JGMA Design & Construction

701 Moore Avenue
Lewisburg, PA 17837
(570) 577-1720 FAX (570) 577-1112

Letter of Transmittal

May 8, 2023
Professor Ronald Ziemian and Professor Alomir Favero
Project Executives
Senior Design Advisors, LLC.
701 Moore Avenue
Lewisburg, PA 17837

Dear Professor Ziemian and Professor Favero:

This report summarizes the analysis of the feasibility study of Bucknell University's new Bucknell West Apartments and the comparison of an alternative design. The Bucknell West Apartments are located on the west side of Route 15 from Bucknell University's campus, which is located at One Dent Drive, Lewisburg, Pennsylvania. This report has been prepared for Bucknell University in response to your request on August 25, 2022.

This report first provides how JGMA Design and Construction reached an eight-story design alternative to the current Bucknell West plan. In short, our steel structure building will most likely be less expensive and help Bucknell reach a net zero carbon neutral goal by taking advantage of more greenspace, geothermal heating, a green roof, and a greywater recovery system and other key items found in the element analysis.. Furthermore, we estimate that the project will be able to become profitable to Bucknell after 23 years of its construction. The building will also provide extra rooms and a large community space for students to take advantage of. Therefore we recommend that the University follows this plan and begins construction on the eight story, single structure.

Thank you for your time and consideration, and please do not hesitate to contact Mike Devlin (570) 577-1720 with any questions.

Sincerely,
JGMA Design and Construction

Mike Devlin
Mike Devlin

Graham Allardyce
Graham Allardyce

Andrew Matton
Andrew Matton

Jonathan Stiefel
Jonathan Stiefel

Enclosure: Conceptual Design Report Multi-Story Residential Building Bucknell University

FINAL DRAFT DESIGN REPORT
MULTI-STORY RESIDENTIAL BUILDING
BUCKNELL UNIVERSITY

May 8, 2023

Submitted to:

Professor Ronald Ziemian and Professor Alomir Favero
Bucknell University
701 Moore Avenue, Lewisburg, Pennsylvania 17837

Prepared by:

JGMA Engineering
Bucknell University
701 Moore Avenue, Lewisburg, Pennsylvania 17837

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Executive Summary

Bucknell University currently plans to renovate the Bucknell West student residences, known as the Mods, into four apartment-style complexes, similar to the South Campus apartments. However, JGMA Design and Construction has been tasked to find, evaluate, and design alternative plans for the renovation that improve upon sustainability and the cost of the project. The following report thoroughly describes the project objectives. Criteria and constraints were identified, of which the most important are cost effectiveness and consideration of Bucknell University's goal for carbon neutrality by 2030. The new residential building must also be ready by the Fall semester of 2024 to avoid a sustained loss of campus housing. The team assessed the construction of a multi-story building for the Bucknell West Renovation with two main alternatives: a four-story building with a large footprint and an eight-story building with a smaller footprint. Both alternatives were compared to the University's original plan in order to evaluate an improvement in sustainability and cost, and ultimately, the eight-story alternative was chosen through a weighted-ranked based decision matrix.

JGMA then developed architectural and structural layouts from which specific design elements and structural components were designed. The entire development features 286 total beds split into triple and quad apartment-style rooms in addition to common spaces, laundry rooms, an elevator, and a stairwell. The building utilizes a steel gravity frame with composite beams and moment connections, in addition to concrete slabs and shallow foundations. In order to resist lateral loading, a moment frame was designed. The structural steel members were designed using the Load and Resistance Factor Design approach with loadings specified by ASCE/ SEI 7-22 and meets the specifications outlined in the AISC Steel Construction Manual. The foundations were designed using information given to us from a set of boring logs. Using the General Bearing Capacity Equation, specifications from NAVFAC DM7-02, and Terzaghi and Peck's Method, the spread foundations were designed to not exceed the bearing capacity of the soil while maintaining a settlement of under 40 millimeters.

A cost estimate for the entire project was developed using RSMeans templates that were altered to consider specific design elements. The total projected construction cost is $42,911,320, and an income analysis estimated that the project will break even after 23 years. Additionally, a project schedule was created to display the sequence and time to complete individual components across the entire project timeline, including structural components as well as interior and exterior finishing.

A sustainability analysis of the project was conducted to determine the environmental impacts associated with the construction of the structure. Specific elements with high impacts were identified, and alterations were found to improve sustainability.

1.0 INTRODUCTION

In recent years, Bucknell University has experienced a simultaneous need for a slight increase in bed capacity and an update to the Bucknell West residential units, known as "The Mods." Built in the 1950s, the Bucknell West Mods have been a housing location for sophomores, juniors, and seniors. However, they have become outdated due to their discrepant style when compared to the rest of the campus, and they lack a common quad area. Bucknell has given the green light for a replacement development that will provide an eight bed increase in bed capacity, an improved standard of living for its residents, and additional recreational amenities. The current design features four three-story apartment-style residence halls that will feature the traditional Bucknell colonial brick aesthetic, recreational quad area, and features geothermal heating to reach the University's goal of carbon neutrality by 2030. JGMA Design and Construction has been tasked with creating alternative designs that improve upon the efficiency and sustainability of the original plan, by combining the four buildings into one multi-story building and comparing its efficiency and sustainability to the original plan. Our report should help the University explore other options as they are designing future campus buildings.

1.1 Project Setting and Background

Bucknell University is a private liberal arts college located in Lewisburg, Pennsylvania, in between the west branch of the Susquehanna River and US Route 15. Bucknell's campus is split by Route 15 with the majority of campus located on the east side and some student housing and athletic facilities located on the west side. This project is located across US Route 15 in Bucknell's West Campus. These units currently house 272 sophomores, juniors, and seniors, and they can be seen by the "H" footprints in the bottom right portion of Figure 1.1. The area is located in East Buffalo Township in Union County. According to the East Buffalo Township Zoning Map, Figure 1.2, this location is within zoning district B-U (for Bucknell University).

According to Bucknell's plans, the new residential complex to be built will have four apartments that can house 70 students each, combining to house 280 students in total. (Ferlazzo, 2022). Bucknell's plan for the layout of the four apartment buildings will be similar to those of the South Campus Apartments, with apartments of various sizes and configurations that have single bedrooms with a shared kitchen and common space. The four buildings will be the border for a recreational quadrangle space, which will meet students' desires for more outdoor spaces. JGMA Design and Construction is creating a design that will replace the current plans for the new West Campus Apartments. This design will be a single, multi-story residential building with common areas on the ground floor. The building needs to accommodate the same number of students as the four apartment buildings.

The new campus residency would remain close to campus locations such as the athletic facilities, the art barn, and the golf course. This advantageous location would encourage students to visit these campus spots as it would act as a hub for those students living there. The vicinity to these campus spots is seen in Figure 1.1. Funded by University funds and donations as referenced by the campus master plan, (Bucknell Master Campus Plan, 2017), the renovated Bucknell West will breathe life into this outdated part of campus. The building will also act towards the university's carbon neutral goal by implementing several environmental benefits that will help reduce the footprint of the project.

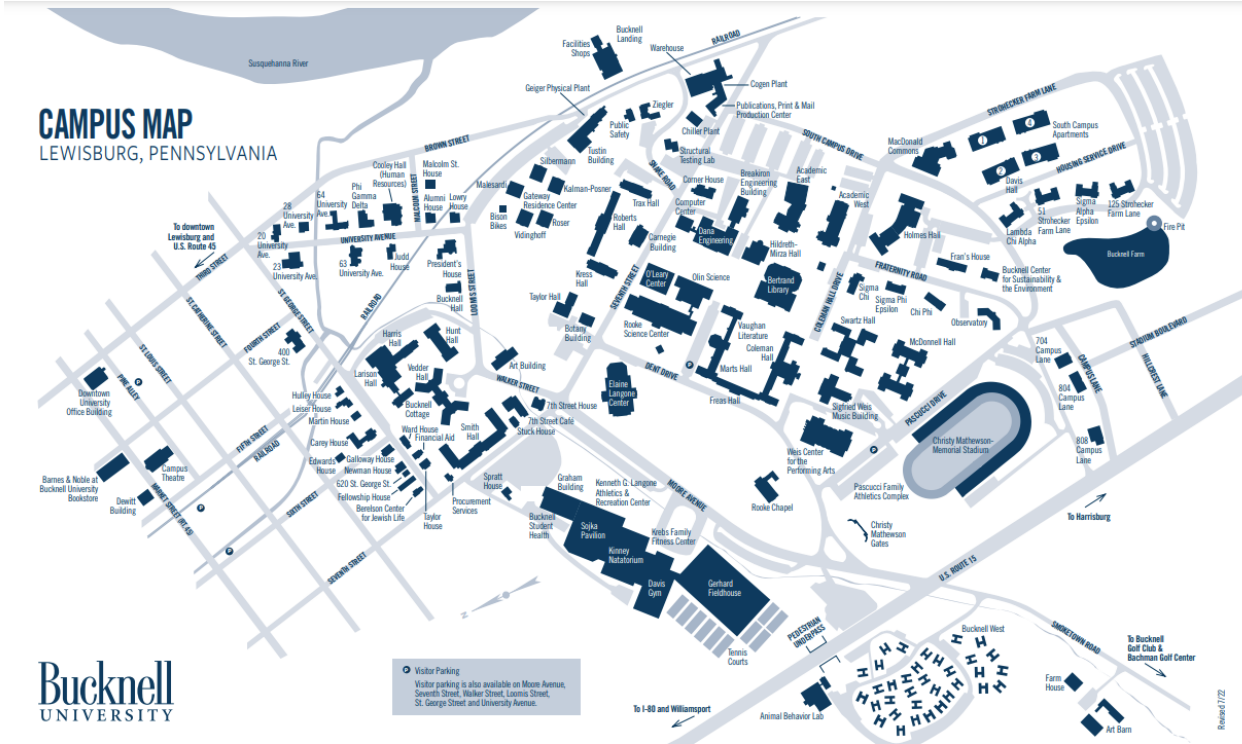


Figure 1.1: Location of project site on Bucknell University's Campus located at the bottom right of the image, with the "H" shaped footprint (*Bucknell University, 2022*).

1.2 Project Objectives

The initial two of the four proposed buildings are scheduled to be completed by the start of the 2023 academic year to simultaneously add more living spaces on campus and significantly revitalize Bucknell West. Additionally, the project will highlight several environmental features that will limit its environmental footprint as well as the landscaping footprint which will be discussed further in the report. JGMA Design and Construction has been tasked with evaluating any advantages to combining those four buildings into one multi-story building in order to compare for sustainability and cost. Ideally, this would be the more beneficial solution in terms of both environmental and economic aspects. In order to comprehensively evaluate our alternative solutions we aim to understand the project setting, site characteristics, local restrictions and constraints, and building codes. Once the underlying conditions have been made we can pursue the analysis of the different alternative design options to fully realize the best option. From there, the team can move forward with the design and early project management of the project. JGMA will need this understanding to effectively evaluate each design as the better alternative under the criteria of sustainability and cost.

1.3 Report Organization

The report is organized in five sections. Section 2 introduces the site in more depth and explores the history of the area as well as its current characteristics. Section 3 details the governing constraints and criteria that set the guidelines and assessment of alternatives for the project. These constraints are broken down into different categories that are applicable to the project such as: environmental, geotechnical, structural, architectural, and construction. Section 4 describes the identification and consideration of the alternatives which discusses the three main alternatives that are being evaluated. Finally, Section 5 discusses the conceptual design of the project, which incorporates the overview of the project and the scope of work for the next phase.

2.0 SITE HISTORY AND CHARACTERISTICS

Most of the data will be retrieved from the Pennsylvania department of environmental protection, Bucknell facilities, and data compiled by JGMA Design and Construction. This section will detail the site's location, including the surface and subsurface conditions, general topography, and other important details. Using the information from this section the team will relate it to the design of the structural elements and to the significance of the project's presence on campus.

2.1 Location

The new Bucknell residence at the Bucknell West Mods, shown in Figure 1.2, falls under the zoning district B-U within East Buffalo Township, Union County, and it is on the west side of Route 15 from Bucknell's main campus. As a result, the design must follow Bucknell University's codes as well as the East Buffalo Township and Union County's codes as seen in Figure 2.1. The site has coordinates of latitude 40.95265 and longitude of -76.88988. For simplicity, we established a rectangular plot of land for building within the site location. From Google Maps, it can be found that the actual size of this plot is 100,674.55 ft^2 or 2.31 acres, as seen in Figure 2.2. Also, the site is constrained by the locations of the baseball and softball stadiums to the west, the soccer and field hockey fields to the north west, Route 15 to the east, and Miller Run which runs from the south to north east of Bucknell West. The site has a vehicle entrance located on the south east corner at the intersection of Smoketown Road and Bucknell West Drive. It also has a pedestrian tunnel under Route 15 to the north which serves as a pedestrian and bike entrance. Both entrances can be seen in Figure 2.3.

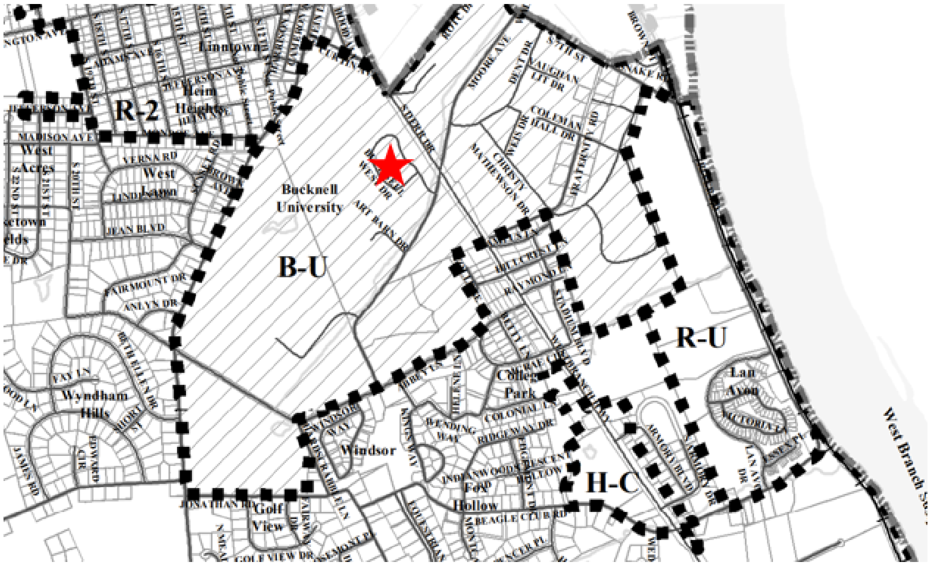


Figure 2.1: Portion of East Buffalo Township zoning map where the site is located (*East Buffalo Township, 2022*).

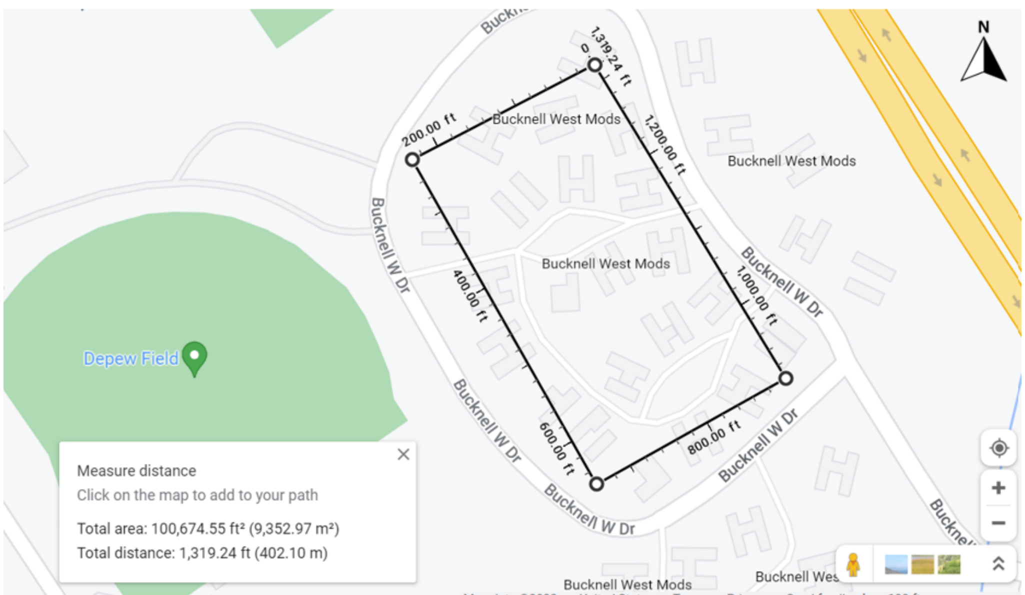


Figure 2.2: Selected plot of land for the site that includes total area and scale. Source: (*Google, 2022*).

Figure 2.3: Pedestrian entrance (left) and vehicle entrance (right) (*Google, n.d.*).

2.2 Site History

The site was acquired by the University in 1920 as part of its expansion plan. It was part of a 170-acre parcel of land bought from the George Barron Miller Farm (Dennis, 1996). From 1946-1947 construction began to create the Bucknell Village on this land with funds allocated from the Federal Public Housing Authority. The 16-building complex accommodated 50 apartment units for veterans and their families as seen in the left panel of Figure 2.4. This construction was built on a greenfield as there were no pre-existing buildings on the site. In 1961-1962 half of the units were demolished and reconditioned until Bucknell's next phase in 1972. After the deconstruction of Bucknell Village in June of 1972, 21 temporary buildings, each housing eight students, were built. Bucknell subsequently added 14 more units, adding 112 beds by 1985, and created what is now known as Bucknell West. Figure 2.4 displays a satellite shot of the current site on the right hand side. Since the site was no longer a greenfield, some earthwork was needed for completion, but the records could not be recovered.

(a) (b)

Figure 2.4: (a) Photo of pre-existing site conditions, Bucknell Village circa 1965 *(Dennis, 1996)*. (b) Satellite imagery of Bucknell West, current layout (*Google, n.d.*).

2.3 Surface Conditions

It is important to take into consideration all factors that affect the surface of the site. This may include but is not limited to topographic conditions, flood zones, wind conditions, and climatic conditions. The site was found to have a mild slope in the south to north direction as shown in Figure 2.6. According to the geotechnical report (F.T. Kitlinski & Associates, Inc., 2022), the elevations range from 485 to 493 within the building's footprint. The location of Miller Run to the site could be harmful to the geotechnical work; since Miller Run is adjacent to the site, it is important to analyze the flood zone. The Federal Emergency Management Agency (FEMA) characterizes building sites with a certain likelihood of flooding occurring, and they categorize the proposed site as Flood Zone X (FEMA, 2020). Flood Zone X is characterized as one of the safest flood zones as it is outside the 500-year floodplain, and it has the capability of being outside the 1000-year floodplain if a control system is in place. As a result, the risk of flooding is quite low, and it is of little concern for the project's feasibility. However, preventative measures will need to be in effect during construction to make sure that the stream is not being polluted by rainwater construction runoff.

It is also important to review the wind conditions on the site. According to the US Department of Energy, Lewisburg has an annual average wind speed of four meters per second, which equates to approximately nine miles per hour; a breakdown of the monthly average wind speed of the building can be found in Figure 2.7. During the winter months, there will be snowfall that must be taken into consideration. Lewisburg, which is located below Williamsport in the light blue section, has an average annual snowfall of 30 to 36 inches as seen in Figure 2.8.

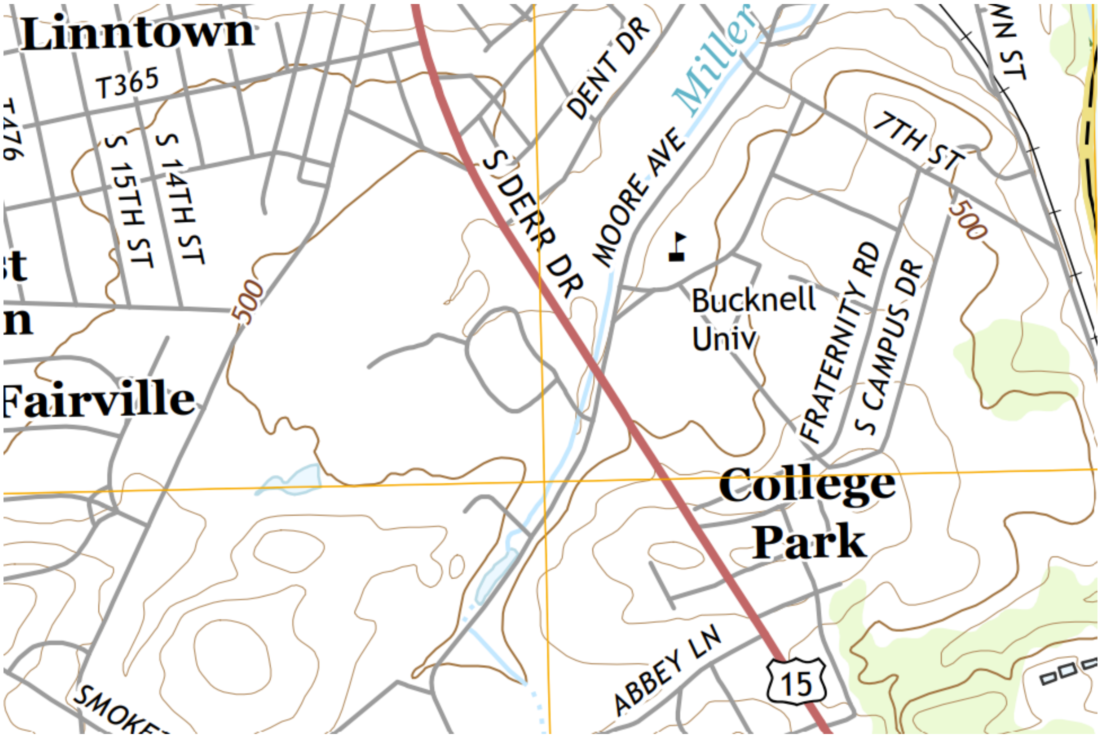


Figure 2.5: Topographic map of the site (*Union County GIS Viewer*).

