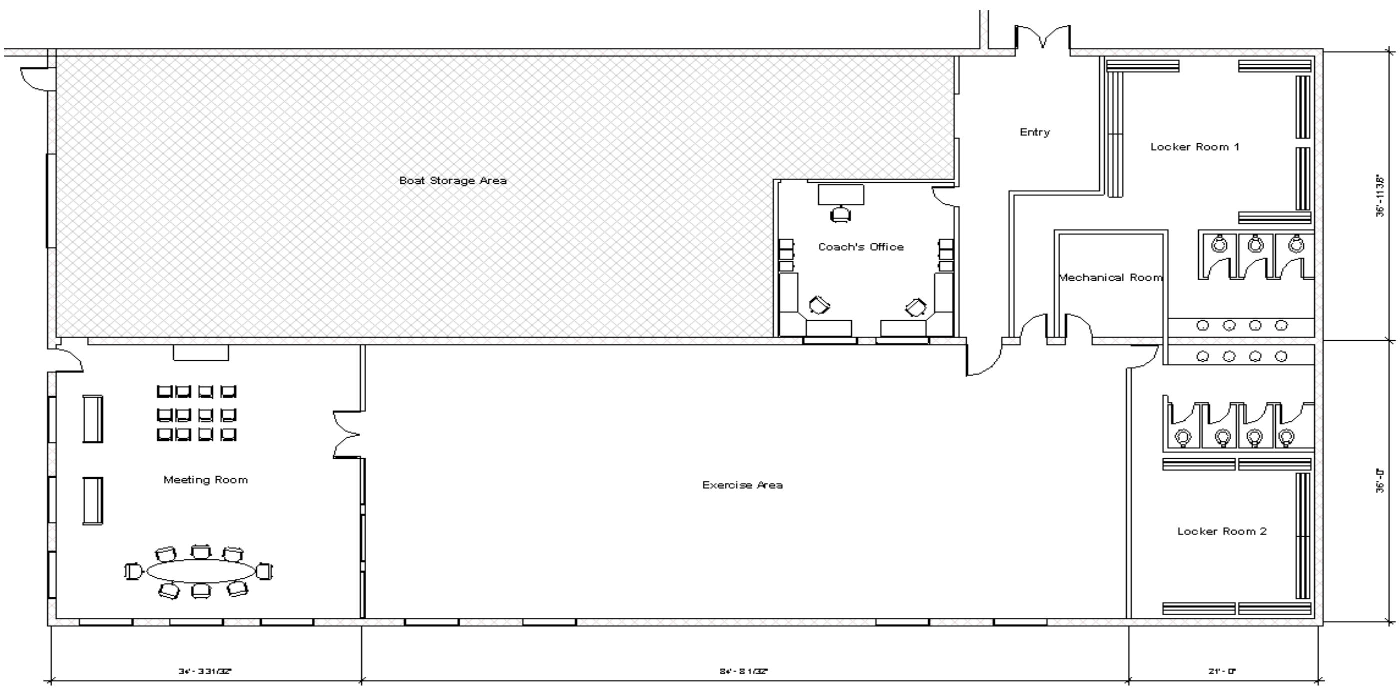


Figure 2: Floor Plan

The figure below shows the west elevation, which faces the lake. The building is 72' wide. It features three windows in the meeting room facing the lake, and a door exiting the meeting room to the exterior. There is also a door exiting the boat bay, and a large overhead door from where the boats would be carried. The roof has a pitch of 4"/12".

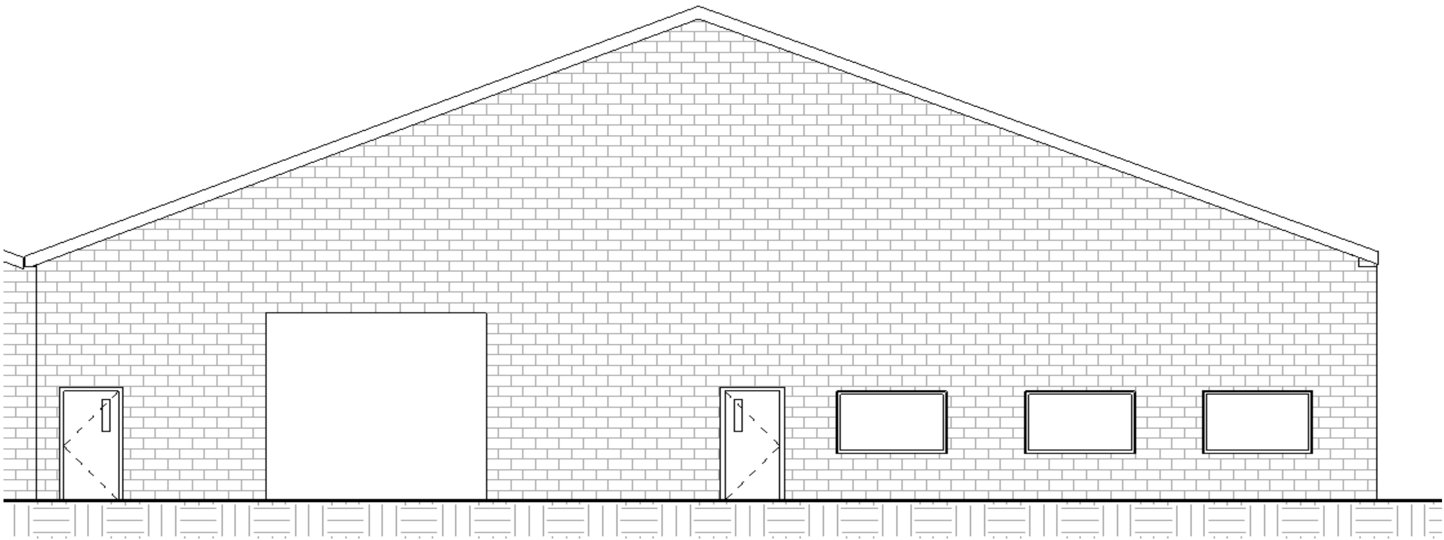


Figure 3: West Elevation

Figure 4: View of Meeting Room

Section 4.5: Foundation Design

Foundation designs were conducted for the proposed structure. The foundations were designed to fulfill the capstone design requirement of this project. The major calculations for the design included the bearing capacity of the foundations, and the allowable settlement. The bearing capacity was determined using Terzaghi's equation. This equation accounts for the shape of the foundations, the width, the density of the soil, the internal angle of friction of the soil, and the cohesive strength of the soil. The equation gave an ultimate stress that was reduced by a factor of safety, giving the allowable stress. Then the actual stress and allowable stress were compared, to make sure the allowable stress was greater than the allowable stress. The allowable settlement was calculated for the soil using Coduto's equation for settlement. The equation gives a value for the settlement of the structure, which must be less than the allowable settlement of the structure. In this case the allowable settlement was 1", and the calculated settlement was 0.03255". There were no available soil profiles of the site, so a representative profile was assumed. This profile was assumed based on the author's observations of the banks surrounding the lake, which are very sandy. The values for the variables used in the equation were taken from the Foundation Engineering Handbook. The full foundation calculations can be found in Appendix C. The foundations are continuous strip footings, with a 2' width. The walls are 1' thick, and have a height of 5'. #5 rebar reinforcement is in the walls and footings, and a keyway runs beneath the wall. The foundations are under the exterior walls of the building, and also bisect the building longitudinally. The figure below shows the cross section of the foundation walls, with the rebar and keyway shown.

