Alumni Stadium Redesign

A Major Qualifying Project Report
Submitted to the Faculty of
Worcester Polytechnic Institute
In partial fulfillment of the requirements for the
Degree in Bachelor of Science
In
Civil Engineering

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Abstract

Alumni Stadium, home to the Worcester Polytechnic Institute Engineers, supports intercollegiate athletics, and provides an impressive facility for club sports, intramural programs, and recreational use by the WPI community. Our project involved the redesign of Alumni Stadium to better accommodate the respective teams that use this facility on a daily basis. After interviewing stakeholders and investigating constraints, we provided a feasible design for future consideration. In completion of our design, our team used AutoCAD and Revit Software to generate renderings to be used as a visual aid.

Executive Summary

Worcester Polytechnic Institute is home to Alumni Stadium, where a multitude of sporting events are held, ranging from Varsity Football games to club lacrosse practice. In its current state, there are several opportunities for enhancement that will contribute to a more useful and spectator-friendly stadium. These areas were highlighted through interviews with WPI community involved with operations within the stadium, along with spectator data provided through surveys sent to WPI students. Through this research, it was deduced that there are five key areas within the stadium that should be improved: the press box, the away side hill adjacent to the Sports and Recreation Center, the track, the scoreboard, and the facilities building. To develop our solutions for each area, the team evaluated the current conditions of the stadium in order to develop constraints. These constraints in conjunction with survey data governed our final design.

Location	Current Deficiencies	Future Design Wants	Constraints
Press Box	- Poor roof access - Lacks separation between coaches and media personnel	- President's Box - Wide field of view from inside	- Available area - The loading that can be placed on the superstructure
Awayside Hill	- Difficult to maintain - Potential hazard due to large slope	- Spectator seating - Aesthetic appeal	- Footprint of the space - Soils ability to support loading
Track	- Poor condition	- Longer Straight Away -Ability to host NCAA meets	- NCAA track regulations
Facilities Building	- Vehicle accessibility - Insufficient size	- Overhead doors	- Footprint of available space
Scoreboard	- Small compared to other options	-Video Board	- Price

In addition to the highlighted needs and constraints, the proposed solutions seemed to focus on value added, maintaining the school's aesthetic image, and most importantly being economical. Based upon our findings, our team recommends the following:

- Fabricate a new press box that would include a president's suite, windows that span the buildings corners to provide optimal site lines, sectionalized coaching room and elevator access to the roof.
- Construct terraced-style seating on the Away Side Hill. This should be constructed using a series of mechanically stabilized earth retaining walls, that would provide roughly 200 additional seats and require little maintenance, while not producing additional water runoff due to the design's infiltration properties.
- Extend the track at the southwest corner for a 100-meter straightaway. Install a polevault area behind the south endzone. This, in addition to resurfacing the entire track, would allow for better running conditions, more space for jumping events and allow for Alumni Stadium to host track and field meets.
- Demolish the current facilities building and construct a new one at one of the WPI-owned lots near the school. This space would then be replaced with a restroom and potential storage room, which will allow spectators to stay in the stadium to use the restroom.
- Replace the current scoreboard with a tandem score and videoboard. This will allow for replays, advertising, and school promotions.

Each proposed solution is independent of one another which allows for adaptability in planning and construction. If all designs were to be implemented, it would cost roughly 1.3 million dollars if built in 2020. In its entirety, it would be an economical way to revamp the stadium and promote WPI's commitment to excellence.

Authorship

This report consists of the work from Daniel Hoag, Sean McAllen, Nick Ostrowski, and Stephen Peterson. All of the group members contributed equally to the report and the presentation. Hoag and Peterson took the lead in creating the designs and cost estimates for the away side seating, the press box, and the field restroom. Ostrowski took the lead in putting those designs into Revit while McAllen had the lead in all phases of the track design. McAllen and Ostrowski assisted with several design tasks as well. Finally, all parts of the project were edited by the whole project team.

Acknowledgements

The project team would like to thank the project advisor Professor Leonard Albano for his guidance and support throughout the duration of the project. We would also like to thank the stakeholders we interviewed, most notably William Spratt, Director of Facilities Operations and Dana Harmon, Director of Physical Education, Recreation, and Athletics.

Capstone Design

Alumni Stadium is home to a variety of sporting events at WPI, but as the school grows and changes, upgrades to the field will need to be addressed in order to meet the new demands placed on it. In doing so, our group focused on six design considerations that are essential in the engineering field: Economic, Environmental, Sustainability, Social, Health and Safety, and Ethics. Through the completion of these constraints, this MQP experience successfully demonstrated the capstone design requirements outlined for an ABET-accredited curriculum.

Economic

When choosing a design for Alumni Stadium, cost was assessed to determine the most feasible design. The cost of the project was analyzed using past renovations to Alumni Stadium as well as other construction projects throughout different college campuses across the United States as a benchmark to compare costs and aid the team in choosing the most cost-effective design. Projects at WPI are funded by donations, and we want our design to have the biggest impact while maintaining an appropriate price.

Environmental

Our proposed design has a minimal impact on the environment. We analyzed the effects of stormwater on each design, most notably our away side seating alternatives, and ultimately chose the design with the least impact. The necessary precautions were made for our design to be environmentally friendly.

Sustainability

In order for our design to be a successful one, it must be one that offers a sustainable solution. Our group used environmentally responsible materials that come from local sources and we incorporated the most energy efficient products. In doing so, we provided the new stadium with a design that would create long term savings for WPI through lower energy and maintenance costs.

Social

Athletics have a great social impact on a college campus. With that being said, our team aimed to produce a design that would have a positive effect on the WPI community as a whole. We wanted the school's athletes and fans to have the best experience using its athletic facilities and our plan of action used multiple ideas from people outside of athletics to create a balanced and well-rounded design.

Health and Safety

The health and safety of the WPI community is at the utmost importance. Our Alumni Stadium design proposal must address the safety and health of both athletes and spectators. The design elements were defined in accordance with the rules and regulations set forth in the Massachusetts building codes, and we held the health, safety and welfare of all occupants as the number one priority. Examples of these codes include the *Massachusetts State Building Code* (780 CMR), and *International Code Council Standard for Bleachers, Folding and Telescopic Seating, and Grandstands* (ICC 300).

Ethics

Our team followed all the ethical standards all civil engineers adhere to. These standards are found in ASCE (American Society of Civil Engineer) Code of Ethics. This code was used as a reference when making professional decisions for our design and when we talked to stakeholders, clients, and other people of interest.

Professional Licensure

In the discipline of civil engineering, engineers have the opportunity to obtain a Professional License (PE). This certification allows engineers to prepare and review construction documents that will be used when constructing a structure. PE licensure is the engineering profession's highest standard of competence, and gives the profession and the public an assurance of quality of work. For this reason, the PE license makes engineers valuable to employers, for their high level of responsibility, which leads to increased salaries. Each state has its own licensing board that requires each candidate to complete certain steps.

The first step in achieving a PE in Civil Engineering is graduating from an ABET-accredited university. Another requirement by the Massachusetts licensing board is the completion of the Fundamentals of Engineering Exam (FE). The passing of this exam allows engineers to obtain the title of Engineer-in-Training (EIT). Once under the title of EIT, the engineer must have a progressive and verifiable work experience in the industry for a minimum of four years. The work experience will ensure that the engineer gains valuable knowledge in their field of concentration. The last step in obtaining a PE is passing the Principles and Practice of Engineering Exam, and eventually receiving their unique PE seal. In order to maintain the PE license, many licensing boards require engineers to continue to improve their skills through continuing education courses for further professional development.

The degree of importance to the profession, the individual, and the public of the Professional Licensure is extremely high. Not only is it the highest degree of mastering a discipline, but it also assures the public that the structures they use every day are at a high standard.

In this particular project, a PE would successfully create an alternative design that would be aesthetically appealing, have the least environmental impact and most importantly, ensure the safety of its occupants. PE's with different disciplines would be needed as well. Geotechnical PEs would be needed to ensure the structural integrity of the soil and Structural PEs would be needed to guarantee the safety of the structures that would be built in the design.

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Figures and Tables

Chapter 1: Introduction

Alumni Stadium is the home for Worcester Polytechnic Institute's athletics. Football, soccer, field hockey, club sports and intramurals use Alumni Stadium for games and practice. The stadium has not been modified since its last renovation in 2007, and with ever changing demands created through consistent growth, considerable upgrades will need to be made in order to meet these challenges. The track is in a highly degraded condition and WPI has not been able to host a track meet in over 10 years (D. Harmon, 2019). Also, there is open-space within Alumni Stadium which can benefit fans; however, the south side of the stadium is poorly designed and does not take advantage of the limited open space that it has. With that being said, the goal of our project was to redesign Alumni Stadium to better accommodate WPI's multiple varsity athletics teams while maintaining a feasible and cost-effective design.

The following project objectives were completed in order to achieve our project goal in a successful and fulfilling way:

1. Examined Existing Conditions

2. Gathered Input from Stakeholders

3. Identified Design Criteria

4. Created and Evaluated Design Alternatives

5. Developed Final Design

From these objectives we were able to ensure a feasible design that would benefit the various users of Alumni Stadium. We then chose the best design that satisfied our stakeholders, and completed our goals. The design would have a positive impact on the WPI community and maintained a reasonable price.

Chapter 2: Background

The background chapter first outlines the history and current condition of Alumni Stadium. The next subjects up for discussion are why we need to talk to stakeholders and design constraints in regards to building codes. Lastly, cost saving techniques are examined.

2.1 History of Alumni Stadium

Alumni Stadium is located at the cross section of Park Ave and Institute Rd in Worcester Massachusetts, and is the home stadium for the Worcester Polytechnic Institute Engineers. Its first use was back in 1914 when WPI’s football team faced off against the RPI Engineers. The stadium’s first renovations came in 1926 when bleachers were added to both sides of the field, providing enough seating for 2,800 spectators. In 1985, WPI replaced the grass playing surface with its first artificial turf, which has seen routine replacements since its installation. The facility’s most recent upgrades came in 2007 with a complete overhaul, consisting of a new 2,000-seat bleacher with a press box, new turf and track surfacing, a scoreboard, and a lighting system. Since these renovations in 2007, Alumni Stadium has remained largely unchanged, but the surrounding area has seen rapid changes that have greatly affected the way the teams and spectators of WPI interact with the stadium. Some of these changes include a brand new recreational center and a parking garage equipped with a turf softball field and another all sports turf field located above.

2.2 Alumni Stadium Currently

The entirety of Alumni Stadium has not been modified since its renovation in 2007 besides a turf replacement in the summer of 2015. Since the turf replacement occurred recently, it is in great condition. It is tested annually for how well it absorbs impacts by WPI facilities, as well as contractors. The track surrounding the turf, however, is in fairly inadequate condition and needs to be replaced (D. Harmon, 2019). As for spectator viewing and seating, the stands are in good condition and can accommodate nearly 2,000 fans. The home stands also support the press box, which can be modified in order for better use of the space. There is a hill on the away side of Alumni Stadium, and it is an area for some fans to watch the game. It can potentially be a space to install new seating.

There are a few miscellaneous areas around the stadium that can be considered within our design as well. The facilities building on the far side of the field is very old and used for storage of vehicles. This building is used inefficiently because there is one garage door for multiple facility vehicles and lawn equipment. It does, however, provide proximity to Alumni Stadium and the Institute for the facility workers. A picture of the building can be seen below. Furthermore, the scoreboard is also a piece that could be affected, in order to further enhance the "tech" feel to Alumni Stadium.

Figure 1: Facilities building located within Alumni Stadium (Photo by Sean McAllen)

2.3 The Need to Talk to Stakeholders

Alumni Stadium serves a multitude of people across WPI and beyond. In order for a new design to be successful, it has to take into consideration all the people it affects: the fans, athletes, students, athletic directors, coaches and more. Also, talking to different stakeholders can help generate new ideas and make us look at design options in a different perspective. Some potential ways to contact stakeholders are through emails, personal interviews, and/or surveys.

2.4 Implications of Potential Design

When designing a new stadium, it is imperative to observe the constraints that are present in the given area. These constraints can include physical constraints such as issues with stormwater management and drainage, and/or code constraints that need to be compliant with the governing building/zoning codes of the area.

2.4.1 Building Codes and Standards

The International Code Council (ICC) is a nonprofit organization that provides a wide range of building safety solutions. It develops model codes and standards used worldwide to construct safe, sustainable, affordable and resilient structures (*International Code Council,* 2019). Two codes that were utilized within our project that were written by the ICC are the

International Building Code (IBC 2015) and ICC 300*: Standard for Bleachers, Folding and Telescopic Seating, and Grandstands* (2017).

The IBC is used for all construction in Massachusetts, existing and new, and was used throughout the design process of the stadium. In Massachusetts, there are amendments made to the IBC that are found within a regulatory document called the 780 CMR, or the *Massachusetts State Building Code*. The 780 CMR covers nearly all aspects of the building process from structural loads, mechanical work, and plumbing, to permissible materials to use. Certain provisions in the 780 CMR to be considered are Occupancy Classification and Use; Permissible Height and Areas; Type of Construction; and Means of Egress to name a few.

The International Code Council has specific guidelines and regulations to adhere to when designing new or renovating old stadiums. These provisions fall under the S*tandard for Bleachers, Folding and Telescopic Seating, and Grandstands*, ICC 300, which specifically uses the IBC as a reference. The reasons for adhering to this code is to safeguard public health, safety, and welfare. Additionally, the code goes into details on the potential operation and maintenance routines, as well as establishes a uniformity amongst similar projects, so that potential upgrades can be made in the future without drastic alterations being required.

2.4.2 ADA Compliance

In order to make full use of the proposed renovated area, the stadium must incorporate ADA Regulations. ADA stands for the Americans with Disabilities Act. This act "is one of America's most comprehensive pieces of civil rights legislation that prohibits discrimination and guarantees that people with disabilities have the same opportunities as everyone else to participate in the mainstream of American life." (*ADA Accessibility Guidelines*, 2019). There are a multitude of guidelines that a new structure must follow to comply with ADA. Some examples of regulations include handicap accessibility through sidewalks, buildings, and parking. Any new structure or access way that is added to Alumni Stadium for design will have to comply with ADA regulations.

2.4.3 Stormwater Management

When building a new structure, it reduces the pervious surface area. With less pervious surface, water can collect in the area and can potentially increase the risk of flooding. Because of this, there are stormwater drains that collect the water. The current drains from inside Alumni Stadium lead out to the circle by the parking garage and the Recreational Center. The drains line the border between the track and turf and discharge to the circle for stormwater collection. The assembly found within the circle is the StormTech MC-4500 Chamber and holds a large amount of water (162.5ft^3). It was built around 2012 during the construction of the parking garage rooftop field and can be seen in Figure 2. It collects stormwater from Alumni Stadium, Rooftop Field and adjacent parts of the Sports and Recreation Center. It then is infiltrated into the soil with access getting distributed to the municipal stormwater system. The existing drainage is not anticipated to be modified or affected in any way with any renovation we make to the stadium. Any added impervious surface area must be calculated to determine if the chamber can handle the extra stormwater. If not, alternative measures must be taken to collect the excess stormwater.

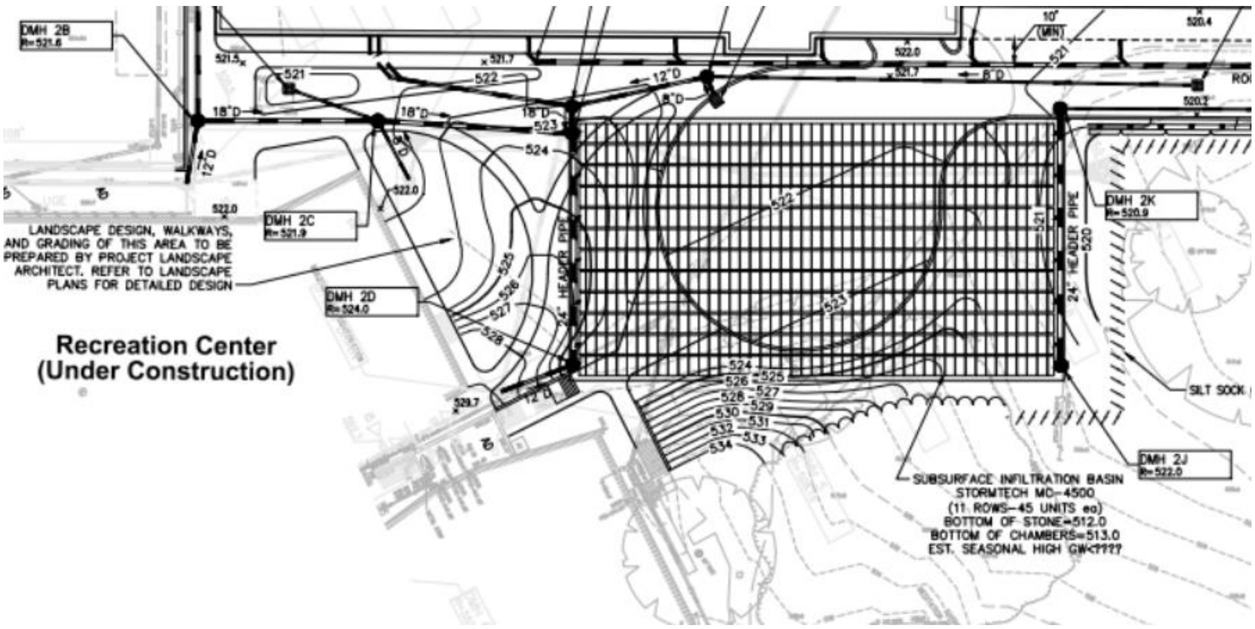

Figure 2: MC-4500 Chamber underneath the circle (Photo by Grading and Drainage Plan C-3.0: WPI Athletic Fields and Garage)

2.4.4 Structural Design

When designing new stadium seating for Alumni, we considered a safe and cost efficient structural design. Doing so will require utilizing loading information regarding stadium seating and occupancy loads. We followed the *ICC 300: Standard for Bleachers, Folding and Telescopic Seating, and Grandstands* (2017) standards for our design loads. The proper sizing of materials to ensure occupant safety requires knowledge of these loads. For the current stadium, member sizing must be known in order to determine maximum loading capacities that are currently available. In addition, soil load capacities must be considered to design foundations accordingly.