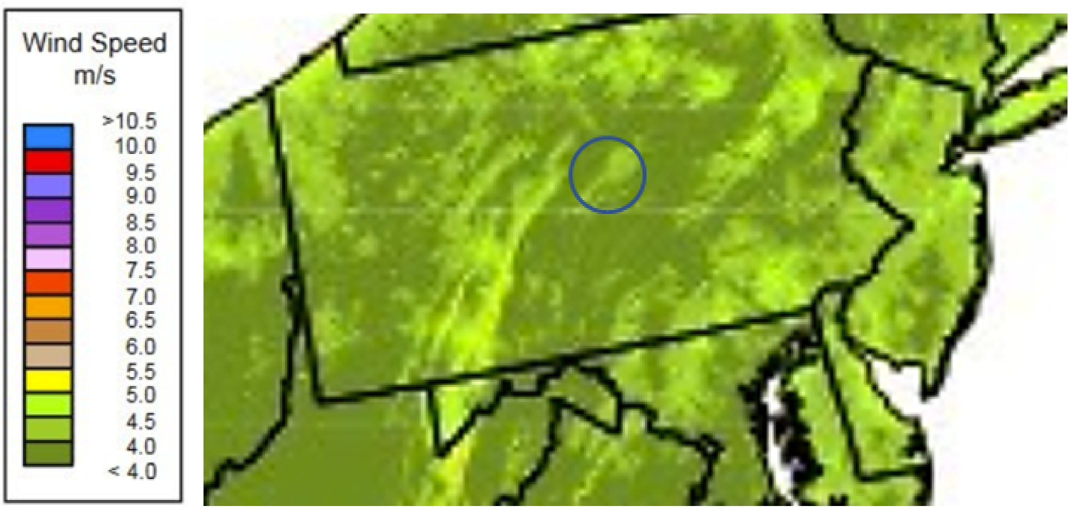


Figure 2.6: Annual average wind speed at 30 meters in Lewisburg, PA *(US Department of Energy, 2022).*

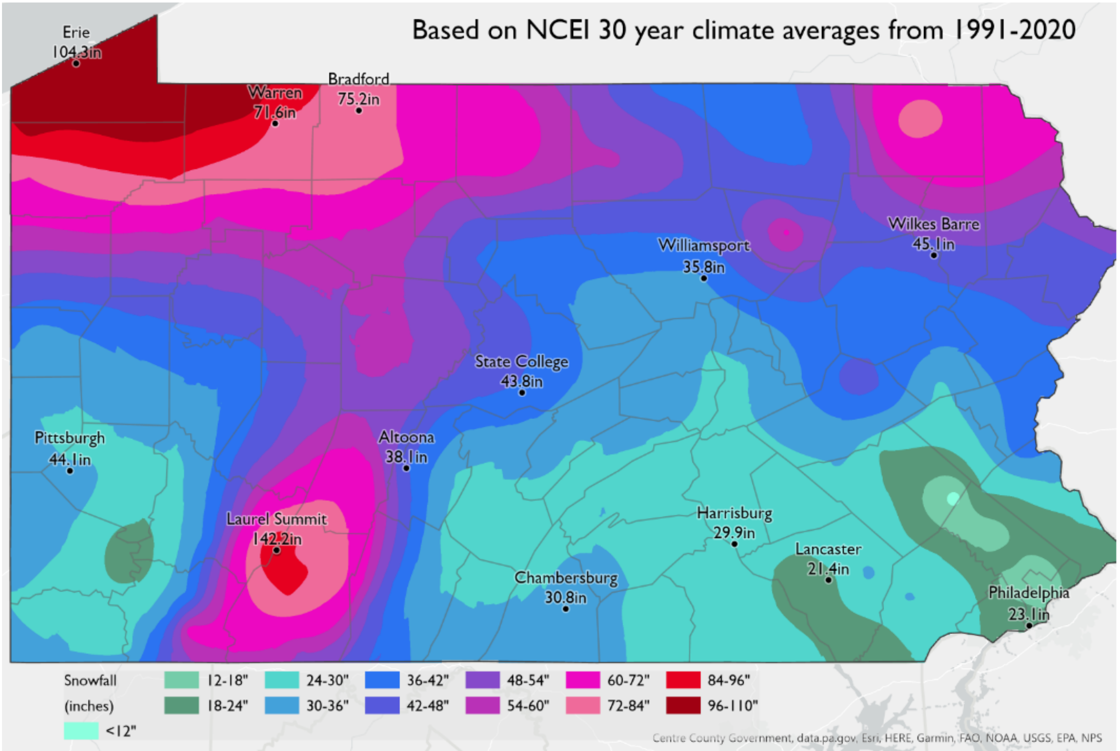


Figure 2.7: Average annual snowfall in Pennsylvania based on National Center for Environmental Information 30 year climate averages from 1991-2020 (*NOAA, 2022.).*

2.4 Subsurface Conditions

The subsurface composition and strength play a significant role in determining if the site is unsuitable for the construction of the residential building. The type of soil at the project will affect the type of foundation the building will have.

As a part of the subsurface investigation, JGMA collected historical testing on the Bucknell West site conducted by F.T. Kitlinski & Associates, Inc in March, 2022. Ten boring samples were collected from the project site. Two borings were drilled to 15 feet in the stormwater management area and eight borings drilled to 22 feet in the area of the proposed structure (boring locations shown in *Boring Location Plan* in Appendix A). The hollow stem auger method was used and terminated either at reaching the scheduled boring depth or at reaching bedrock. The standard penetration test (SPT) was conducted in accordance with American Society and Testing Materials (ASTM) 1586. During boring operations, groundwater level and presence was monitored through observations and can be found in *Appendix B*.

Additionally, F.T. Kitlinski & Associates, Inc conducted general soil classification tests on the soil retrieved from the borings. These tests were four grain size analyses, four Atterberg Limits determinations, and four moisture content determinations. Tests were conducted in accordance with ASTM D422, D2216/D4138, D2434 respectively and the results can be found in *Appendix B*.

Structural borings, B-1 through B-10, were found to have a depth that ranges from eight feet to 23 feet with an average depth of 16 feet (F.T. Kitlinski & Associates, Inc., 2022). The overburden consisted mainly of decomposed bedrock, but fill material was encountered at locations of Boring Nos. B-4, B-7, and B-9 through B-12. The fill material consisted mainly of brown silty sand, sandy silt, and sandy clayey silt, but there were traces of cinders and organics. Further lab tests have shown that the larger portion of soil consists of clayey silts and silty clays with varying amounts of sand and fine gravel, while a smaller portion consists of silty sands and sandy silts with increased amounts of gravel (F.T. Kitlinski & Associates, Inc., 2022). Furthermore, bedrock was contacted at a range of elevation varying from 485 ft at Boring No. B-5 to 461.5 ft at Boring No. B-3. Another important consideration is the location of groundwater relative to the surface, and the drilling tools were monitored for signs of groundwater. The groundwater readings show that the phreatic surface, the location where pore water pressure is below atmospheric conditions, is over 20 feet below the surface.

Bucknell University is located in an area that is affected by rock formations creating the Appalachian Mountains. The geology of this area as with much of Pennsylvania contains folds in rock formations. Softer rocks of this area erode and become the valleys while stronger rock formations better resist erosion and become mountain ridges. Bucknell is built over the Keyser, Tonoloway, and Wills Creek formations. These formations contain shale, siltstone, shaley siltstone or limey shale, so this can be expected from boring logs.

3.0 GOVERNING CONSTRAINTS AND CRITERIA

3.1 General Criteria

This development is expected to provide apartment style housing for at least 280 students within a single freestanding structure. This structure is expected to be constructed without implementing significant changes to the existing road network, although there is no exact required plot size.

3.2 Environmental

3.2.1 Governing Agencies

Given that the site is within East Buffalo Township zoning ordinances, it is subject to the Union County Vision and Framework for the Future (EBT, 2022). This document provides a set of sustainability principles by which all new developments must abide. These principles include developing around existing communities, preserving rural resources, and conserving energy and fiscal resources. They work together to foster sustainable growth in the region while maintaining its culture and character. Given that the proposed apartment complex is a replacement of an existing on-campus housing complex, all reasonable alternatives should work under these principles.

Bucknell University has a number of sustainability committees, groups, and councils that work to ensure that all future developments are carried out with social and environmental sustainability in mind. These bodies are made up of board members, administrators, faculty, and students who work to provide strategy, research, and varying perspectives on how Bucknell can meet its sustainability goals. They advise with the intention of following Bucknell's sustainability journey roadmap, which will eventually be expanded on with the introduction of the sustainability plan. For instance, the campus is currently pursuing a goal to achieve carbon neutrality by 2030, and this goal will likely have more facets and requirements in the future. If any proposed alternatives cannot feasibly contribute to the university achieving the goals and expectations set by this plan, they may have to be altered significantly.

3.2.2 Measuring Impact

Preliminary sustainability analyses will be conducted for each alternative to gain a preliminary understanding of the environmental impact of alternatives. For instance, using LEED v4.1 Building Design and Construction (*USGBC*, 2022) swing credits, innovation credits, and location specific credits into account will provide insight towards the end certification of each alternative. Some examples include site management, energy use, and material life-cycle impact reduction. Given the ratings achieved by other recent on campus developments, LEED gold is expected and higher ratings are strongly encouraged.

3.3 Geotechnical

A geotechnical survey performed by F.T. Kitlinski & Associates, Inc. provides the team with key information regarding the design of the foundation. The auger penetrated all borings but only one bore made it the scheduled testing depth of 22 feet. The average boring depth was 16 feet before auger refusal occurred at bedrock. This bedrock is likely highly weathered bedrock due to the nature of the last 1.5 feet of material (F.T. Kitlinski & Associates, Inc., 2022).

As mentioned the fill material also contains varying amounts of cinders and organics, however should not have a significant effect on the structural supports and site development. The fill material in this region must be excavated and replaced with fresh structural fill material. This is the only region that was found to require structural fill replacement, however additional boring is necessary for verification.

The residual soil deposits found beneath the fill material created by in situ weathering of the underlying bedrock had thickness ranging from 8 feet at some locations to 22 feet at others and averages 12.7 feet over all borings taken. Additionally, no correlation was found between surface elevation and the thickness of weathered bedrock suggesting that the bedrock elevation has an undulating profile resulting from differential weathering.

3.4 Structural

3.4.1 Relevant Building Codes

East Buffalo Township (EBT) has designated this site as Bucknell University (B-U) land use according to the Zoning Map provided in the Code of Ordinances (EBT, 2022). This makes this development subject to the codes found in appendix A. Ordinance §407.5 is the most concerning of these codes given intentions to develop a single freestanding structure that would exceed the current building height limits. Amendments or waivers to this ordinance may be possible to acquire through petitioning the EBT.

3.4.2 Design Philosophy

This structure will be designed for superimposed dead loads (HVAC, plumbing, etc), self-weight, live loads, snow loads, rain and ice, wind, and seismic loads according to the material of the superstructure. A steel building will abide by ANSI/ AISC 360-16 *Specification for Structural Steel Building* (ANSI/ AISC, 2016). On the other hand, a concrete building will follow all guidelines outlined by American Concrete Institute (ACI) *Building Code Requirements for Structural Concrete (*American Concrete Institute, 2019*)*. Factors of safety on these loads will be accounted for using the LRFD (Load and Resistance Factor Design) design philosophy. Given that the purpose of this project proposal is to build vertically, horizontal loads that act across the face of the building, wind loads primarily, will become increasingly more important to account for serviceability such as excessive deflections and shear and moment forces.

According to ASCE/ SEI 7-10, the site would be classified as Risk Category II which is any building not classified as agricultural storage, essential facilities, or buildings that can cause a substantial economic impact. As a result, Figure 3.1 should be used to determine the basic wind speed for design. The 2010 edition shows that the wind speed that is needed for design is 115 mph based on the region. This will need to be updated when a new edition of ASCE/ SEI 7-10 is acquired.

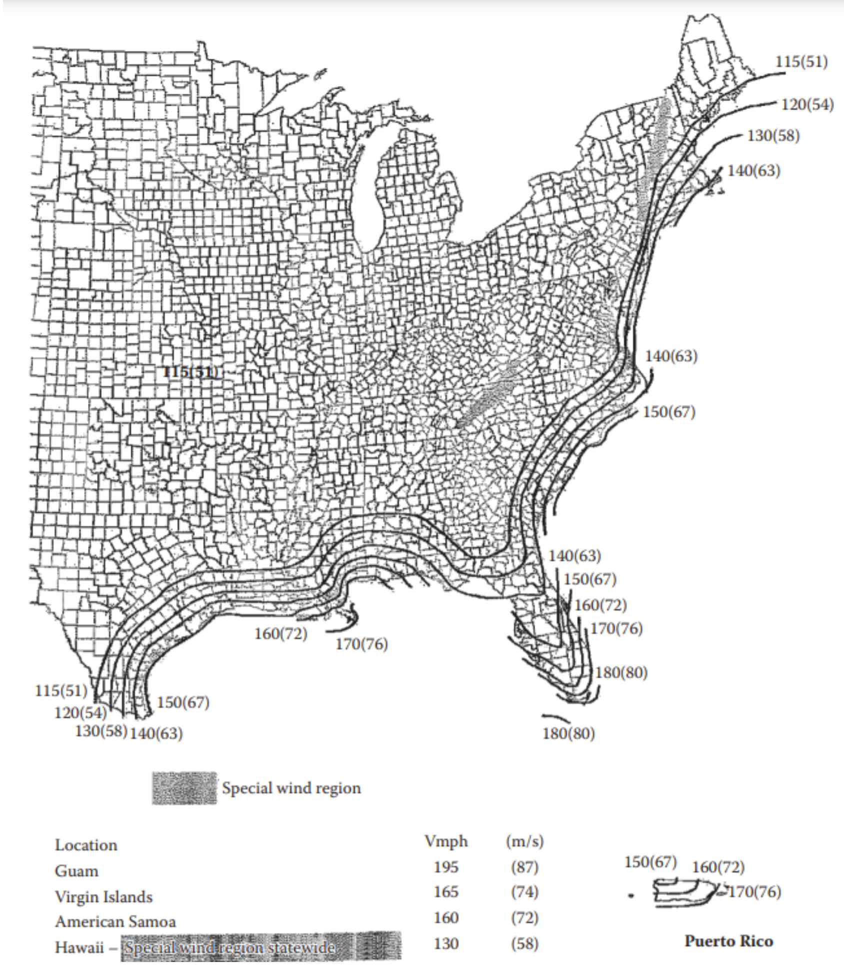


Figure 3.1: Basic wind speed for risk category II buildings (*ASCE/ SEI-7-10, 2010*).

3.5 Architectural

3.5.1 Amenities

Given that this development is intended to be a significant improvement to the living experience in Bucknell West, there will be a raised standard for provided amenities. Each apartment is expected to have heat and air conditioning, single bedrooms, a small shared kitchen, and a living room. Several public lounge rooms and laundry facilities are also expected. Outdoor amenities include green space, seating, paths, bike storage, game tables, and volleyball or basketball courts.

For energy intensive amenities such as heating, exploration into high efficiency systems will be performed within basic architectural designs. For instance, building orientation and material choice, and heat systems could have an impact on the passive heating performance of a design, which would have substantial impacts on energy use and sustainability.

3.5.2 Access

This development is expected to comply with all standards outlined in the American Disability Act (ADA), featuring inclusions such as ramps, parking spaces, bathrooms, and elevators that ensure all are welcome. An important ADA compliance to follow is space allowance to allow those with wheelchairs and their occupants to move freely. According to ADA 224.2, a building containing between 201-300 residences is required to feature seven rooms that can accommodate wheelchair accessibility. This includes a minimum width for two wheelchairs to pass, which is 60 inches (ADA Compliance Directory, 2010). The space required for a wheelchair to make a 180-degree turn is a clear space of 60 inches diameter. The minimum clear floor or ground space required to accommodate a single, stationary wheelchair and occupant is 30 inches by 48 inches (ADA Compliance Directory, 2010). The current site location features a loop of parking spaces around the Mods giving first responders access around the entirety of the development.

3.6 Construction

3.6.1 Governing Constraints

The governing constraints of construction are in place to ensure that the safety, design, and the timeline of the project are maintained which is observed through several stakeholders. Many of these constraints are achieved through approvals by the university and permits from governing agencies, township, and the Union County conservation district. The university will approve the final design and the schedule to make sure it will reach the intention of the project and be put into use within the University's timeline. The township will approve that the project can undergo construction, excavation, and any road closures that are required for the project. Furthermore, the conservation district will provide final approval after it has been approved by the JGMA and the client for the different environmental, geotechnical, and water resources design elements before they can be constructed. Finally, testing and inspections from third parties as requested by the client to ensure acceptable work from all trades must be conducted.

Based on the soil, along with the nature of the proposed construction, the foundation system will not be required to extend to the bedrock, nor is the position of the bedrock such that it could be economically employed for foundation support. However, in some instances where the durable bedrock surface is positioned above foundation bearing level, it will be recommended that the rock be over-excavated and cushioned in order to reduce the effects of differential settlement (F.T. Kitlinski & Associates, Inc., 2022).

According to F.T. Kitlinski & Associates, the more granular residuum can safely support a unit load of 1,800 pounds per square foot, while the larger part of the residuum can safely support 1,500 pounds per square foot. This must be acknowledged prior to the design of the foundation towards any of the proposed alternatives.

3.6.2 Safety

Safety is one of the most important factors throughout the construction process as many people are working both on and near the site where they can be severely injured due to lack of compliance. The Occupational Safety and Health Administration (OSHA) governs the safety of projects and offers guidance to maintain the safety for all trades on the site. Using the 29 CFR 1926 Standard , OSHA provides several regulations and guidelines for the several trades on the jobsite (OSHA, 2022). The intent of OSHA is to prevent and reduce workplace incidents and will often provide inspections at the jobsite to ensure the site is complying with their guidelines. On the jobsite, basic requirements call for all on the jobsite to be equipped with basic personal protective equipment: including hard hats, gloves, eye protection, and closed toed shoes (US Department of Labor, n.d.). A major point of emphasis of OSHA is requirements regarding fall protection which are major sources of injuries and fatalities among construction workers. Fall protection must be supplied whenever a worker is six or more feet above a lower level (US Department of Labor, n.d.). Finally, the jobsite must be secured to prevent any unwelcome guests into the site which could lead to theft or injury. An incident would not only be detrimental due to the human cost but it could also cause a shutdown delaying the schedule.

3.6.3 Timeline of the Project

The most significant constraint that must be addressed during the construction phase is remaining within the timeline of the project. The Bucknell West plan notes that two of the buildings will be ready for Fall 2023 and the next two will be completed in the following Fall (Bucknell University). It is important to remain within the final Fall 2024 timeline to be consistent with the University's original plan.

4.0 IDENTIFICATION AND CONSIDERATION OF ALTERNATIVES

4.1 General

4.1.1 Evaluation Techniques

As the project's constraints have been thoroughly recognized the team can use them to evaluate the different alternatives to the University's original four building plan. Combining different studies, JGMA will be able to move forward with the strongest alternative.

Prior to exploring the multi-story alternatives, the University's original four building plan would be a do nothing alternative. This is used as a control to compare with the other alternatives. Each proposed alternative will be evaluated on cost and sustainability and will be viewed through several lenses, such as environmental, geotechnical, structural, architectural, and construction. After these evaluations have been completed, a decision matrix will be created to identify the alternative with the best overall performance. Each category will be evaluated and ranked comparatively based on two factors: sustainability and cost. However, the sustainability category has been given greater value with a weight factor of 2 compared to cost's weight factor of 1. This weighting ratio was determined based on the University's current long term plan to achieve net carbon neutrality by 2030. In a study exploring the economic challenge of sustainable construction, the authors claim that sustainable construction is obtained through higher capital costs that are returned in the long term (Zhou, L., & Lowe, D. J. 2003, September). This means that a high upfront cost of the project can be paid off by offsetting sustainability.

4.1.2 Material Choice

When designing the core and shell of the building JGMA Construction must select the material with which the building will be constructed. The two leading materials in the industry are steel and concrete. To select either, they must be compared through sustainability, cost, and ease of construction. A study conducted by Angela Guggemos and Arpad Horvath compared the environmental effects of steel and concrete framed buildings. Within the study the authors conducted a life cycle analysis during the construction phase of two and four story buildings. The energy use, carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter, sulfur dioxide (SO_2), and hydrocarbon emissions were measured to compare the two buildings (Guggemos, A. A., & Horvath, A., 2005), and based on these impacts, the authors found that both materials had similar environmental impacts that do not give either material the edge in sustainability.

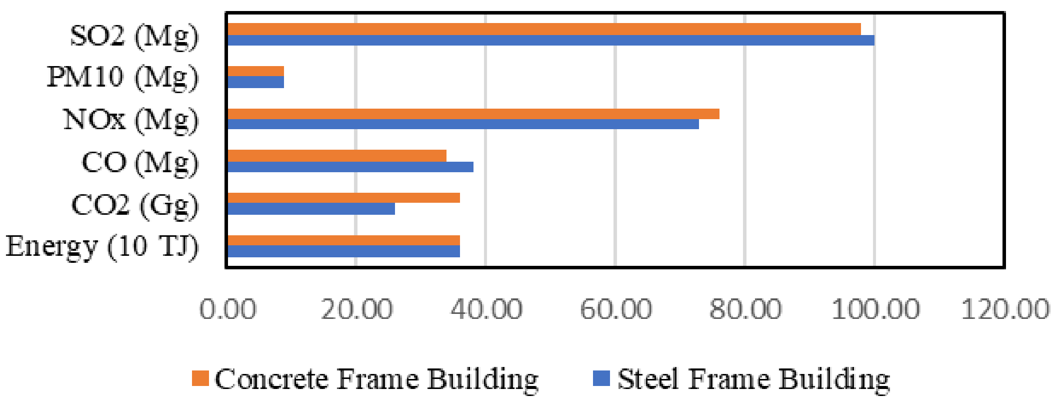


Figure 4.1: Sustainability comparison of Steel and Concrete Buildings. Source: (Guggemos, A. A., & Horvath, 2005)

The comparative values shown in Figure 4.1 display that the construction phase impact of either material has no significant difference on the sustainability of the project. JGMA aims to complete this by incorporating sustainable energy use, and mechanical, electrical, and plumbing systems of the building. When evaluating the cost of each material, concrete is a lower cost material, and requires less specialized labor while steel saves time and money through a fast erection time that is handy for schedules heavily constrained by time (Natsoulis, N. 2022). The time saved through the steel erection would allow a steel building to be completed faster than the concrete building, assuming they remain on schedule.

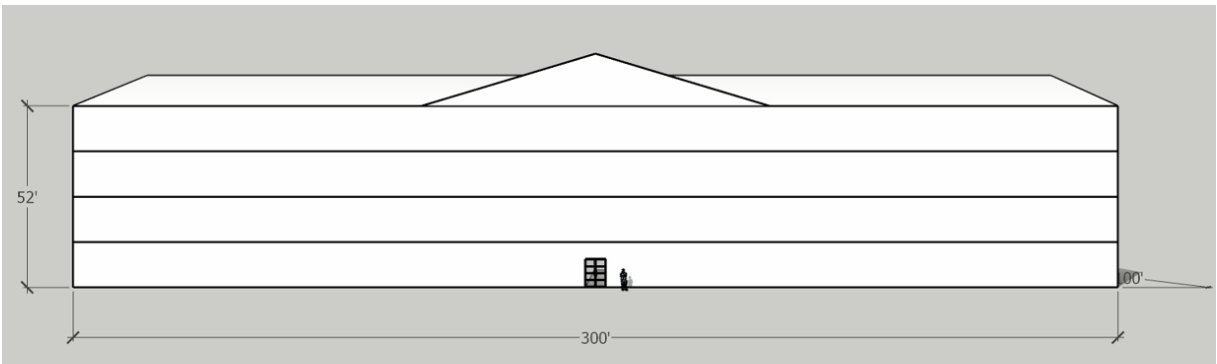
JGMA acknowledges the advantages of the quick installation of steel and its high strength to weight ratio, making it the perfect material for the superstructure. A steel shell design was chosen due to our team's strengths and confidence through the steel design classes taken at Bucknell. We believe that it will make for a more exciting and thoroughly executed project for the upcoming spring semester.