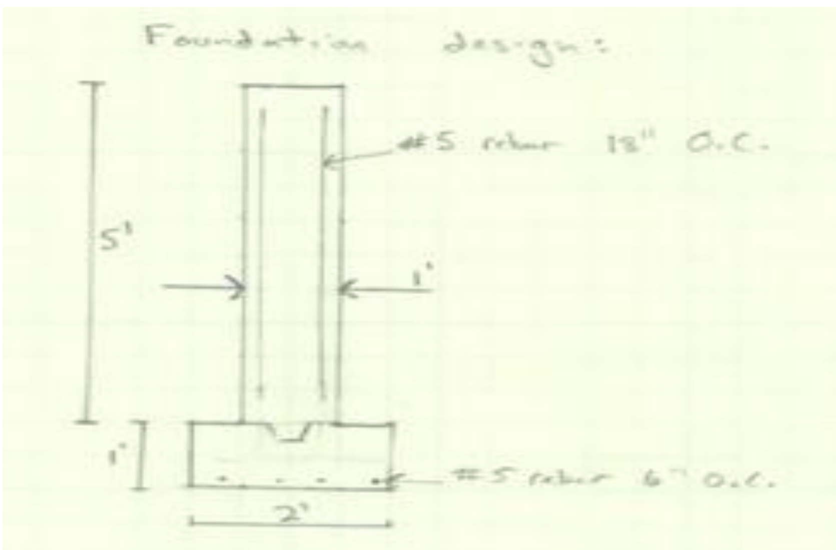


Figure 5: Cross Section of Foundation

Section 4.6: Cost Analysis

Once the facility was designed, cost for the facility was estimated. This was done by conducting a quantity take off, which quantifies all of the materials, labor, and equipment necessary for the project. To ascertain the quantities to be estimated, a quantity take off was conducted using the dimensions from the Revit model. This allowed wall, floor, ceiling, etc. areas to be calculated. These quantities were then multiplied by an estimated unit cost from a 2011 copy of R.S. Means, a estimate guide with national averages for construction materials and labor. The labor costs were based on the national average, and were not adjusted to a specific area. Most portions of the projected were evaluated using this method, but certain portions of the project were estimated using a lump sum, since there was not enough information about them. The lump sum estimates were general conditions, plumbing, electrical, and HVAC. To have a figure for these portions, I contacted a general contractor within the construction industry. The contractor provided a cost estimate for each division, and provided an approximate duration for the completion of each lump sum division. Below is a summary table containing the overall cost for each division, and a total cost. The estimated total cost of the project is $868,940.83. The detailed quantities from the takeoff can be found in Appendix D. These quantities are used in combination with the unit prices from R.S. Means to create an item by item cost estimate, which can be found in Appendix D.

Table 2: Summary of Cost Estimate

Division	Estimated Cost
Division 1: General Conditions	50,000.00
Division 2: Site Work	21,068.75
Division 3: Concrete	76,321.81
Division 4: Masonry	75,808.07
Division 6: Wood	24,944.00
Division 7: Dampproofing and Thermal Protection	74,163.56
Division 8: Openings	13,217.00
Division 9: Finishes	111,901.60
Division 10: Specialties	10,000.00
Division 15: Mechanical	80,000.00
Division 16: Electrical	35,000.00
Subtotal	572,424.79
Contingency	114,484.96
Overhead	103,036.46
Profit	78,994.62
Total	$868,940.83

Section 4.7: Financing

The final cost of the project is projected as $868,940.83. This would most likely be funded by taking out a loan, over a period ranging from the duration of construction, to 30 years. WPI would be the institution taking out the loan, since the building would be WPI property. Hopefully WPI would be able to partially fund the project through donors, to reduce costs. Reasons for a shorter or longer loan length can be available funds, loan rates, cash flow, and other financial reasons. Some sample loan lengths are listed in the table below, and sample calculations can be found in Appendix E. An interest rate of 4.5% was assumed for all loans.

Table 3: Finance Options

Loan Length	Interest Paid	Total
6 month	$19772.78	$888,713.61
1 year	$39995.49	$908,936.32
3 year	$125593.91	$994,534.74
5 year	$219253.51	$1,088,194.34
7 year	$321733.43	$1,190674.26

From the above table it is very obvious that the longer the length of the loan, the more interest costs incurred. Therefor it is advisable to finance the project over as short a period as possible. It is not always possible to pay a loan back over a short period of time due to cash flow difficulties, and sometimes a longer loan period is necessary. As can be seen in the table, the longer then length of the loan, the greater the cost of interest that is incurred. So it would be practical for WPI to try and raise funds through alumni donations, or grants, to avoid incurring these interest costs.

Section 4.8: Project Management

To give more detail about this project, a timeline was created using Microsoft Project. The duration for each activity in the project was determined using productivity rates from 2011 R.S. Means. By multiplying the estimate quantity by the productivity rate, it gives the duration of each activity. A Gantt chart and list of activities are included in Appendix F. The table in Appendix F lists each of the individual items taken off and estimated earlier in the project. The items are listed with their proposed duration, start date, end date, and predecessors. The predecessors are used to establish a hierarchy of activities, showing which activities must be completed before others can be started. The project is predicted to take place between the dates of 5/9/11 and 10/14/11. The start date was chosen because it comes after the completion of the collegiate racing season. This means that the majority of the use of the facility will not begin again until the fall. These construction dates also avoid any periods of extremely harsh weather, such as winter.