2.4.5 Track Surface Design

The top layer of a track is a synthetic material. There are different types of synthetic track surfaces, so our team established selection criteria of durability and porosity. Under the track surface is typically concrete or asphalt. Asphalt is the better option in the Northeast because of its flexibility during freeze/thaw activity (What you Need to Know About Modern Running Tracks, 2009). Furthermore, the surface markings must follow NCAA regulations, which are shown in Figure 3. The regulations are typically ranges of dimensions which offers universities some flexibility in construction of its track facilities. An example of track dimensions can be seen in the figure below.

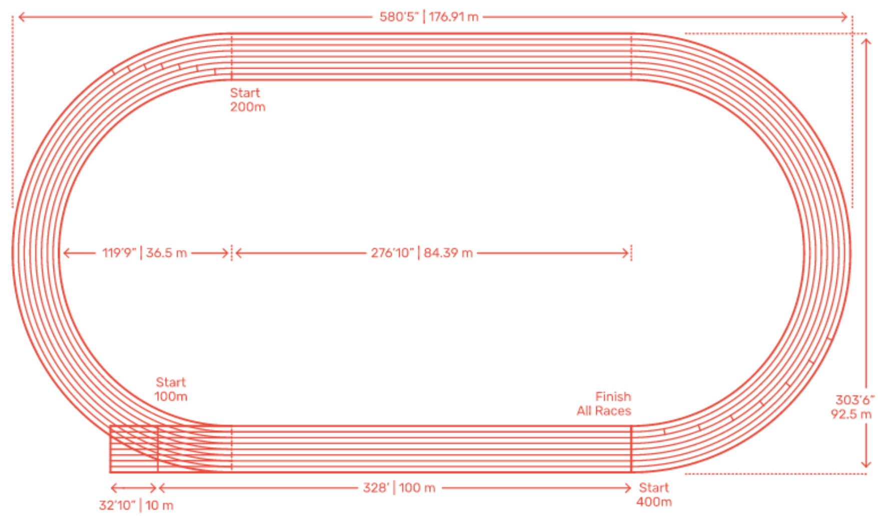

Figure 3: Common track dimensions for a 400 meter running track (Photo by Dimensions Guide)

2.5 Cost Estimating

In order for our design to be successful, it will have to be cost-effective. To estimate the final cost of the encompassing project, everything from materials, design and planning, and labor must be in consideration. Multiple cost estimating resources must be used to reach a final number. Depending on the edition or year in which the cost values were published, an inflation rate must be used to acquire a figure that is accurate for 2020. Typical values for cost estimates in construction can be roughly determined using data from RS Means.

Chapter 3: Methodology

In order to achieve our goal of redesigning Alumni Stadium to better accommodate WPI's multiple varsity athletics teams while maintaining a feasible and cost-effective design, we assembled several objectives that established our plan of action. This chapter outlines the five objectives our group took in order to complete the project.

3.1 Examined Existing Conditions

Alumni Stadium encompasses all the structures within the area between the Recreation Center, rooftop field/parking garage, Park Avenue, and Institute Road. Our group identified all the structures within this area by looking at past Major Qualifying Projects, past photos, google maps, as well as conducting site visits. We then took photos of our own (Appendix I) to capture the current condition of Alumni Stadium. We were also able to acquire design plans on the Sports and Recreation Center and the Rooftop Field from facilities to gather more information on Alumni Stadium's existing conditions.

3.2 Gathered Input from Stakeholders

After we identified the existing condition of Alumni Stadium, we interviewed multiple stakeholders to see what they would want improved within the stadium. Our stakeholders hold a variety of positions within WPI. This helped us to understand the needs of all people affected by Alumni Stadium, not just sports teams. Table One lists the people we interviewed, their, title, and type of information we asked. We also created a fan survey that was distributed to the current CE, EE, and AE students to ask about their fan experience watching athletics competitions at Alumni Stadium. This fan survey can be found in Appendix B.

Table 1: Stakeholder Information

Contact Name	Contact Title	Information Gathered
Dana Harmon	Director of Physical Education, Recreation and Athletics	-Existing plans in place or in the works for Alumni Stadium -Her vision of Alumni Stadium
William Spratt	Director of Facilities Operations	-Existing plans of Rec Center and parking garage -Current need for the facility building located within Alumni Stadium
Shawn McAvey	Facilities Manager	-Current condition of athletic equipment storage
Rusty Eggen	Associate Athletic Director and Sports Information Director (SID)	-Current condition of press box -Other features of college stadiums he liked
Brian Chabot	Head Track and Field Coach	-Current condition of track -New features of track he would like to see added

3.3 Identified Design Criteria

Once information was gathered from the stakeholders, our group identified the most important aspects of Alumni Stadium that need to be changed or improved. We created a table of all the areas within Alumni Stadiums and what we evaluated within each area (Table 2). Evaluations were conducted based on areas that the project team felt were primary needs or additions to the stadium versus desirables that were wanted by stakeholder within the stadium.

Table 2: Areas of Improvement within Alumni Stadium

Area of Improvement	Actions Taken
Track Surface	-Evaluated track surface and its NCAA meet eligibility
Facilities Building	-Evaluated current condition of building and its function within the Facilities Department
Away Side Seating	-Evaluated how fans currently use the hill during games and how we can improve it
Press Box	-Evaluated its condition from the point of view of the coaches and the Sports Information Director point-of-view
Scoreboard	-Evaluated the function and aesthetic appeal
Restrooms	-Evaluated feedback of fans on the location of the restrooms during athletic competition

3.4 Created and Evaluated Design Alternatives

The areas of improvement were identified, which provided the information for our group to investigate alternative ideas and designs for each different area. To create new potential designs, each group member was tasked with doing their own investigations regarding architectural aspects that they would like to see incorporated within the new design proposal. The team flushed out the ideas further together, and then decided on an individual plan for each area of improvement moving forward. Once the team created alternative ideas, an evaluation process was put forward in order to select the best alternative design.

3.4.1 Away Side Seating

During the design phase for the away side seating, the group first determined if there was a true need for more seating and exactly what that need would be. This need was determined by first consulting the stakeholder surveys to develop an understanding for how the school planned to grow and change around the stadium. With this need, the group determined a target value for the number of seats to be added. After this was calculated, the next step was to determine the physical limitations of the hill side. Using information from aerial photos and design documents of the Sports and Recreation Center, the team computed the area of the space as well as the slope of the present hill. From here, the group came up with four potential conceptual designs. These were then narrowed down to two based on what the group felt was most unique and fitting for the school. These two alternative designs were then further developed and were evaluated for structural soundness and constructability. To do this, the group considered overturning, soil bearing strength, and sliding. Additionally, the team designed for rebar placement and maximum stresses within the structures. With both design alternatives completed the group prepared a cost estimate for each using a material take-off and unit price estimating method. The framework for this method can be seen in Figure 4. After the costs were determined, the team set up a value matrix to grade both designs based on a variety of characteristics, identified through our surveys. The design that scored the highest was ultimately chosen for the final design.

Description	QTY.	Units	Unit Cost	Total Cost	Source
Sitework and Labor					
Materials and labor					
Multipliers					
Location: Worcester			1.077		
Time: 2020			1.076		
Design Fees			7%		
Contingency			15%		
Total Cost Without Multiplyers					$ 78,648.50
Total Cost With Multiplyers					$108,444.64

Figure 4: Cost estimating sheet

3.4.2 Track Design

The creation of a new track design was crucial to the success of the project. The track had to be redesigned in order to abide by NCAA regulations and to fit within the constraints of Alumni Stadium (Cross Country/Track and Field 2019 and 2020 Rules). We also used the information we gathered from our stakeholders, most notably the head track and field coach, Brian Chabot, for this portion of the project. Our group then consulted with Kevin Fuselier, a licensed landscape architect with many years of experience in track construction about different designs. Next, the design of the layout of the track was made using AutoCAD in order for the project team to consider different layouts and integrate them into the existing space. The type of track surface was then researched and chosen. The track surface was chosen on certain criteria which included durability, performance, and material that will have the most positive impact at WPI.

3.4.3 Press Box

Initially the entirety of the stands was considered for reconstruction and renovation, but from surveys and attendance records, the value of seating was determined to be sufficient. However, the press box itself was seen as an essential area for improvement. After the determination of need, the team examined whether or not the current structural system supporting the press box could handle alternate loadings. To do this, measurements of all of the structural components were taken on the site as well as their layout (Appendix E). This information enabled us to determine the design capacity. When configuring the design capacity, dead loads, live loads, snow loads and wind loads were estimated. Dead loads were assumed based on material used for the new press box along with potential furniture. Live loads were based on conservative values of the capacity the building will reach and snow loads were based on local area conditions. Using LRFD design methods in tandem with RISA 3D structural modeling software, the team computed and concluded that the new press boxes could be supported by the current structure.

From here, the team progressed in a similar method as in Section **3.4.1.** The group individually proposed ideas for the final design. The aspects that the team judged most essential in accomplishing the goals, as laid out by stakeholder feedback, were combined to form two alternative designs. These two designs were then priced and ranked on a similar value scale as the away side seating (Appendix F). The highest scoring design was then incorporated into the final design for the overall facility.

3.4.4 Scoreboard

From our fan survey and talking to our stakeholders, it was evident that a new scoreboard captured the likes of many people. Our group researched the current type of scoreboard in Alumni Stadium and looked at different alternatives manufactured by the same company, Daktronics. We assessed the aesthetic appeal, price, and feasibility of the different designs that Daktronics offers. We ultimately chose the scoreboard that would best engage the players and fans, while having the most reasonable price.

3.4.5 Facilities Building/Bathroom

From speaking with the Head of WPI Facilities Office, the team discovered that there is a desire to have a more suitable facilities building and, as the school grows, the need is expected to be amplified. This information in combination with the user survey, led the team to conclude that demolishing the facilities building and replacing it with a restroom facility would better fit the needs of the stadium. As a consequence, the team researched specific locations within WPI jurisdiction that could provide a suitable replacement location for the new facilities building. To determine a design for the restrooms, the team gathered inspiration from similar facilities. The key considerations when planning such designs, were the limited footprint the building could take up, and the fact that building would only be seasonally operational. With this information the team provided two designs for final consideration. Both designs were highly restricted by the available footprint of the building and the ADA codes governing restroom design and approval. Once completed both designs were priced out and compared using a similar value matrix as presented in Section **3.4.1.** The criteria for this matrix were determined primarily from needs determined from user surveys and the overall constructability of the final design.

3.5 Developed Final Design

After our group evaluated the designs, we chose the most appropriate ones based on our criteria described in the previous Section **3.4**. We then integrated each design into one overall project. Finally, we generated the cost estimate to complete the entire project and made recommendations in order to maintain Alumni Stadium for years to come.

Chapter 4: Results

The Results Chapter first examines the existing conditions within Alumni Stadium and then a summary of information we gathered from our stakeholders. Design constraints were then identified and multiple designs of the press box, away side seating and field restrooms were generated. Lastly, cost estimates were made for each and a final design of all aspects were chosen.

4.1 Existing Conditions

Understanding the areas surrounding Alumni Stadium and the constraints within the stadium is crucial in our development of a new and innovative design. This section outlines and evaluates the present condition throughout Alumni Stadium.

4.1.1 Location

Alumni Stadium is located within Worcester Polytechnic Institute's campus. It is surrounded by the parking garage to the north, the Sports and Recreation Center to the east, and Institute Road/Park Avenue on the south and west sides as seen in Figure 5. The field and track is also enclosed by a chain-link fence. Due to these structures and roads, there is little to no room for expansion of Alumni Stadium, only renovations and revised layouts within the space.

Figure 5: Aerial view of Alumni Stadium and WPI campus (Photo by Laval Lee Photography)

4.1.2 Entrances

In order to access the stadium for viewing purposes, there is currently only one entrance that is used. The entrance is located near the home side bleachers, and originates directly from the parking garage. Ticket sales for fans are also located inside the parking garage near this entrance. At times, especially during football games, the influx of fans entering the stadium is very disorderly and results in a crowd of people. Also, the only way for the opponent's fans to access the away side or bathrooms is to walk entirely around the circumference of the fence surrounding the perimeter of the track, which can take some time.

Despite these downsides the current system of having one entrance does reduce the staffing needed to collect tickets. The limited access to the away side section does separate locker rooms from spectators, which is a necessary drawback. The issues of fans having to walk from the stadium around the field and to the bathroom would be alleviated with the addition of the bathroom where the facilities building is.

4.1.3 Track

The track inside Alumni Stadium, named the Merl Norcross Track was installed in 2007, and it has not been maintained, aside from a few patches to account for cracking. Some recent pictures of the track condition can be seen in Figure 6. The condition of the track is deteriorating, and it needs to be replaced to ensure the safety of its users. Below the track surface is asphalt which may also need to be replaced if it is in inadequate shape. There are also drains along the inside of the track. The water is drained into the StormTech MC-4500 Chamber talked about in Section **2.4.3** Stormwater Management.

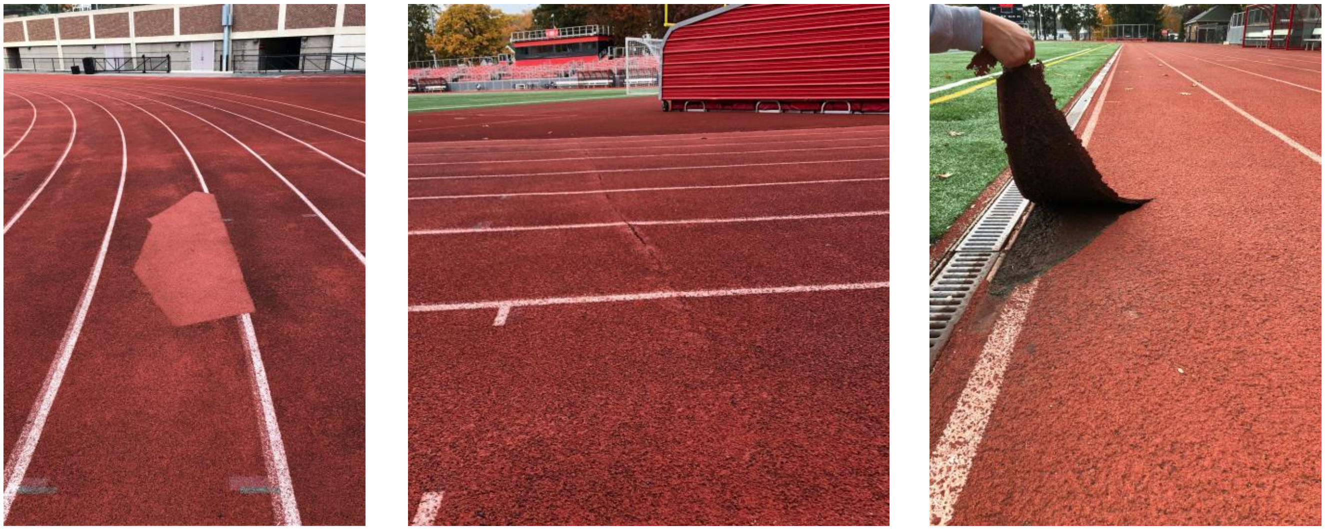

Figure 6: Merl Norcross Track current condition (Photo by Sean McAllen)

4.1.4 Turf

New synthetic turf called Fieldturf was installed at Alumni Stadium in the summer of 2015 (Alumni Stadium and Norcross Track, 2019). The turf has a sand substrate, and water is drained from the field using a herringbone pattern that drains to perimeter drains. The perimeter drains lead out of Alumni Stadium and into the stormwater chamber talked about in Section **2.4.3** Stormwater Management.

4.1.5 Away Side Hill

The away side hill at Alumni Stadium pictured below, is currently empty and it offers the flexibility to be redesigned to improve the atmosphere when visiting Alumni Stadium for any type of athletic competition (Figure 7). There are two manholes in the upper left corner of the hill closer to the Sports and Recreation Center. There are also electrical lines located at the base of the hill to power the stadium lights. With the help of the Facilities Office, data was obtained for the soil located at the parking garage. It was assumed that the soil located at the parking garage and the soil at the away side hill are consistent with its characteristics. Soil elevations were taken from facilities documents from the construction of the Sports and Recreation Center (Figure 8).

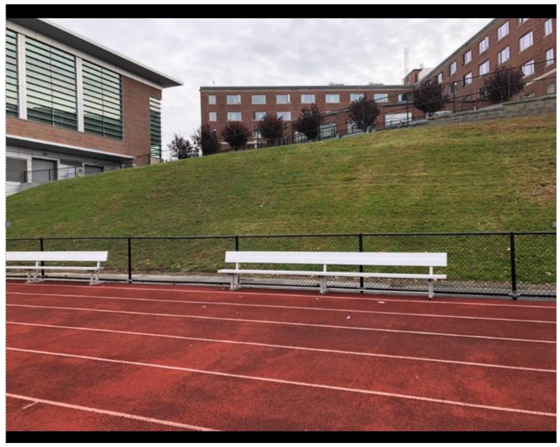

Figure 7: Picture of the away side hill (Photo by Sean McAllen),

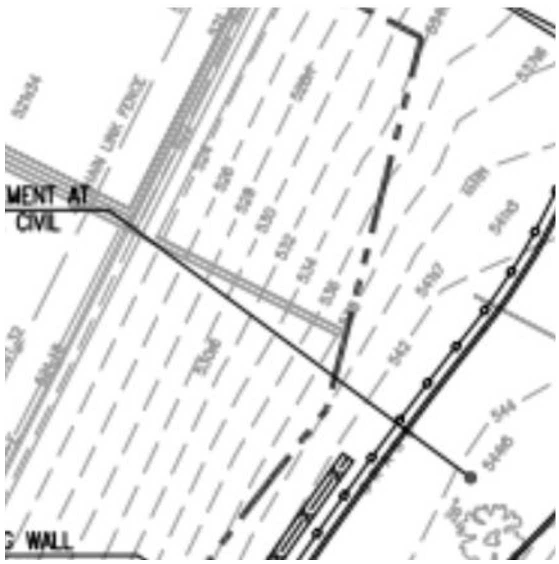

Figure 8: Away side hill elevations (Photo by Landscape Specifications Plan LA-2: Sports and Recreation Center)

4.1.6 Press Box

The press box located on the top of the stands is in fully functioning condition with a newly added air conditioning system. There is an elevator lift that leads up to the top landing of the stairs for easy access into the press box for any accessible needs. The press box is essentially broken up into three separate parts. On each of the sides of the space, there is a coach box for each respective team, which fits about three to four people. These coach boxes have been criticized for multiple viewing obscurities and size. The middle of the press box includes room for PA announcing, space for Sports Information Directors (SID) and stat keeping, and even a spot for the president of the university. Within the middle of the space, there is a ladder that allows for access to the roof of the press box. Throughout the fall sports seasons, several people need access to the top of the roof for their obligations during the game, which could introduce an accessibility problem.