4.1.3 Identification

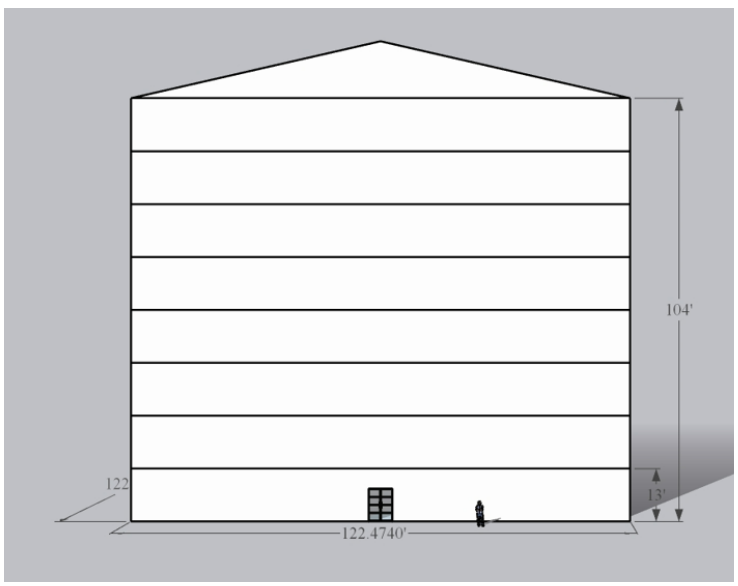
JGMA arrived at two different alternatives to the University's plans; the first being a tall eight-story building with a small footprint and the second being a four-story building with a wide footprint. Both buildings will have a total area of 120,000 square feet, but feature different layouts, which will be described in the architectural section. We are tasked with determining which alternative would be more effective regarding the sustainability efficiency compared to the four separate three-story buildings, while maintaining cost and constructability.

4.2 Architectural

The original plan for the Bucknell West Apartments consists of four separate buildings. Each building is to have three stories in height and no basement levels, only a crawlspace (F.T. Kitlinski & Associates, Inc., 2022). According to the proposed construction section of the geotechnical report, the four residential buildings' footprints will vary from 6,750 square feet to 12,000 square feet. The other two alternatives would have different footprints. The eight-story, more slender building would have a footprint of 15,000 square feet, while the four-story, wider building would have a footprint of 30,000 square feet. As seen in Figure 4.1, these footprints were determined using the size of each apartment, the amount of apartments on each floor, and the assumption that 80 percent of the entire floor plan corresponds to apartments. Based on the design of the current South Campus Apartments on Bucknell's campus, each apartment will have an area of 1,200 square feet and house four students. The eight-story, slender footprint building will have 10 apartments on each floor ranging from the second to the eighth floor with the first floor only being allotted for amenities. The four-story, wide footprint building will have 20 apartments ranging from floors two through four, while the first floor will only have 10 apartments to allow for an amenity space.



(a)



(b)

Figure 4.2: (a) Model of the four story, wide footprint alternative. (b) Model of the eight story, slender footprint alternative.

4.3 Environmental

To create a reasonable approximation of each alternative's environmental impacts, a preliminary life cycle assessment was created with a program called EPIC (Early Phase Integrated Carbon). EPIC takes a variety of inputs such as building geometry, structure material, use category, and site characteristics to calculate a baseline of categorized impact values based on calculations, projections, and assumptions. Reductions can then be applied to this baseline with changes such as reused or low carbon building materials, longer refurbishment periods, renewable energy use, and increases in high carbon storage plantings. For each alternative, the same reduction was applied to gain a general understanding of how responsive each alternative is to considerable efforts to improve sustainability. EPIC is capable of generating a variety of plots to visualize this data. Figure 4.2 shows plots of the net tonnes of CO_2 emitted across multiple categories for a 30 year life cycle for both proposed alternatives.

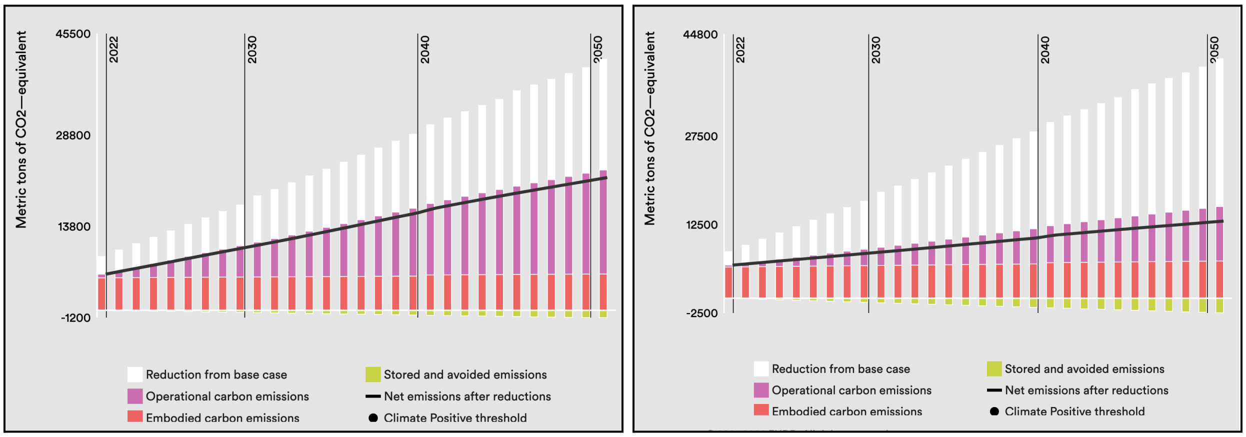


Figure 4.3: Sustainability profile for four-story (left) and eight-story (right) across life cycle

It can be seen that the eight-story alternative benefits much more significantly from the reduction than the four-story. This is largely due to its smaller footprint providing benefits within calculations for operational emissions and stored emissions. Table 4.1 summarizes the net emissions for the base case and reduction for both proposed alternatives and Bucknell's original design.

Table 4.1: Summary of Net CO_2 profile

Alternative	Net Tons CO_2 Equivalent Emissions	
	Base	Reduced
Original	31800	17400
Single Four-Story	40100	21800
Single Eight-Story	38300	13100

This clearly indicates that the eight-story alternative has the highest potential to benefit from substantial use of sustainable design techniques, making it the most viable alternative from an environmental sustainability perspective. The original proposal was the second most viable, while the proposed four-story alternative lacked significantly.

4.4 Geotechnical

All of the alternatives introduced will have geotechnical consequences that will need to be analyzed to determine which alternative would be the best. In general, there are two different types of foundations used when designing buildings: deep and shallow. Within these categories, however, there are different ways to complete the same goal. It is important to understand the subsurface of the site in order to choose the most appropriate and efficient foundation. According to the geotechnical report done by F.T. Kitlinski & Associates on the proposed Bucknell West site, "employing deep foundation systems for [the original, four-building design] support is not considered necessary or economical" (F.T. Kitlinski & Associates, Inc., 2022). This means that a shallow foundation design will suffice. This is due to the composition of the soil and the fact that the proposed structures will be moderately loaded. For the single, four-story alternative, the foundation design would be similar because the loads are more dispersed over the soil. They are not concentrated over a small area, so the soil bearing capacity would not be breached. As a result, a shallow foundation design would suffice. The same can be determined for the single, eight-story alternative. Since the loads would be more concentrated in a smaller area, the concrete footing would need to be larger based on the net allowable soil pressure.

The different foundation types, deep and shallow, have associated environmental impacts. It is important to take into consideration the sustainability aspects of each foundation to help come to a decision. The four single-story buildings and single four-story building both would have a shallow foundation but large footprints. This would impact sustainability as more land is taken up for the building. Likewise, the single eight story building would still have a shallow foundation, but the smaller footprint of the building would result in lower land use. However, the footings would likely need more concrete as they would need to be larger to not exceed the soil bearing capacity and not excessively settle. The larger footings could impact sustainability, but it is common to use alternative cementitious materials in the concrete to help offset the sustainability impacts. The amount of materials needed would also differ depending on the foundation type, which has sustainability implications. However, it is difficult to compare the materials needed between the different types of foundations.

The costs associated for each foundation type and alternative is important to take into consideration when deciding which alternative to select. Typically, shallow foundations are more cost effective. According to Sivakugan, when compared to shallow foundations, deep foundations "cost more and require specialized equipment and skill" (Sivakugan 2021).

4.5 Structural

When deciding whether to construct a four story building versus an eight story building, the primary structural factor is how the height difference will affect the cost of construction and materials. A ranking can then be determined based on the cost of each alternative with consideration of the height and number of buildings. A more in depth cost analysis is performed in the next section using RS Means.

The structural system of a high-rise building often has a more pronounced effect than a lowrise building on the total building cost and the architecture. High-rise design comes into play when a structure's slender nature makes it dynamically sensitive to lateral loads, such that a premium is associated with its lateral system development (John Zils and John Viise 2003). In addition to a more robust lateral system design, the high-rise will require more materials to support loads. Constructing a high rise will ultimately require more materials and a more costly lateral system.

4.6 Construction

Evaluating the sustainability through the lens of construction of each design, the team used EPIC to analyze the embodied energy of the construction of each alternative design.

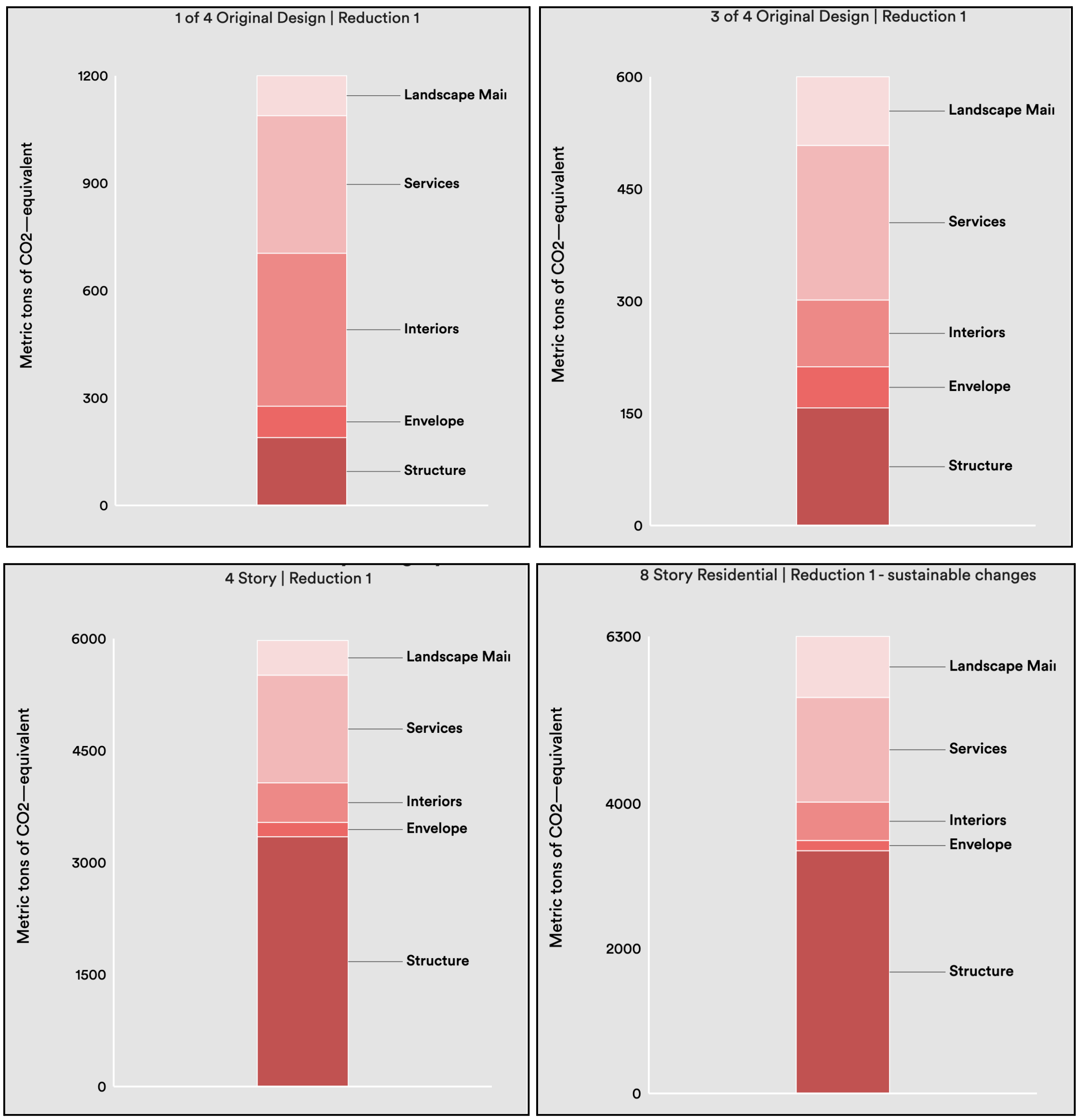


Figure 4.4: Embodied Carbon for the Original Building Plan, Four Story, and Eight Story Building (EPIC, n.d.)

The University's original plan that consists of four buildings includes two differently sized buildings, two smaller and two larger ones. The tonnes of CO_2 equivalent for these buildings are reflected by the top two figures of Figure 4.4. The four story alternative design is represented by the figure on the bottom left and the eight story alternative design is represented by the figure on the bottom right of Figure 4.4. An evaluation of the data shown in Figure 4.4 both of the proposed alternatives are very comparable in embodied carbon, the original proposal does feature much lower emissions, at around 3,600 tonnes compared to around 6,300 and 6,000 tonnes. The original design has the best embodied energy due to the wooden structure of the buildings, yet, there is little impact to the envelope, interiors, systems, and landscape maintenance of the design. However, the much smaller footprint on the eight-story alternative could allow for much more green space and natural high carbon-storage plantings to counteract embodied emissions. Finally, the increased available green space added from the stacked designs allow for future reduction of CO_2 equivalent emissions.

Evaluating the approximate cost JGMA Design and Construction used the square foot cost derived from RS Means (Charest, 2016). RS uses the national averages then interpolates the cost based off of total square feet of the project while also including perimeter adjustments, story height adjustments, and common additives. When comparing each building, the team chose the green commercial college dormitory tables, using the 2-3 story table for the original university plan and the 4-8 story table for the alternative stacked buildings. To maintain a similar frame of reference the University's original plan was estimated using a steel frame. Finally, major assumptions were made for consistency and simplification due to the preliminary design phase. First, the total square footage of each project is 120,000 ft^2. Second, the perimeter of each building was determined by finding the square root of the square footage of the building divided by how many floors each building will have. This value will be multiplied by four assuming the building is a square to find the perimeter. Finally, it will be assumed each building will have a story height of 14 feet. Once these assumptions are made, a simple preliminary estimate can be made and evaluated for each project.

Table 4.2: Cost per Square Foot from RS Means (Charest, 2016)

	Cost per Square Foot	Required Perimeter Adjustment Cost per Square Foot	Adjust for Story Height per Square Foot	Cost

Original 4 Building 3 Story Plan	$229.37	+$21.26	+$4.77	**$30,279,067**
4 Story Steel Alternative	$226.06	-$5.11	+$3.00	**$26,873,742**
8 Story Steel Alternative	$226.06	+$2.05	+$3.00	**$27,733,312**

Our early estimates show that the original project is the most expensive, followed by the eight story alternative, followed by the four story alternative using RS means (Charest, 2016). It is important to note that this is a preliminary estimate as a frame of reference rather than an accurate cost estimate as additives were ignored as well as future additions the team would like to add.. As each value was calculated using the same method we evaluated each project against each other. With that, the 4 story alternative was the most cost effective, followed by the 8 story alternative, and finally the original University plan. However, the alternatives were very close while very

4.7 Summary

We weighted the decision matrix to favor the better building in terms of sustainability to complete the university's goal of neutral carbon by 2030. However, we did allow cost to play a role in the decision in efforts to protect the financial feasibility of the project. Ultimately, the eight story alternative design scored the best in terms of CO_2-equivalent, followed by the original design then the four-story alternative design. Next, the four-story alternative was deemed the most cost effective followed by the eight story alternative and finally the original university plan. The resulting scores favored the eight story alternative based on our decision matrix in Table 4.2. Within the ranked based matrix the best design scored a three and the worst design scored a one for each respective category. Our team will move forward with designing the eight story alternative and describe the scope for the next phase of our project in the following section.

As seen in the decision matrix in Table 4.3, the eight story alternative was ranked the most sustainable based on its high performance in the environmental category due to its small footprint and potential for high carbon storage. The original proposal was ranked second due to its wood frame construction, and the four-story alternative was ranked last due to its substantial footprint.

The four-story alternative was ranked best on cost, due to it being the most cost effective within the rough RS Means preliminary estimate, which was used as a frame of reference. The eight- story alternative was ranked second based while less than a million more, and the original plan came in at about 3 million more for about 30 million dollars.

Table 4.3: Decision Matrix

	Sustainability	Cost	Total
Weighting	2	1	
Original Plan	2	1	**5**
Four Story Alternative	1	3	**5**
Eight Story Alternative	3	2	**8**

Overall, the eight-story alternative performed best overall considering its performance against other alternatives in each category as well as the weighting of the two main factors, with a total score of 8 compared to 5 for the other alternatives. We determined that the nearly $900,000 more expensive alternative would be paid off through the more efficient sustainability of the project.

5.0 CONCEPTUAL DESIGN

5.1 Overview

After careful consideration of the three alternatives, the University's original four building plan, the eight story high-rise, and the four story low-rise, JGMA identified a steel eight-story building to be most sustainable and remained a cost and timely effective alternative. An example mock up of the building can be found in Figure 5.1. Various components of the design work were addressed in a detailed design including conceptual architectural layouts of the eight-story high rise, design of the steel superstructure, design of the foundation, cost estimates, and construction scheduling.

5.2 Design Scope of Work

The following subsections describe the scope of work for each trade and the necessary operations that JGMA Design and Construction completed.

5.2.1 Architectural

JGMA produced a 3D model of a basic exterior design that features basic architectural elements as well as an 2D example floor plan produced in AutoCad. Additionally, a comprehensive list of specific architectural elements has been provided, with notes on their functionality as well as any contributions or setbacks to sustainability or cost. Example categories that these elements fall under would be building design elements, landscaping, building operating systems, apartment amenities, and common amenities.

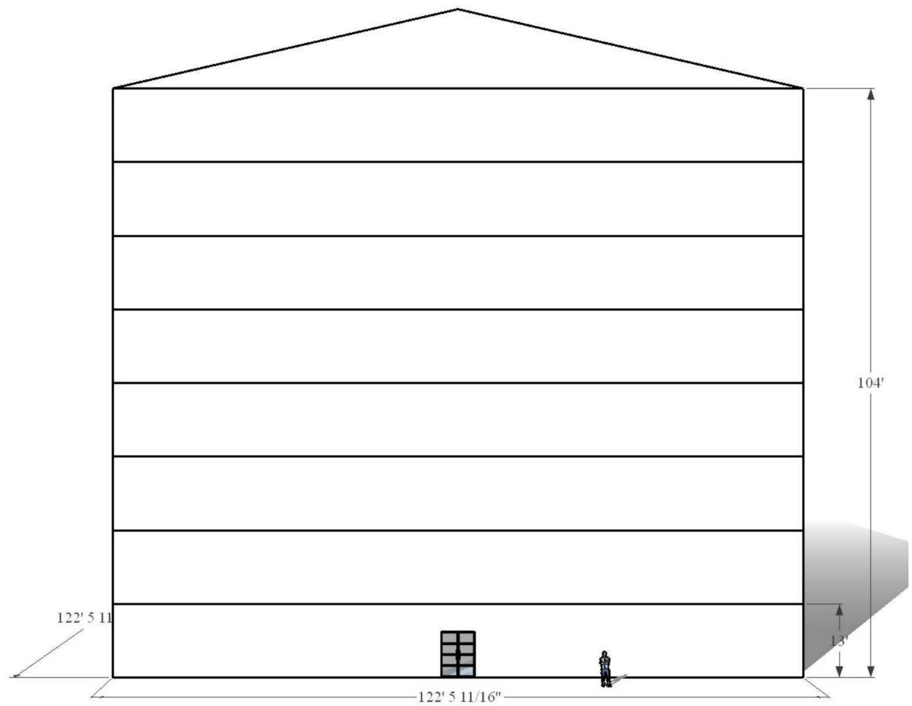


Figure 5.1: Single building eight-story alternative

5.2.2 Superstructure

Based on the analysis of the alternatives, JGMA has decided to continue the project as an eight-story, small footprint steel building. We utilized ASCE 7-22 to find the loads associated for each apartment. We needed to use the data on the wind speeds, in combination with ASCE/SEI 7-22 to determine the strength of the building needed to oppose lateral deflections. Per ASCE/SEI 7-22 and the location of the site, seismic loads were not accounted for. Given the region the site is located, the horizontal loads were primarily due to wind. JGMA also analyzed the snow loads when we designed the frame of the building. Using all of these loads, abiding by Steel Construction Manual, 15th Edition we began to design the slabs, beams, and columns for the frame system.

5.2.3 Substructure

JGMA provided calculations for a spread footing foundation based on comparable soil data from the geotechnical report by F.T. Kitlinski & Associates. Prior to any foundation calculations, JGMA extrapolated the information from the boring logs to create a soil profile of the site. We calculated the unfactored and factored loads of the building and determined the footing size based on the net allowable soil pressure and unfactored loads. We then checked the settlement failure mode to make sure the foundation complies.

5.2.4 Cost Analysis

JGMA Design and Construction provided the client with a complete estimation of the cost of the project using RS Means (Charest, 2016). This included the detailed cost of the construction of the building and the expected operation of maintenance of the building. Additionally, a sensitivity analysis of the building's rate of return was performed to evaluate the financial severity of the project for the University. Each analysis was compared to the cost of the original plan along with the impact of the sensitivity analysis.

5.2.5 Sustainability Analysis

JGMA Design and Construction will perform a detailed life cycle assessment of the structural design and determine whether it is advantageous towards the university's original plan by evaluating the embodied energy and CO_2-equivalent emissions produced throughout the lifespan of the building. Additionally, a qualitative analysis of specific architectural features or complex design elements will be conducted to gauge the overall sustainability profile of the development. These features could include building layout, HVAC systems, landscaping, or any other features deemed to have the potential for a significant impact.

5.2.6 Project Management

JGMA Design and Construction will provide several items needed for the construction management scope of work. First, the team will create a detailed construction schedule, a site logistic plan, and an income analysis of the project. The construction schedule will display the construction sequencing and be accompanied with a 3D SketchUp to visually show the process. The construction schedule will begin at the end of the Fall 2022 semester and will aim to be completed by the start of the 2024 Fall semester in accordance with the University's original plan. However, we aim to create a schedule that will beat that overall timeline due to their only being one building constructed. The site logistics plan will be created in order to show how materials will be stored and delivered as well as job trailers and other necessities. The income analysis will display how and when the building will earn money for Bucknell through selling energy back to the grid via the geothermal heating and income from students rent. These items will cover the different phases of construction and will allow us to thoughtfully evaluate the construction management of the project.