Chapter 5: Conclusions

The goals of this project were to assess needs, review building code, analyze site possibilities, design building, design foundations, takeoff quantities, estimate cost, discuss financing and determine the project timeline. After interviewing various coaches, including the WPI coach, it was determined that the main needs of the facility were additional boat storage, exercise area, ergometer area, and access to weight lifting equipment. The new Sports and Recreation center does add additional weight lifting equipment and rowing tanks, but additional renovations remove the current ergometer room. This made it important to incorporate ergometer space and exercise area into the facility design. Review of building code gave certain restrictions on facility size and fire suppression equipment for occupancy that were incorporated in the design. After reviewing the possibilities for the location of a new facility, it was decided that the most practical and cost effective solution would be to make an addition to the boat house facilities on Lake Quinsigamond. Once a location was selected, a design of the building was made using Revit Architectural. The foundations were designed using Terzaghi's and Coduto's equations for allowable bearing stress and allowable settlement. The building model created in Revit was used to takeoff material quantities needed for the project. These quantities were used with unit prices from R.S. Means to estimate a cost of the proposed facility. Although there are numerous options for financing the proposed facility, the key finding from the financial section was that the length of the loan should be kept to as short as possible, and an attempt to raise money from donors should be made. The duration of individual activities in the project were calculated using productivity rates from R.S. Means. These activities were scheduled using a hierarchal system to create a timeline and order of activities leading to the completion of the project.

In summary, all initial goals of the project were completed, and additional tables, plans, calculations, and timelines can be seen in the appendices, as referenced earlier in the project.

Bibliography:

1. Day, Robert W. (2006). *Foundation Engineering Handbook*. McGraw-Hill. New York City, NY
2. (2010). *Building Construction Cost Data*. R.S. Means Company. Kingston, MA
3. (2009). *2009 International Building Code*
4. Ching, Francis (2008). Building Construction Illustrated 4th Edition. Wiley. Hoboken, NJ
5. Dagostino, Francis; Peterson, Steven (2011). Estimating in Building Construction 7th Edition. Pearson. Upper Saddle River, NJ

Appendices

Appendix A: Availability of Land on Lake Quinsigamond

Below is a table showing the location, acreage, price, and status of any existing structure of any available land on Lake Quinsigamond.

Table A1: Available Lots on Lake Quinsigamond

Address	Acreage	Price	Existing Structure?
213 N Qunisig Ave	0.324	$675,900	Yes,house
15 Groveside Path	0.090	$269,900	Yes,house
Lot A N Quinsig Ave	0.268	$699,900	Yes, house
136 South Quinsig	0.082	$259,900	Yes, house
40 Huntington Ave	0.118	$126,00	Yes, house
252 South Quinsig Ave	0.340	$385,00	Yes, house
12 Old Faith Road	0.096	$224,700	Yes, house
20 Old Faith Road	0.349	$1,379,900	Yes, house
210 South Quinsig Ave	0.214	$489,000	Yes, house
208 A South Quinsig	0.178	$389,000	Yes, house
208 South Quinsig Ave	0.148	$289,000	Yes, house
Lot 1 South Quinsig Ave	0.785	$499,000	No
Lot 2 South Quinsig Ave	1.3	$625,000	No
77 Bay View Drive	0.198	$317,500	Yes, house
5 Smith Lane	0.251	$559,999	Yes, house
232 South Quinsig Ave	2.1	$1,050,000	Yes, condemned
128 South Quinsig Ave	0.178	$279,000	Yes, house
110 South Quinsig Ave	0.408	$399,900	Yes, house
Average	0.41261	$525,475	

Appendix B: Additional Views of Proposed Facility

The figures below show an additional elevation of the structure, a south-facing section of the building showing the locker room, exercise room, and meeting area, as well as on overhead image of the boat house and Donahue Rowing Center on Lake Quinsigamond.

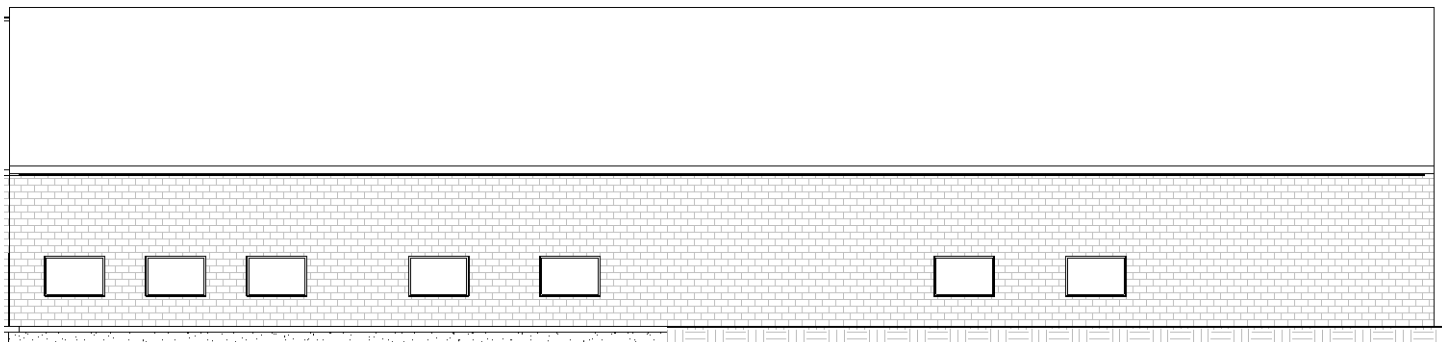


Figure B1: South Elevation

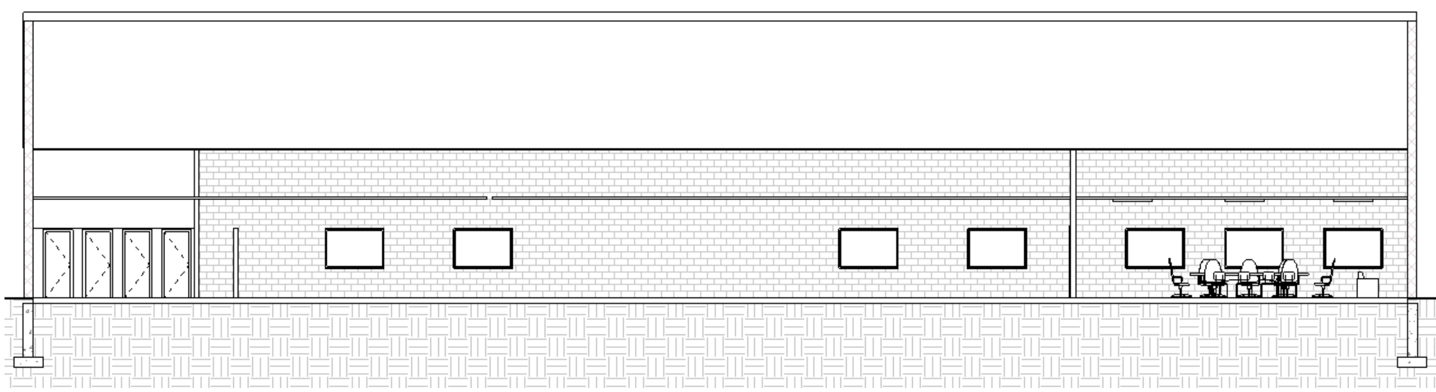


Figure B2: Section A-A of Building

Appendix C: Foundation Designs

Below are the scanned copies of the foundation calculations and design.

pg 1 of 2 | MQP Foundation Design

According to IBC, frost penetration depth for this region is 60". So the top of the footing must be at least 60" below finish grade. 1' thick footing, depth to bottom of footing = 72" = 6'

All following calculations are performed using Equations from Foundation Engineering Handbook (2006) and using Terzaghi's Eq.