Figure 9: Alumni Stadium press box (Photo by Sean McAllen)

4.1.7 Scoreboard

Currently there is a multisport scoreboard at the south side of the stadium. The model of technology is from Daktronics and it allows for fans to be frequently updated on the scenarios and scores of the game. The scoreboard, even though it serves its purpose, has been criticized as of late, due to advancements in scoreboard technology that many other universities have adopted.

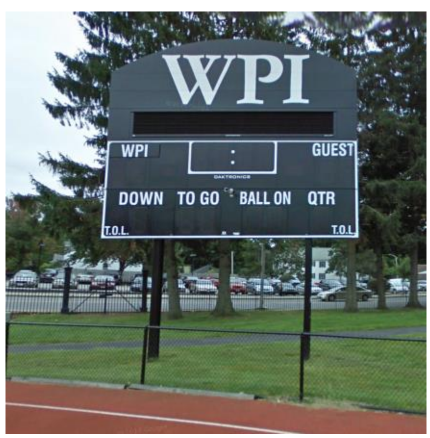

Figure 10: Alumni Stadium scoreboard (Photo by Dan Hoag)

4.1.8 Throwing Events

Currently, the only true throwing event located within Alumni Stadium is shot put. The pit is located in the southwest corner and can be seen in the picture below. Also, javelin can be thrown on the turf field with rubber tips. However, WPI plans to relocate all of the throwing events across Park Avenue next to the tennis courts. This plan can be found more in depth in our interview with Dana Harmon in Appendix B. The relocation of throwing events would eliminate the current shot put pit which can add room to allow for the extension of the track for a full straight away.

Figure 11: Shot put pit located in Alumni Stadium (Photo by Sean McAllen)

4.1.9 Facilities Building

There is currently a facilities building located in the southwest corner of Alumni Stadium (Figure 12). It is adjacent to Park Avenue, and it has two entrances that facility employees can use. The building has office space, and it also stores lawn care equipment as well as other machinery. However, this building only has one garage door which makes it difficult for facility employees to organize and mobilize equipment. Also, the entrance driveway on Park Avenue is not very large, leading employees to drive on the grass to maneuver the vehicles.

Figure 12: Facilities building located within Alumni Stadium (Photo by Sean McAllen)

4.1.10 Miscellaneous Areas

Other areas that could have an effect on our design proposals are the locations of the restrooms and the opponent's locker room. The restrooms used by the public during the games are located in the Sports and Recreation Center, which is a long walk for some fans, and can result in missing some of the game. Also, the opponent's locker room is located in the parking garage. This location causes facilities to block off the whole area around it, to limit fan interaction with members of the opposing team. The blocking off of this area also contributes to a larger amount of people going through the main entrance.

4.2 Input from Stakeholders

In order to include the multiple desires for the future of Alumni Stadium, certain stakeholders were selected and interviewed to obtain their input. The shortened responses to our questions with each respected stakeholder can be seen in Table 3. The full summaries of the interviews can be found in Appendix B.

Table 3: Input from Stakeholders

Contact Name	Main Questions Asked	Key Takeaways
Dana Harmon (Director of Physical Education, Recreation and Athletics)	Does WPI have any existing plans to improve its athletic facilities in the future? Were there any restrictions relating to zoning or building codes when Alumni Stadium was renovated in 2007 that can pose a problem for today? How does WPI pay for its new construction projects for athletics?	- New track within the next few years and move the throwing events to the opposite side of Park Avenue -Height Restriction for press box - Generous donations are usually used for projects
William Spratt (Director of Facilities Operations)	What is the facilities building located in the corner of Alumni Stadium used for? Are there any evident obstacles our group will encounter when redesigning Alumni Stadium?	- The building is used mostly for storage of equipment - Utilities, roots from trees, stormwater
Shawn McAvey (Facilities Manager)	Is there enough room for athletic equipment storage? Is moving equipment from storage to the fields efficient?	- Would like some more storage - Add a safer access route from rec center to field because it is currently inefficient
Rusty Eggen (Associate Athletic Director and SID)	Are there any improvements needed to the press box for coaches and SID? What have you seen from other stadiums that you would like incorporated into Alumni?	- Accessibility problems with the ladder within the box - Isolated coaches boxes from announcers and media personnel for press box
Brian Chabot (Head Track and Field Coach)	Is there anything that you've seen at other stadiums that you would like to see at WPI? How would you like to see the track be changed to better accommodate your athletes?	-Straightaways to be able to deal with wind for running events -Be able to host track meets

We also conducted a fan survey to the current CE, EE, and AE students which was 6 questions long, and generated 47 responses. From the figure below, 76.6 percent of respondents wish to see bathrooms closer to the field. We also left an open-ended question which asked if they had some ideas for Alumni Stadium and the surrounding areas. A multitude of respondents mentioned they would like to see seating on the away side hill. Other key takeaways from this survey included closer bathrooms, a designated student section, and the likes of a jumbotron. A descriptive summary of the fan survey can be seen in Appendix B.

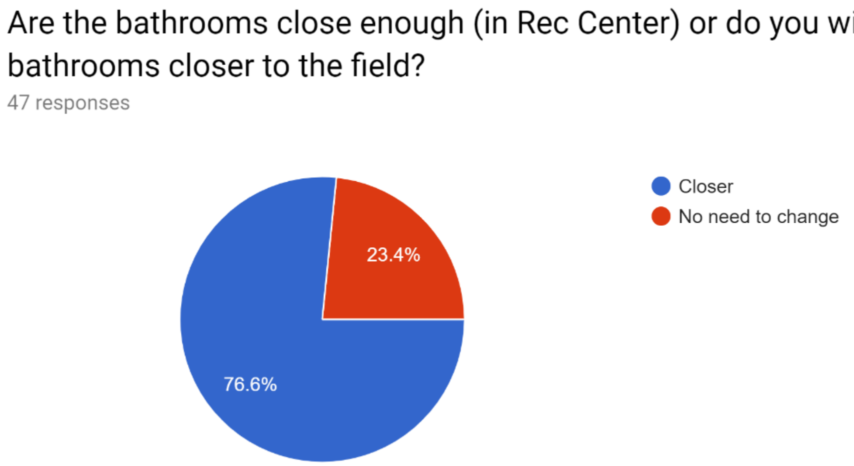

Figure 13: Question from Fan Survey (Photo by Google Forms)

4.3 Design Criteria

4.3.1 NCAA Track Regulations

In order to hold a collegiate track meet, a track must abide by NCAA (National Collegiate Athletic Association) regulations. The regulations can be found in the publication NCAA Cross Country and Track and Field Rules 2019-2020 under Rule 1: Construction of Facilities (IAAF, n.d.). The regulations are rather broad which gives colleges the ability to make their track unique. Some rules are very strict while others define minimum requirements that schools must follow if they want to host track meets. In the table below are some prominent track surface requirements specified by the NCAA for colleges and universities to host Outdoor Track and Field Meets. There are a multitude of rules that deal with the actual markings on the track but this table only presents the features of the track that will have an effect on the required area and how we organize field events within the area of Alumni Stadium, such as long jump/triple jump, high jump, and pole vault.

Table 4: NCAA Outdoor Track Dimensions*

Specific Area of the Track	Required Dimensions
Width of Running Lanes	Equal width 1.067m to 1.22m Lane marking width 5 cm
High Jump	Approach octagon or square and run-up must exceed at least 15 meters
Pole Vault	Length at least 40m long Max width of runway 1.22 m
Long Jump/ Triple Jump	Runway Length: at least 40 meters from events takeoff board Landing area: width 2.75m to 3m Length: at least 10 m from long jump foul line

*Dimensions taken from NCAA Cross Country/Track and Field 2019 and 2020 Rules

4.3.2 Zoning Implications

Worcester Polytechnic Institute is located within the IN-S Educational Zoning District. In Table 4.2 of the City of Worcester's Zoning Ordinance, it outlines each district's permitted dimensions. In the IN-S district, there are not any restrictions in regards to maximum height. The minimum yard setbacks in linear feet, are 15 in the front, 10 on the side, and 10 in the rear. Our designs would fall within these restrictions so as to minimize the likelihood of problems in acquiring permits from the City of Worcester's Planning and Zoning Commission.

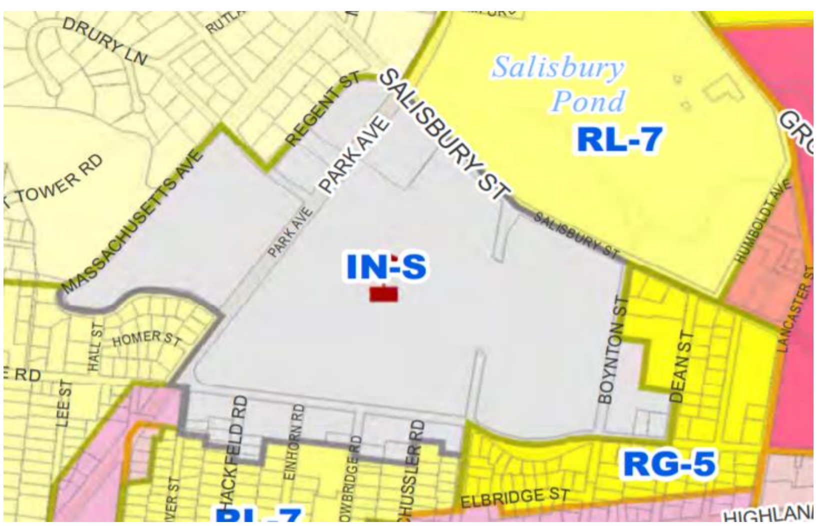

Figure 14: Zoning map of WPI main campus (Figure taken from City of Worcester, MA Zoning Districts Map)

4.4 Design Alternatives

Potential designs were made for away side seating, the press box, and a field restroom. This section discusses how we created each design and how we considered those alternative solutions for each element.

4.4.1 Away Side Seating Designs

For the away side hill two designs were ultimately considered. Both were designed in a minimalistic way due to the low number for seating required. The team also looked to maintain the school's image due to the location being adjacent to the Sports and Recreation Center.

The first preliminary design that was considered is essential terracing the away side hill with a series of stepped retaining walls, see Figure 15. The initial retaining wall at the base of the structure consists of an 8-foot-tall reinforced concrete vertical wall with a 6 foot 8-inch base. The width of the vertical portion is 8 inches. The exterior portion of the wall has a brick facade, with a matching top brick. Bricks are selected to match with the facade of the Sports and Recreation Center. The top of the wall has a guardrail sized to achieve ADA safety compliance. Corrugated drainage pipes are provided behind the walls, and a granular backfill would be selected to allow for proper drainage. Subsequent walls are spaced at 3 feet to provide ample leg and walking space between rows. These walls are mechanically stabilized earth retaining walls, due to their lower loadings and to achieve a more easily constructible design. These walls are comprised of 4 rows of 8 inch exterior bricks with a top piece to provide a space for sitting. Attached to the brick are 2 layers of geogrid for the purpose of stabilizing the earth behind the wall. Heights between levels are roughly 2 feet so that guardrails are not required. Between rows are coarse gravel with paver blocks. The calculations for this design can be found in Appendix C. A rendering of the design can be seen in Figure 16.

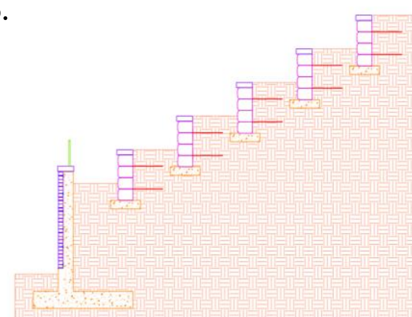

Figure 15: AutoCAD section of away side seating design one

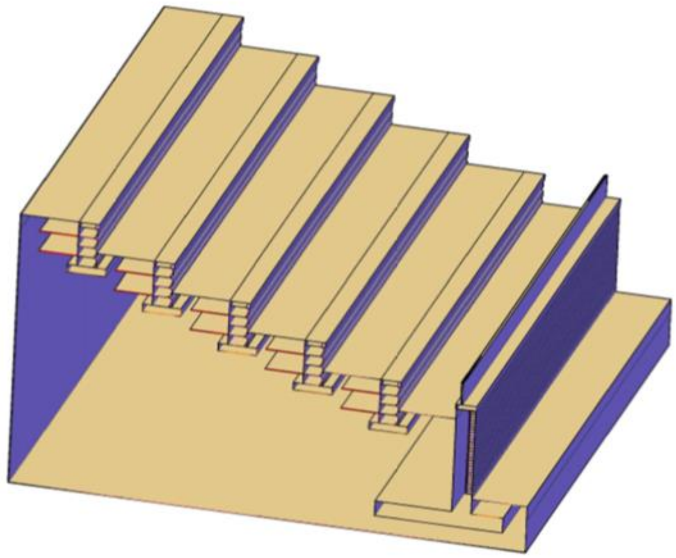

Figure 16: AutoCAD 3D drawing of away side seating design one

The other preliminary design that was considered is essentially a staircase built into the side hill (see Figure 17). This is a basic and cost efficient design that still allows flexibility with seating arrangements. This design would achieve ADA safety compliance while spanning roughly 14 feet vertically. This design is constructed with a concrete foundation complemented with a brick facade on the front (facing the field) and bluestone spanning the front edge for seating. Each seat has a height of 17" and each step is 8"x12". It is constructed with cast-in-place reinforced concrete that will be on grade. This will offer a cost effective design that meets the needs for this piece of land. The calculations for this design can be found in Appendix D. A rendering for this design can be seen in Figure 18.

As these stands would be a new addition to Alumni Stadium, there are some current conditions that must be moved in order to achieve a full range of view. For example, the lights that are currently on the away side of the hill will have to be relocated to the rear of the stands. As this will be an added cost, this also allows lighting on the new stands for night games along with providing a clear view of the field.

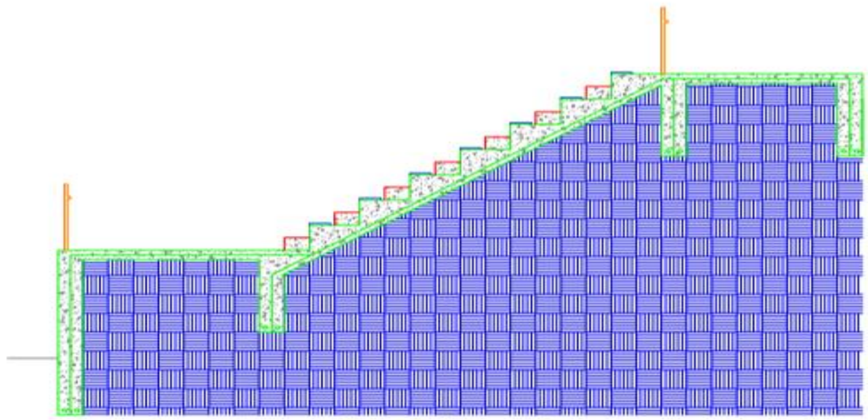

Figure 17: AutoCAD section of away side seating design two

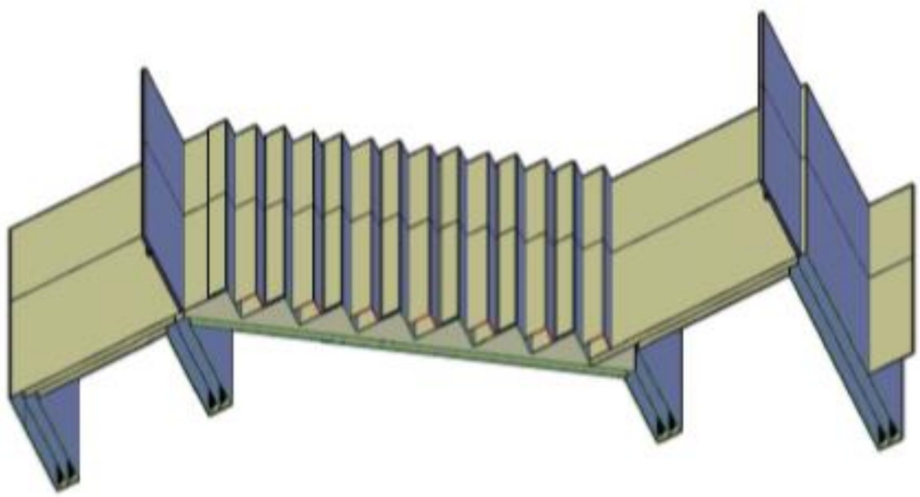

Figure 18: AutoCAD 3D drawing of away side seating design two

4.4.2 Press Box

Two press box designs were created and considered for the project. The first design includes a similar design to the current press box, and incorporates a President's Box on the east side of the press box. A rendering of the first design can be seen below in Figure 19. The second design includes a three room press box with a rear corridor. Attached to each press box is an exterior standing space for coaches that offers an alternative to going on the roof and introduces a stairway that allows for easy access to the roof of the press box. Both designs were evaluated using the group's design choice matrix. A floor plan of press box design two can be seen in Figure 20.