6.0 DETAILED DESIGN

6.1 Architecture

The first step of the team's architectural design process was the floor layout. The team designed all rooms to have all living spaces provided with a window for quality of life purposes. This was achieved by placing the common rooms and bedrooms on the outside of the rooms, but this sacrificed a symmetrical design of the building. Each room is given an A, B, C, D, or E designation as the room of the same letter has the same dimensions. We designed the first floor of the building to have 27 beds, a large common space, and a study space as the layout of the first floor is shown in Figure 6.1.

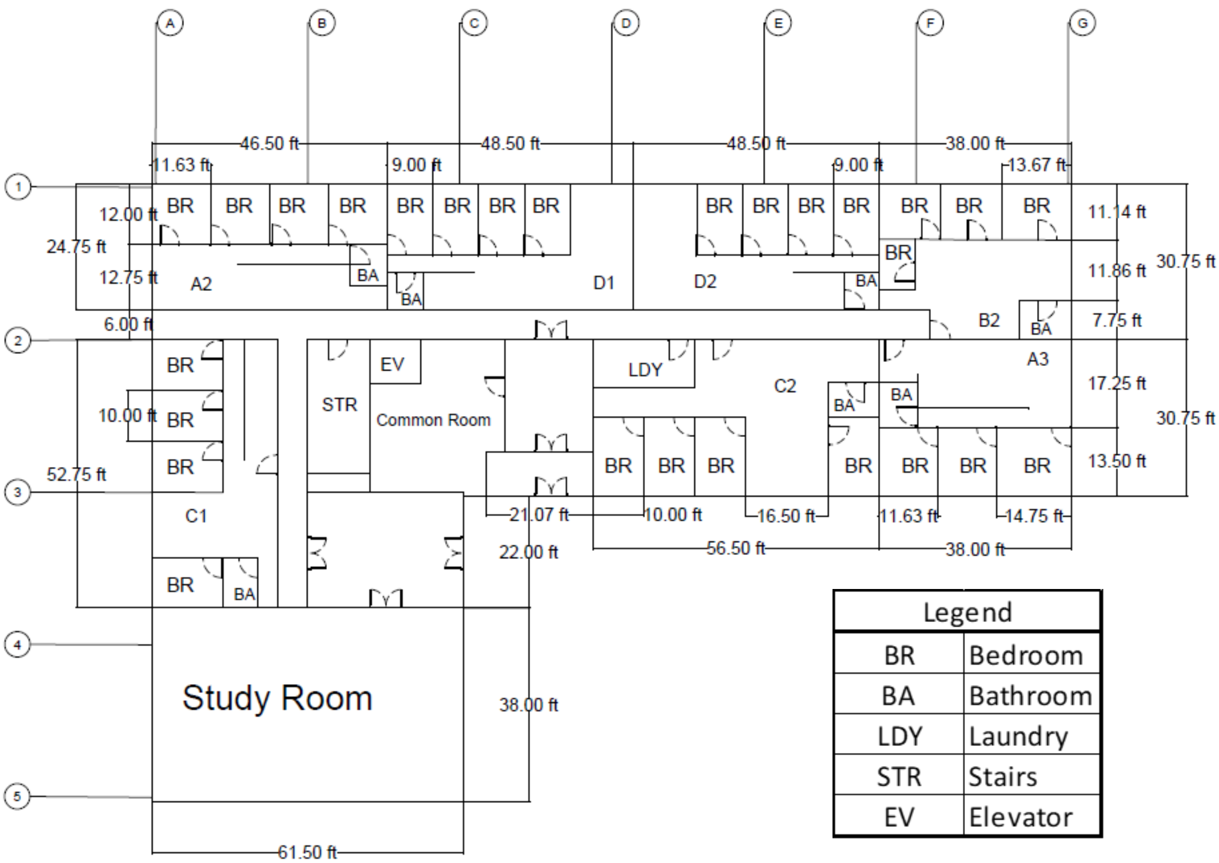


Figure 6.1: Architectural plan of the first floor of the multi-story building.

The team designed the study room to be a large space where all students of the building can meet to do homework or study. The team determined the smaller extra space would work well as a common room as it is near the entrance, stairway, and elevator, which would generate noise making it a poor location for the study room. The apartment style rooms are identical to the rooms of the same designation of the rooms on the higher floors. The architectural layout of the rooms, elevator location, and laundry of our building is seen in Figure 6.1 below.

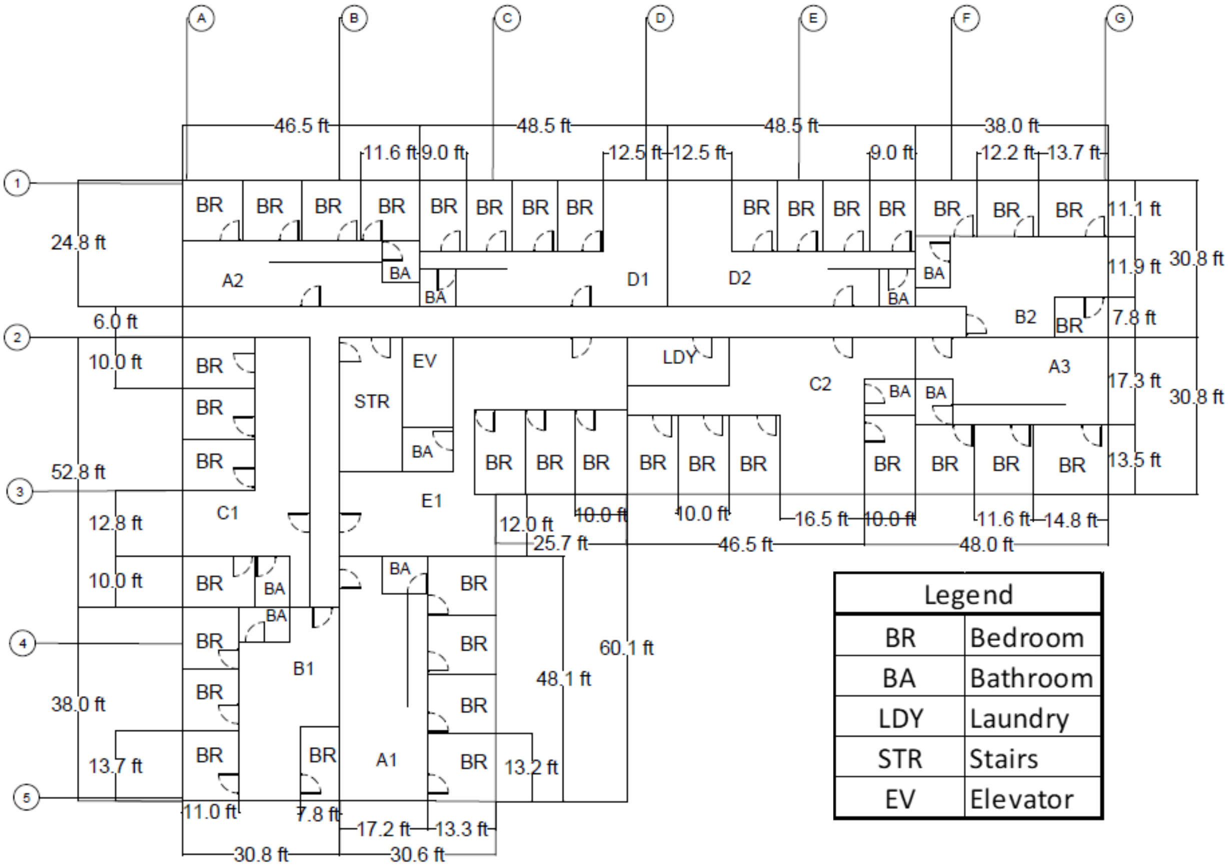


Figure 6.2: Architectural plan of floors two through eight of the multi-story building.

These higher level floors all achieve 37 beds per floor providing the entire building with 286 total beds. Within all of the rooms the hallways range from three and a half to six feet to maintain ADA compliance. Outside of rooms the hallways are designed to be up to six feet, however, we ignored the thickness of the wall. Additionally, our design has an elevator that achieves the 36 inch requirement as it is a four foot by five foot cab.

6.2 Superstructure

The structural grid, composed of the beams, girders, and columns, refers to the framework that supports the weight of the building and the lateral forces acting on it. The structural system we are basing our design on is a gravity system. In this system, the gravity loads are supported by the beams which transfer the loads to the girders, then the columns, and eventually down to the foundation. Figure 6.3 shows the structural grid created for the multi-story building. The open block in the plan for floors 1-8, between frames B and C, is the location of the elevator shaft and stairway. The columns are spaced a distance of 30 feet, creating square bays connected by 30 foot long girders. Within the girders, floor beams span 30 feet and are spaced every 10 feet. On each floor, there are a total of 27 columns, 42 girders, 32 beams on the roof, and 30 beams on each floor spanning from floor 1-8.

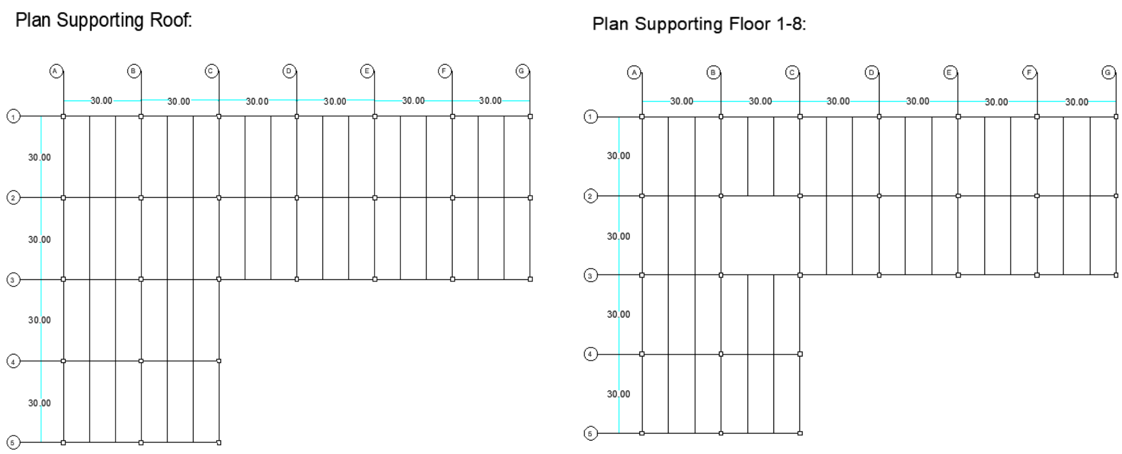


Figure 6.3: Structural plans for the multi-story building.

6.2.1 Beams and Girders

The live loads and dead loads for design were found using Table 4.3-1 in ASCE 7-22, and the ASCE Hazard Tool (Hazard Tool, n.d.) provided snow and wind loads. Due to the design of the building, the live loads varied. The roof had live loads of 20 pounds per square foot because of the green roof. Residential areas of the building were designed for a live load of 40 pounds per square foot. Lastly, the live loads of all corridors and the entire first floor were found to be 100 pounds per square foot. In addition to the live loads, there are also dead loads needed for design. After discussing with our consultant, JGMA assumed a superimposed dead load of 25 pounds per square foot. Given the region where the site is located and the information provided from the ASCE Hazard Tool, the snow load is 61 pounds per square foot and the wind speed required for design is 119 Vmph.

With the loads assessed, JGMA began designing the beams. As seen in the structural plans in Figure 6.3, the beam length is quite long at 30 feet, and JGMA was concerned with the possibility of the beams failing in lateral torsional buckling. To ensure this failure mode would not control the design, we decided to use composite beams, where the concrete slab would be directly attached to the steel I-beams using studs, as seen in Figure 6.4. As a result of this decision, the unbraced length would be zero as the length of the beam would continuously be braced by the concrete slab.

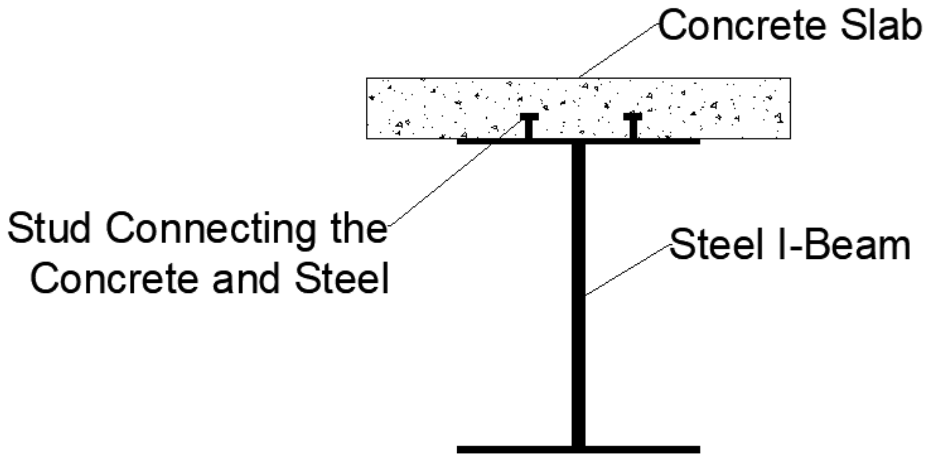


Figure 6.4: Cross section of a typical composite beam (Devlin, 2023).

Similar to steel beams, the composite beams were designed to resist the factored load effects using the LRFD philosophy. In order to find the maximum moment and shear force, we first had to identify the tributary width and area (width and area of effectiveness) of each beam. After that we reduced the live load in accordance with ASCE-7. We then found the factored loads using the LRFD load combinations as seen in Table 6.1. In these combinations, each letter represents a different load; D is dead load, L is live load, Lr is roof live load, S is snow load, R is rain load, and W is wind load. We calculate which combination would result in the largest distributed force for design. It is worth noting that a composite beam is not considered a composite beam until the concrete cures, so there is a brief time where the steel beam needs to support the weight of the wet concrete. In order to take this into consideration, we found the wet concrete load effects by multiplying the dead load by a factor of 1.2. There was no standardized way to complete this, so we followed the example outlined in Paul Richard's book *Build With Steel* (Richard, 2011).

Table 6.1: Load Combinations Considered in Design

	Load Combinations
1	1.4D
2	1.2D + 1.6L + (0.5Lr or 0.3S or 0.5R)
3	1.2D + (1.6 Lr or 1.0S or 1.6R) + (L or 0.5W)

To proportion our beams, we used Table 3-19 in the AISC Steel Construction Manual to find sections that can support the maximum moment determined. For a beam located on the roof, we calculated the ultimate moment to be approximately 122 kip-ft. Whereas a beam located on floors 1-8 would have an ultimate moment of approximately 189 kip-ft. As a result, different shapes were selected for the roof and floors 1-8. As seen in Appendix D under Roof Beam Design, three trial shapes were recognized as possible sections: W14x22, W16x26, and W18x35. From those three, we selected the least-weight section, W14x22, and began checking the amount of studs needed, the shear capacity, and the moment capacity. The moment capacity for this specific shape in combination with the concrete slab came out to be 255 kip-ft, found from Table 3-19, which is greater than the required strength of 122 kip-ft. In addition to checking the strength of the steel beam and concrete slab together, we needed to check the steel beam section under the weight of the wet concrete load to make sure it would not fail as the concrete is curing. Lasly, we checked the live load deflection of the beam and compared it to the permitted live load deflection of L/360. Once all checks were satisfied, we iterated the process to find the best design and computed the required camber for the beam. A summary table for the values checked for the roof beam can be found in Table 6.2. This process was carried out again for the beams on floor 1-8. Using the same approach, we found that a W16x45 would be sufficient. These calculations can be found in Appendix D and the summary table for the values can be found in Table 6.3.

Table 6.2: Summary Table for Roof Beams, section W14x22

Section	**W14x22**					
Criteria	**units**	**Design Value**		**Required**		**Check**
Strength	kip-ft	**φMn**	255	**Mu**	122	**Good**
Shear Capacity	kip	**φV**	94.5	**Vu**	16.24	**Good**
Studs	-	**N**	12	**Nmin**	5	**Good**
Stud Spacing	in	**s**	30	**smin**	4.5	**Good**
				smax	36	
Deflection	in	**δL**	0.54	**δpermit**	1	**Good**

Table 6.3: Summary Table for Beams for Floor 1-8, section W16x45

Section	**W16x45**					
Criteria	**units**	**Design Value**		**Required**		**Check**
Strength	kip-ft	**φMn**	486	**Mu**	189	**Good**
Shear Capacity	kip	**φV**	167	**Vu**	25.2	**Good**
Studs	-	**N**	12	**Nmin**	5	**Good**
Stud Spacing	in	**s**	30	**smin**	4.5	**Good**
				smax	36	
Deflection	in	**δL**	0.92	**δpermit**	1	**Good**

In a gravity frame system, the loads from the floor are carried by the beams and sent to the girders. The design of the girders were similar to the design of the beams. The area of influence for the girder was the main difference in design between the two. While the beams had a tributary width of 10 feet, the girders had tributary widths of either 15 feet or 30 feet, depending on the location. Four different types of girders were recognized for design: the girders supporting the roof, perimeter girders, interior girders, and girders outlining the elevator shaft. The calculation sheets for all the beams and girders are located in Appendix D. The process was almost identical to the beams. However, in the design of the girders, the live load deflection seemed to control much of the design. Even though the moment capacity was met, we needed to use larger sections to abide by the deflection limits. The sections we ended up selecting were a W18x35 for the roof, a W21x73 for a typical interior girder on floors 1-8, a W18x50 for the girders surrounding the elevator, and a W18x50 for the perimeter girders on floors 1-8. The summary tables of these designs are outlined in Tables 6.4, 6.5, and 6.6 for the roof, interior girder for floor 1-8, and the elevator and perimeter girders respectively.

Table 6.4: Summary Table for Girders for the Roof, section W18x35

Section	W18x35					
Criteria	**units**	**Design Value**		**Required**		**Check**
Strength	kip-ft	**φMn**	419	**Mu**	357.75	**Good**
Shear Capacity	kip	**φV**	159	**Vu**	47.7	**Good**
Studs	-	**N**	12	**Nmin**	5	**Good**
Stud Spacing	in	**s**	30	**smin**	4.5	**Good**
				smax	36	
Deflection	in	**δL**	0.55	**δpermit**	1	**Good**

Table 6.5: Summary Table for Typical Interior Girder for Floors 1-8, section W21x73

Section	W21x73					
Criteria	**units**	**Design Value**		**Required**		**Check**
Strength	kip-ft	**φMn**	921	**Mu**	506.25	**Good**
Shear Capacity	kip	**φV**	289	**Vu**	67.5	**Good**
Studs	-	**N**	16	**Nmin**	15	**Good**
Stud Spacing	in	**s**	22.5	**smin**	4.5	**Good**
				smax	36	
Deflection	in	**δL**	0.88	**δpermit**	1	**Good**

Table 6.6: Summary Table for Typical Perimeter and Elevator Shaft Girders for Floors 1-8, section W18x50

Section	W18x50					
Criteria	**units**	**Design Value**		**Required**		**Check**
Strength	kip-ft	**φMn**	550	**Mu**	334.13	**Good**
Shear Capacity	kip	**φV**	192	**Vu**	44.55	**Good**
Studs	-	**N**	12	**Nmin**	5	**Good**
Stud Spacing	in	**s**	30	**smin**	4.5	**Good**
				smax	36	
Deflection	in	**δL**	0.88	**δpermit**	1	**Good**

6.2.2 Columns

The design process for steel columns involves calculating both the demands on the column and the capacity of the column. The demands on a column are determined by the loads that it must support, such as the weight of the floors and the roof. The capacity of a column depends on its section properties, length, end connections, and the strength of the steel. JGMA chose to utilize a moment frame to resist lateral forces such as earthquake and wind. The implications of this are that end connections for columns can be pin-pin connections as they do not transmit moment, thus columns can be assumed to transmit pure axial force.

To calculate the demands on a column, the idea of tributary areas is used. Tributary areas are defined by lines running halfway between all of the columns in both directions. Once the tributary area for a column has been determined, the load effect is calculated as the uniformly-distributed load multiplied by the tributary area. For multi-story buildings, the tributary areas for columns increase as you move down the frame. Live load reduction is also considered in this process to reduce the design live load for members that receive loads from large areas that are unlikely to receive heavy live loading at the same time. This prevents over designing.

The next step is to choose a column that meets demand requirements. The design process involves selecting a cross-sectional shape based on the loads that the column must support and ensuring that the column length does not exceed its capacity. Since column demands decrease as we move up the frame, JGMA decreases the column weight with decreased demands on the upper levels. The section size however remains the same as a W12 to facilitate splicing. To optimize section manufacturing costs, JGMA limits the number of column shapes by changing sections every other level instead of changing the sections every level. The end connections of the column must also be designed to resist the loads that the column will experience, which will be discussed in later sections. Once all is considered, JGMA calculated designs for three column sections as detailed in Appendix D. The first and second floor will be constructed with W12x53, third and fourth floors a W12x45, and the fifth through eighth floors a W12x40.

6.2.3 Moment Frame

JGMA has decided to incorporate the use of a moment frame in the design to aid in the resistance of wind loads. This was done using structural analysis software MASTAN2. This involves an iterative process of performing 1st and 2nd order analysis of the windward, leeward, and sides of the building. JGMA chose to design three moment frames to resist each direction of deflection as shown in Figure 6.5. This design includes a moment frame on each side wall to resist windward and leeward deflection and a moment frame on the leeward side of the building to resist side to side deflection. Each moment frame consists of moment connections designed based on the reaction loads from each connection, as discussed further in section 6.2.4.