Assume subsurface conditions will be sand with $\gamma = 125pcf$, $\phi = 35°$, $c = 0$, $GW = 15'$, $D_r = 60\%$

Terzaghi Eq. with shape factors: for strip footings, shape factors = 1

$$q_{ult} = s_c c N_c + \frac{1}{2} s_\gamma \gamma_t B N_\gamma + \gamma_t s_q D_f N_q$$

$s_q = 1$, $s_\gamma = 1$, $s_c = 1$, $c = 0$, $N_\gamma = 38$, $N_q = 34$, $B = 3'$, $D_f = 6'$

Try $B = 3'$

$$q_{ult} = \frac{1}{2} \gamma_t B N_\gamma + \gamma_t D_f N_q$$

$$q_{ult} = \frac{1}{2}\left(\frac{125\ lb}{ft^3}\right)(3ft)(38) + \left(\frac{125\ lb}{ft^3}\right)(6ft)(34)$$

$$q_{ult} = 32625\ lb/ft^2$$

$$q_{all} = \frac{q_{ult}}{F.S.} \quad F.S. = 3$$

$$q_{all} = 10875\ lb/ft^2$$

From load calculations: $q_{actual} = 6225.5\ lb/LF$ use 1 ft section, $L = 1'$ $B = 3'$

$q_{actual} = 2075.2\ psf$

$q_{actual} < q_{all}$ ✓ OK

Try with $B = 2'$ use 1 ft section, $L = 1'$ $B = 2'$

$q_{ult} = 30250\ lb/ft^2$

$q_{all} = 10083\ lb/ft^2$

$q_{actual} = 3112.75\ lb/ft^2$

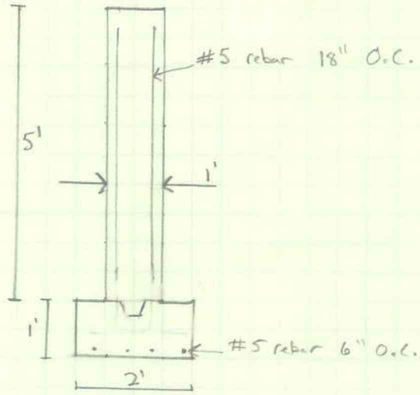
$q_{actual} < q_{all}$ ✓ OK

Will use $B = 2'$

Figure C1: Foundation Calculations

pg 2 of 2

Foundation design:



Settlement calculations: Allowable settlement = 1" (Table 2.1, Coduto)

$$S = \frac{8qB^2}{K_v(B+1)^2}$$

$q = 3112.75$ psf
$B = 2$ ft
$K_v = 170$ tons/ft^3 (Fig 7.7)

$$S = \frac{8(3112.75)(2)^2}{\left(170 \text{ tons/ft}^3\right)\left(\frac{2000 \text{ lb}}{1 \text{ ton}}\right)(2+1)^2}$$

$S = 0.03255$ in $\qquad S < S_{all}$ ok ✓

Figure C2: Foundation Design

Appendix D: Quantity Take off and Details of Cost Estimating

The first 5 sheets are scanned copies of the quantity take off. Following that is a table using the take off quantities and unit prices to determine the cost of each activity and division.

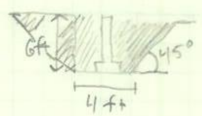
pg 1 of 5 | Cost Estimating Calculations

Division 2

Topsoil Removal: 1' removed area of building + 5' on all sides

Area = 150' x 77' = 11550 ft² x 1 ft = 11550 ft³ = 428 BCY

Foundation Excavation using End Area method:



Excavation area = 60 bsf x 424 ft = 25440 bcf = 943 bcy
(424 ft → Foundation length)

Backfill area = (60 bsf − 7bsf) x 424ft = 22472 ccf = 833 ccy

Assume swell factor = 1.2 and compaction factor of 0.9

Haul Away = 943 x 1.2 bcy = 1132 CY − (833/.9) x 1.2 = 21 CY
(1111 CY)

Hand Finishing at bottom of footings = 424 x 2ft = 848 ft²

Base course (under slab) 6" gravel

= 139 x 70 = 9730 sf

Fine grading (under slab) = 9730 sf

Apron 6 ft wide, length of Front of building

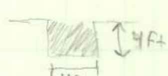
6 ft x 72 ft = 432 sf = 48 SY

Mobilization: Assume excavator, backhoe, lull

3

Also excavation and backfill to existing water & sewer lines

distance 220 ft



Area = 16ft² x 220ft = 3520 bcf = 131 bcy

Backfill = 131 ccy

Figure D1: Quantity Take Off Page 1

pg 2 of 5

Division 3

Formwork - Footings in SFCA

2 SFCA/ LF of foundation $\frac{2 SFCA}{LF} \times 424 LF = 848$ SFCA

Walls

10 SFCA/LF $\frac{10 SFCA}{LF} \times 424 LF = 4240$ SFCA

Keyway - LF 424 ft

Expansion joints every 20 ft, 6 joints,

6 x 72 ft = 432 LF

Reinforcement

Footings - #5 @ 6" O.C.

$424 LF \times \frac{2 ft}{.5 ft O.C.}$ = 1696 LF #5 rebar = 1696 LF x 1.043 lb/LF = 1769 lb

Walls - #5 @ 18" O.C.