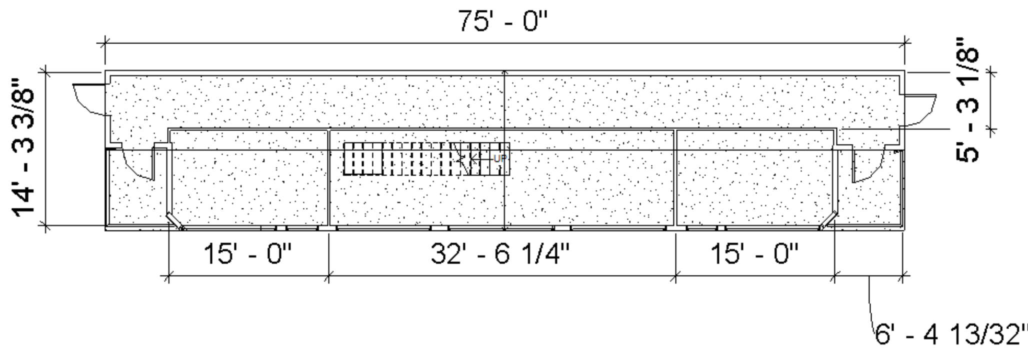

Figure 19: Revit floor plan of press box design one

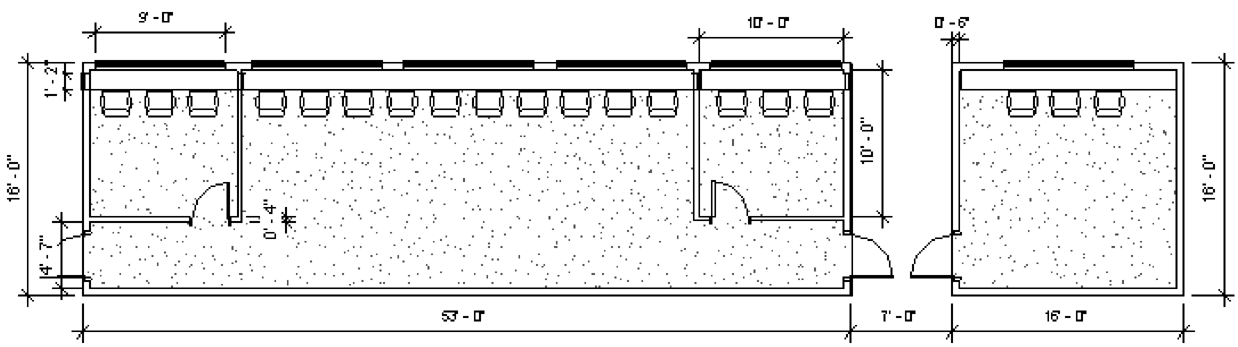

Figure 20: Revit floor plan of press box design two

4.4.3 Facilities Building Demolition and Field Restroom

Primarily from conversations with facilities personnel, it was quite evident that the current facilities building underserves the department, and with a rapidly growing school, weaknesses of this building will only be amplified. Due to this, it would be best for the current building to be demolished and a more strategically designed building be erected in a location where space is more abundant. Potential locations for this new building are the lot at 15 Sagamore street and the lot at the Salisbury Estates located on Park Avenue. Due to the relatively small stature of the building it can be demolished with bulldozers and excavators. There should be almost no hazardous waste to deal with due to the nature of the building's usage. With no surrounding structures, no added precaution will be needed.

Due to the newly created space that demolishing the facilities building would create, a restroom can now be erected in its place (Figure 21). A new restroom would eliminate the need for spectators to leave the stadium in order to use a restroom. This new building will provide both a male and female bathroom with an appropriate sized handicap restroom. Some constraints outlined by the ADA that the restroom must have, includes having an open space of at least 60 inches in diameter to allow for wheelchair maneuverability, toilet seats being stalled at heights between 17 and 19 inches and guardrails at 36 inches from the floor. In addition to providing a convenient restroom for spectators, the back end of the structure will be evaluated as a potential storage area for athletic equipment, which was one of the most consistent needs highlighted by stakeholder interviews (Figure 22).

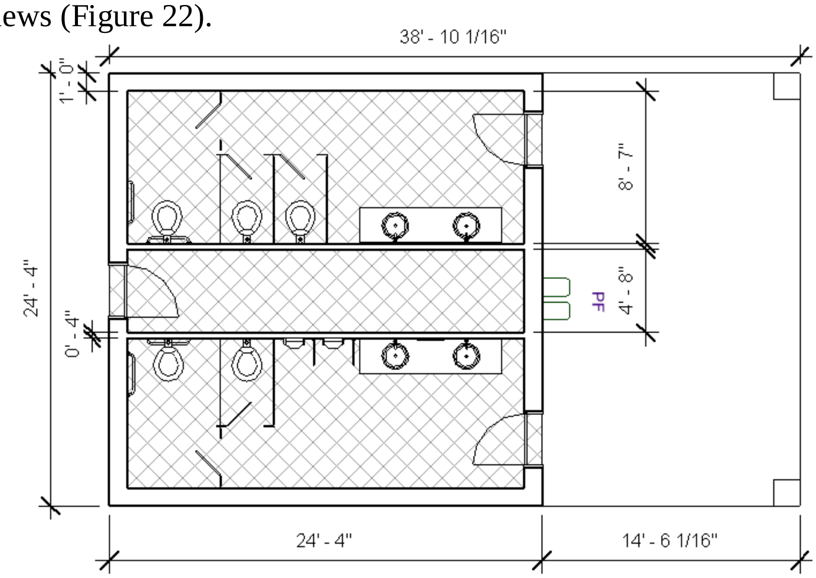

Figure 21: Floor plan of potential bathroom design one

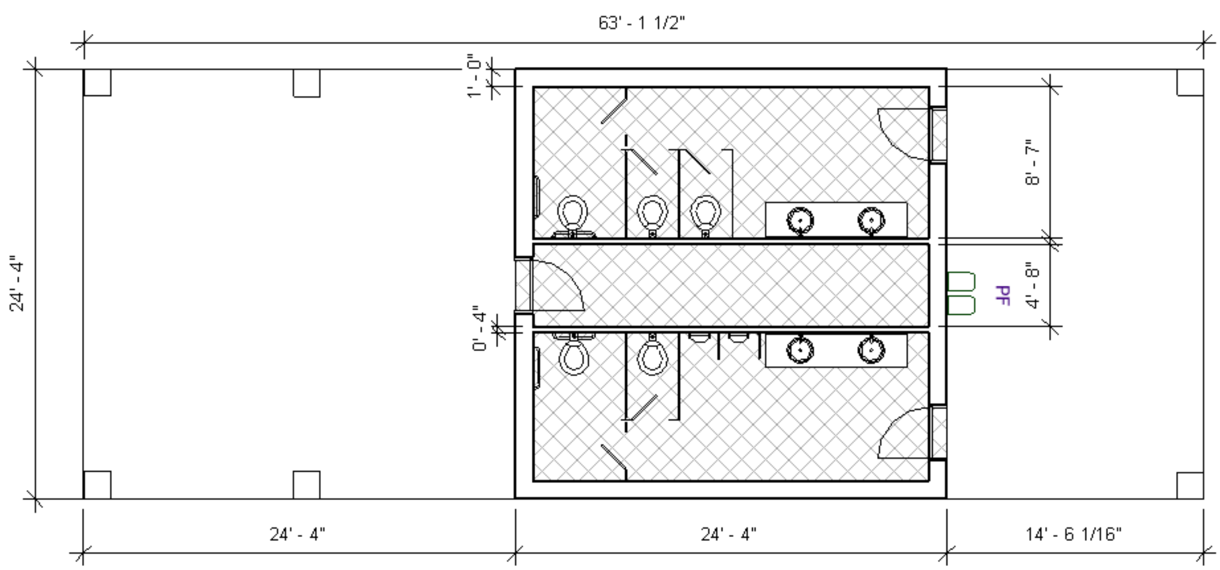

Figure 22: Floor plan of potential bathroom with storage design two

4.5 Final Design

After evaluating our different designs for away side seating, facilities building/field restroom, and the press box, we chose the most appropriate one. This section also presented the proposed track design as well as solutions for other areas of the stadium.

4.5.1 Away Side Seating

A ranking system of the away side seating is found in Appendix F: Away Side Seating Designs Matrix. Based upon this, the team chose away side seating design one. From the design matrix, both design alternatives produced similar scores, having near equal value per price. Design one was determined to be more economical and due to its usage of permeable surfaces, created no need for additional water management. This design would add a minimum of 150 seats and maintains similar architectural appeal to adjacent buildings.

4.5.2 Track

The track surface located within Alumni Stadium will be replaced as well as some additions. Our solution for the track includes adding a pole vault lane and takeoff behind the south end zone and a new straightaway in the southwest corner. The straightaway will extend perpendicular to the edge of the 7th track lane. We will keep the same long jump pits on the north side to aid with time and cost. A rendering of the track layout can be seen in Figure 23. The subsurface of the track layer is asphalt and after rip up of the track it will be replaced so it will be in perfect condition for the new track surface. The pole vault lane behind the south end zone will be made using concrete because it is easier to form (K. Fuselier, 2020). Once the asphalt, concrete has cured the track surface will be layered on. Next, the track markings are painted on the surface. There will be 8 lanes and each lane will be 1.1 meters wide (3.61 ft). Each additional marking on the track will abide by NCAA regulations. Some examples of the markings include relay zones, start/finish line, and placement of hurdles. A distinguished finish line for all events will be established in the southwest corner. Furthermore, the fence around the track will have to be adjusted to surround the new straightaway.

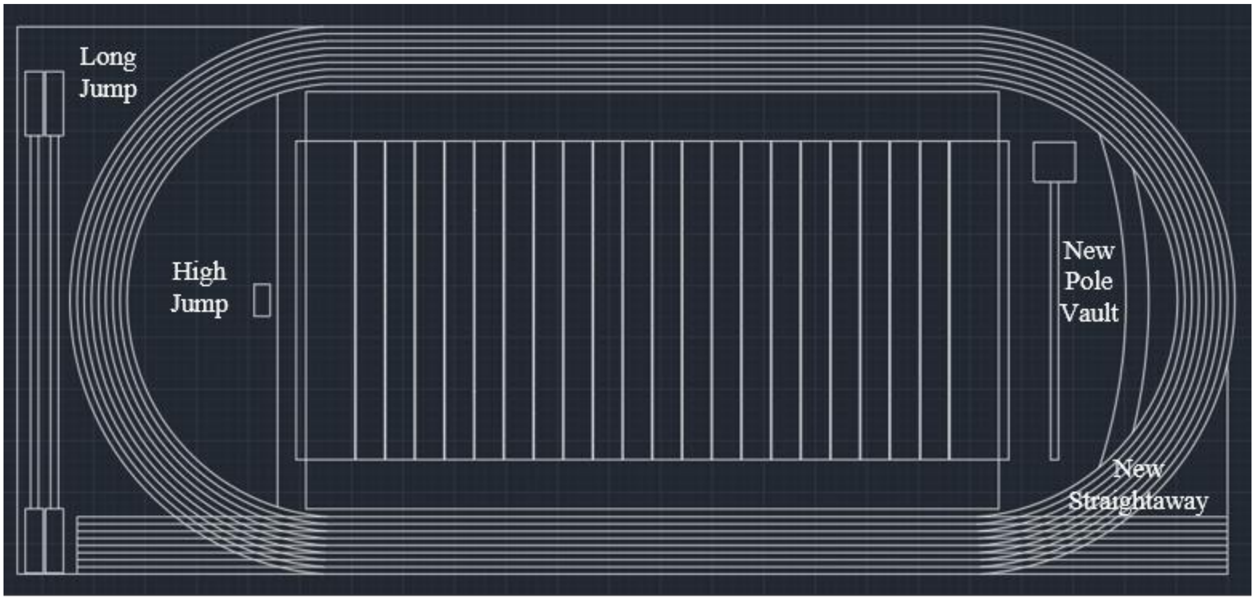

Figure 23: Track design layout

The new track surface will be impermeable. Water will be removed by evaporation and by the drains on the inside of the track. Typically, an impermeable track surface will drain faster than a permeable track surface (ASBA, 2009). There are four potential impermeable track surfaces: polyurethane sealed base mat structural spray surface, polyurethane base mat sandwich system, polyurethane full pour surface and premanufactured tracks. For this project, we will use a polyurethane full pour surface. Of this surface type, there are different classifications of polyurethane full pour surfaces that different companies offer. We will use the Beynon BSS-1000 polyurethane full pour surface. (Figure 24). We chose this type of surface because it is an all-weather surface that can be used in outdoor applications. The BSS-1000 surface is IAAF certified, and it is also used by established Division 1 programs such as Duke University, and the University of Virginia (Beynon Sports, n.d.). It has a self-leveling polyurethane coating which is applied in multiple layers. Once completed, colored EPDM rubber granules are put over the surface. The track surface color will also be the same as the previous track surface (red).

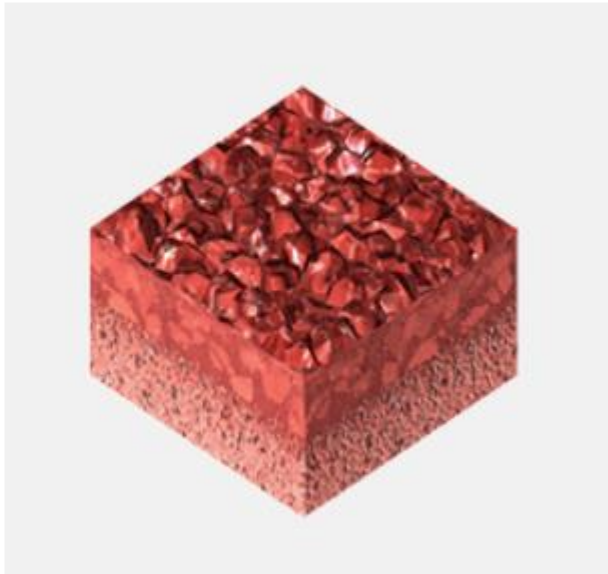

Figure 24: Beynon BSS-1000 polyurethane full pour surface

The track reconstruction will be done during the summer months and it will have a timeline of around 3-4 months depending on the weather. A contractor recommended by a Professional Landscape Architect, for the track surface is Cape and Island Tennis and Track (K. Fuselier, 2020). Mr. Fuselier, PLA, also recommended R.A.D. Sports as the contractor for the turf removal for pole vault, the fencing around the track, and other smaller aspects of the project.

4.5.3 Press Box

The team considered two different press box designs and used the design choice matrix in order to evaluate each design's attributes. According to the team's evaluation, Press box design 2 was chosen to be incorporated into the final design. The feature that makes this press box design unique is the addition of a 16'x16' President's Box. The main press box structure is a 53'x16' building made of linear metal siding on metal studs. Access to the roof was a main consideration within this design. Although the current ladder to the roof will remain, the current elevator will be modified in order to provide access to the roof as well. Visibility in each respective coaches' box was also a main concern. 1'6" x 5' windows were installed on the sides of the coaches box to allow coaches vision to extend from endzone to endzone without any constraint. The floor plan of the press box can be found in Figure 20 in Section **4.4.6**, and a full rendering of the final design can be found in Figure 25 below.

Figure 25: Rendering of final press box

4.5.4 Scoreboard

The new scoreboard's most predominant added feature would be the new video board. The model includes all the information needed for presentation of all scores of sporting events held at WPI. The video display model LVX series is approximately 32' x 13'2". The scoreboards and timing systems model FB-2025 series is approximately 32' x 8' x 8". The audio systems will include the model Sportsound 1000 series. The new technology also allows for video replay of highlights or video introductions of players. The new features of the scoreboard allow for a better spectator experience. A similar design of the video board being added to Alumni Stadium can be seen in Figure 26.

Figure 26: Similar design to scoreboard model (Daktronics, Davenport Community School)

4.5.5 Facilities Building Demo/New Restroom

The facilities building within the stadium will be demolished. According to RS Means (2018), the cost per square foot for the demolition of mason-like bearing wall buildings is $11.17 per square foot. The facilities building was estimated to be approximately 1500 square feet.

Upon the new area available for construction, the team reviewed several designs for potential restrooms to be added there, in proximity to the field. The team decided to include both designs to the final design, and let the owner decide which restroom to incorporate. This restroom was chosen because the unique feature of this design adds a 24.33'x24.33' potential covered outdoor storage area (Figure 28), which allows facilities personnel to utilize the space for a small added cost to the project. The 24.33'x24.33' building contains a men's and women's bathroom as well as a space for mechanicals and piping. The total concrete slab-on-grade pour will be approximately 63'x24', and the left-over space will be used as a roof-covered waiting area for the restrooms. The project team decided to present the owner with both designs and let the owner decide whether or not the extra storage will be needed.