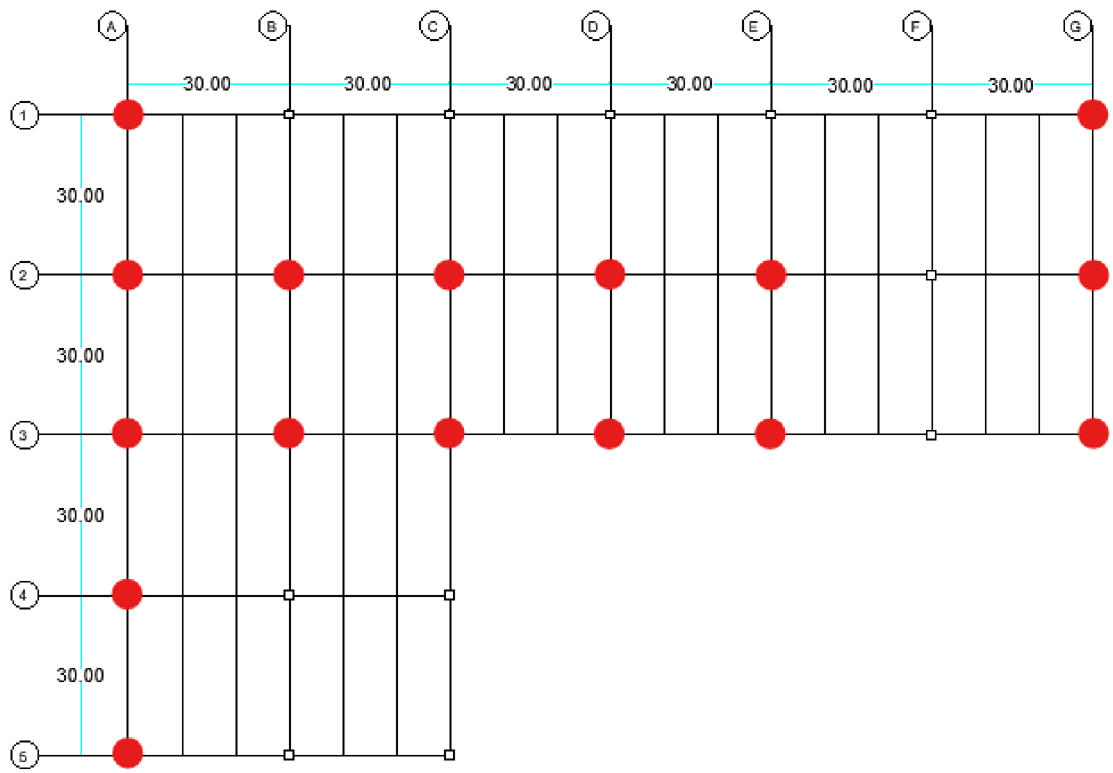


Figure 6.5: Conceptual plan for location of moment connections for moment frame. The red markers indicate a direct-welded moment connection throughout all 8 levels.

6.2.4 Connections

The first step to designing moment connections is to determine the moment and shear demands that need to be transferred between connected members based on structural analysis from the moment frame. The next step is to select the appropriate connection type based on the required moment capacity and the available space for the connection. The direct-welded flange connection (shown in Figure 6.6) was JGMA's choice of moment connection because it is a simple and efficient design that allows for easy fabrication and construction. It's easy to fabricate and construct because it requires very few connecting elements, welds for each flange and a web plate for shear. As the name implies, the flanges are directly welded to the supporting member, in this case the flange of a column. These welds could be either complete joint penetration groove welds or a pair of fillet welds on each side of the beam flanges, however JGMA chose to utilize the fillet welds. This decision comes with one notable drawback for construction and erection that the fillet welds require overhead welding on the bottom of each flange, which requires more time, skill for the welders, and physical space to work. JGMA began the design process with assumptions of electrodes, bolt diameter, and bolt material.

Through an iterative design process balancing the strength of the moment connection with the strength of the beam and local strength of the column (calculations in Appendix D), JGMA utilized three different connections in the design. The beam-column moment connections will be constructed as a direct welded flange connection with two ¾ inch A325-N bolts in a ⅜ x ½ x 6 inch plate. This connection design transfers load from a W16x45 beam to a W12x53 column, W12x45, and a W12x40 column. For column to exterior girder connections and column to elevator girder connections, another direct-welded flange connection is used with three ¾ inch A325-N bolts in a ⅜ x ½ x 9 inch plate. This connection transfers loads from the W18x50 exterior and elevator girders to the columns. Lastly, JGMA designed another direct-welded flange moment connection to transfer loads from the W21x73 interior girders to the columns by using four ¾ inch A325-N bolts in a ⅜ x ½ x 12 inch plate.

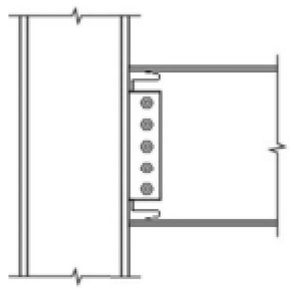


Figure 6.6: Direct-welded flange moment connection (Geschwindner 2017)

6.3 Foundation

6.3.1 Spread Footing

JGMA utilized spread footing as the foundation type to distribute loads from the columns to the soil. Deep foundation was not pursued because of the cost of a deep foundation. A shallow, spread footing foundation would be sufficient due to the soil characteristics of the building. Figure 6.7 shows a basic example of a spread footing pad and how the load is applied on it.

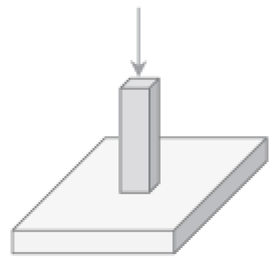


Figure 6.7: Spread footing diagram (Sivakugan 2021)

6.3.2 Soil Analysis

JGMA used the boring log data supplied by F.T. Kitlinski & Associates, Inc to create a geotechnical profile of the soil under the site surrounding the foundations. We first placed our building footprint on the site and identified relevant boring logs for the design. Figure 6.8 shows the specific boring logs that would be the most pertinent to the design as well as their location relative to the locations of the foundation. We identified that borings B-7, B-4, B-8, and B-5 will have the greatest impact on the design. Using the boring logs, we interpreted the subsurface conditions to create a soil profile. We used the number of blows, N value, from the Standard Penetration Test (SPT) to find the corrected blow count or N_{60} value. For hammer efficiency, we used the United States' standard of 85 for an automated hammer release. The boring logs did not specify the borehole diameter so we assumed a standard size which made the borehole correction factor one. We also assumed that it was a standard sampler, meaning there was no sampler liner, so the sampler liner correction factor we used was one. The rod length correction factor we employed depended on the length of the bore. All bores tested were under 20 feet, so we used a factor of 0.75 for lengths up to 13 feet and 0.85 for lengths in between 13 and 20. This process is outlined in Appendix B. Then, based on the N_{60} and the physical description of the soil, we extrapolated the information to create a profile between the bores. These are also located in Appendix B, under "Soil Profiles for Relevant Boring Locations on Site."

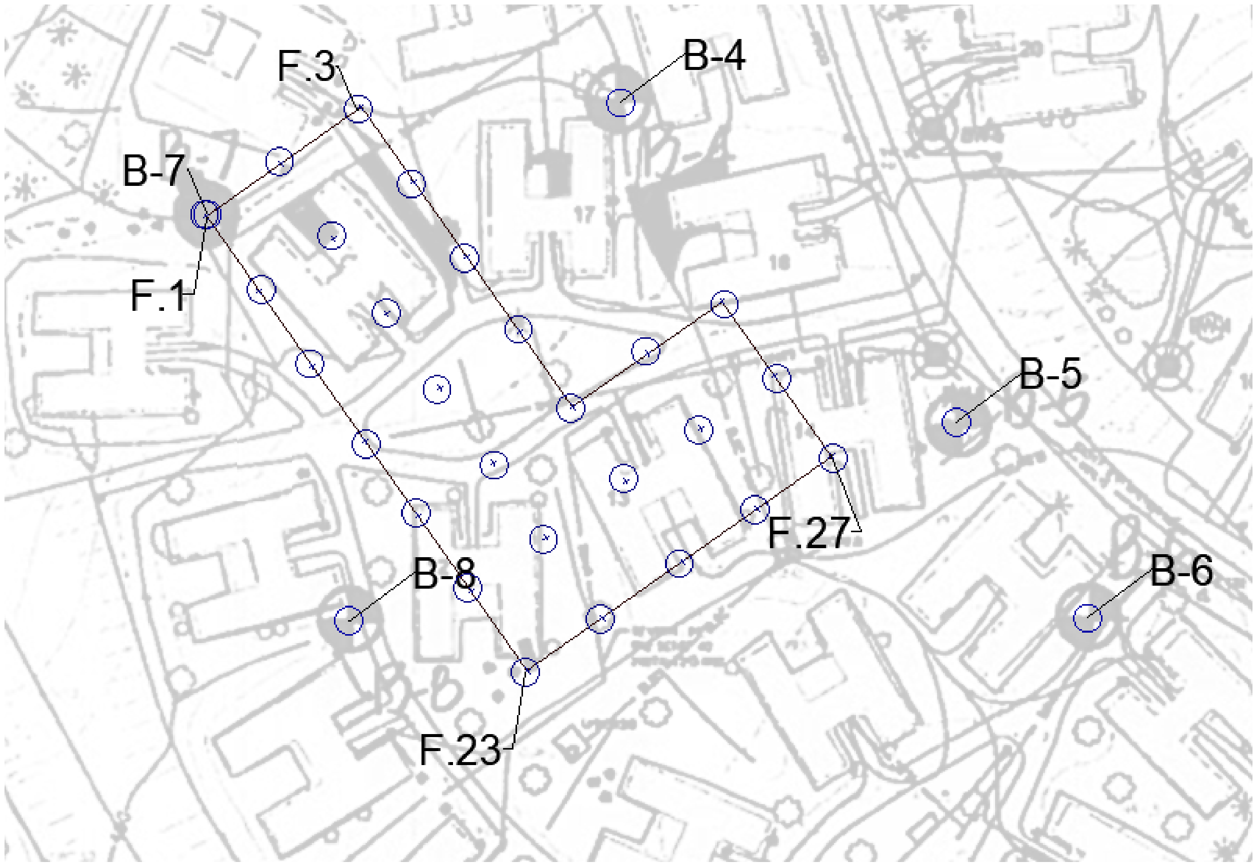


Figure 6.8: Locations of boring logs and foundations relative to the footprint of the building.

We converted the N_{60} value to a normalized blow count or $(N_1)_{60}$ value using a correction factor C_N which we calculated to be 1.03 using the Liao and Whiman method as outlined in Table 11.7 of *Soil Mechanics and Foundation Engineering: Fundamentals and Applications, 1st Edition* (Sivakugan 2021) and Equation 6.1. In the equation, p_a is atmospheric pressure and σ'_{vo} is the standard overburden correction factor, assumed to be 1.0 ton per square foot (Sivakugan 2021). Once we calculated the normalized blow counts, we were able to use Wolff's approximation to find the internal friction angle of the soil. Since the soil is cohesive, we were able to calculate the moist density of the soil using the equation in Equation 6.2. Note, this is an assumption and generalization that is not necessarily accurate for our profile. However, it gives us a value to use for foundation design computations. The full calculations for each of the relevant boring locations are outlined in Appendix B.

$$C_N = \sqrt{\frac{p_a}{\sigma'_{vo}}}$$

Equation 6.1: Liao and Whitman method to calculate the overburden correction factor (Sivakugan 2021).

$$\gamma_{moist} = 107 + 0.95N_{60}$$

Equation 6.2: Correlation of moist unit weight of soil using the N_{60} values (Rahman 2020).

6.3.3 Concrete foundation design

The bearing capacity is the maximum load the soil can carry without experiencing failure, which is largely based on the foundation depth, base dimensions, and soil properties. These soil properties include cohesion and friction angle, which are critical to finding the soil's bearing capacity. Using those parameters and the general soil bearing capacity equation, Equation 6.3, we were able to find the ultimate bearing capacity of the soil. For the site, the ultimate bearing capacity of the soil generally ranged from 19 kips per square foot to 24 kips per square foot. Specifically, Foundation 23, located close to boring log B-8 had an ultimate bearing capacity of 18.95 ksf; Foundation 27, located close to boring log B-5 had an ultimate bearing capacity of 19.32 ksf; Foundation 1, located close to boring log B-7 had an ultimate bearing capacity of 22.35 ksf; and Foundation 3, located close to boring log B-4 had an ultimate bearing capacity of 23.04 ksf. The process and values are laid out in Appendix D.

$$q_{ult} = s_c d_c i_c c N_c + s_q d_q i_q q N_q + s_\gamma d_\gamma i_\gamma 0.5\gamma^* B N_\gamma$$

Equation 6.3: The General Bearing Capacity Equation for finding the ultimate bearing capacity (Sivakugan 2021).

In order to design the foundation, we followed NAVFAC's suggested values for allowable bearing pressure for spread footings in Table 1 of Chapter 4 of NAVFAC DM7-02 (NAFVAC, 1986). We used the allowable bearing pressure with the factored axial load of the columns, 343 kips as well as the horizontal loading from the wind, to determine the area needed for the foundation. We also initially assumed that the final weight of the foundation element was 2 percent of the axial load so we could proportion the size of the footing. Afterwards, we checked to make sure the actual self weight of the footing would be sufficient. This gave us a required area of 69.97 feet squared. Rounding up to an area of 72.25 feet squared, we made the foundation a square of dimensions 8.5 by 8.5 feet. We made sure this was sufficient by dividing the applied pressure by the ultimate bearing pressure and maintaining a factor of safety above 3. The calculations associated with the foundation can be found in totality in Appendix E.

6.3.4 Foundation Settlement

Once we found the ultimate bearing capacity of the soil and found an appropriate foundation size that would not exceed the bearing capacity, we checked the settlement. Settlement is an important parameter to check because the foundation might not fail but excessive settlement can cause structural damage. Since the foundations sat within a sandy layer with only sands or gravely layers beneath them, we checked settlement using a granular soil approach. Specifically, we utilized the Terzaghi and Peck (1967) method outlined in Sivakugan

2021. This method related the settlement of our initial foundation to that of a 300-mm-wide square plate under the same loading conditions. We utilized Equation 6.4 in combination with the experimental test data of settlement of the 300 mm by 300 mm plate for varying pressures as shown in Figure 6.9 to determine the foundations' settlements. We discovered that our initial design of the 8.5 foot square footings were no longer acceptable, as they exceeded the maximum settlement (40 mm) as outlined in O'Brien's findings (O'Brien, 2013). As a result, we had to increase our footing size to 12 feet by 12 feet. We designed the footings to be a square of 12 feet so that they can be used in all locations. This decision further increased our confidence that the foundation would not exceed the ultimate bearing capacity while maintaining an appropriate level of settlement. The calculations can be found in Appendix E.

$$s_{footing} = s_{plate}\left(\frac{2B}{B+0.3}\right)^2\left(1 - \frac{1}{4}\frac{D_f}{B}\right)$$

Equation 6.4: Terzaghi and Peck's (1967) Method of finding settlement of a shallow foundation in granular soil (Sivakugan 2021).

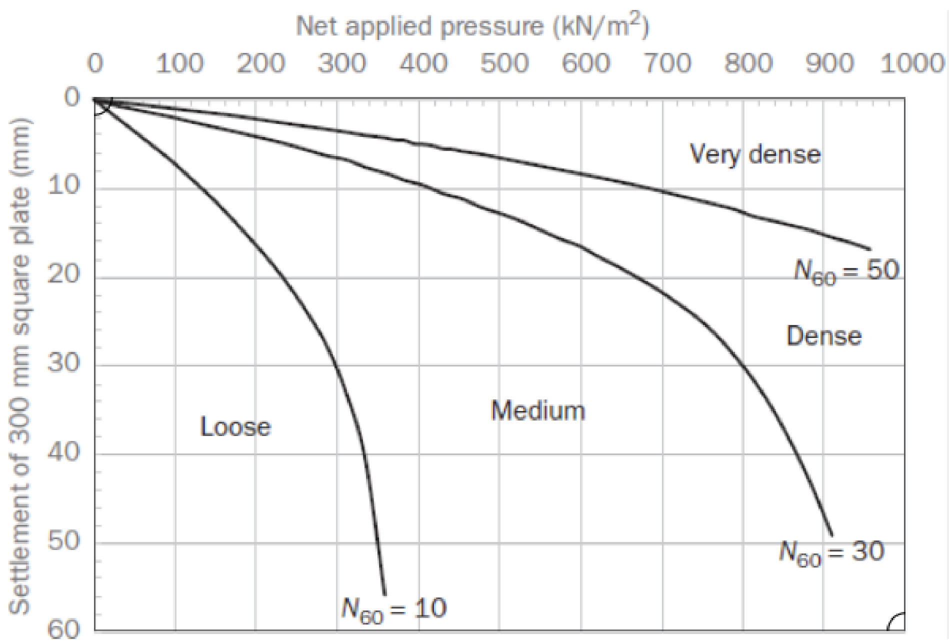


Figure 6.9: Settlement vs. applied pressure plots for 300 mm x 300 mm plate load test used in settlement calculations (Sivakugan 2021).

6.4 Project Management

Project management plays a crucial role in the development of a project that works simultaneously with the structural design team. JGMA has prepared a cost estimate, income analysis, construction sequencing plan, construction schedule, and a site logistics plan for the client to advise them for our alternative design to Bucknell West. Prior to the constriction of the project, a cost estimate and income analysis will be performed to determine its feasibility. Also, an understanding of the construction sequencing is necessary to understand how the building will go up and how to build a project sequencing. During the project the construction management team will put together a site logistics plan to determine where the materials will be kept, personnel and heavy machinery routing, and entrances and exits for the many deliveries. This is crucial for each phase of the project to maintain efficiency and prevent incidents.

6.4.1 Cost Estimate

A cost estimate is necessary for both the feasibility assessment for the client and can serve as a baseline for the project budget. In order to create a thorough estimate JGMA has used *RSMeans* 2016 (Charest, 2016) to provide Bucknell with a complete estimate of the eight-story steel frame apartment style dormitory. The estimate also assumes a face brick with concrete block backup exterior wall with a steel frame superstructure which matches the design of our building. An advantage to *RSMeans* is that it has a vast collection of projects that use national cost per square foot averages. The project provided by *RSMeans* that best fits ours is the green energy, commercial, college four to eight story dormitory. The primary steps of the estimate are shown in Table 6.7.

Table 6.7: Initial Step in *RSMeans* Estimate

Step	Calculations/Notes				Adjustment in $/SF	Cumulative $/SF
	15000 SF, Face Brick on Concrete Block Walls, with Steel Frame					
	Low Estimate	Interpolation	High Estimate			
	110000	120000	135000	SF		
	$ 227.50	***$* 226.06**	$ 223.90	$/SF	***$*226.06**	**$226.06**

The first step to starting the estimating process is to interpolate the cost per square foot based on the square footage of our project. *RSMeans* provides several square footage estimates based off of other projects, however we had to interpolate based off of our project's total square footage of 120,000 ft^2. As a starting point the cost of the project is $226.06 per square foot. The next step of the estimate requires us to take out the architect and contractor fees due to the additives that are required from our project exhibited in Table 6.8.

Table 6.8: Removal of Architect and Contractor Fees

2	Remove AE Contractor fees				Adjustment in $/SF	Cumulative $/SF
	Architect (AE)	6% fee	$213.26			
	Contactor	25% fee	$170.61		**-$55.45**	**$170.61**

This step is necessary because it undervalues the architect and contractor fees before the building additives are added to the estimate. The AE contractor fees are then added back into the project once all additives are included in the estimate. The removal of the fees decreases the cumulative cost of the project by $55.45 per square foot. Next, to determine the baseline of the building estimate is to evaluate how the required perimeter of the building adjusts the cumulative cost per square foot value which is displayed in Table 6.9.

Table 6.9: Adjustment for the Building's Perimeter

3	Adjust for Perimeter				Adj. in $/SF	Cumulative $/SF
S.F.	110000	**120000**	135000	Actual Perimeter		
Perimeter	540	**548.00**	560	489.65	**$2.06**	**$172.67**
$/S.F.	3.85	**3.53**	3.05			

The team had to adjust the estimate for the perimeter of the architectural design of the multi-story building by interpolating the square feet of the provided RS Means project into a general perimeter, bolded in Table 6.3 above. Then, using the project's actual architectural perimeter the adjustment in cost per square foot can be calculated and added to the cumulative cost per square foot. The adjustment of the baseline cost per square foot of the building was an increase of $2.06. The same process is done for the story height of the multi-story building as *RSMeans* 2016 assumes the building to have a 12-foot story height while ours has a 14-foot story height (Charest, 2016). Next, the cost of the basement is added into the estimate as our building calls for 180 square feet of basement for elevator maintenance, which *RSMeans* 2016 assumes that every square foot of basement costs $34.90. The cost of the basement is then divided by 120,000 square feet so it can be integrated into the cumulative cost per square foot. These initial adjustments provide the building's physical cost per square foot, but the building's additives are required to be calculated into the building's cumulative cost per square foot. The additives that are included in our building are as follows: CCTV system, parking lot and light poles, elevator, furniture, laundry, commissioning fees, energy modeling fees, green fees, greywater recovery system, kitchen appliances, green roof, and remaining sitework. Each additive uses the same method where the cost of it is divided by the square footage of the project so the adjustment of the cost per square foot for that item can be quantified for the cumulative cost per square foot of the entire building. The following steps were taken by the team in order to finish the estimate.

First, JGMA had to adjust the cost for the location of the project. The closest place that *RSMeans* 2016 lists is Sunbury, Pennsylvania which lists the location adjustment factor as 0.96 (Charest, 2016). Second, JGMA had to adjust for inflation as *RSMeans* 2016 does not account for the inflation rate since it was published. In order to adjust for inflation we obtained the January 2023 consumer price index and divided it by the January 2016 consumer price index which is a direct reflection of the accumulated inflation since RSMean 2016 publication. Finally, the AE adjustment factor had to be reincluded into the estimate.

Once all of this was completed JGMA construction reached a final cost of $357.59 per square foot and a total cost of $42,911,320.85 cost per square foot for the eight-story residential building. In comparison to the current University project which costs about $50,000,000, this design alternative saves Bucknell about $7,000,000 as per a conversation JGMA had with the project manager of the University's current plan (J. Salyards, personal communication, 2023). The full cost estimate can be found in Appendix A.

6.4.2 Income Analysis

JGMA conducted a thorough income analysis to gain an understanding of the value this project will provide to Bucknell university in the long term. It used the *RSMeans* cost estimate in conjunction with a series of housing and operating cost estimates to produce an estimate on the cumulative net income over time which can be seen below in Figure 6.10. Housing price estimates were based on the Bucknell south campus apartments. The O&M estimate was based on a facilities study conducted by California State University, which produced a cost per square foot estimate that was adjusted to fit the current price index. The analysis predicted that the project would become profitable for Bucknell shortly after 23 years of operation and reach the 100% profit mark shortly after 35 years, which is more than adequate for a project of this magnitude and value. The complete income analysis calculations can be seen in Appendix A.