$\frac{424 LF}{1.5' O.C.} \times 12 ft$ = 3392 LF #5 = 3392 x 1.043 lb/LF = 3538 lb

Slab WWF

Area = 140 x 72 = 10080 ft²

Concrete

Footings

424 LF x 2 ft x 1 ft = 848 ft³ = 31.5 CY

Walls

424 LF x 5 ft x 1 ft = 2120 ft³ = 78.5 CY

Slab

140' x 72' x .5' = 5040 ft = 187 CY

Dampproofing (Exterior walls)

284 LF x 5 ft = 1420 SF

Vapor barrier (6 mil plastic)

= 140 x 72 = 10080 ft²

Figure D2: Quantity Take Off Page 2

Division 7

Drip edge - 8" - perimeter of roof

76+76+140 = 292 LF x 8/12" = 195 ft²

Ice and water shield - Area of roof

76ft x 140 ft x 2 = 21280 ft²

Asphalt shingles & plywood sheathing

76ft x 140 ft x 2 = 21280 ft² = 213 square

Spray Urethane insulation (In heated areas) walls

height of walls 12ft x (140+72+40+38+140+20+20+36+10+28+24+36)
= 7308 SF

Fiberglass insulation (Areas with suspended ceiling)

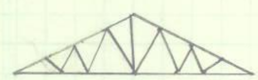
(140 x 36) + (40 x 36) + (20 x 20) = 6880 SF

Base flashing - steel - 12" perimeter of building

72+72+140 = 284' x 1' = 284 SF

Division 6 - Wood

Trusses Type T60 span - 72' profile
2x6 construction pressed plate connections
Spaced 3' on center, 142' = 46 regular, 2 gable



cost = 265.62, gable = 376.97

Doors

Type	Dimension	Quantity	Price
1 Overhead	12' x 12'	1	
2 Single - Flush vision	36" x 84"	4	
3 Double, Glass	72" x 84"	2	
4 Single - Flush vision	48" x 84"	1	
5 Single Glass	36" x 84"	1	
6. Single Flush	36" x 84"	3	

Figure D3: Quantity Take Off Page 3

pg 4 of 5

Windows

Type	Dimension	Quantity	Price
1. Awning	72"x 48"	10	
2. Fixed	72"x 48"	2	

Finishes

Interior Wall Construction
287 ft of wall

Metal studs = $\frac{287 \text{ ft} \times 12''}{18'' \text{ O.C.}}$ + 2x5 + 2x2 + 2x8 = 221 studs x12' height = 2652 LF

Runners = 287 ft x 2 = 574 LF

Gypsum board = 287 LF x 12' height x 2 = 6888 sf

Base board = 36x2 + 32x2 + 36x2 + 88x2 + 20x4 + 36x3 + 10x2 + 36x2 + 20x2 + 16x2 + 12x4 + 15x2 + 15 =
= 829 LF

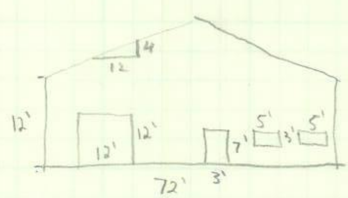
Acoustic ceiling = 36 x 140 + 40x36 + 20x20 = 6880 sf

Flooring:
Carpet
(Meeting room, Office, lobby) = 20x20 + 5x20 + 16x16 + 36x32 = 1908 sf

Tile
(Locker rooms) = 36x20 + 36x20 + 4x24 = 1536 sf

Rubber Flooring
(Exercise area) = 88x36 = 3168 sf

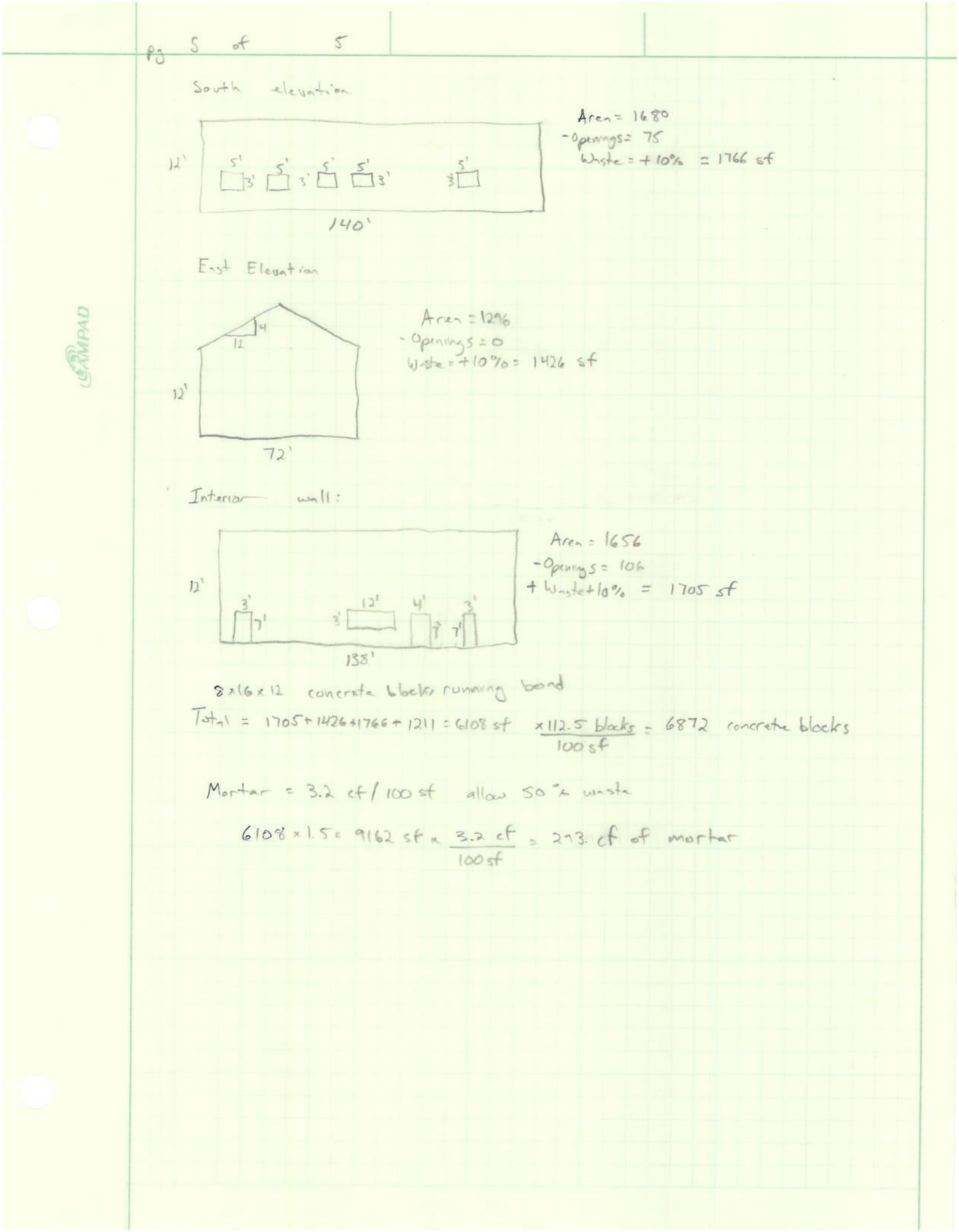
Masonry
West Elevation



Area = 1296
- Openings = 195 = 1101
Waste = +10%
= 1211 sf

36
36
36
36
20
20
10
18
25
12
10
10
18

Figure D4: Quantity Take Off Page 4



Pg 5 of 5

South elevation

Area = 1680
- Openings = 75
Waste = + 10% = 1766 sf

12'
5' 5' 5' 5' 5'
3' 3' 3' 3'
140'