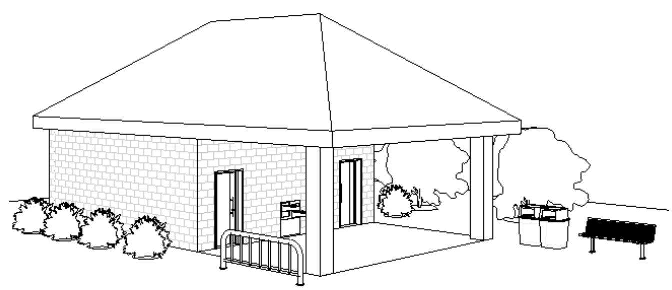

Figure 27: Revit drawing restroom without storage

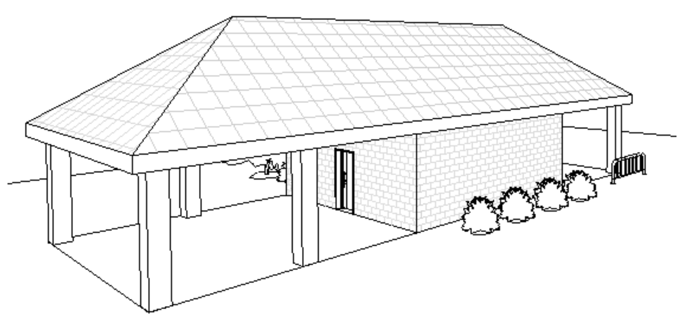

Figure 28: Revit drawing restroom with storage

4.6 Cost Estimate

The costs of each component of our final design were calculated using excel spreadsheets. The costs are found in Table 5 below. The cost estimating sheets used for the calculations can be seen in Appendix H: Cost Estimations.

Table 5: Cost of Alumni Stadium Redesign

Component	Price ($)
Away Side Seating	109,000
Track	760,000
Facilities Demolition	17,000
Field Restroom (with storage)	255,000
Field Restroom (without storage)	223,000
Press Box	132,000
Scoreboard	65,000
Total with Restroom storage	**1,338,000**
Total without Restroom storage	**1,306,000**

Chapter 5: Conclusion and Recommendations

Through extensive research and practical design, the team managed to achieve our objective: Redesigning Alumni Stadium for the present and future of WPI. The Alumni Stadium Redesign offers the university improvements and new entities that will benefit the school in a positive way. The final cost of the entire project would be around $1.3 million. Each moving part of the project has a different timeline of completion so the length of the project can vary based on the Institute's desire to get each part done. However, if WPI is eager to complete the project, it can be done within a year. A final site design layout can be seen in Figure 29 below.

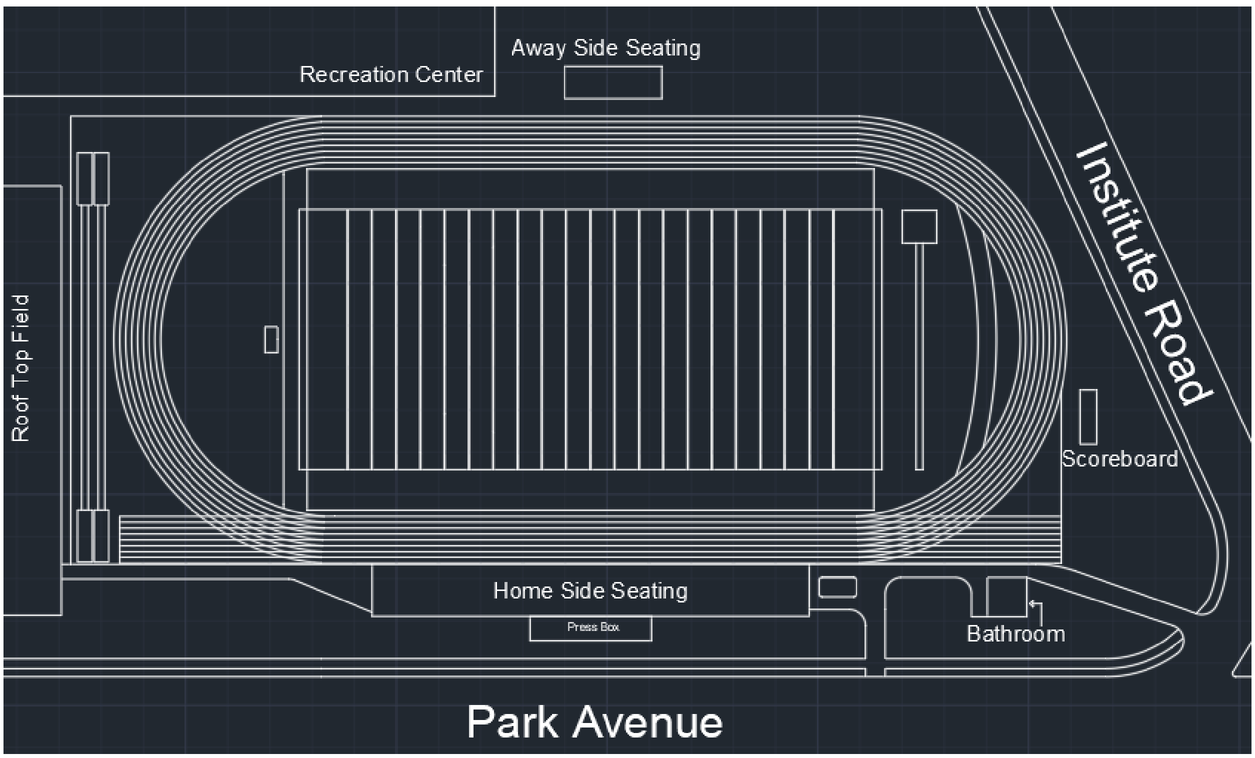

Figure 29: Final site design layout

5.1 Comparing Other Stadium Costs

As a point of reference, in order to support the realism of our final cost, we researched several recent stadium upgrades. Coughlin Field at neighboring Worcester State University was recently upgraded in 2019. This upgrade included, “new turf for the field, a refurbished track, and a new scoreboard, among other enhancements” (Worcester State, 2019). The total cost of the project was $2.9 million.

Shepherd Hill Regional High School in Dudley, MA renovated their athletic field in 2014-2015. This renovation included a new turf for the field that used to be grass, a new track surface, a new scoreboard, multiple areas for track and field such as shotput and a sand pit, and finally the rental of two sets of metal bleacher seating. The total cost of the renovation was approximately $2.4 million. (LaPlaca, 2015).

5.2 Recommendations

We have several recommendations to help maintain the new facility. These recommendations will help extend the life of each new structure which in the end will help save the school money. These recommendations for each area will be formatted in bullet point form.

5.2.1 Track

- Keep the track clean
- Do not plow the track during the winter
- Do not drive any vehicles on the track
- Regulate the use of spiked shoes used in track and field events
    - Limit spike length to ¼ inches
    - Only pyramid or xmas tree spikes
    - Do not permit needle spike pins on track surfaces
    - Buy mats to put on the track for football, soccer, field hockey games, to protect the track surface from non-sanctioned cleats

5.2.2 Away Side Seating

- Keep seating area clean year round
- Monitor any possible future cracking of concrete
- Seal all cracks that reach ¼ inches using concrete sealing compound
- Replace gravel to maintain level height

5.2.3 Field Restroom

- Keep restrooms clean
- Manage bathroom toiletries
- Manage trash

5.2.4 Press Box

- Keep Press Box Clean
- Maintain clean and clear corridors

5.3 Future MQP Projects

Though the course of the project, we were in contact with various representatives of the WPI Athletics and Facilities departments. Many of these individuals were intrigued by our design and had specific areas they would like to see redesigned in the future. One of these areas was the facilities building that was demolished within our design. Members of the facilities department were interested in a larger space for storage of equipment and materials for maintenance. Although the building could not have fit in our final design, there was an area mentioned to be large enough for a Facilities Headquarters that was still in proximity to the field. WPI has recently bought land on Sagamore Road, which appears to be an open warehouse building. WPI could decide to repurpose this building for facilities operations, which would call for a total redesign of the space.

Another problem that arose during our investigation of existing conditions was the issue of accessibility. Facilities Staff admitted that the path from the loading docks of the Sports and Recreational Center to Alumni Stadium is unsafe. Moving materials to and from these areas requires the use of Institute Road, which is a main road with pedestrian and vehicular traffic. A future MQP could research a safer and more efficient access, such as a private access road.

One other possible project that could be done is to create an entryway for the stadium. Throughout the project the team recognized this as an area of improvement, but set it aside do to it only providing aesthetic value. While this one task may be small for an MQP, it may provide the starting point for other entryway developments throughout the campus.

5.4 What would we have done differently?

As the team progressed through the project we found a multitude of areas where improvements and replacements could be made. This made the project feel more holistic, but potentially lessened the overall quality of each solution. Looking back, it may have been beneficial to have concentrated on two or three of the major areas: Home Bleachers, Away Bleacher, and the Track.

Another thing the team would have done differently was the fan survey. It was only sent out to CE, EE, and AE students, this ideally should have been sent to every student at WPI.

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Appendix

Appendix A: Proposal 10-10-2019

Alumni Stadium Proposal

A Major Qualifying Project Proposal

Submitted to the Faculty of

Worcester Polytechnic Institute

In partial fulfillment of the requirements for the

Degree in Bachelor of Science

In

Civil Engineering

By:

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Date: 10/10/2019

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Abstract

Alumni Stadium is the home to the Worcester Polytechnic Institute Engineers. It supports intercollegiate field hockey, football, track, and soccer, and provides an impressive facility for club sports, intramural programs, and recreational use by the WPI community. Our project involves the redesign of Alumni Stadium to better accommodate the respective teams that use this facility on a daily basis. Alumni Stadium has not been renovated since 2007 and is in need of some major upgrades. After interviewing stakeholders and investigating constraints, we will provide a feasible design for this area that WPI could use in the future.

Capstone Design

Alumni Stadium is home to a variety of sporting events at WPI, but as the school grows and changes, upgrades to the field will need to be addressed in order to meet the new demands placed on it. In order to successfully do this, a solution must first meet these new needs and then adhere to six design considerations that are essential in the engineering field: Economic, Environmental, Sustainability, Social, Health and Safety, and Ethics. Through the completion of these constraints, the project will successfully demonstrate the capstone design requirements outlined for an ABET accredited curriculum.

Economic

When choosing a design for Alumni Stadium, cost will be assessed to determine the most feasible design. Projects at WPI are funded by donations, and we want our design to have the biggest impact while maintaining an appropriate price. The cost of the project will be analyzed using past renovations to Alumni Stadium as well as other constructions projects throughout different college campuses across the United States as a benchmark to compare costs and aid in the team choosing the most cost-effective design.

Environmental

Our proposed design will have a minimal impact on the environment. The design could have an effect on the amount of stormwater runoff. This will be taken into consideration and the necessary precautions will be made for our design to be environmentally friendly.

Sustainability

In order for our design to be a successful one, it must be one that offers a sustainable solution. This means using environmentally responsible materials that come from as local sources as possible and incorporating the most energy efficient products. Doing so will provide the new stadium with a design that will create long term savings for WPI through lowering energy costs.

Social

Athletics have a great social impact on a college campus. With that being said, our proposal with have a positive effect on the WPI community as a whole. We want the the school's athletes and fans to have the best time using its athletic facilities and our plan of action will take in multiple ideas from people outside of athletics to have a balanced and well-rounded design.

Health and Safety

The health and safety of the WPI community is at the utmost importance. Our Alumni Stadium proposal will be safe for athletes and spectators to be able to enjoy and participate in multiple varsity athletics. The design will abide by the rules and regulations set forth in the Massachusetts building codes and we will look to hold the health, safety and welfare of all occupants as the number one priority.

Ethics

Our team will abide by the ethical standards all civil engineers adhere to. These standards can be found in ASCE (American Society of Civil Engineer) Code of Ethics. This code will be used as a reference when making professional decisions for a design and when talking to stakeholders, clients, and/or other people of interest.

Professional Licensure

In the discipline of civil engineering, engineers have the opportunity to obtain a Professional License (PE). This certification allows engineers to observe and certify construction documents that will be used when constructing a structure. PE licensure is the engineering profession's highest standard of competence, and gives the profession an assurance of quality of work. For this reason, the PE license makes engineers valuable to employers, for their high level of responsibility, which leads to increased salaries. Each state has its own licensing board that requires each candidate to complete certain steps.

The first step in achieving a PE in Civil Engineering is graduating from an ABET-accredited university. Another requirement by the Massachusetts licensing board is the completion of the Fundamentals of Engineering Exam (FE). The passing of this exam allows engineers to obtain the title of Engineer-in-Training (EIT). Once under the title of EIT, the engineer must have a progressive and verifiable work experience in the industry for a minimum of four years. The work experience will ensure that the engineer has valuable knowledge in their field of concentration. The last step in obtaining a PE is passing the Principles and Practice of Engineering Exam, and eventually receiving their unique PE seal. In order to maintain the PE license, many licensing boards require engineers to continue to improve their skills through continuing education courses for further professional development.

The degree of importance to the profession, the individual, and the public of the Professional Licensure is extremely high. Not only is it the highest degree of mastering a discipline, but it also assures the public that the structures they use every day are at a high standard.

Section 1: Introduction

Alumni Stadium is the home for Worcester Polytechnic Institute's athletics. Football, soccer, field hockey, club sports and intramurals use Alumni Stadium for games and practice. The stadium has not been modified since its last renovation in 2007, and with ever changing demands created through consistent growth, considerable upgrades will need to be made in order to meet these challenges. The track is in a highly degraded condition and WPI has not been able to host a track meet in over 10 years (D. Harmon, personal communication, September 6, 2019). Also, there is open-space within Alumni Stadium which can benefit fans; however, the south side of the stadium is poorly designed and does not take advantage of the limited open space that it has. With that being said, the goal of our project is to redesign Alumni Stadium to better accommodate WPI's multiple varsity athletics teams while maintaining a feasible and cost-effective design.

Certain project objectives will need to be completed in order to achieve our project goal in a successful and fulfilling way. These generic steps can be seen below:

1. **Examine Existing Conditions**
2. **Generate Input from Stakeholders**
3. **Identify Design Criteria**
4. **Generate Multiple Alternatives and Evaluate**
5. **Create Final Design**

Using these steps as guidelines we will be able to ensure a feasible design that will benefit the various users of Alumni Stadium. We will then choose the best design that satisfies our stakeholders, and completes our goal. The design will have a positive impact on the WPI community and maintain a reasonable price.

Section 2: Background

2.1 History

Alumni Stadium is located at the cross section of Park Ave and Institute Rd in Worcester Massachusetts, and is the home stadium for the Worcester Polytechnic Institute Engineers. Its first use was back in 1914 when WPI's football team faced off against the RPI Engineers, and has hosted 52 matchups between the two schools since. The stadium's first renovations came in 1926 when bleachers were added to both sides of the field, providing enough seating for 2,800 spectators. In 1985, WPI replaced the grass playing surface with its first artificial turf, which has seen routine replacements since its installation. Its most recent upgrades came in 2007 with a complete overhaul, consisting of a new 2,000-seat bleacher with a press box, new turf and track surfacing, a scoreboard and a lighting system. To this day, it has remained largely unchanged, but the surrounding area has seen rapid changes that have greatly affected the way the teams and spectators of WPI interact with the stadium. Some of these changes include a brand new recreational center and a parking garage equipped with a turf softball field and another all sports turf field located above.

2.2 WPI

2.2.1 Surrounding Areas

As we focus on Alumni Stadium for our project, we are held to many constraints. These include total amount of available space, zoning limitations within the city of Worcester, and existing conditions. Alumni Stadium is surrounded by the parking garage on the north, the Recreation Center to the east, and Institute Road/Park Avenue on the south and west sides. Consequently, there is little to no room for expansion of Alumni Stadium. Fortunately, WPI has land directly across the street (Park Ave) from Alumni Stadium that is used for many different activities such as tennis, track and field throwing events, and storage for facilities. That piece of property allows expansion to happen outside of Alumni Stadium, yet still close enough to collaborate with. Another unique feature to complement Alumni Stadium is the rooftop field that is located on top of the parking garage; this gives the area a "one of a kind" type of feeling. As Alumni Stadium is mainly constrained by space, the surrounding areas such as the tennis courts/throwing area across the street offers a lot of room to work with which can be a factor for a final design.

2.2.2 WPI Size, Growth and Long Term Plan

As WPI enters another academic year in 2019, this incoming class is the biggest Boynton Hill has ever seen. Over the recent years, WPI has seen a large increase of students attending campus in the fall, and it has been growing exponentially. As the school continues to grow, the demands for new buildings and technology will continue to rise. Due to the increase in general student population, there is an expected demand increase that will arise due to increased recreational use, larger crowds, and the potential for new uses to be explored. This will eventually create a challenge for WPI to accommodate this new influx of students.

WPI has already begun to construct multiple buildings for this large increase of students and faculty. In 2018, the Foisie Innovation Center finished construction which includes study areas, work areas, classrooms, and multiple floors of dormitories. Set to begin construction this year (2019) on Boynton Street is a new building that will also include some new innovations to WPI. Through many examples, it is apparent that WPI is committed to introducing new buildings and technology to improve its campus.

However, Alumni Stadium is lacking some of the state-of-the-art innovations that the rest of the campus has enjoyed in recent years. WPI wants to fully replace the track around Alumni Stadium and continue to maintain the turf field (D. Harmon, personal communication, September 6, 2019). In the coming years, the turf will need to be replaced, along with some other amenities around the stadium.

2.2.3 The WPI Look

Over the past ten years, WPI has been adding many new buildings throughout campus. They have developed their own “look” or “vision” to their new construction which is a mix of Jacobean and Modernism (*Jacobean Era Architecture*, 2019). This look is a facade with brick, glass, and pillars all incorporated into one. In Figure 1, you can see how WPI is committed to keeping the same design with their athletic facilities, residential halls and academic buildings. You will see this on many new buildings around WPI such as the Recreation Center and East Hall. We would like for our design to fit in with the WPI architectural vision as best as it can. As we may not be designing a building, we still would like our structures to fit in as much as possible.

Figure 1: Aerial View of Alumni Stadium and Campus

2.3 Standards and Regulations

To construct any type of new structure, whether it be a building, bridge, or stadium, there needs to be a set of standards and regulations to follow in order to maintain sustainability, safety, and order. Certain requirements were found in order to ensure that the stadium will encompass all of those things. The codes we have researched to follow are *International Building Code* (and the amendments made by Massachusetts), the ICC 300, and the ADA.