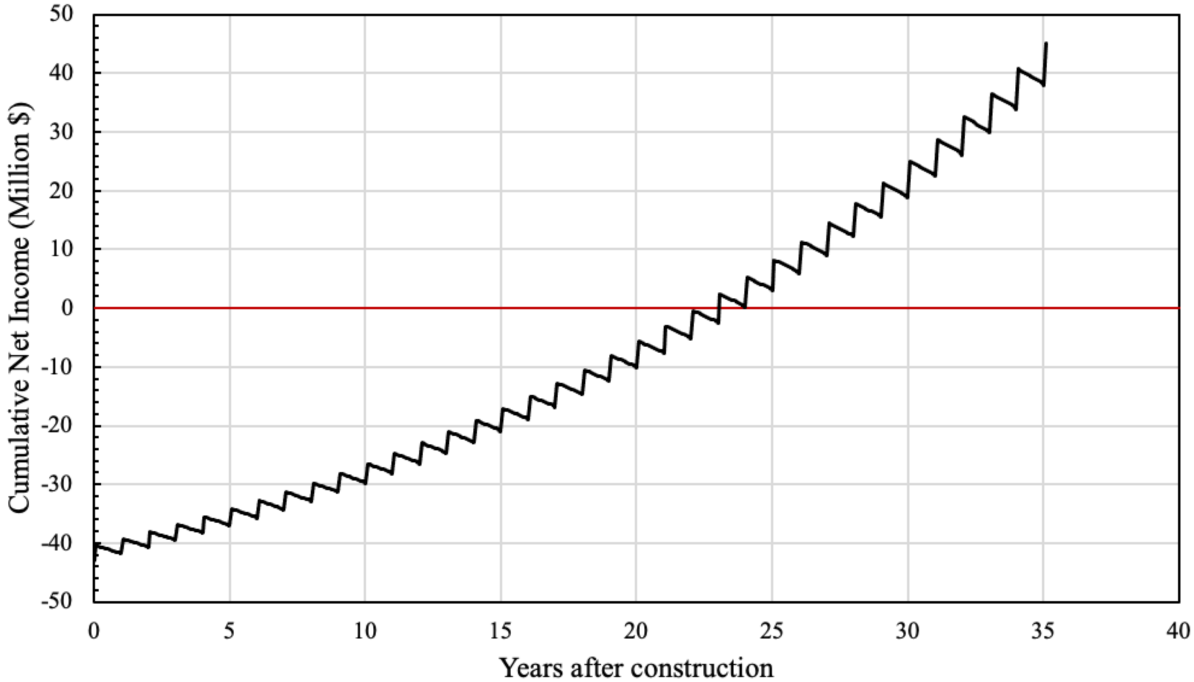


Figure 6.10: Plot of cumulative net income over timespan required to reach 100 percent profit margin.

6.4.3 Project Schedule

In the creation of a Project Schedule, JGMA needed to understand construction sequencing to create a consistent and realistic timeline for the completion of the project. The basic categories of construction sequencing include excavation, foundation, structure, and finishing. However, within those categories there are several construction tasks that come from the many different divisions of labor. Some examples of excavation include soil tests and site removal of the existing mods. While foundation activities include concrete pouring and beginning the connection to the super structure. Additionally, some major examples of structural construction activities include: erecting steel , concrete slab pouring, and roofing. Finally, some major examples of finishing activities include: completion of exterior, insulation, drywall, floor finishes, paint, mechanical, plumbing, and electrical systems setting, flooring, exterior landscaping, hardware installation, cleaning, and a final punch list.

To effectively create a schedule out of all of those tasks, JGMA used Microsoft Project to display an approximate timeline of the total project and its activities. However, due to the time constraint of the project, JGMA is unable to accurately determine the timing of completion of the entire project and each individual task. As a helpful exercise to idealize a project schedule, the team created a project schedule that displayed how the construction sequencing would be performed with placeholder durations for each activity. The schedule of the project is shown in Figure 6.11.

Resource Names: Floor 1	**Tue 11/21/2:**	**Wed 2/7/24**
Floor 1 - Framing	Tue 11/21/2:	Mon 12/4/23
Floor 1 - Plumbing Rough-In	Tue 11/28/2:	Mon 12/11/23
Floor 1 - Rough-In	Tue 12/5/23	Mon 12/18/23
Floor 1 - Electrical Rough-In	Tue 12/12/2:	Mon 12/25/23
Floor 1 - Insulation	Tue 12/19/2:	Mon 1/1/24
Floor 1 - Drywall	Tue 12/26/2:	Mon 1/8/24
Floor 1 - Millwork	Tue 1/2/24	Mon 1/15/24
Floor 1 - Finsh MEP	Tue 1/9/24	Mon 1/22/24
Floor 1 - Flooring Install	Tue 1/16/24	Mon 1/29/24
Floor 1 - Painting	Tue 1/23/24	Mon 2/5/24
Floor 1 - Cleaning	Tue 2/6/24	Wed 2/7/24
Resource Names: Floor 2	**Tue 12/5/23**	**Wed 2/21/24**
Floor 2 - Framing	Tue 12/5/23	Mon 12/18/23
Floor 2 - Plumbing Rough-In	Tue 12/12/2:	Mon 12/25/23
Floor 2 - HVAC Rough-In	Tue 12/19/2:	Mon 1/1/24
Floor 2 - Electrical Rough-In	Tue 12/26/2:	Mon 1/8/24
Floor 2 - Insulation	Tue 1/2/24	Mon 1/15/24
Floor 2 - Drywall	Tue 1/9/24	Mon 1/22/24
Floor 2 - Millwork	Tue 1/16/24	Mon 1/29/24
Floor 2 - Finsh MEP	Tue 1/23/24	Mon 2/5/24
Floor 2 - Flooring Install	Tue 1/30/24	Mon 2/12/24
Floor 2 - Painting	Tue 2/6/24	Mon 2/19/24
Floor 2 - Cleaning	Tue 2/20/24	Wed 2/21/24

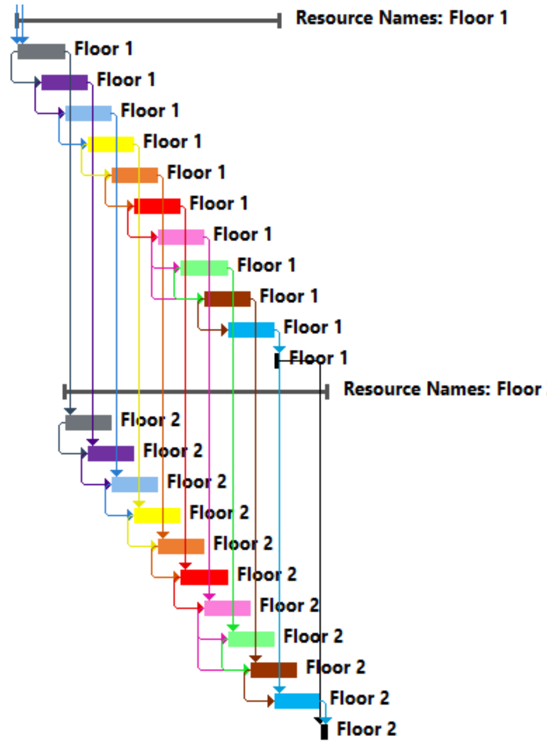


Figure 6.11: Project schedule of the fit-out for the multi-story building.

As the superstructure of the building is completed, the interior trades can begin the finishing process as they work up the building. In the figure above, once a trade is finished on the first floor they will move up to the next one. A start start lag is used in between each trade to speed up for the flow of work so they can take advantage of completed work on a floor so there is less waiting around, which would save money and time. The full project schedule can be viewed in Appendix H.

Another important step of understanding the construction sequencing is determining the layout of the construction site during each phase. This includes where heavy machinery can be placed on site, employee entrances and exits, delivery entrances and exits, on-site job trailers, and materials. A site logistics plan has been created for the construction sequence to efficiently guide the flow of materials and labor and to maintain safety. The multi-story construction site logistic plan is shown in Figure 6.12.

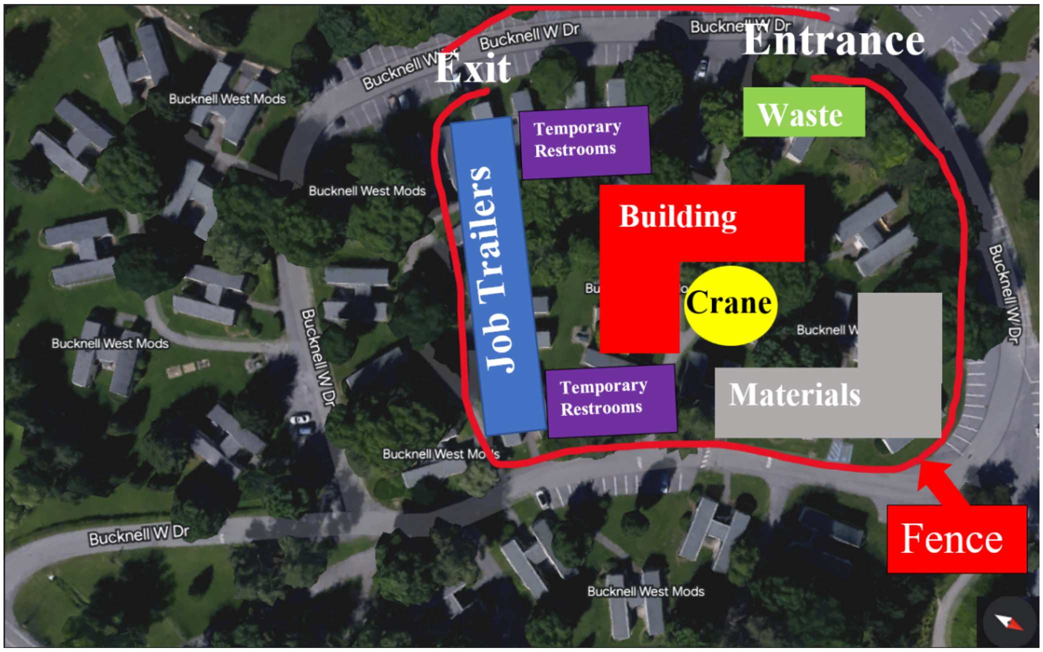


Figure 6.12: Site Logistics Plan

As the construction site is near buildings that students would live in during construction fences with gated entrances and exits must be put up to only allow authorized people to enter the construction site. The construction site of the building takes advantage of the existing infrastructure to transport the materials and construction vehicles to the site. At the gates and along the roads flaggers must be present to guide the flow of construction vehicles and student traffic. In the south corner of the site is where materials will be designated as they are near the building and within a tower crane's radius if needed. A tower crane would need to be used due to the height of the eight story building. On the northwest side of the site is where job trailers and restrooms are located to separate the foot traffic from the construction vehicles using the materials and collecting the construction waste. Finally, in the northeast corner is where the construction waste will be designated so vehicles can collect them upon entrance and leave quickly on the existing road without disturbing the rest of the site. JGMA created a 3D site logistic plan in SketchUp to better contextualize the placement of construction materials and vehicles as seen in Figure 6.13 below.

Figure 6.13: 3D Site Logistic Plan

Using information from the structural design and site logistics plan, a three dimensional model of the structure was developed using SketchUp. This model includes all major structural components to proper scale, and representative connections. Images of the entire model as well as specific components can be seen in Figures 6.14 and 6.15.

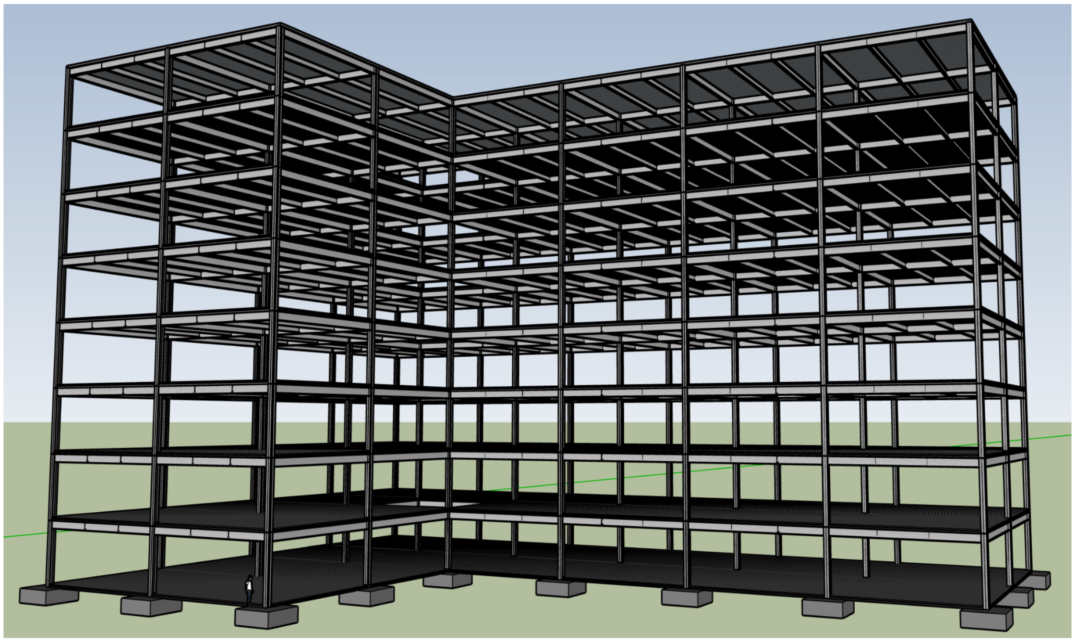
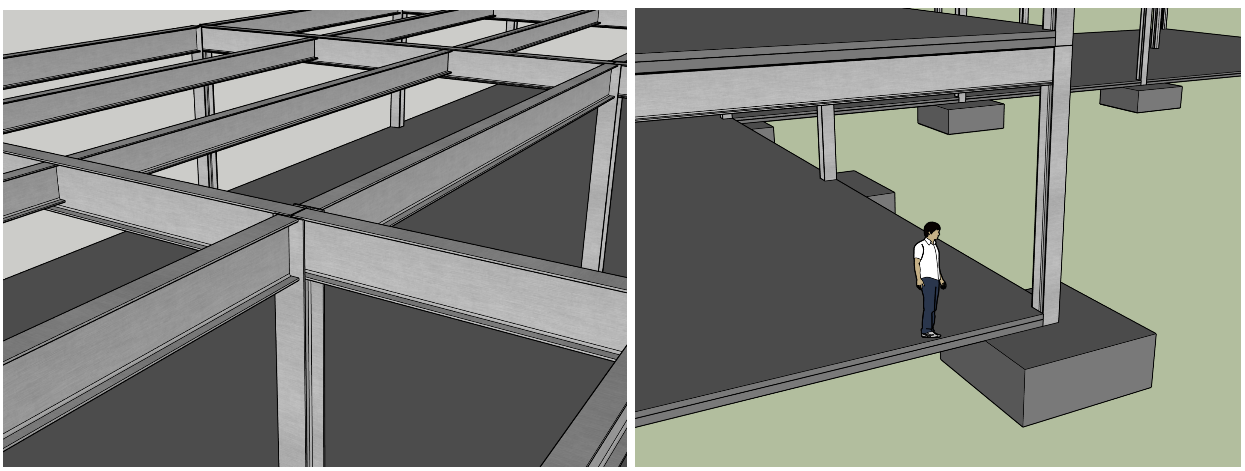


Figure 6.14: Isometric view of the entire structural model.



(a) (b)

Figure 6.15: (a) Connection between column, girders, and beams located on the eighth floor. (b) Concrete foundation located on an outer corner.

6.5 Sustainability

6.5.1 Embodied Carbon Analysis

Given the data produced by the preliminary CO_2 analysis conducted using EPIC, it is clear that an overwhelming percentage of total CO_2 emissions produced by this project will be due to operation. However, given the importance of reducing carbon output drastically by 2030, (Jeong, 2018), there is a time value to carbon, meaning that a reduction now can be more valuable than a reduction in the future. Knowing this, a detailed analysis of the total embodied CO_2 emitted by the construction of the building was conducted.

EC3, or Embodied Carbon in Construction Calculator, is an extensive sustainability analysis software that can be used to measure environmental impacts associated with the materials, transportation, and construction of a structure. It is able to account for details such as structural frame type, architectural layout, usage, and specific materials included. Additionally, it features a variety of options to customize each individual component of the structure, which allows for a number of different scenarios to be analyzed. For instance, concrete components can be adjusted to include specific amounts of fly ash replacement, CO_2 curing, specific cement mixes, and manufacturing adjustments.

JGMA conducted an analysis to calculate the embodied carbon footprint of the project using material amounts based on the structural design and estimates for standard envelope and finishing materials. Specific material components can be seen in Appendix F. A Sankey diagram of global warming potential by component can be seen below in Figure 6.15. The width of each component's flow represents the total kg CO_2 equivalent emitted throughout the manufacture and transportation of the material, which is then summed into subcategories and total footprint. A material's flow width including the hatched width represents a conservative estimate using standard materials, and the solid width represents the footprint when accounting for the best possible material options within each Material category. For instance, the conservative estimate for all hot-rolled structural steel members is 702 kg CO_2eq, while the achievable estimate is 423 kg CO_2eq.

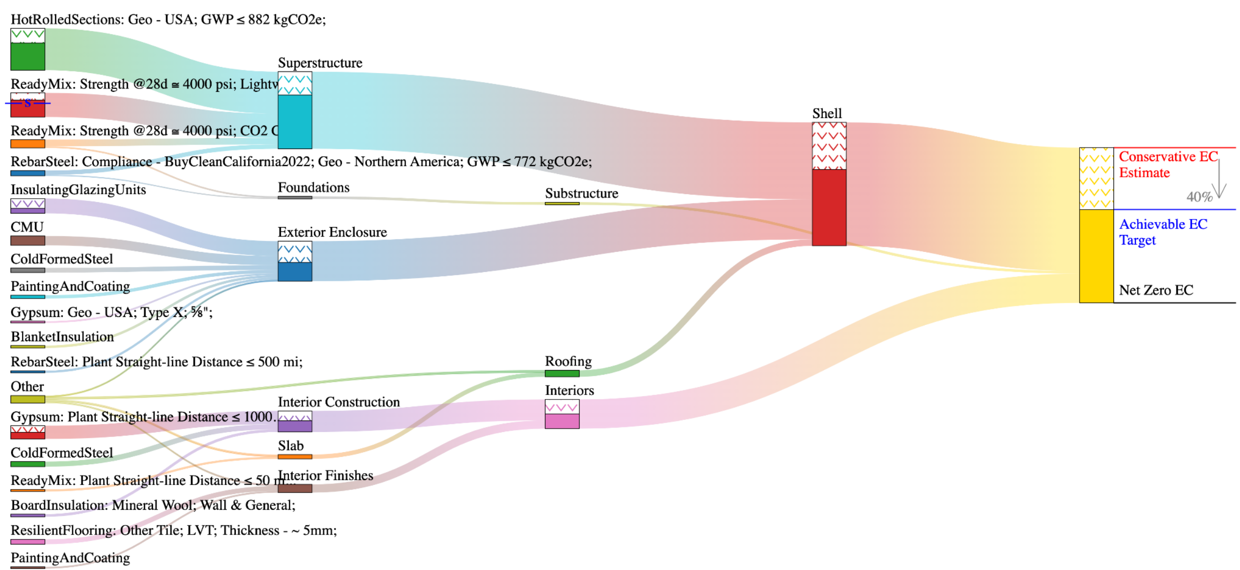


Figure 6.16: Sankey Diagram showing different materials as a percentage of total embodied carbon (EC3).

An analysis of specific components with high impacts indicated that the specific materials that would benefit most significantly from sustainable alterations according to the EC3 database are concrete, steel, insulation, and gypsum board, which can be seen in Figure 6.16.

Concrete saw potential benefits with CO2 curing, fly ash replacement, and alternative cement mixes. Steel benefited most from high recycled material content and compliance with clean manufacturing standards, such as Buy Clean California. Insulation varied significantly by material type and gypsum varied by manufacturer, and both components featured a variety of alternatives that would be acceptable for the project.

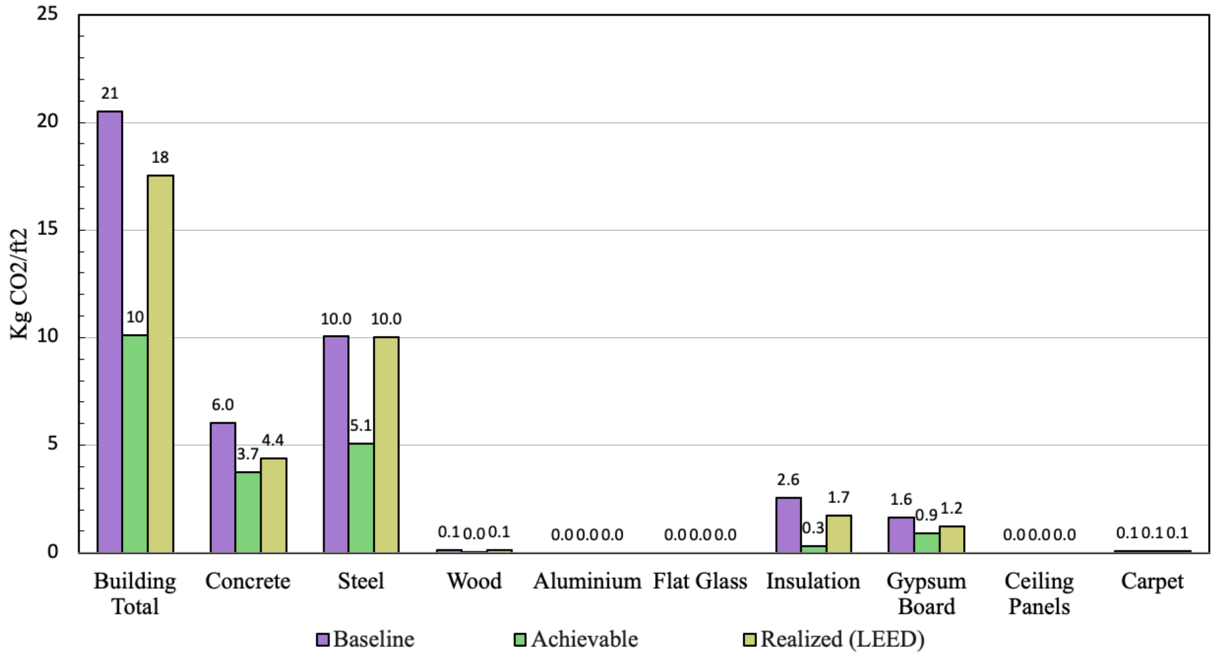


Figure 6.17: Environmental impacts of specific components (EC3).

In total, the conservative embodied estimate for the entire structure is 2.55 million kg CO_2eq, and the achievable estimate is 1.39 million kg CO_2eq. When converted to metric tons per square foot, the achievable estimate of 0.012 tons CO_2eq/ft^2 approaches LEED standard certification of approximately 0.009 tons CO_2eq/ft^2 for a complete project. However, this comparison is not fully representative of what certification would be achievable for the entire project when including considerations such as credit for carbon offset plantings, a green roof, geothermal heat, and overall operational profile. Considering the large amount of carbon footprint credit that is expected from these additions, a high level of LEED certification is to be expected.

6.5.2 Analysis of Specific Elements of Design

The preliminary sustainability analysis conducted using EPIC indicated that operation of the building will account for significantly more CO_2 equivalent emissions over time than construction. This warrants an analysis of specific design elements that would contribute to a reduction in operating emissions. Within the design the elements that most impact the sustainability of the project are the geothermal heating system, green roof, landscaping, and architectural design.