East Elevation

Area = 1296
- Openings = 0
Waste = + 10% = 1426 sf

4
12
12'
72'

Interior wall:

Area = 1656
- Openings = 106
+ Waste + 10% = 1705 sf

12'
3' 12' 4' 3'
7' 3' 7' 7'
138'

8 x 16 x 12 concrete blocks running bond

Total = 1705 + 1426 + 1766 + 1211 = 6108 sf $\times \frac{112.5 \text{ blocks}}{100 \text{ sf}}$ = 6872 concrete blocks

Mortar = 3.2 cf / 100 sf allow 50 % waste

6108 × 1.5 = 9162 sf × $\frac{3.2 \text{ cf}}{100 \text{ sf}}$ = 293 cf of mortar

Figure D5: Quantity Take Off Page 5

Table D1: Cost Estimating Spreadsheet

Activity	Quantity	Unit	Material	Price Labor	Equip	Unit Price	Total Price	Production/Day	Duration (days)	Subtotal
Division 1										
General Requirements		Lump sum	-	-	-	-	50,000	-	-	
Subtotal										50000
Division 2										
Topsoil Removal	428	bcy		0.58	1.21	1.79	766.12	865	0.5	
Structural Excavation	943	bcy		3.19	1.75	4.94	4658.42	200	4.7	
Backfill	1111	lcy		0.63	1.81	2.44	2710.84	800	1.4	
Haul away	21	lcy		1.91	2.19	4.1	86.1	144	0.1	
6" Gravel	9730	sf	0.6	0.2	0.02	0.82	7978.6	8600	1.1	
Fine Grading	1081	sy		0.61	0.52	1.13	1221.53	3000	0.4	
Utility Excavation	131	bcy		3.19	1.75	4.94	647.14	205	0.6	
Mobilization	3	each		500	500	1000	3000	3	1.0	
Subtotal										21068.75
Division 3										
Formwork										
Footings	848	SFCA	1.63	2.7		4.33	3671.84	485	1.7	
Walls	4240	SFCA	0.82	3.99		4.81	20394.4	505	8.4	
Keyway	424	LF	0.18	0.65		0.83	351.92	530	0.8	
Expansion Joints	432	LF	1.41	1.72		3.13	1352.16	200	2.2	
Reinforcement										
Footings	0.9	ton	855	740		1595	1435.5	2.1	0.4	

Walls	1.8	ton	855	515		1370	2466	3	0.6	
Slab	101	csf	21.5	26.5		48	4848	29	3.5	
Concrete										
Footings	31.5	CY	103	14.3	0.39	117.69	3707.235	120	0.3	
Walls	78.5	CY	103	17.15	0.47	120.62	9468.67	100	0.8	
Slab	187	CY	103	15.6	0.42	119.02	22256.74	130	1.4	
Floor Finishing	9730	SF	0	0.39	0.04	0.43	4183.9	2400	4.1	
Dampproofing	1420	SF	0.2	0.44		0.64	908.8	665	2.1	
Vapor Barrier	101	Square	3.34	9.3		12.64	1276.64	37	2.7	
Subtotal										76321.81
Division 4										
12" ConcreteBlock	6108	SF	4.29	7.5		11.79	72013.32	250	24.4	
Mortar	293	CF	8.8	1.95		10.75	3149.75	143	2.0	
Expansion Joints	250	LF	1.72	0.86		2.58	645	400	0.6	
Subtotal										75808.07
Division 6										
End Trusses	2	each	376	159		535	1070	20	0.1	
Trusses	46	each	366	153		519	23874	30	1.5	
Subtotal										24944
Division 7										
Drip Edge	292	LF	0.46	0.86		1.32	385.44	400	0.7	
Plywood sheathing	21280	SF	0.7	0.53		1.23	26174.4	1300	16.4	
Asphalt Shingles	213	Square	74	53		127	27051	27.5	7.7	
Polyurethane Insulation	7308	SF	0.82	0.26	0.2	1.28	9354.24	3000	2.4	
Fiberglass	6880	SF	0.7	0.77		1.47	10113	1350	5.1	

Insulation (9 1/2" R30)						.6			
Base Flashing	284	SF	1.57	2.25	3.82	1084.88	130	2.2	
Subtotal									74163.56
Division 8									
Doors									
Overhead	1	each	1700	460	2160	2160	1.5	0.7	
Single Flush, Vision	5	each	435	40.5	475.5	2377.5	17	0.3	
Double, Glass	2	each	640	86	726	1452	11	0.2	
Single Glass	1	each	650	40.5	690.5	690.5	17	0.1	
Single Flush	3	each	345		345	1035	17	0.2	
Windows					0	0			
Awning	10	each	335	129	464	4640	6	1.7	
Fixed	2	each	315	116	431	862	6	0.3	
Subtotal									13217
Division 9									
Partition wall, Metal Stud, Gypsum, tape and finish	6888	SF	0.86	1.97	2.83	19493.04	350	19.7	
Base Board	829	LF	2.22	1.43	3.65	3025.85	240	3.5	
Acoustic Ceiling	6880	SF	2.31	0.91	3.22	22153.6	380	18.1	
Carpet	212	SY	51	4.31	55.31	11725.72	75	2.8	
Tile	1536	SF	4.71	3.21	7.92	12165.12	180	8.5	
Rubber Flooring	3168	SF	12.5	1.18	13.68	43338.24	275	11.5	
Subtotal									111901.6
Division 10									
Boat Storage System	1	each	4000	6000	10000	10000		3.0	

Subtotal								10000
Division 15								
Plumbing and Sprinkler System	1	each	15000	10000	25000	25000	22.0	
HVAC	1	each	40000	15000	55000	55000	19.0	
								80000
Division 16								
Electrical	1	each	20000	15000	35000	35000	21.0	
Subtotal								35000
Subtotal								572424.8
Contingency (20%)								686909.7
Overhead (15%)								789946.2
Profit (10%)								868940.8

Appendix E: Calculations for Financial Options

Below are a set of sample calculations used to determine interest and total cost based on an interest rate and principal amount.

Financing Options: Equations used A=Pe^rt, I A=Total cost P=Principal r=rate t=time periods I=interest costs

Sample Calculation: P=868,940.83, r=4.5% t=1 year

A=(868940.83)e^(.045*1)= 908936.32 I=888713.61-868.940= 39995.49

Appendix F: Project Timeline Information

Below is a table containing information for the individual activities needed for the construction of the project. Following that are images of the timeline extracted from Microsoft Project.