2.3.1 International Building Code

To construct a new stadium in Massachusetts, the *International Building Code* (IBC) will need to be consulted. This code is used for all constructions in Massachusetts, existing and new, and will be used throughout the design process of the stadium. In Massachusetts, there are amendments made to the IBC that are found within a document called the 780 CMR. The 780 CMR covers nearly all aspects of the building process from structural loads, mechanical work, and plumbing, to permissible materials to use. Certain provisions in the 780 CMR to be considered are Occupancy Classification and Use; Height and Areas; Type of Construction; and Means of Egress to name a few. Additional requirements listed in the 780 CMR can include the accessory occupancies in the other buildings in the proposed area. These buildings will need to comply with the code in the designs in order to obtain a permit to build.

2.3.2 Stadium Codes

The International Code Council has specific guidelines and regulations to adhere to when designing new or renovating old stadiums. This section of code fall under ICC 300: *Standard on Bleachers, Folding and Telescopic seating and Grandstands*. The reasons for adhering to this code is to safeguard public health, safety, and welfare. Additionally, the code goes into details on the potential operation and maintenance routines, as well as establishes a uniformity amongst similar projects, so that potential upgrades can be made in the future without drastic alterations being required. Some of the code sections that we believe will apply to the redesign of Alumni Stadium are included in the table below.

Table 1: Potential ICC Sections to be used for our design

ICC 300 Section of Code	Why it Might Apply	Where it Might Apply
302 Permitted Materials	All material used will need to meet the standards specified	New bleachers, hillside seating
303 Structural Design	Provides loading tables and safety factors	New Bleachers
307 Roof Heights	Provides minimums for roofs	Potential canopy on bleachers
308 Fire Protection	Gives stadium specific guidelines	All egress routes
400 Egress	Provides sizings for means of egress	All egress routes
500 Existing Bleachers	Gives maintenance practices	For long term plans

The codes established by ICC 300 will provide many of the governing standards when designing outdoor seating arrangements. These codes work in conjunction with the International Building codes to fully encompass all aspects of design.

2.3.3 ADA Requirements

In order to utilize the full use of the proposed renovated area, the stadium must incorporate ADA Regulations. ADA stands for the Americans with Disabilities Act. This act "is one of America's most comprehensive pieces of civil rights legislation that prohibits discrimination and guarantees that people with disabilities have the same opportunities as everyone else to participate in the mainstream of American life." (*ADA Accessibility Guidelines*, 2019). There are a multitude of guidelines that a new structure must follow to adhere to in this act. Some examples of regulations include handicap accessibility through sidewalks, buildings, and parking. Any new structure or accessway that is added to Alumni Stadium for design will have to comply with ADA regulations.

2.4 Worcester Zoning

2.4.1 Standard Laws and Procedures

When building a new structure, it has to adhere to zoning laws. Zoning laws range from the regulation of a building's dimensions, its location and even what it can be used for. They are in place to protect the health, safety, and welfare of the public that uses the land or is affected by it. WPI is located in Worcester so it has to follow the City's Zoning Ordinance as well as regulations set forth in of Massachusetts Zoning Act. Furthermore, the land of Worcester, and all cities/towns around the US, are separated into zoning districts. These districts abide by different zoning laws. WPI is located in the Educational Zoning District IN-S as seen in the picture below; so when constructing a new stadium, our design has to follow specific guidelines for this type of district.

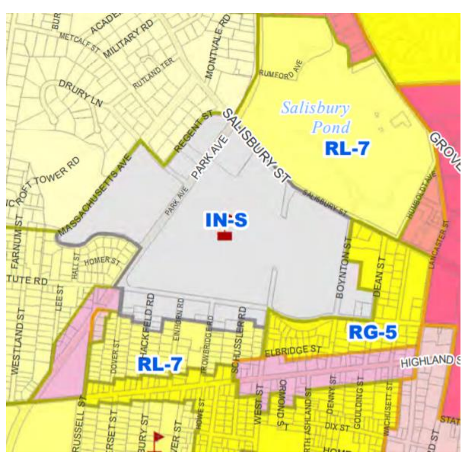


Figure 2: City of Worcester, MA Zoning Districts Map as amended May 3, 2016

2.4.2 Emergency Evacuation

The Federal Emergency Management Agency (FEMA) requires cities to have a Hazard Mitigation Plan. The Hazard Mitigation Plan can have an effect on a city's buildings and roads because of potential dangers. Some dangers which affect the city of Worcester are flooding, snow storms, and other natural disasters common to the New England area. As a result, there can be constraints that can affect a new stadium design because it is located so close to the main road. For example, Alumni Stadium is located parallel to Park Avenue and this could affect our design if we have to build within certain constraints.

2.5 Physical Constraints

2.5.1 Track Physical Constraints

Alumni Stadium has to meet the needs of many different varsity athletic sports teams. Track and Field is a priority when redesigning this area. The WPI Track and Field (T&F) team has not been able to host a home event in almost a decade. With that in mind, we would like to configure Alumni Stadium so that it would be able to host meets again. Since the T&F team has not been able to host meets, the maintenance to the actual track itself has not been sustained. With proper maintenance and proper resurfacing, a track should last 10-20 years (W.Spratt, Personal Communication, 9/6/19). The Alumni Stadium track has not received any attention in the last 10 years so it is imperative that the track will have to have a complete tear up and resurfacing if WPI would like to host any NCAA track meets. As the track in Alumni Stadium is almost impossible to move or modify due to the limitations, it will have to stay in the location that it is in. That is the main physical constraint that will govern our redesign.

2.5.2 Away Side Hill

The next physical constraint that will impact our redesign is the away side grass hill. This side hill is one of the few untouched places that surround Alumni Stadium. A new set of bleachers for away fans is a possibility for this area. This will be a challenge for design purposes as keeping an ADA compliant design while also dealing with a dramatic change in elevation is not the ideal combination. As there is not much "depth" to make up for this elevation change, this will be a physical constraint that we will have to work with.

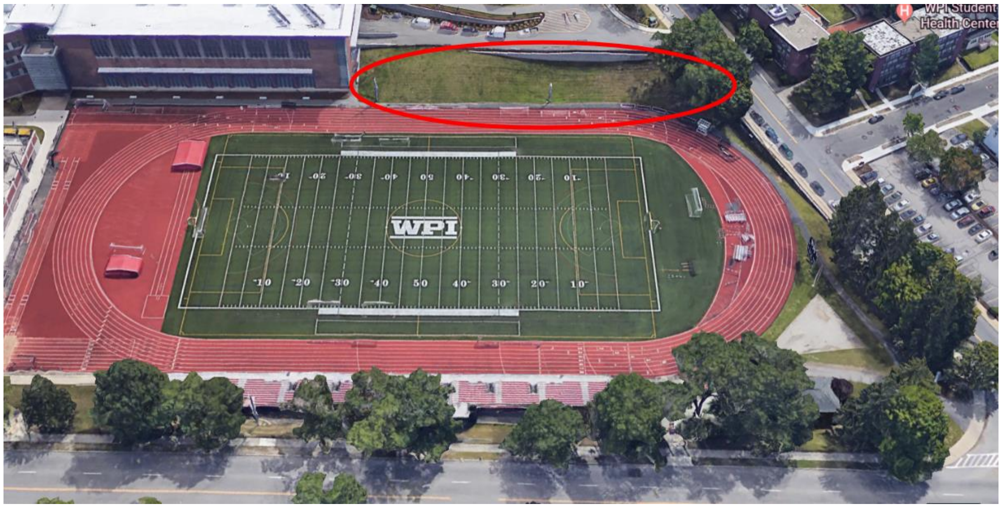


Figure 3: Aerial picture of the away side hill

2.5.3 Stormwater

A final main physical constraint that will be factored in is the amount of stormwater runoff that will be generated from new impervious surfaces that could be created. As Alumni Stadium stands now, all of the stormwater generated has to be delayed before entering the city drainage as there is a large amount. We will have to do a calculation of how much stormwater we can allow our current system before it is too much to handle, and make any modifications if needed.

2.6 Financials

2.6.1 Small Donors

With a set amount of money that is budgeted for athletics at a technologically centered school, WPI mainly looks for help for projects from its large and generous alumni base. For as long as there have been athletic teams at WPI, there have been multiple student-athletes who have succeeded after their time at WPI in the workplace, and want to give back.

Like many amenities and locations on campus, our Alumni Stadium Proposal will need to be funded by donors. This does not mean that all the money required for this project needs to come from one large contribution, but multiple small contributions would suffice. The funding for this project will come in over time, as long as it is known that a new and improved Alumni Stadium is in consideration.

2.6.2 Cost Estimating

To ensure the feasibility of the end design of the stadium, a cost estimate will be calculated. To do this, research will need to be conducted in order to determine material cost, labor rates, and typical pricing for larger assemblies. This will require significantly completed designs that will then be broken down by area and priced out.

2.7 Existing Stadiums for Considerations

When trying to design the stadium, it will be essential to understand what potential design is already existing and how they can be improved or incorporated into WPI's stadium. To properly do this, stadiums that will be used for the basis of our design will have to meet some criteria that will allow for it to be adapted into WPI's existing land space and community. Due to this, large-scale stadiums will not be considered, as they would be impractical for a smaller school with limited expected attendance. This leaves similar-sized Division III and II schools that have like-minded stadium usages.

One stadium in particular that will be considered is the East Campus Stadium at Rensselaer Polytechnic Institute (RPI). The stadium seats 5,200 spectators and possesses two very unique features for a Division III program, a video board and a two-story press box.

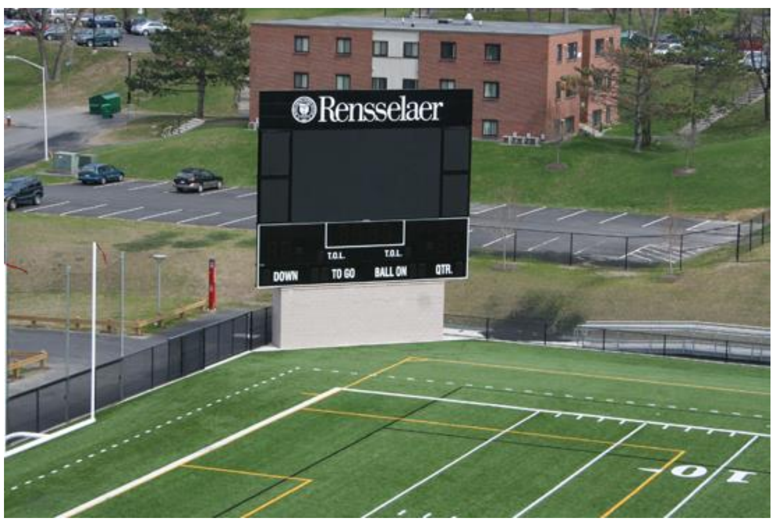


Figure 4: East Campus Stadium at RPI

The video board gives RPI the unique opportunity to have instant replays at games, show season highlights, and even promote the school through videos. Having been to the stadium, it feels very special and it added to every event held here. The dual-leveled press box allows for improved sight lines as well as sectionalizing of the space. The improved sight lines come from the higher elevation that the second floor provides. Having two floors allows for the separation of coaching personnel and media personnel. This creates an organized environment where the particular needs of each group can both be met.

Another stadium that possesses a unique feature is the Chet Anderson Stadium at Bemidji State which is the picture on the next page. The school faces similar space constraints that are present at WPI. Prior to being reconstructed in 2014 Chet Anderson Stadium had a track that intersected the stadium, which allowed for an increased spectator view on the side with the larger bleachers from the proximity to the field of play. This view is typically sacrificed when a track is present, due to the eight running lanes that force the bleachers further away, which is only partially the case here. They were able to accomplish all this while still being able to play both regulation size football and soccer games. An idea such as this one could allow for the optimization of the space, but will have to be further investigated for potential drawbacks that might be faced when trying to host a track and field meet.

Figure 5: Chet Anderson Stadium at Bemidji State before reconstruction in 2014

Section 3: Methodology

In order to achieve our goal of redesigning Alumni Stadium to better accommodate WPI's multiple varsity athletics teams while maintaining a feasible and cost-effective design, we will assemble several objectives that will layout our plan of action.

3.1 Stakeholder Inputs

The first step our group will take in our project is to talk to stakeholders. We want our design to accommodate the most people, and represent the school in the best way possible. To complete this task, we will send out emails, conduct interviews, and administer a fan survey to students in the Civil and Environmental Engineering Department. In the table on the next page, we will identify principal contacts within the WPI community and the main questions we plan to ask, which are unique to each stakeholder.

Table 2: Questions for Each Stakeholder

Contact Name	Main Questions To Ask
Dana Harmon (Director of Physical Education, Recreation and Athletics)	Does WPI have any existing plans to improve its athletic facilities in the future? Were there any restrictions relating to zoning or building codes when Alumni Stadium was renovated in 2007 that can pose a problem for today? How does WPI pay for its new construction projects for athletics?
William Spratt (Director of Facilities)	What is the facilities building located in the corner of Alumni Stadium used for? Are there any evident obstacles our group will encounter when redesigning Alumni Stadium?
Shawn McAvey (Facilities Manager)	Is there enough room for athletic equipment storage? Is moving equipment from storage to the fields efficient?
Rusty Eggen (Associate Athletic Director and SID)	Are there any improvements needed to the press box for coaches and SID? What have you seen from other stadiums that you would like incorporated into Alumni?
Brian Chabot (Head Track and Field Coach)	Is there anything that you've seen at other stadiums that you would like to see at WPI? How would you like to see the track be changed to better accommodate your athletes?
Fan Survey (CE, EE, and AE Students)	Where do you typically watch a game? Do you feel there is enough room for fans? Are bathrooms close enough to where you are sitting? What is your opinion on having a jumbotron?

3.2 Collect Physical Data

Before a design can be made, the existing land will have to be evaluated. Certain constraints such as existing structures, underground utilities, and the topography will be assessed in order to create feasible design. Collecting this data will be done in a variety of ways using visual analysis, land surveying tactics, and gathering informational resources from previous renovations and upgrades.

3.2.1 Survey Land

Our team will use a transit, theodolite, level staff, and a measuring wheel to determine elevations within Alumni Stadium. Areas of interest include the away side hill, the hill near the main home bleacher entrance, and the area near the scoreboard (See Figure 6). We will use landmarks and surveying spikes as benchmarks for our note keeping.

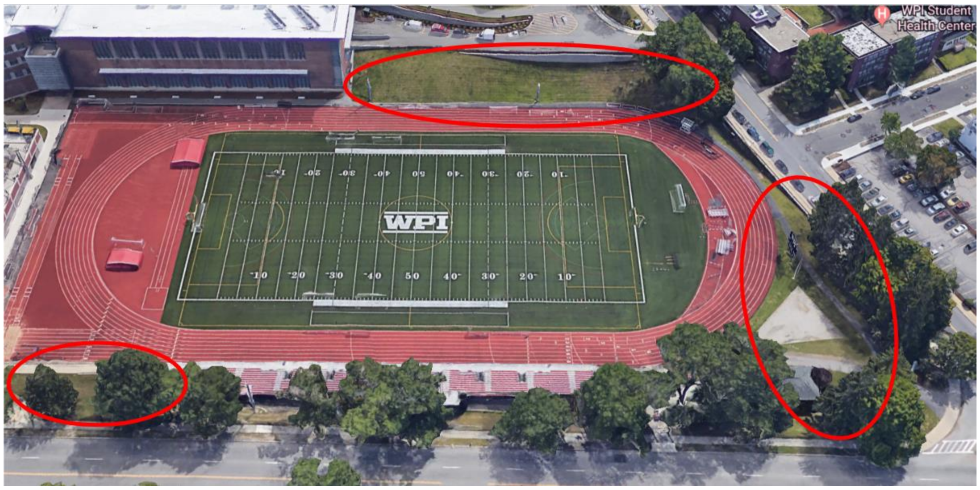


Figure 6: Aerial View of Alumni Stadium

3.2.2 Plans from Facilities

Our team will talk with the Director of Facilities, to receive documents relating to Alumni Stadium. These documents will include drawings of utilities, surrounding areas, and architectural design of the bleachers. But in order to receive said documents, our team and advisor will have to sign a Non-Disclosure Agreement Form and complete a Facilities MQP Projects Request Form.

3.2.3 Existing Conditions

Our team will walk around Alumni Stadium and look for any physical features that were not seen in the documents given to us by facilities that will have an effect on our project. Some examples could be a storm drain, light fixture, or even an electrical handhole. We will do our own quality inspection of the existing conditions and will address anything we see that will need attention.

3.3 Applicable Building and Stadium Codes

In order to portray several codes and standards in our report in a clear and concise manner, our team will list the multiple provisions that we will comply with throughout the design process. A table of these provisions is seen on the next page.

Table 3: Building Codes to be Used for our Design

Code	Chapter / Section	Name	Impacts to Area
IBC (780 CMR)	**Ch. 3**	Use and Occupancy Classification	Select Occupancy Group & Use
	Ch. 5	General Building Height & Area	Determine Height & Area Limitations
	Ch. 6	Types of Construction	Determine Construction Type
	Ch. 8	Fire Protection Systems	Determine which Fire Protection Systems are needed
	Ch. 10	Means of Egress	Means of Egress routes
	Ch. 11	Accessibility	Determine Accessibility Needs
	Ch. 16	Structural Design	Design in accordance with Structural Design
	Ch. 29	Plumbing Fixtures	Determine the amount of fixtures required
ICC 300	**Ch. 3**	Construction	Loading, fire protection and roof heights
	Ch. 4	Egress	Stadium Specific Egress plans
	Ch. 6	Reference Material	IBC and Maintenance plans
ADA	**Ch. 4.1**	Minimum Requirements	Standard Guidelines
	Ch. 4.8	Ramps	Determine dimension and pitch
	Ch. 4.9,4.10,4.11	Stairs, Elevators, Platform Lifts,	Determine dimensions
	Ch. 4.37	Benches	Determine dimensions

3.4 Applicable Worcester Zoning Codes and Regulations

Alumni Stadium is located within the IN-S Zoning District. There are certain restrictions within this district that will affect our new design. Our team will look into the Worcester Zoning Ordinance so our design will abide by its rules. Furthermore, contact with the Worcester Zoning

Board will be essential to see if there are any other special regulations the design will have to follow.