The geothermal system reaches towards the project's net zero carbon emission goal as it generates power much more efficiently than oil. For this particular project, the best application of geothermal heat would be from a geothermal heat pump as it uses water a few feet underground that remains a constant 50 to 60 degrees Fahrenheit year round. Using a loop the fluid would circulate through a series of pipes beneath a building and go through an electric compressor and heat exchanger that pulls the heat from the pipes to send it through a duct system throughout the building (Watson, 2009). In the summer the process would be reversed to cool the building and the heat would be absorbed underground (Watson, 2009). This makes excellent steps of sustainability for our project as the heat and cooling is coming from a natural source all day. While expensive to originally install the geothermal energy generated can be paid back to the grid and due to its efficiency (Watson, 2009). This would back the energy source very useful for Bucknell as the dorm will be on campus for an extended period of time. Additionally, in a case study about energy sources and their CO_2 emissions, geothermal fields used for electricity production generate 13-380 g CO_2 g/kWh versus natural gas which generates 453 CO_2 g/kWh (Fridleiffson, 2001). Even at the ceiling, geothermal proves to have a smaller footprint than natural gas. Additionally, the architectural design of the building creates a carbon sink through the green roof and extra land created from removing the three other buildings from the University's original plan. This is a long-term advantage as the greenery absorbs the carbon dioxide that would otherwise be prevented from the buildings.

A significant advantage that this development holds over the original Bucknell plan of four separate buildings is the drastic decrease in impervious surface. the structures in the original design would have a combined footprint of approximately 38,000 ft^2 compared to the 15,000 ft^2 of JGMA's design. This would allow for significantly more green space and high carbon sequestration plantings to be installed, which would allow for the project to take credit for a significant amount of emission reductions. Additionally, less impervious surface would reduce overall runoff on the site, which would significantly improve concerns regarding pollution of the nearby Miller Run waterway.

These advantages to our design all work towards the net zero carbon goal desired by the client, and show significantly more promise than the original design in achieving this goal.

7.0 IMPACTS OF DESIGN

JGMA Construction and Engineering not only wants to deliver a high quality product to the client but also values a design that meets social, environmental, and economic expectations in accordance with ethical and professional responsibilities.

A primary objective of the team was to create a living environment for the students where they would feel safe and be able to recharge after an academic day at Bucknell. First, we aimed to create rooms that were provided with a common space so that students can talk to each other and work on their studies after classes. Additionally, all common and bed rooms are supplied with windows as the absence of sunlight would significantly reduce a students mental health. Next, we planned to ensure safety and welfare by following ADA compliance by providing hallways and rooms that are wheelchair accessible. This ensures students with disabilities would be able to live in the multi-story residential building during their time at Bucknell. Finally, through our income analysis our project will be profitable for Bucknell after about 23 years making the project financially feasible as it is not a significant portion of the building's lifespan. Our income analysis assumes that the cost of student living remains consistent with Bucknell's senior apartments which allows most students the opportunity to live in the new apartment style dormitory.

When considering major social, environmental, and economic factors that would influence our design, we took advantage of a 'doughnut' model, a sample of which can be seen in Figure 7.1. It features an inner ring that represents societal expectations of development across a number of impact categories, and a larger ring of planetary boundaries, which represent the upper bounds of environmental impacts. The model itself is conceptual, and each ring could be rotated and scaled to represent a connection between specific social foundations and environmental impacts. For instance, the foundation of water may have considerably more room regarding its impact on aerosol loading than climate change or freshwater use impact categories. By retaining a position within these rings, our team would guarantee that the multi-story project meets all expectations and requirements that would make the project worthwhile, while simultaneously ensuring that it does not generate substantial negative impacts. For instance, the architectural and structural scopes of work dealt with meeting the basic requirements of the development in an efficient manner. The project management and sustainability scopes then worked to further improve and optimize the impacts of the development to ensure that the entire project could be completed with the smallest achievable impacts.

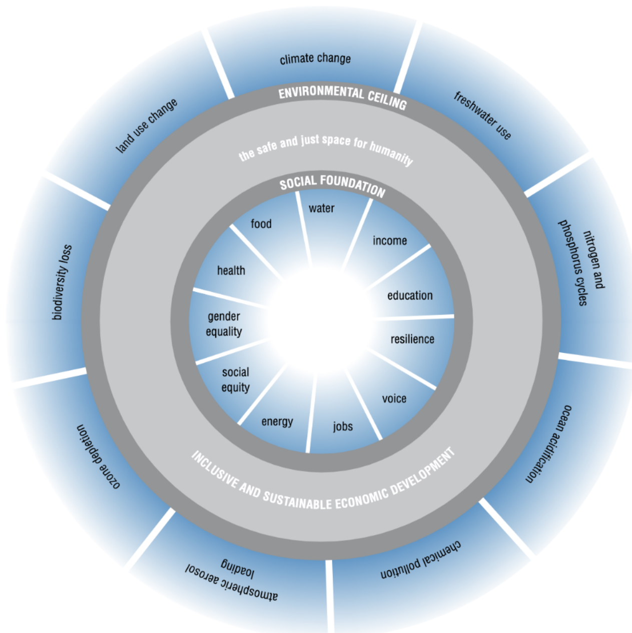


Figure 7.1: Example of a doughnut model representing social foundations and environmental ceilings (Leach, 2013).

Many of the cost and environmental specific considerations can be seen throughout the project management and sustainability sub-sections within section six. These include the addition of geothermal heating systems, a green roof, and high carbon storage landscaping. A secondary benefit of the new development is the drastic increase in potential green space available due to the reduced footprint. Socially, this building would drastically improve the sense of community within the Bucknell West campus, given that students would be sharing a single building and common spaces. The previous development, The Mods, encouraged residents to interact primarily with their direct roommates, while welcoming common spaces in the new development, particularly outdoors, will foster new relationships and interactions. Additionally, The Mods are traditionally home to a large number of athletes given their proximity to outdoor practice facilities. Encouraging athletes to take advantage of this new space, and possibly even supplementing common spaces with athlete-specific facilities, could improve performance, camaraderie, and recruiting opportunities. Additionally, this development represents a clear improvement in quality compared to the previous housing units. This aligns with Bucknell University's goal to continually improve campus with the student body as the foremost beneficiary.

JGMA Construction and Engineering aims to follow the many ethical and professional standards that are essential to the ethos of being an engineer. As a guide our team follows the NSPE 2018 Code of Ethics that provides an engineer with the guidelines on how to conduct themselves within a professional environment. Cannon II.1 states, "Engineers shall hold paramount the safety, health, and welfare of the public" (NSPE, 2018). In order to follow this cannon we have employed several engineering design institutions to maintain the safety of the building. The team has used ASCE 7-22 for the design loads of the structure, AISC for the steel superstructure, and ACI for the foundation of the building. The guidelines provided by these institutions allow the safety, serviceability, and constructability of each part of the building to prevent serious incidents. Also, through the architectural design it was of the utmost importance to maintain ADA compliance for students with disabilities to live in the building.

Above all else, JGMA Construction and Engineering takes purpose, passion, and integrity into all projects to deliver a high standard product to its clients. The design process of the multi-story residential building followed standard engineering practices and guidelines that abide to the public health, safety, and welfare of the Bucknell and Lewisburg community. Finally, with the significant design choices the team considered the global, economic, environmental, and social contexts to maintain the engineering principles provided by the national society of professional engineers.

8.0 SELF-LEARNING

8.1.1 Graham Allardyce

8.1.1.1 Construction Sequencing and Logistics

A major part of the construction management scope was the sequencing and logistics. I determined that it would be a great self learning topic to create a project schedule and site logistic plan which would be a familiar task in the construction industry after Bucknell. In the preliminary stages I learned about the main phases of a construction project and the typical trades that would be involved during each phase. I also aimed to learn how a construction site is typically organized to maximize safety, efficiency, and to use the existing infrastructure. Learning about each part of the sequencing and logistics scopes I took advantage of scholarly articles, videos on YouTube, and creating continued conversations with professional connections I have made throughout my summer internships and professors at Bucknell. In our earlier conversations I asked about the general phases of construction and what needs to be in a construction site logistics plan. The major phases of a construction schedule are excavation, foundation, structure, and finishing. Each phase can be split up into the core and shell of a project and also the fit out of the building. In each of my conversations I was advised that I could not accurately make a schedule for each task as schedules often change throughout the course of a project. However, I was given a general idea of how long the complete building would take to complete. However, scheduling and sequencing is still a valuable exercise and topic to learn so I was advised to create a schedule with placeholder durations. This way I could instead display the several sequences that are included into a typical schedule and the different types of lagging that is included in a schedule. For the site logistics plan our conversations mostly focused on safety, paths of egress, construction materials, and waste disposal. In order to maintain the safety of the site it was essential that pedestrian pathways would be separated from where construction vehicles would be routinely used. In the cases where they would collide, I learned about the role of flaggers and how they must be present. In the continued conversations I had with my connections about the schedule and the site logistics plan, I learned a lot about the project management scope that I produced in the project. Additionally, working on the construction management scope I have become much more proficient in estimating and AutoCad. After focusing on this scope for the past year I believe it has given me a great head start to my professional career and given me the tools I have needed for the scope required for this project.

8.1.2 Mike Devlin

8.1.2.1 Composite Beam Design

A major part of this project was completed through self learning. Although I learned how to design both steel and concrete beams from my design classes, I had never worked with composite beam design. I chose to do composite beams to reduce the chance of lateral torsional buckling of the beams, per Professor Ziemian's recommendations. I utilized three main sources while teaching myself how to design composite beams. Paul Richard's textbook *Build With Steel* and Geschwindner textbook *Unified Design of Steel Structures (3rd Edition)* provided excellent insight into the steps of designing composite beams. Both of the textbooks discussed the strengths, limitations, and design aspects of composite beams. The end of the sections provided design examples which were especially helpful when proportioning my beams. I also used the *AISC Steel Construction Manual* for the tables and design procedures. The commentary section helped when designing the amount of studs required and the strength of the steel anchors.

8.1.2.2 Correlation of N Values and Soil Properties

In order to design the foundation, I needed to have the soil parameters like unit weight and the internal friction angle. However, we were only provided with the boring logs at certain locations. As a result I had to extrapolate from the given boring logs to try and create a soil profile and find the soil parameters from the SPT test. Both of these topics were never covered in either of the geotech classes at Bucknell, so I needed to find resources to learn how to do it. The first problem was learning how to connect two boring locations with limited information between the two locations. Besides attending Professor Favero's office hours, I watched several videos on little tips to help create a profile. After that, it was sort of a guess and check method. Even then there is still uncertainty in the profile, but I tried to be as conservative as possible in my design. Once the profiles were created, I needed to correlate the SPT values to soil parameters Luckily, the textbook we use for Geotech II, *Soil Mechanics and Foundation Engineering: Fundamentals and Applications, 1st Edition* by Dr. Nagaratnam Sivakugan has a section that goes over it. I had to read section 11.6.4 of the textbook to learn how to correlate the SPT value to the friction angle. Even then, there were some assumptions I had to make on the specific method. In addition, I had to use the SPT value to determine the unit weight of the soil. For this I went to Manzar Rahman's research paper titled "Foundation Design using Standard Penetration Test (SPT) N-value."

8.1.3 Andrew Matton

8.1.3.1 Sustainability Analysis

Throughout the length of the project, I spent substantial time developing an understanding of how to measure and understand the environmental impacts of a structure. During the conceptual design, I performed a great deal of research on how specific design elements and architectural decisions can impact the overall sustainability profile of a project, and used this information to develop a Life Cycle Analysis of our proposed design. I was familiar with the general principles of LCAs from CEEG 443, but the quantitative work conducted throughout that course did not cover structural designs. This led me to use EPIC, a relatively simple LCA tool designed specifically for preliminary or estimated structural designs.

Once our structural and architectural design was fully realized, I used a much more robust LCA software program called EC3. This program allowed me to use exact material amounts and specifications to create a detailed model of the carbon footprint of the structure, which enabled me to analyze it and identify specific improvements that could be made that would most benefit the overall carbon footprint. This took some research into how to use the program most effectively, such as creating assemblies of different materials to make up a specific component of the structure. Additionally, I developed an understanding of all specific components included in a complete structure and how each of them could be altered to best contribute towards our sustainability goals.

8.1.3.2 Architectural 3D Model

One component of our team's project management scope was to develop a three dimensional animation detailing the construction sequencing of the structure. I spent a great deal of time watching tutorials and looking up methods for developing such a model, and was able to generate an accurate representation of the complete structural design. Unfortunately, I was unable to model specific connections with bolts and plates, although each representative connection is placed accurately. Additionally, the animation tools within the free browser version of SketchUp did not enable me to generate a sequencing animation that would add substantial value, although clips detailing the shape, scale, and specific components or connections of the structure were created for the final presentation.

8.1.4 Jonathan Stiefel

8.1.4.1 SMath

SMath was a key tool for every calculation I made because it accelerated the design process by facilitating iterative and repetitive design calculations. Initially, syntax was sometimes difficult to recall and I would often have to refer back to my notes on SMath syntax from Professor Ziemian's lecture on SMath. This seemed to temporarily slow down the design process, however, quickly paid off with its quick auto calculations.

8.1.4.2 Frame Design

Out of all design elements including column design, composite beam design, and moment connection design, the frame seemed to have the most missing variables resulting in the most iterative process. Such variables include the three different elements that could fail, column, connection, or the beam, and each having their own failure modes. MASTAN2 was quick to relearn since taking Steel Design with Professor Ziemian and a significant help for running analysis on the moment frames interactions with truss.

8.1.4.3 Moment Connection Design

Moment connection design was a familiar process to me since I had learned about connections and welds in my steel design course with Professor Ziemian. However, for the multi-story building, there seemed to be fewer constraints, and I had more room to choose connection types, materials, and welds. This freedom allowed me to explore different options and optimize the design for performance and cost, something that was not focused on as much in my concrete and steel design courses.

For guidance during the moment connection design, I turned to Geschwindner's textbook *Unified Design of Steel Structures (3rd Edition).* The book provided me with valuable insights into the steps for design and tips to keep in mind throughout the process.

9.0 TEAMWORK REFLECTION

As a whole we are happy with the performance of our group for the submission of the eight story building design alternative to Bucknell West. Our group worked successfully in communicating with each other, meeting consistently, meeting our intended scope. In the Fall, we all agreed that our time management as a whole needed improvement as some submissions were met with a time crunch. An area we could have improved on was meeting more often in the beginning of the project to prevent rushed work towards the end. This semester the group was much better at managing our time and was met with a much less significant time crunch for our deadlines. Furthermore, our use of a group chat made it very easy to communicate with each other outside of meetings. We found that clear communication was essential for the success of the project. We scheduled regular meetings to discuss progress, share ideas, and address any issues moving forward. Additionally, we used online collaboration tools such as Google Drive to share documents, which allowed us to work on the project simultaneously.

The distribution of tasks also helped us to stay organized and manage our time efficiently. We recognized that each team member had unique strengths and skills, and we leveraged those strengths to assign tasks that aligned with those skills. This approach ensured that every team member could contribute to the project in an effective way and allowed us to optimize the quality of the report. For example, two of our team members have an interest in construction and are currently enrolled in courses that further develop these skills, so they were assigned to handle project management aspects of the report. On the other hand, the other two team members have an interest and experience in structures, so they were assigned to design the structural frame and foundation.

The dynamics that we would carry forward for into future collaborations are the use of a group chat, a shared folder, and weekly meetings. Each of the dynamics help improve the collaboration and a more structured final design. However, moving forward we would not use the cycling job roles as it may interfere with the natural role of the group where members understand how to best work together.

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APPENDIX A: Project Economics Calculations

Cost Estimate:

	CEEG Senior Design 2023 SF Estimate of a Bucknell West Apartment Based on RS Means 2016 Square Foot Costs					Graham Allardyce Andrew Matton		
Step	**Calculations/Notes**					**Adjustment in $/SF**	**Cumulative $/SF**	**Cumulative Cost**
1	**15000 SF, Face Brick on Concrete Block Walls, with Steel Frame**							
	Low Estimate		Interpolation	High estimate				
		110000	120000	135000	SF			
	$	227.50	$ 226.06	$ 223.90	$/SF	*$226.06*	**$226.06**	**$27,127,200.00**
2	**Remove AE Contractor fees**							
	architect (AE)		6%	$213.26				
	contactor		25%	$170.61		*-$55.45*	**$170.61**	**$20,473,358.49**
3	**Adjust for perimeter**							
		110000	120000	135000	Required Perimeter			
		540	548.00	560	489.65	*$2.06*	**$172.67**	**$20,720,529.09**
		3.85	3.53	3.05				
3	**Adjust for story height**							
		110000	120000	135000	Extra/less feet height			
		1.6	1.50	1.35	$2.00	*$3.00*	**$175.67**	**$21,080,529.09**
4	**Add Basement**							
	Cost $34.9/SF		$ 34.90	per SF				
	Floor Area		180	SF				
	Cost of Basement		$ 6,282.00					
	Cost per SF of building SF area		$ 0.05			*$0.05*	**$175.72**	**$21,086,811.09**
	Adjust Price for Common Additives		**Units**	**Cost/unit**	**Cost**	**Adjustment in $/SF**	**Cumulative $/SF**	**Cumulative Cost**
5	**CCTV System**							
	Single Camera and monitor system		1	$2,025.00	$2,025.00			
	five additional cameras		5	$1,100.00	$5,500.00			
					$7,525.00	*$0.06*	**$175.79**	**$21,094,336.09**
6	**Parking Lot and Lightpoles**							
	Pavement 50 spots		50	$1,245.00	$62,250.00			
	Aluminum Light poles, 30 feet 2 arm - 10		10	$3,850.00	$38,500.00			
	Total Cost				$100,750.00	*$0.84*	**$176.63**	**$21,195,086.09**
7	**Elevator**							
	Elevator, 5 stops, 350lb capacity		1	$177,600.00	$177,600.00			
	Additional stop		3	$10,500.00	$31,500.00			
	total cost				$209,100.00	*$1.74*	**$178.37**	**$21,404,186.09**
8	**Furniture**							
	Per student		286	$5,000.00	$1,430,000.00			
					$1,430,000.00	*$11.92*	**$190.28**	**$22,834,186.09**
9	**Laundry**							
	Dryer, 30 lb capacity		32	$3,950.00	$126,400.00			
	Washer		32	$1,625.00	$52,000.00			
					$178,400.00	*$1.49*	**$191.77**	**$23,012,586.09**
10	**Commissioning fees**							
	Sustainable institutional construction		120000	$1.75	$210,000.00			
					$210,000.00	*$1.75*	**$193.52**	**$23,222,586.09**
11	**Energy modeling fees**							
	Up to 10,000sqft		1	$9,000.00	$9,000.00			
	Greater than 10,000 sqft add		11	$0.20	$2.20			
					$9,002.20	*$0.08*	**$193.60**	**$23,231,588.29**
12	**Green Fees**							

	Per Project Basis	1	$900.00	$900.00			
				$900.00	*$0.01*	**$193.60**	**$23,232,488.29**
13	**Greywater recovery system**						
	3090 gal prepackaged	1	$58,265.00	$58,265.00			
				$58,265.00	*$0.49*	**$194.09**	**$23,290,753.29**
14	**Kitchen appliances**						
	equipment, burner, oven, appliances	76	$1,100.00	$83,600.00			
	Kitchen sink w/ trim, countertop	76	$1,435.00	$109,060.00			
				$192,660.00	*$1.61*	**$195.70**	**$23,483,413.29**
15	**Green Roof**						
	6" soil depth, w/ treated wd edging and sedum mats	15000	$11.76	$176,400.00	*$1.47*	**$197.17**	**$23,659,813.29**
16	**Geothermal Closed Loop Energy System**						
	upfront cost (installation)			$3,000,000.00	*$25.00*	**$222.17**	**$26,659,813.29**
17	**Remaining site work**						
	Sitework	1	$60,000.00	$60,000.00	*$0.50*	**$222.67**	**$26,719,813.29**
18	**Adjust for location**						
	Sunbury Adjustment	0.96				**$213.76**	**$25,651,020.76**
19	**Adjust for 2023**						
	Index 2016	236.9					
	Index 2023	299.1				**$269.88**	**$32,385,902.53**
	Interpolated Adjustment:	1.2626					
20	**Subtotal of direct costs**				*$269.88*	**$269.88**	**$32,385,902.53**
21	**Add in contractor fees**						
	Contractor	25%	$67.47 per SF		*$67.47*	**$337.35**	**$40,482,378.16**
22	**Add in AE design fees**						
	AE design fee	6%	$20.24 per SF		*$20.24*	**$357.59**	**$42,911,320.85**
	FINAL ESTIMATED COST					**$357.59**	**$42,911,320.85**

Income Analysis:

Year over year rent increase:	3.00%	**Inital Housing Cost:**	$ 11,000.00	per student
O&M year over year increase:	2.00%	**Financial Aid percentage:**	20.00%	given
Occupancy:	100.00%			
Monthly MARR:	0.00833			