Table F1: List of Activities

Task Name	Duration	Start	Finish	Predecessors
Begin Project	0 days	Mon 5/9/11	Mon 5/9/11	
Excavation for foundation and footings	5 days	Mon 5/9/11	Fri 5/13/11	1
Formwork for footings	2 days	Mon 5/16/11	Tue 5/17/11	2
Install footing rebar	1 day	Wed 5/18/11	Wed 5/18/11	3
Pour footings	1 day	Thu 5/19/11	Thu 5/19/11	4
Formwork for walls	8 days	Fri 5/20/11	Tue 5/31/11	5
Install wall rebar	1 day	Wed 6/1/11	Wed 6/1/11	6
Pour walls	1 day	Thu 6/2/11	Thu 6/2/11	7
Waterproof foundation	2 days	Fri 6/3/11	Mon 6/6/11	8
Install perimeter drain	1 day	Fri 6/3/11	Fri 6/3/11	8
Backfill around foundation	1 day	Mon 6/6/11	Mon 6/6/11	10
Dig and run utilities from source	1 day	Mon 5/9/11	Mon 5/9/11	1
Run under slab utilities	1 day	Tue 5/10/11	Tue 5/10/11	12
Run under slab pipes	1 day	Tue 5/10/11	Tue 5/10/11	12
Level and fine grade interior	1 day	Wed 5/11/11	Wed 5/11/11	13,14
Install vapor barrier	1 day	Thu 5/12/11	Thu 5/12/11	15
Install floor WWF	1 day	Fri 5/13/11	Fri 5/13/11	16
Pour slab on grade	1 day	Mon 5/16/11	Mon 5/16/11	17
Install base flashing	2 days	Tue 6/7/11	Wed 6/8/11	11
Construct masonry walls	15 days	Thu 6/9/11	Wed 6/29/11	19
Erect roof trusses	2 days	Thu 6/30/11	Fri 7/1/11	20
Sheath roof	8 days	Sat 7/2/11	Tue 7/12/11	21
Drip edge roof	1 day	Thu 6/30/11	Thu 6/30/11	22
Shingle roof	8 days	Fri 7/1/11	Tue 7/12/11	23
Install exterior doors	2 days	Thu 6/30/11	Fri 7/1/11	20
Install exterior windows	2 days	Thu 6/30/11	Fri 7/1/11	20
Enclosed structure	0 days	Tue 7/12/11	Tue 7/12/11	24,25,26
Install metal studs	9 days	Wed 7/13/11	Mon 7/25/11	20,22
Insulate building	8 days	Tue 7/26/11	Thu 8/4/11	28,22,20
Rough in electric	14 days	Tue 7/26/11	Fri 8/12/11	28
Rough in plumbing	13 days	Tue 7/26/11	Thu 8/11/11	28
Rough in HVAC	16 days	Tue 7/26/11	Tue 8/16/11	28
Install sheetrock	7 days	Wed 8/17/11	Thu 8/25/11	30,31,32
Install suspended ceiling	18 days	Fri 8/26/11	Tue 9/20/11	33

Install interior doors	2 days	Wed 9/21/11	Thu 9/22/11	33
Install counters and cabinets	2 days	Wed 9/21/11	Thu 9/22/11	33
Paint walls	4 days	Fri 9/23/11	Wed 9/28/11	33,35
Install baseboard	3 days	Wed 9/21/11	Fri 9/23/11	37
Install carpet	3 days	Mon 9/26/11	Wed 9/28/11	38
Install tile floors	9 days	Mon 9/26/11	Thu 10/6/11	38
Install rubber flooring	12 days	Mon 9/26/11	Tue 10/11/11	38
Finish electric	9 days	Wed 9/21/11	Mon 10/3/11	37
Finish plumbing	8 days	Wed 9/21/11	Fri 9/30/11	37
Finish grade exterior	1 day	Wed 7/13/11	Thu 7/14/11	24
Substantial completion	0 days	Tue 10/11/11	Tue 10/11/11	44,38,39,40,41,42,43
Punch List	3 days	Wed 10/12/11	Fri 10/14/11	45
Final Completion	0 days	Fri 10/14/11	Fri 10/14/11	46