3.5 Propose New Stadium

After all data is collected, our team will create multiple designs for Alumni Stadium. We will have different design alternatives for the multiple features of Alumni Stadium we want to enhance. For example, if we want to build stands on the away side hill. Our team will create multiple designs for stands and we will talk to stakeholders on which design is best.

3.5.1 Architectural Designs

Architecturally, the design that we will come up with conceptually will have to fit WPI's "look". As we will produce a 3D rendered model of our design, this is where we will have a deliverable for the architectural look. We will come up with a few different models for our architectural design and then reach back out to our stakeholders to see which design they favor. Our architectural designs will focus on the structures of our design. Some drawings that could be produced are as follows: Architectural site plan, exterior assemblies, partition types, press box floor plan, roof plan (MEP's), reflected ceiling plan, building elevations, exterior wall systems, enlarged plans for specific sections (stairs, bathrooms), elevator, general details, finish schedule, door schedule and details, and possible furniture plans.

3.5.2 Civil Design

Our civil design will focus on the site work for Alumni Stadium. We will be assuming the role of a site contractor to define the scope of work. Some drawings that we will produce are as follows: existing conditions, new layout plan, specific ADA requirements throughout our site, grading plan, utilities plan, erosion and sediment control plan, landscape plan, exterior lighting, and some typical construction details.

3.5.3 Foundation

Our foundation design will rely on previous data from soil reports in order to determine the amounts of loading the soil can support based on various types of foundations. With this information, in conjunction with architectural plans, footings will be able to be designed to handle all required loading combinations.

3.5.4 Structural Design

Our structural design will focus on the design of any new bleachers we decide to add along with any modifications we add to the current design. Modifications could include a new press box, away side bleachers, modifications to the home side bleachers, a possible new building on the south-west entrance and a video board. The additions or renovations will mainly depend on the responses from stakeholders and feasibility of the addition or renovation. Our structural design will likely include both concrete design and steel design.

3.6 Analyze Cost

Since the design of Alumni Stadium is incorporated within a college campus with finite resources for improvements, cost projections will be made to ensure the proposed design is one that adds values and is financially feasible. To do this, cost estimates for each aspect of our design will need to be calculated at different stages of the project with varying degrees of precision. These estimates will come at the 30, 60 and 100 percent completion points of our designs.

To determine the cost of each design that is proposed, the team will employ an empirical estimating technique. This relies on information and pricing from older projects to give effective cost for different assemblies within a construction project. In conjunction with using empirical data, the team will seek out local contractors to get additional judgement on prices that will be more specific to our unique design and will represent trends in the Worcester area opposed to a more generically calculated number. In addition, local contractors will have a greater understanding as to the duration of construction processes which will further help with the overall cost estimation and planning of the design. If local contractors are not forthcoming our team will explore other options with contractors not present to the Worcester area and incorporate adjustment factors to provide more accurate and conservative estimates.

3.7 Design Evaluation

When comparing our designs at each stage (30, 60 and 100 percent complete design) the group will use a scoring system to determine which designs are worth continuing and further developing. To do this, a variety of factors will be taken into consideration based upon what WPI values the most and the cost associated with the design solution. These values will primarily be based on the information obtained from the interviews with the athletic department and the fan surveys, which will be weighted based on their value added. Additional factors will be incorporated to take into account the constructability and the practicality of a design. Each factor will have a clear description and method for calculation that will attempt to be done in the least subjective way possible. Some factors the group anticipates will be ease of adaptability, storage creation and aesthetic appeal.

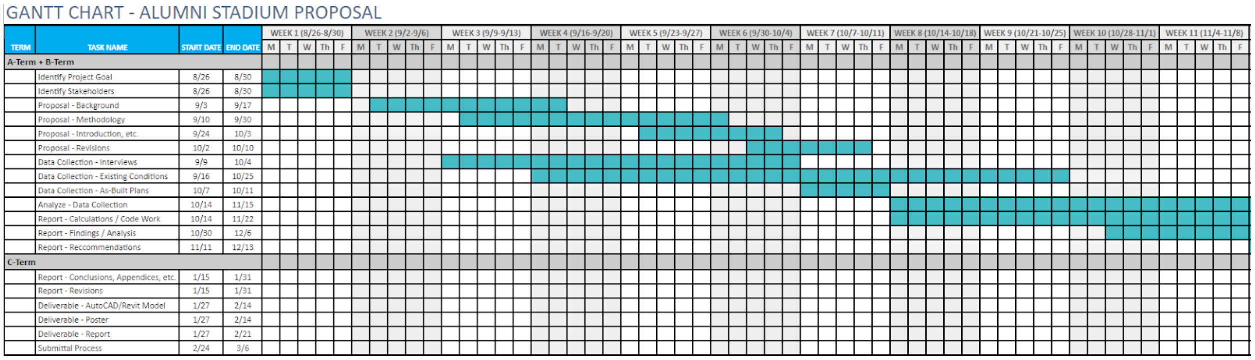
While further information will be needed to determine absolute factors, an example of the Design Evaluation for a particular feature is depicted below.

Design Evaluation at 30% Complete									
Criteria	Seats Added	Aesthetic appeal	Adaptability	Storage Added	Fan Engagement	Wow Factor	Total Points	Cost ($)	$/point
Design #1	3	5	1	1	0	1	11	$17,000.00	$1,545.45
Design #2	4	2	5	1	2	0	14	$22,000.00	$1,571.43
Design #3	1	1	3	2	2	3	12	$30,000.00	$2,500.00
Design #4	2	4	4	5	2	2	19	$29,000.00	$1,526.32
Design #5	3	3	2	4	0	2	14	$23,000.00	$1,642.86
Seats Added- ranges 1-5, 1= (0-50), 2 = (50-200), 3= (200-500), 4= (500-1,000), 5= (1,000+)									
Aestetic Appeal- ranges 1-5, ranked between design options (most aesthetically pleasing =5)									
Adaptability - ranges 1-5, ranked between design options (most adaptable pleasing =5)									
Storage Added- ranges 1-5, 1= (0-50), 2 = (50-200), 3= (200-500), 4= (500-1,000), 5= (1,000+) in square feet									
Fan engagement- binary 0-2, 0 = no new fan engagement, 2= added level of engagment									
Wow Factor- ranges 0-3, subjective factor regarding unqiue features and advertising tools									

Figure 7: Example of Design Evaluation Chart

3.8 Anticipated Deliverables

Through our research and work on our project, we are expecting to have deliverables that will represent the process of designing and evaluating a stadium revamp for Alumni Stadium. Deliverables will include a thorough report that will portray our full research and analysis of our project goal, a poster for Project Presentation Day that includes key points within our report, a computer-aided design of the proposed area of the new Alumni Stadium, and a schedule of activities over three terms (See Figure 8). Computer-aided designs will include architectural 3D renderings, elevations, and floor plans for proposed structures. In addition, we will provide typical drawings and calculations for different aspects of our proposal, such as at footings, structural member connections, and grading plans.



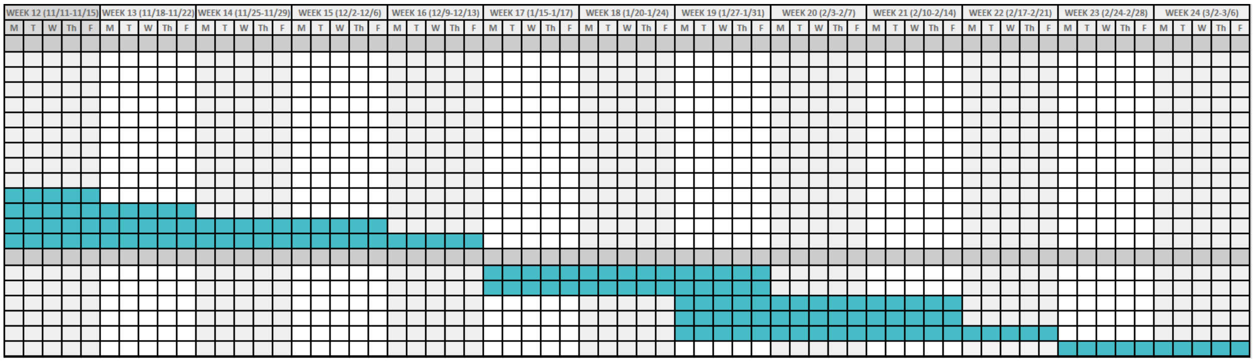


Figure 8: Schedule of Activities for Project

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Appendix B: Summary of Input from Stakeholders

Dana Harmon: Director of Physical Education, Recreation and Athletics

- Need for ADA compliance
- Need to resurface the track in the next 1-3 years
- Press box is suitable for 5 game a year (home football games)
- Track throwing area are getting moved across Park Avenue within 1-2 years
- Open to idea of videoboard
- Maybe put arch for teams to run under at entrance of stadium by recreation center
- Concession stand only open for WPI football and MIAA sporting events
- To get the money for these projects normally they will work with donors to do many small projects. In our case those small projects would be each individual aspect of our entire design

William Spratt: Director of Facilities Operations

- Facilities building in southwest corner of Alumni Stadium is most used for storage of equipment
- During construction of project, some obstacles include utilities, roots, and stormwater
- It would be best to redo the track during the summer months
- If new facilities building were to be built, it would be ideal to be 3,000-4,000 square feet
- WPI bought land off Sagamore Road which potentially be used for facilities equipment
- Current facilities building is cramped but its location is ideal being so close to campus

Shawn McAvey: Facilities Manager

- New stands can eliminate area to cut grass
- Would be ideal to add more storage
- Would like to find a way to gain access from the south side of the rec center to the field

Rusty Eggen: Associate Athletic Director and SID

- There are accessibility problems with the ladder to the roof within the press box
- Likes isolated coaches' boxes from announcers and media personnel for press box
- The speaker placement could be improved to create better sound quality within the stadium
- LED lights for the stadium lights so there is not take long to turn fully on like they currently do

Brian Chabot: Head Track and Field Coach

- Would like additional storage for all sports equipment
- Need new track surface because current track is almost 20 years old and tracks typically have a 12-year lifespan
- Straightaway on the southwest corner to allow us to account for changes in the wind
- Put pole vault in behind south endzone of the field
- Ability to throw discus on the turf for competition
- In general, he wants a facility to be able to host the NCAA and high school track meets.
    - Believes it would help with recruiting

Fan Survey

- Current CE, EE, and AE students which generated 47 responses.

Table: Questions asked in Fan Survey

Where do you typically watch games at Alumni Stadium?	65.2% Bleachers 21.7% Away Side Stands 13.1% Other
While watching a game do you feel there is not enough space for all the fans?	62.2% Sometimes 20% Yes 15.6% No 2.2 % Never
Are the bathrooms close enough (in Rec Center) or do you wish to see bathrooms closer to the field?	76.6% Closer 23.4% No need to change
Would you like to see changes to the concession stand? Check all that apply.	52.4% Larger variety of food 38.1% Larger Variety of drinks 38.1% No change 31% Shorter wait times
What is your opinion on having a jumbotron?	53.2% That would be awesome! 40.4% I do not really care 6.4% Distraction to the game

Appendix C: Away Side Seating Design One Calculations

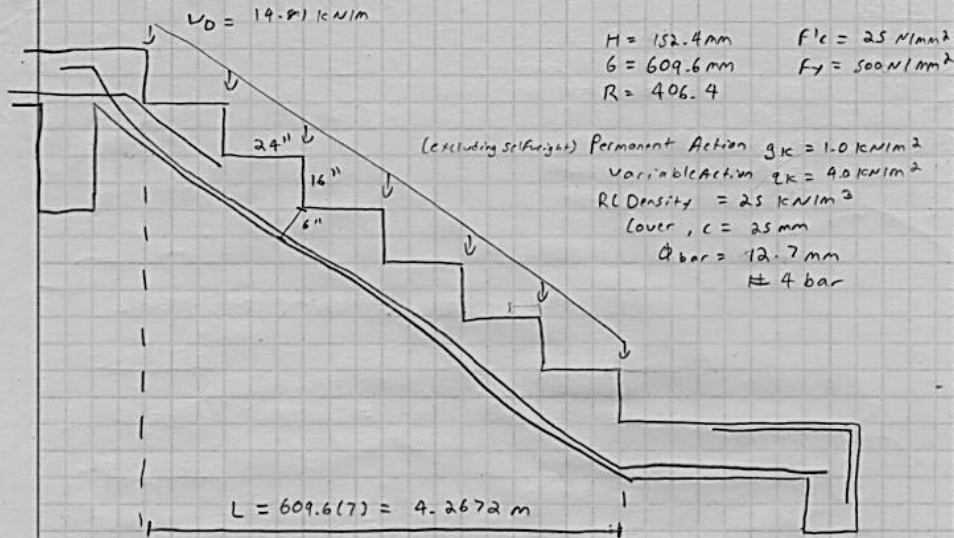
Variables			
Live Load (LL)	120		plf
Snow load (SL)	50		psf
Density of Soil (delta)	125		lb/ft3
C Coension value	0		N/a
phi (slip plane)	35	0.6	degrees/radian
Ny	15		N/a
Nq	19		N/a
B width	4		ft
D depth	3		ft
Front Backfill	1		ft
Laterial distance from toe (a)	1.75		ft
Total retaining wall width	3.5		ft
Surcharge 1	97.6301244		plf
Surcharge 2	15.0390651		plf
Weight (W)	360		plf
Weight of Retaining wall	3		lb
Retaining wall thickness	1		ft

Secondary Variables		
P	1312.5	plf
Z	1.5	ft
R	3.35	ft

Allowable Bearing Capacity Calc		
q ult=	10875	psf
	1/2*d*B*Ny+d*D*Nq	
q all=	5437.5	psf
q calc=	510.0390651	
Foundation Sliding Analysis Calc		
F = [W * tan (delta) + Pp]/Pa		
ka =	0.27119479	
Pa=	250.1771939	plf
kp=	3.687380588	
Pp=	230.4612868	plf
F=	1.928112962	
Overturning Calc		
F= (W * a)/ (1/3*Pa*H+.5*H*ka*Q)		
Wa =	2296.875	
F=	7.682055148	

Snow Load	50 psf
Ref IBC 1608.2	
Live Load	120 plf (vertically)
Ref ICC 300 303.2	

Appendix D: Away Side Seating Design Two Calculations



Determine Avg thickness of Staircase

$$y = h\left[\frac{\sqrt{G^2+R^2}}{G}\right] = 152.4\left[\frac{\sqrt{609.6^2+406.4^2}}{609.6}\right] = 183.2 \text{ mm}$$

Avg thickness

$$t = \frac{y + (y+R)}{2} = \frac{183.2 + (183.2 + 406.4)}{2} = 386.4 \text{ mm}$$

Action

Slab selfweight = 25.0 × .221 = 5.52 kN/mm²

Permanent Action (excluding selfweight) = 1.00 kN/mm²

Characteristics permanent action, g_k = 5.52 + 1.00 = 6.52 kN/mm²

Characteristics variable action, q_k = 4.00 kN/m²

Design Action, $p_d = 1.35\, g_k + 1.5\, q_k$

$$p_d = 1.35(6.52) + 1.5(4.00) = 14.81 \text{ kN/m}^2$$

Consider 1 m width $v_d = p_d \times 1\text{m}$ = 14.81 kN/m

$$F = w_0 \times L = 14.81\,(4.2672) = 63.20\ kN$$

$$M = \frac{FL}{10} = \frac{63.20\,kN\,(4.2672\,m)}{10} = 27.0\ kNm$$

Main Reinforcement

Effective Depth $d = 152.4mm - 25mm - \frac{12.7mm}{2} = 121.1\ mm$

$$K = \frac{M}{f'_c\, bd^2} \qquad K = \frac{27.0 \times 10^6}{25\,(1000)\,(121.1)^2} = .073 < K_{bal} = .167$$

Compression Reinforcement NOT Required

$$z = d\left[.25 - \left(\frac{K}{1.134}\right)\right] = .93d < .95d$$

$$A_s = \frac{M}{.87\, F_{yk}\, z} = \frac{27.0 \times 10^6}{.87(500)(.93)(121.1)} = 551\ mm^2/m$$

Minimum and Max Area of Reinforcement

$$A_{s,min} = .26\left(\frac{F_{ctm}}{F_y}\right) bd = .26\left(\frac{2.56}{500}\right) bd = .0013\,bd \geq .0013\,bd$$

$$A_{s,min} = .0013\,bd = .0013\,(1000)\,(121.1) = 157.4\ mm^2/m$$

$$A_{s,max} = .04A_c = .04\,bh = .04\,(1000)\,(152.4) = 6096\ mm^2/m$$

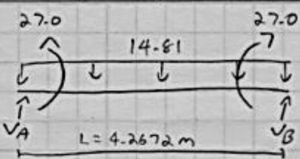
Secondary Reinforcement

A_s = 20% of the Main Reinforcement = .2 (551) = 110.2 mm^2/m

Main Bar #9 645 mm^2
#29 soft metric

Secondary Bar #4 bar 129 mm^2
#13 soft metric bar

Shear



$\Sigma M @ B = 0$

$4.2672 V_A - 27 + 27 - (14.81 \times 4.2672 \times 2.1336) = 0$

$V_A = 31.6$ kN/m

$V_B = 31.6$ kN/m

Max Design shear Force , $V_{ED} = 31.6$ kN/m

$k = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{121.1}} = 2.29 > 2.0$ use $k = 2.0$