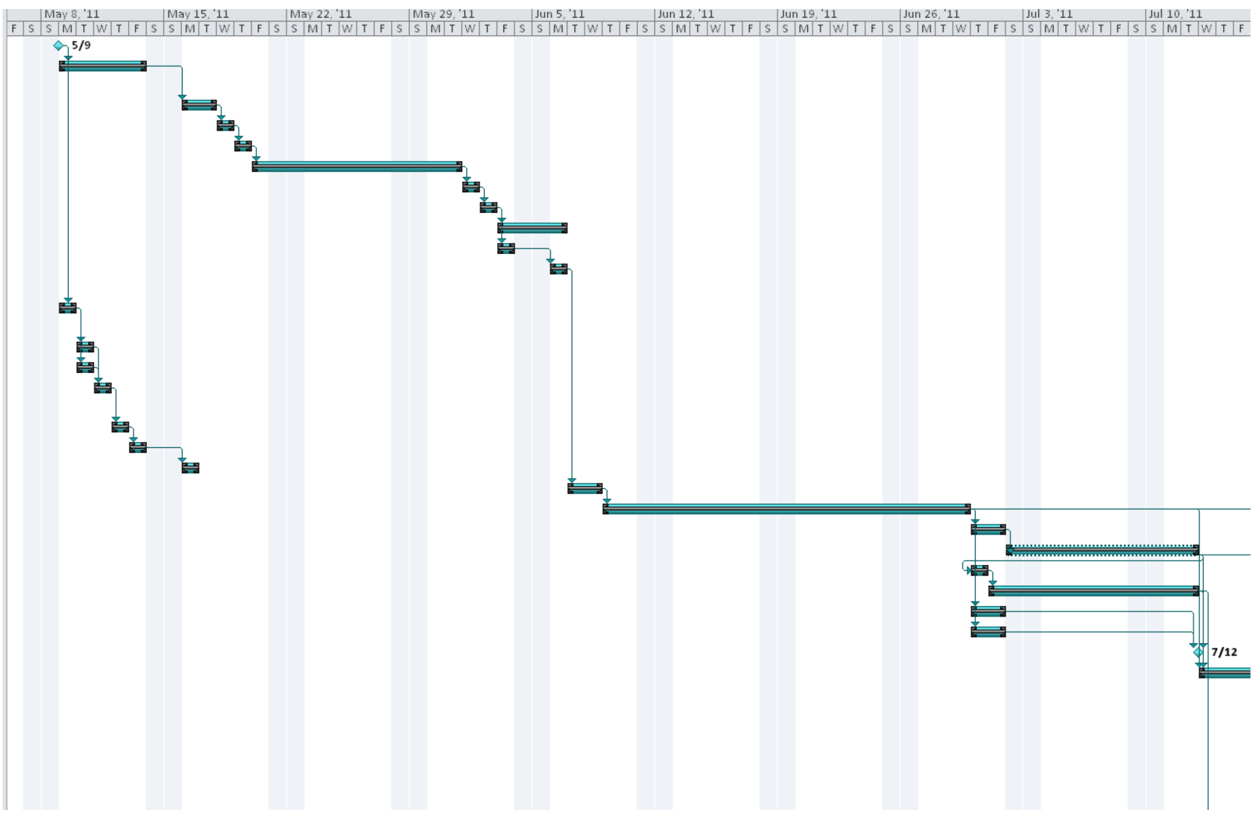


Figure F1: Gantt Chart Part 1

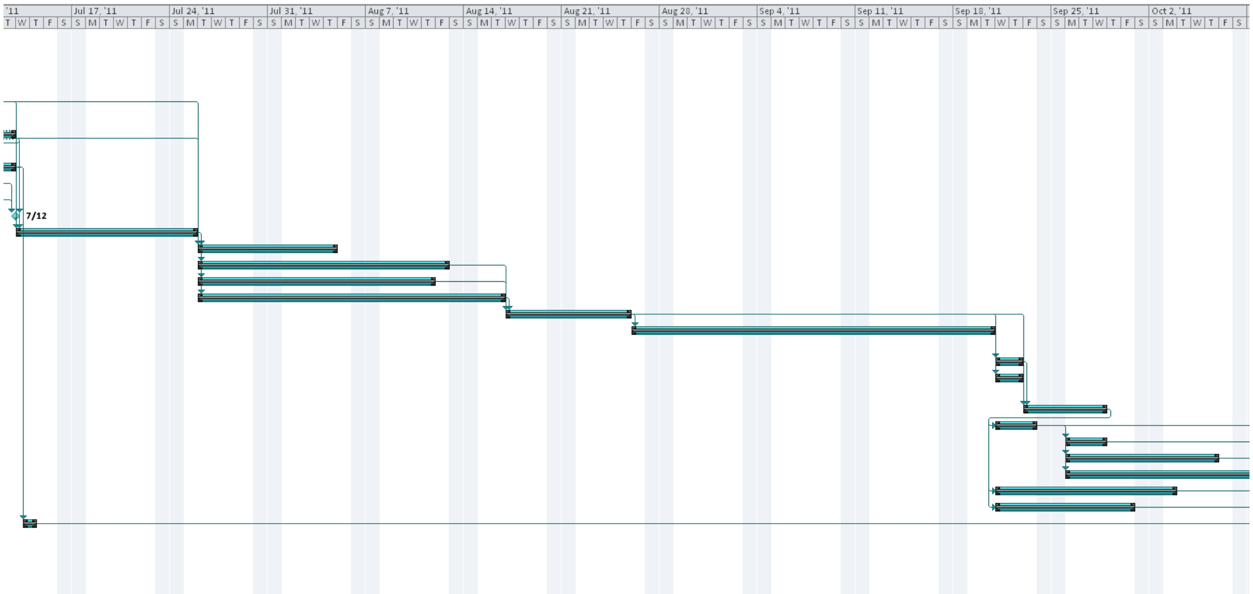


Figure F2: Gantt Chart Part 2

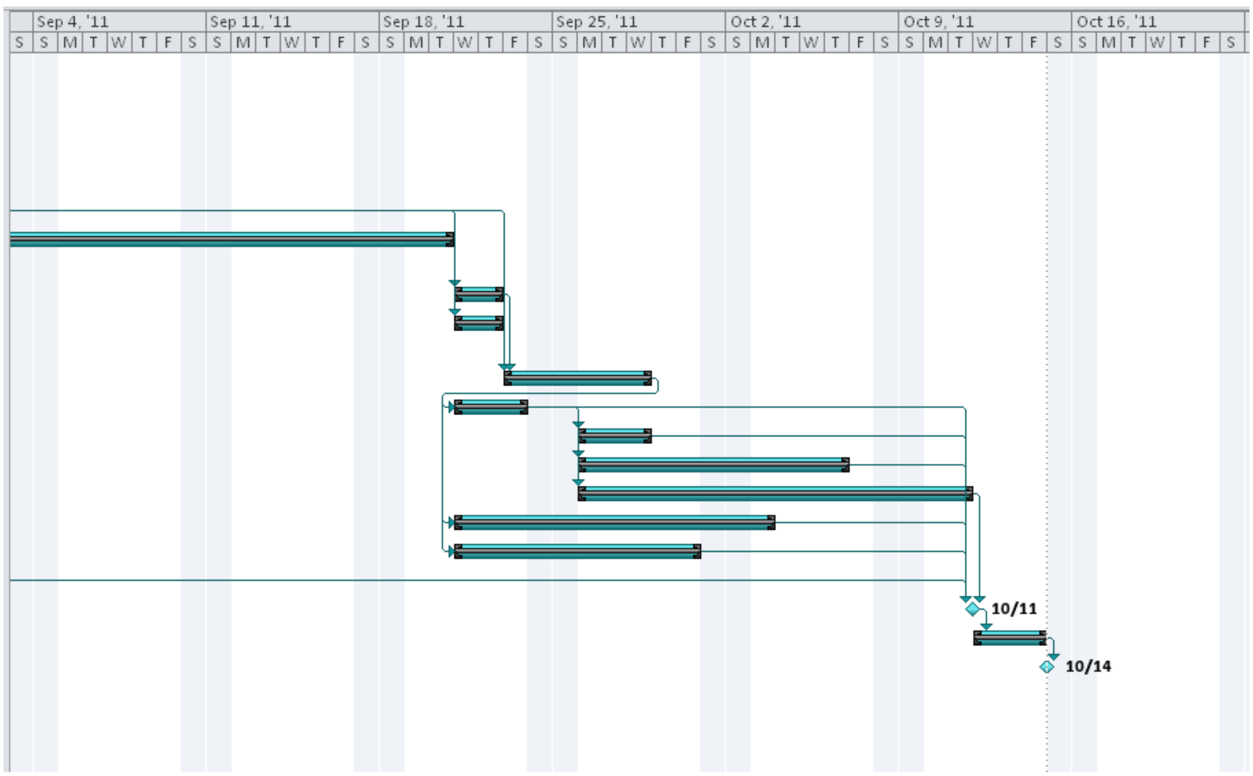


Figure F3: Gantt Chart Part 3