$\rho_1 = \frac{A_{s1}}{bd} = \frac{645}{1000(121.1)} = .0053 \leq .02$

$V_{RD,c} = [.12 k (100 \rho_1 f_{ck})^{1/3}] b d$

$= [.12 (2.0) (100(.0053)(25)^{1/3}] 1000 (121.1) = 68.8$ kN/m

$V_{min} = [.035 k^{3/2} \sqrt{f_{ck}}] b d$

$= [.035 (2.0)^{3/2} \sqrt{25}] 1000 (121.1) = 59.9$ kN/m

V_{ED} (31.6 kN/m) < $V_{RD,c}$ (68.8 kN/m) ✓

Deflection

Percentage of required tension reinforcement

$\rho = \frac{A_{s,req}}{bd} = \frac{551}{1000(121.1)} = .0045$

Reference Reinforcement Ratio

$\rho_0 = \sqrt{f_{ck}} \times 10^{-3} = \sqrt{25} \times 10^{-3} = .0050$

Since $\rho \leq \rho_0$ → use eq (7.16a) in EC 2 (1.7.4.2

Factor or structural system, $K = 1.5$

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\,\frac{\rho_0}{\rho} + 3.2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{3/2}\right]$$

$$\frac{l}{d}_{basic} = 2.0\,(11 + 8.3 + .59) = 39.8$$

Modification Factor for span less than 7m = 1.00

Modification for steel Area provided $\frac{A_{s,prov}}{A_{s,req}} = \frac{645}{551} = 1.17 < 1.5$

$(l/d)_{allow} = 39.8 \times 1.00 \times 1.17 = 46.5$

$(l/d)_{actual} = 4267.2 / 121.1 = 35.2$

allow > actual
Deflection OK

Cracking

$h = 152.4\,mm < 200\,mm$

Main Bar:

$S_{max,slab} = 3h\ (330\ mm) \le 400\ mm$

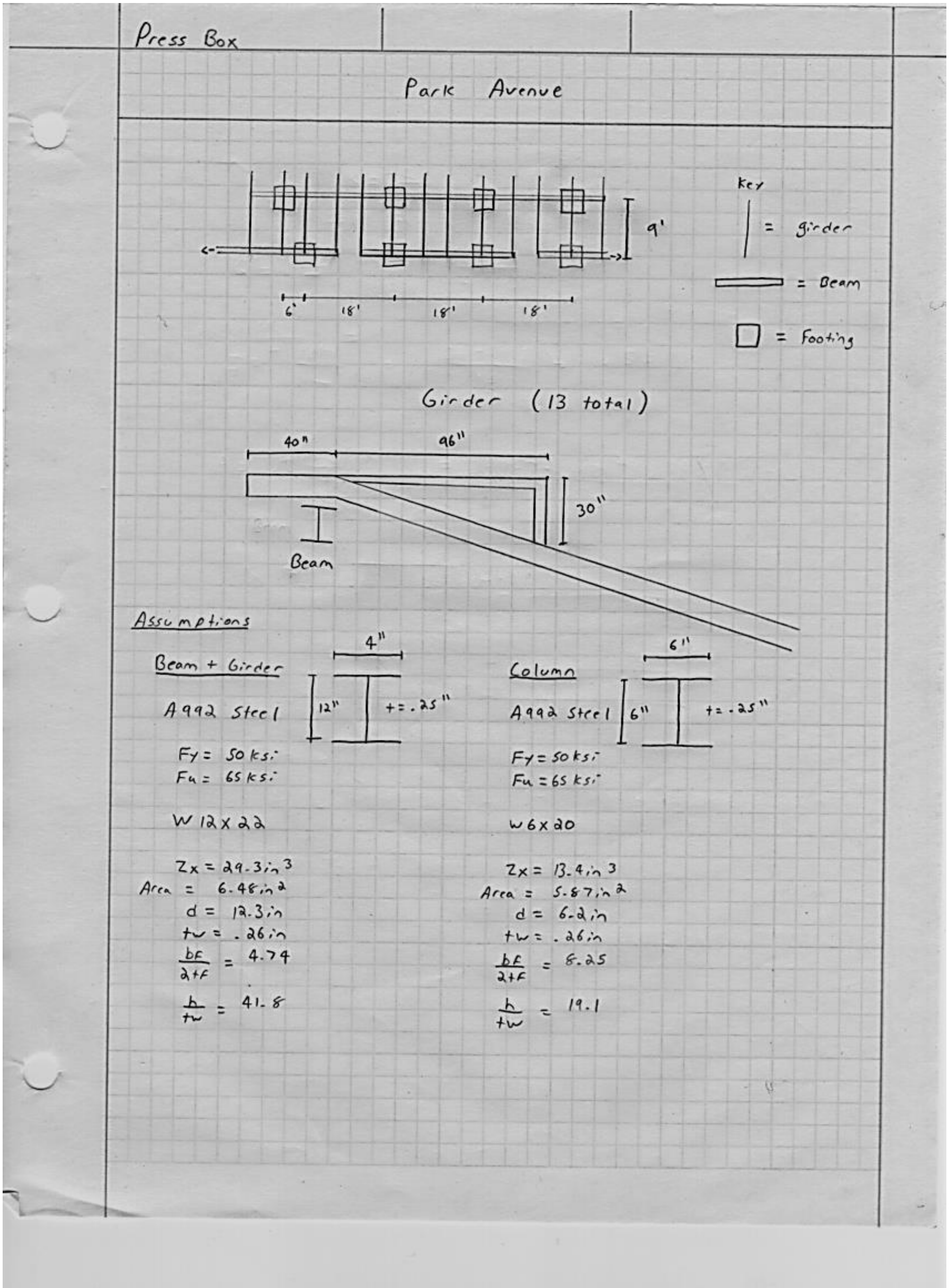
Max bar spacing = $125mm < S_{max,slab}$

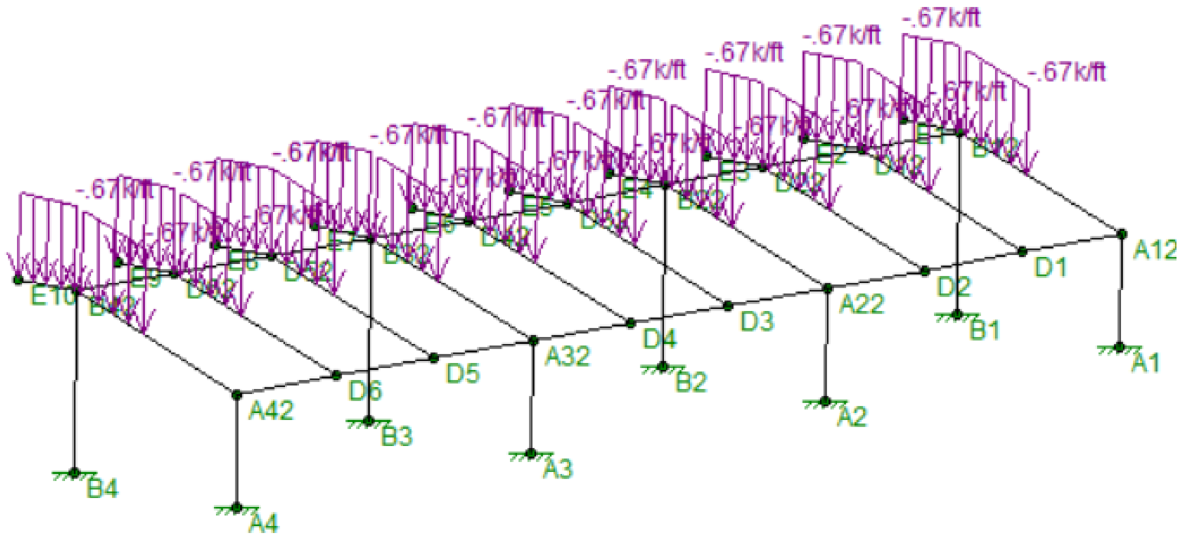
Secondary Bar: $3.5h\ (385\ mm) \le 450\ mm$

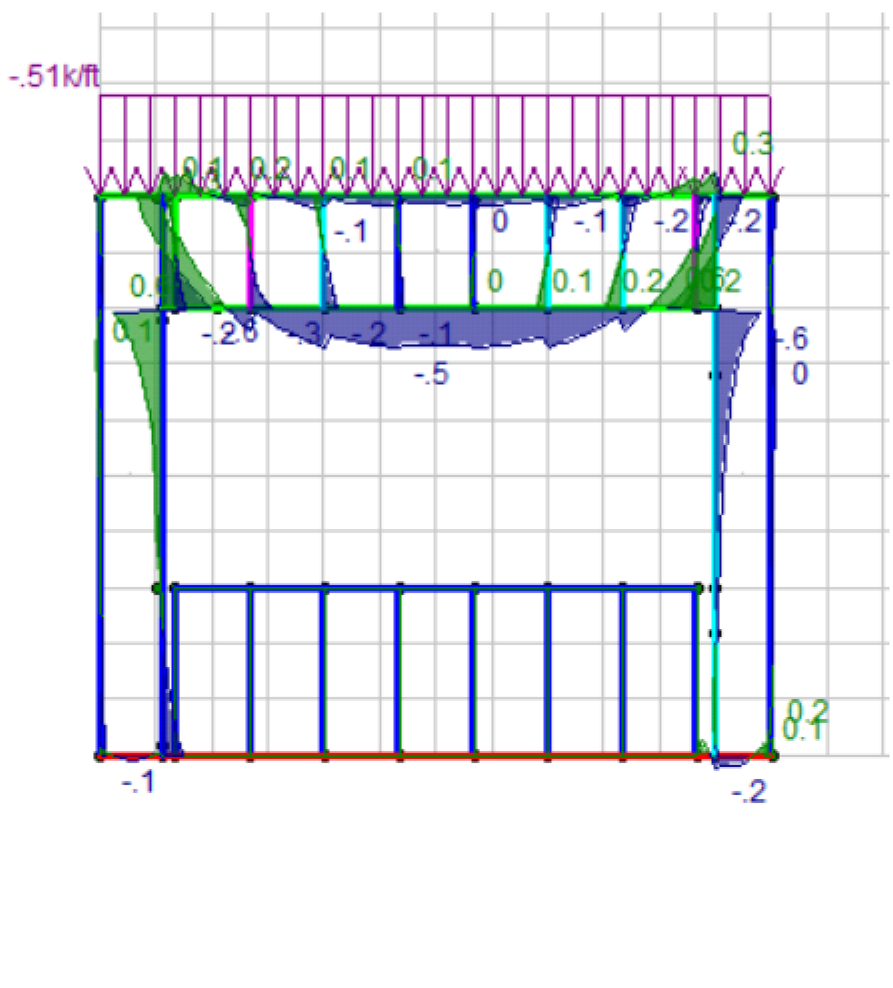
Max bar spacing = $350mm < S_{max,slab}$

Cracking OK

Appendix E: Press Box Structural Drawings




-.67k/ft
A12
D1
D2
B1
A1
A22
D3
D4
B2
A2
A32
D5
D6
B3
A3
A42
B4
A4
E10


-.51k/ft
0.3
-.1
0
-.1
-.2
0.1
0.2
-.5
-.6
-.2

Appendix F: Away Side Seating Designs Matrix

Hillside Seating Evaluation

Design Name	Initial Cost	Maintance Cost per Year	Seating Added	Price per Seat	Ease of Construction	School fit/ appeal	Seating Value	Permeability	Life Cycle Cost	Score	Price Per Score
Terraced Hill	$13,700.00	$1,500.00	150	$101.33	1.2	1	1	1.8	1	60	$1.69
Stepped Seating	$17,465.00	$1,200.00	182	$96.40	1	1	1.213333333	1	1.5	57.13333333	$1.80
				Based off of preliminary material only cost, Terraced Hill design is the more effective deisgn based off of our scoring system.							

Appendix G: Press Box Designs Matrix

Press Box Evaluation

Design Name	Initial Cost	Maintance Cost	Ease of Constuction	Amenities	School Fit	Asthetic Appeal	Wow factor	Unique Feature	Accessability	Accomidations	Score
Design 1	N/A	N/A	1	1	0	1.2	1	1	1.2	1	74
Design 2	N/A	N/A	1	1	0	1	1.2	1.5	1	1	77

Appendix H: Cost Estimations

Away Side Seating

Description	QTY.	Units	Unit Cost	Total Cost	Source
			Sitework and Labor		
Excavation	1500	cy	$ 11.17	$16,755.00	RS Means
Walkways	5	cy	$ 226.00	$ 1,130.00	RS Means
Subgrade	1000	cy	$ 3.79	$ 3,790.00	RS Means
Backfill	1500	cy	$ 3.79	$ 5,685.00	RS Means
			Materials and labor		
Concrete: Cast in Place	40	cy	$ 226.00	$ 9,040.00	RS Means
Masonry	145	lf	$ 244.30	$35,423.50	RS Means
Waterproofing	1000	sf	$ 3.71	$ 3,710.00	RS Means
Railings	65	lf	$ 76.00	$ 4,940.00	RS Means
Rebar	1.3	ton	$ 2,200.00	$ 2,860.00	RS Means
Misc.			$ 1,000.00	$ 1,000.00	
			Multipliers		
Location: Worcester			1.077		
Time: 2020			1.076		
Design Fees			7%		
Contingency			15%		
	Total Cost Without Multiplyers				$ 78,648.50
	Total Cost With Multiplyers				$108,444.64

Track

Description	Units	Unit Cost	Total Cost	Source
		Sitework and Labor		
Aspalt/Track Rip up	9,800 sy	$ 5.20	$ 51,000.00	RS Means
Grading	9,800 sy	$ 0.61	$ 6,000.00	RS Means
Turf Demo	600 sf	$ 0.42	$ 252.00	RS Means
Excavation	11.2 cy	$ 11.17	$ 125.00	RS Means
Paving	9,800 sy	$ 13.40	$131,320.00	RS Means
Track Surface	9,800 sy	N/A	$318,000.00	Beynon
Fencing	150 lf	$ 5.10	$ 765.00	RS Means
Concrete: Cast in Place	11.2 cy	$ 226.00	$ 2,508.00	RS Means
Rebar	.5 ton	$ 2,200.00	$ 1,100.00	RS Means
		Multipliers		
Location: Worcester		1.077		
Time: 2020		1.076		
Design Fees		7%		
Contingency		15%		
	Total Cost Without Multipliers			$511,070.00
	Total Cost With Multipliers			$759,300.00

Field Restroom with Storage

Description	QTY.	Units	Unit Cost	Total Cost	Source
Sitework and Labor					
Demolition	1500	sf	$ 11.17	$16,755.00	RS Means
Walkways	5	cy	$ 226.00	$ 1,130.00	RS Means
Subgrade	100	cy	$ 3.79	$ 379.00	RS Means
Materials and labor					
Rough Carpentry	2225	sf	$ 25.00	$55,625.00	RS Means
Roof - Asphault Shingles	1625	sf	$ 4.98	$ 8,092.50	RS Means
Masonry- Exterior CMU Walls	100	lf	$ 244.30	$24,430.00	RS Means
Concrete: Cast in Place	31	cy	$ 226.00	$ 7,006.00	RS Means
Waterproofing: Walls	1000	sf	$ 3.74	$ 3,740.00	RS Means
Waterproofing: Roof	1625	sf	$ 3.71	$ 6,028.75	RS Means
Insulation	2425	sf	$ 1.18	$ 2,861.50	RS Means
Flooring	625	sf	$ 4.74	$ 2,962.50	RS Means
Acustic Ceiling	625	sf	$ 3.50	$ 2,187.50	RS Means
Exterior Doors	3	Doors	$ 1,175.00	$ 3,525.00	RS Means
Interior Doors	6	Doors	$ 240.00	$ 1,440.00	RS Means
HVAC	625	sf	$ 40.00	$25,000.00	DCAM
Plumbing	625	sf	$ 10.00	$ 6,250.00	DCAM
Electrical	625	sf	$ 22.00	$13,750.00	DCAM
Communications and Security	625	sf	$ 2.00	$ 1,250.00	DCAM
Fire Supression	625	sf	$ 4.00	$ 2,500.00	DCAM
Multipliers					
Location: Worcester			1.077		
Time: 2020			1.076		
Design Fees			7%		
Contingency			15%		
Total Cost Without Multiplyers					$184,912.75
Total Cost With Multiplyers					$254,967.32

Field Restroom without Storage

Description	QTY.	Units	Unit Cost	Total Cost	Source
Sitework and Labor					
Demolition	1500	sf	$ 11.17	$ 16,755.00	RS Means
Walkways	5	cy	$ 226.00	$ 1,130.00	RS Means
Subgrade	100	cy	$ 3.79	$ 379.00	RS Means
Materials and labor					
Rough Carpentry	1625	sf	$ 25.00	$ 40,625.00	RS Means
Roof - Asphault Shingles	1000	sf	$ 4.98	$ 4,980.00	RS Means
Masonry- Exterior CMU Walls	100	lf	$ 244.30	$ 24,430.00	RS Means
Concrete: Cast in Place	18.5	cy	$ 226.00	$ 4,181.00	RS Means
Waterproofing: Walls	1000	sf	$ 3.74	$ 3,740.00	RS Means
Waterproofing: Roof	1000	sf	$ 3.71	$ 3,710.00	RS Means
Insulation	2425	sf	$ 1.18	$ 2,861.50	RS Means
Flooring	625	sf	$ 4.74	$ 2,962.50	RS Means
Acustic Ceiling	625	sf	$ 3.50	$ 2,187.50	RS Means
Exterior Doors	3	Doors	$ 1,175.00	$ 3,525.00	RS Means
Interior Doors	6	Doors	$ 240.00	$ 1,440.00	RS Means
HVAC	625	sf	$ 40.00	$ 25,000.00	DCAM
Plumbing	625	sf	$ 10.00	$ 6,250.00	DCAM
Electrical	625	sf	$ 22.00	$ 13,750.00	DCAM
Communications and Security	625	sf	$ 2.00	$ 1,250.00	DCAM
Fire Supression	625	sf	$ 4.00	$ 2,500.00	DCAM
Multipliers					
Location: Worcester			1.077		
Time: 2020			1.076		
Design Fees			7%		
Contingency			15%		
Total Cost Without multiplyers					$ 161,656.50
Total cost With multiplyers					$ 222,900.39

Appendix I: Existing Conditions of Alumni Stadium