Period	**Cash Flow**						**Analysis**			
	Income		Expenditures							
Month	Rent	Geothermal Credit	Construction	O&M	Repairs	Geothermal	Gross Income	Total Expenditures	Net Income	**Cumulative Net Income**
0	$ -		$ 42,911,320.85	$ -	$ -	$ -	$ -	$ 42,911,320.85	$ (42,911,320.85)	$ (42,911,320.85)
1	$ 2,578,400.00	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ 2,578,400.00	$ 115,000.00	$ 2,463,400.00	$ (40,447,920.85)
2	$ -	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ -	$ 115,000.00	$ (115,000.00)	$ (40,562,920.85)
3	$ -	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ -	$ 115,000.00	$ (115,000.00)	$ (40,677,920.85)
4	$ -	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ -	$ 115,000.00	$ (115,000.00)	$ (40,792,920.85)
5	$ -	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ -	$ 115,000.00	$ (115,000.00)	$ (40,907,920.85)
6	$ -	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ -	$ 115,000.00	$ (115,000.00)	$ (41,022,920.85)
7	$ -	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ -	$ 115,000.00	$ (115,000.00)	$ (41,137,920.85)
8	$ -	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ -	$ 115,000.00	$ (115,000.00)	$ (41,252,920.85)
9	$ -	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ -	$ 115,000.00	$ (115,000.00)	$ (41,367,920.85)
10	$ -	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ -	$ 115,000.00	$ (115,000.00)	$ (41,482,920.85)
11	$ -	$ 35,714.29	$ -	$ 115,000.00	$ -	$ -	$ -	$ 115,000.00	$ (115,000.00)	$ (41,597,920.85)
12	$ -	$ 35,714.29	$ -	$ 115,000.00	$ 100,000.00	$ 25,000.00	$ -	$ 240,000.00	$ (240,000.00)	$ (41,837,920.85)
13	$ 2,655,752.00	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ 2,655,752.00	$ 117,300.00	$ 2,538,452.00	$ (39,299,468.85)
14	$ -	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ -	$ 117,300.00	$ (117,300.00)	$ (39,416,768.85)
15	$ -	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ -	$ 117,300.00	$ (117,300.00)	$ (39,534,068.85)
16	$ -	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ -	$ 117,300.00	$ (117,300.00)	$ (39,651,368.85)
17	$ -	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ -	$ 117,300.00	$ (117,300.00)	$ (39,768,668.85)
18	$ -	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ -	$ 117,300.00	$ (117,300.00)	$ (39,885,968.85)
19	$ -	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ -	$ 117,300.00	$ (117,300.00)	$ (40,003,268.85)
20	$ -	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ -	$ 117,300.00	$ (117,300.00)	$ (40,120,568.85)
21	$ -	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ -	$ 117,300.00	$ (117,300.00)	$ (40,237,868.85)
22	$ -	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ -	$ 117,300.00	$ (117,300.00)	$ (40,355,168.85)
23	$ -	$ 36,011.90	$ -	$ 117,300.00	$ -	$ -	$ -	$ 117,300.00	$ (117,300.00)	$ (40,472,468.85)
24	$ -	$ 36,011.90	$ -	$ 117,300.00	$ 102,000.00	$ 25,208.33	$ -	$ 244,508.33	$ (244,508.33)	$ (40,716,977.18)
25	$ 2,735,424.56	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ 2,735,424.56	$ 119,646.00	$ 2,615,778.56	$ (38,101,198.62)
26	$ -	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ -	$ 119,646.00	$ (119,646.00)	$ (38,220,844.62)
27	$ -	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ -	$ 119,646.00	$ (119,646.00)	$ (38,340,490.62)
28	$ -	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ -	$ 119,646.00	$ (119,646.00)	$ (38,460,136.62)
29	$ -	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ -	$ 119,646.00	$ (119,646.00)	$ (38,579,782.62)
30	$ -	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ -	$ 119,646.00	$ (119,646.00)	$ (38,699,428.62)
31	$ -	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ -	$ 119,646.00	$ (119,646.00)	$ (38,819,074.62)
32	$ -	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ -	$ 119,646.00	$ (119,646.00)	$ (38,938,720.62)
33	$ -	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ -	$ 119,646.00	$ (119,646.00)	$ (39,058,366.62)
34	$ -	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ -	$ 119,646.00	$ (119,646.00)	$ (39,178,012.62)
35	$ -	$ 36,312.00	$ -	$ 119,646.00	$ -	$ -	$ -	$ 119,646.00	$ (119,646.00)	$ (39,297,658.62)
36	$ -	$ 36,312.00	$ -	$ 119,646.00	$ 104,040.00	$ 25,418.40	$ -	$ 249,104.40	$ (249,104.40)	$ (39,546,763.03)
37	$ 2,817,487.30	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ 2,817,487.30	$ 122,038.92	$ 2,695,448.38	$ (36,851,314.65)
38	$ -	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ -	$ 122,038.92	$ (122,038.92)	$ (36,973,353.57)
39	$ -	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ -	$ 122,038.92	$ (122,038.92)	$ (37,095,392.49)
40	$ -	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ -	$ 122,038.92	$ (122,038.92)	$ (37,217,431.41)
41	$ -	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ -	$ 122,038.92	$ (122,038.92)	$ (37,339,470.33)
42	$ -	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ -	$ 122,038.92	$ (122,038.92)	$ (37,461,509.25)
43	$ -	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ -	$ 122,038.92	$ (122,038.92)	$ (37,583,548.17)
44	$ -	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ -	$ 122,038.92	$ (122,038.92)	$ (37,705,587.09)
45	$ -	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ -	$ 122,038.92	$ (122,038.92)	$ (37,827,626.01)
46	$ -	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ -	$ 122,038.92	$ (122,038.92)	$ (37,949,664.93)
47	$ -	$ 36,614.60	$ -	$ 122,038.92	$ -	$ -	$ -	$ 122,038.92	$ (122,038.92)	$ (38,071,703.85)
48	$ -	$ 36,614.60	$ -	$ 122,038.92	$ 106,120.80	$ 25,630.22	$ -	$ 253,789.94	$ (253,789.94)	$ (38,325,493.79)
49	$ 2,902,011.92	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ 2,902,011.92	$ 124,479.70	$ 2,777,532.22	$ (35,547,961.58)
50	$ -	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ -	$ 124,479.70	$ (124,479.70)	$ (35,672,441.27)
51	$ -	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ -	$ 124,479.70	$ (124,479.70)	$ (35,796,920.97)
52	$ -	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ -	$ 124,479.70	$ (124,479.70)	$ (35,921,400.67)
53	$ -	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ -	$ 124,479.70	$ (124,479.70)	$ (36,045,880.37)
54	$ -	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ -	$ 124,479.70	$ (124,479.70)	$ (36,170,360.07)
55	$ -	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ -	$ 124,479.70	$ (124,479.70)	$ (36,294,839.77)
56	$ -	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ -	$ 124,479.70	$ (124,479.70)	$ (36,419,319.46)
57	$ -	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ -	$ 124,479.70	$ (124,479.70)	$ (36,543,799.16)
58	$ -	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ -	$ 124,479.70	$ (124,479.70)	$ (36,668,278.86)
59	$ -	$ 36,919.73	$ -	$ 124,479.70	$ -	$ -	$ -	$ 124,479.70	$ (124,479.70)	$ (36,792,758.56)
60	$ -	$ 36,919.73	$ -	$ 124,479.70	$ 108,243.22	$ 25,843.81	$ -	$ 258,566.72	$ (258,566.72)	$ (37,051,325.28)
61	$ 2,989,072.27	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ 2,989,072.27	$ 126,969.29	$ 2,862,102.98	$ (34,189,222.30)
62	$ -	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ -	$ 126,969.29	$ (126,969.29)	$ (34,316,191.59)
63	$ -	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ -	$ 126,969.29	$ (126,969.29)	$ (34,443,160.89)
64	$ -	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ -	$ 126,969.29	$ (126,969.29)	$ (34,570,130.18)
65	$ -	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ -	$ 126,969.29	$ (126,969.29)	$ (34,697,099.47)
66	$ -	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ -	$ 126,969.29	$ (126,969.29)	$ (34,824,068.76)
67	$ -	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ -	$ 126,969.29	$ (126,969.29)	$ (34,951,038.05)
68	$ -	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ -	$ 126,969.29	$ (126,969.29)	$ (35,078,007.35)

69	$ -	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ -	$ 126,969.29	$ (126,969.29)	$ (35,204,976.64)
70	$ -	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ -	$ 126,969.29	$ (126,969.29)	$ (35,331,945.93)
71	$ -	$ 37,227.39	$ -	$ 126,969.29	$ -	$ -	$ -	$ 126,969.29	$ (126,969.29)	$ (35,458,915.22)
72	$ -	$ 37,227.39	$ -	$ 126,969.29	$ 110,408.08	$ 26,059.17	$ -	$ 263,436.55	$ (263,436.55)	$ (35,722,351.77)
73	$ 3,078,744.44	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ 3,078,744.44	$ 129,508.68	$ 2,949,235.76	$ (32,773,116.01)
74	$ -	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ -	$ 129,508.68	$ (129,508.68)	$ (32,902,624.69)
75	$ -	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ -	$ 129,508.68	$ (129,508.68)	$ (33,032,133.36)
76	$ -	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ -	$ 129,508.68	$ (129,508.68)	$ (33,161,642.04)
77	$ -	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ -	$ 129,508.68	$ (129,508.68)	$ (33,291,150.72)
78	$ -	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ -	$ 129,508.68	$ (129,508.68)	$ (33,420,659.40)
79	$ -	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ -	$ 129,508.68	$ (129,508.68)	$ (33,550,168.08)
80	$ -	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ -	$ 129,508.68	$ (129,508.68)	$ (33,679,676.75)
81	$ -	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ -	$ 129,508.68	$ (129,508.68)	$ (33,809,185.43)
82	$ -	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ -	$ 129,508.68	$ (129,508.68)	$ (33,938,694.11)
83	$ -	$ 37,537.62	$ -	$ 129,508.68	$ -	$ -	$ -	$ 129,508.68	$ (129,508.68)	$ (34,068,202.79)
84	$ -	$ 37,537.62	$ -	$ 129,508.68	$ 112,616.24	$ 26,276.33	$ -	$ 268,401.25	$ (268,401.25)	$ (34,336,604.04)
85	$ 3,171,106.77	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ 3,171,106.77	$ 132,098.85	$ 3,039,007.92	$ (31,297,596.12)
86	$ -	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ -	$ 132,098.85	$ (132,098.85)	$ (31,429,694.97)
87	$ -	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ -	$ 132,098.85	$ (132,098.85)	$ (31,561,793.82)
88	$ -	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ -	$ 132,098.85	$ (132,098.85)	$ (31,693,892.67)
89	$ -	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ -	$ 132,098.85	$ (132,098.85)	$ (31,825,991.53)
90	$ -	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ -	$ 132,098.85	$ (132,098.85)	$ (31,958,090.38)
91	$ -	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ -	$ 132,098.85	$ (132,098.85)	$ (32,090,189.23)
92	$ -	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ -	$ 132,098.85	$ (132,098.85)	$ (32,222,288.08)
93	$ -	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ -	$ 132,098.85	$ (132,098.85)	$ (32,354,386.93)
94	$ -	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ -	$ 132,098.85	$ (132,098.85)	$ (32,486,485.79)
95	$ -	$ 37,850.43	$ -	$ 132,098.85	$ -	$ -	$ -	$ 132,098.85	$ (132,098.85)	$ (32,618,584.64)
96	$ -	$ 37,850.43	$ -	$ 132,098.85	$ 114,868.57	$ 26,495.30	$ -	$ 273,462.72	$ (273,462.72)	$ (32,892,047.36)
97	$ 3,266,239.98	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ 3,266,239.98	$ 134,740.83	$ 3,131,499.15	$ (29,760,548.21)
98	$ -	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ -	$ 134,740.83	$ (134,740.83)	$ (29,895,289.04)
99	$ -	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ -	$ 134,740.83	$ (134,740.83)	$ (30,030,029.87)
100	$ -	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ -	$ 134,740.83	$ (134,740.83)	$ (30,164,770.70)
101	$ -	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ -	$ 134,740.83	$ (134,740.83)	$ (30,299,511.52)
102	$ -	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ -	$ 134,740.83	$ (134,740.83)	$ (30,434,252.35)
103	$ -	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ -	$ 134,740.83	$ (134,740.83)	$ (30,568,993.18)
104	$ -	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ -	$ 134,740.83	$ (134,740.83)	$ (30,703,734.01)
105	$ -	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ -	$ 134,740.83	$ (134,740.83)	$ (30,838,474.84)
106	$ -	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ -	$ 134,740.83	$ (134,740.83)	$ (30,973,215.67)
107	$ -	$ 38,165.85	$ -	$ 134,740.83	$ -	$ -	$ -	$ 134,740.83	$ (134,740.83)	$ (31,107,956.50)
108	$ -	$ 38,165.85	$ -	$ 134,740.83	$ 117,165.94	$ 26,716.10	$ -	$ 278,622.86	$ (278,622.86)	$ (31,386,579.36)
109	$ 3,364,227.18	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ 3,364,227.18	$ 137,435.65	$ 3,226,791.53	$ (28,159,787.83)
110	$ -	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ -	$ 137,435.65	$ (137,435.65)	$ (28,297,223.47)
111	$ -	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ -	$ 137,435.65	$ (137,435.65)	$ (28,434,659.12)
112	$ -	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ -	$ 137,435.65	$ (137,435.65)	$ (28,572,094.76)
113	$ -	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ -	$ 137,435.65	$ (137,435.65)	$ (28,709,530.41)
114	$ -	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ -	$ 137,435.65	$ (137,435.65)	$ (28,846,966.06)
115	$ -	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ -	$ 137,435.65	$ (137,435.65)	$ (28,984,401.70)
116	$ -	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ -	$ 137,435.65	$ (137,435.65)	$ (29,121,837.35)
117	$ -	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ -	$ 137,435.65	$ (137,435.65)	$ (29,259,272.99)
118	$ -	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ -	$ 137,435.65	$ (137,435.65)	$ (29,396,708.64)
119	$ -	$ 38,483.90	$ -	$ 137,435.65	$ -	$ -	$ -	$ 137,435.65	$ (137,435.65)	$ (29,534,144.28)
120	$ -	$ 38,483.90	$ -	$ 137,435.65	$ 119,509.26	$ 26,938.73	$ -	$ 283,883.63	$ (283,883.63)	$ (29,818,027.92)
121	$ 3,465,153.99	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ 3,465,153.99	$ 140,184.36	$ 3,324,969.63	$ (26,493,058.28)
122	$ -	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ -	$ 140,184.36	$ (140,184.36)	$ (26,633,242.64)
123	$ -	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ -	$ 140,184.36	$ (140,184.36)	$ (26,773,427.00)
124	$ -	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ -	$ 140,184.36	$ (140,184.36)	$ (26,913,611.36)
125	$ -	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ -	$ 140,184.36	$ (140,184.36)	$ (27,053,795.71)
126	$ -	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ -	$ 140,184.36	$ (140,184.36)	$ (27,193,980.07)
127	$ -	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ -	$ 140,184.36	$ (140,184.36)	$ (27,334,164.43)
128	$ -	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ -	$ 140,184.36	$ (140,184.36)	$ (27,474,348.79)
129	$ -	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ -	$ 140,184.36	$ (140,184.36)	$ (27,614,533.15)
130	$ -	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ -	$ 140,184.36	$ (140,184.36)	$ (27,754,717.51)
131	$ -	$ 38,804.60	$ -	$ 140,184.36	$ -	$ -	$ -	$ 140,184.36	$ (140,184.36)	$ (27,894,901.86)
132	$ -	$ 38,804.60	$ -	$ 140,184.36	$ 121,899.44	$ 27,163.22	$ -	$ 289,247.02	$ (289,247.02)	$ (28,184,148.88)
133	$ 3,569,108.61	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ 3,569,108.61	$ 142,988.05	$ 3,426,120.57	$ (24,758,028.32)
134	$ -	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ -	$ 142,988.05	$ (142,988.05)	$ (24,901,016.36)
135	$ -	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ -	$ 142,988.05	$ (142,988.05)	$ (25,044,004.41)
136	$ -	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ -	$ 142,988.05	$ (142,988.05)	$ (25,186,992.45)
137	$ -	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ -	$ 142,988.05	$ (142,988.05)	$ (25,329,980.50)
138	$ -	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ -	$ 142,988.05	$ (142,988.05)	$ (25,472,968.54)
139	$ -	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ -	$ 142,988.05	$ (142,988.05)	$ (25,615,956.59)
140	$ -	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ -	$ 142,988.05	$ (142,988.05)	$ (25,758,944.64)
141	$ -	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ -	$ 142,988.05	$ (142,988.05)	$ (25,901,932.68)
142	$ -	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ -	$ 142,988.05	$ (142,988.05)	$ (26,044,920.73)
143	$ -	$ 39,127.97	$ -	$ 142,988.05	$ -	$ -	$ -	$ 142,988.05	$ (142,988.05)	$ (26,187,908.77)
144	$ -	$ 39,127.97	$ -	$ 142,988.05	$ 124,337.43	$ 27,389.58	$ -	$ 294,715.06	$ (294,715.06)	$ (26,482,623.83)
145	$ 3,676,181.87	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ 3,676,181.87	$ 145,847.81	$ 3,530,334.06	$ (22,952,289.76)
146	$ -	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ -	$ 145,847.81	$ (145,847.81)	$ (23,098,137.57)

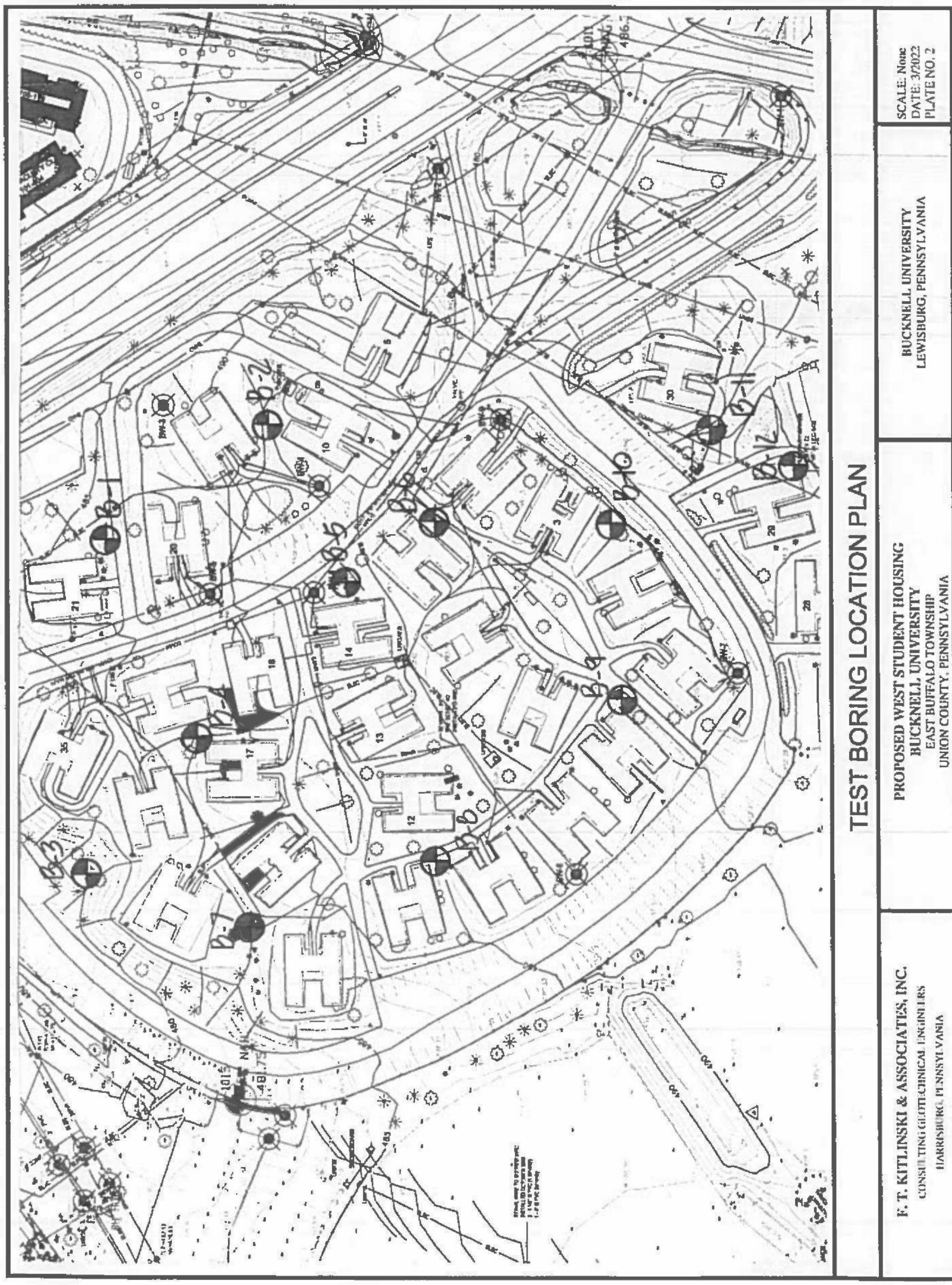
147	$ -	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ -	$ 145,847.81	$ (145,847.81)	$ (23,243,985.38)
148	$ -	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ -	$ 145,847.81	$ (145,847.81)	$ (23,389,833.18)
149	$ -	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ -	$ 145,847.81	$ (145,847.81)	$ (23,535,680.99)
150	$ -	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ -	$ 145,847.81	$ (145,847.81)	$ (23,681,528.80)
151	$ -	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ -	$ 145,847.81	$ (145,847.81)	$ (23,827,376.60)
152	$ -	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ -	$ 145,847.81	$ (145,847.81)	$ (23,973,224.41)
153	$ -	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ -	$ 145,847.81	$ (145,847.81)	$ (24,119,072.22)
154	$ -	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ -	$ 145,847.81	$ (145,847.81)	$ (24,264,920.02)
155	$ -	$ 39,454.04	$ -	$ 145,847.81	$ -	$ -	$ -	$ 145,847.81	$ (145,847.81)	$ (24,410,767.83)
156	$ -	$ 39,454.04	$ -	$ 145,847.81	$ 126,824.18	$ 27,617.83	$ -	$ 300,289.81	$ (300,289.81)	$ (24,711,057.64)
157	$ 3,786,467.33	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ 3,786,467.33	$ 148,764.76	$ 3,637,702.56	$ (21,073,355.08)
158	$ -	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ -	$ 148,764.76	$ (148,764.76)	$ (21,222,119.84)
159	$ -	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ -	$ 148,764.76	$ (148,764.76)	$ (21,370,884.60)
160	$ -	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ -	$ 148,764.76	$ (148,764.76)	$ (21,519,649.36)
161	$ -	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ -	$ 148,764.76	$ (148,764.76)	$ (21,668,414.13)
162	$ -	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ -	$ 148,764.76	$ (148,764.76)	$ (21,817,178.89)
163	$ -	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ -	$ 148,764.76	$ (148,764.76)	$ (21,965,943.65)
164	$ -	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ -	$ 148,764.76	$ (148,764.76)	$ (22,114,708.41)
165	$ -	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ -	$ 148,764.76	$ (148,764.76)	$ (22,263,473.18)
166	$ -	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ -	$ 148,764.76	$ (148,764.76)	$ (22,412,237.94)
167	$ -	$ 39,782.82	$ -	$ 148,764.76	$ -	$ -	$ -	$ 148,764.76	$ (148,764.76)	$ (22,561,002.70)
168	$ -	$ 39,782.82	$ -	$ 148,764.76	$ 129,360.66	$ 27,847.98	$ -	$ 305,973.40	$ (305,973.40)	$ (22,866,976.10)
169	$ 3,900,061.35	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ 3,900,061.35	$ 151,740.06	$ 3,748,321.29	$ (19,118,654.81)
170	$ -	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ -	$ 151,740.06	$ (151,740.06)	$ (19,270,394.87)
171	$ -	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ -	$ 151,740.06	$ (151,740.06)	$ (19,422,134.93)
172	$ -	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ -	$ 151,740.06	$ (151,740.06)	$ (19,573,874.99)
173	$ -	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ -	$ 151,740.06	$ (151,740.06)	$ (19,725,615.04)
174	$ -	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ -	$ 151,740.06	$ (151,740.06)	$ (19,877,355.10)
175	$ -	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ -	$ 151,740.06	$ (151,740.06)	$ (20,029,095.16)
176	$ -	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ -	$ 151,740.06	$ (151,740.06)	$ (20,180,835.22)
177	$ -	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ -	$ 151,740.06	$ (151,740.06)	$ (20,332,575.28)
178	$ -	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ -	$ 151,740.06	$ (151,740.06)	$ (20,484,315.33)
179	$ -	$ 40,114.35	$ -	$ 151,740.06	$ -	$ -	$ -	$ 151,740.06	$ (151,740.06)	$ (20,636,055.39)
180	$ -	$ 40,114.35	$ -	$ 151,740.06	$ 131,947.88	$ 28,080.04	$ -	$ 311,767.98	$ (311,767.98)	$ (20,947,823.37)
181	$ 4,017,063.19	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ 4,017,063.19	$ 154,774.86	$ 3,862,288.33	$ (17,085,535.04)
182	$ -	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ -	$ 154,774.86	$ (154,774.86)	$ (17,240,309.90)
183	$ -	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ -	$ 154,774.86	$ (154,774.86)	$ (17,395,084.76)
184	$ -	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ -	$ 154,774.86	$ (154,774.86)	$ (17,549,859.62)
185	$ -	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ -	$ 154,774.86	$ (154,774.86)	$ (17,704,634.47)
186	$ -	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ -	$ 154,774.86	$ (154,774.86)	$ (17,859,409.33)
187	$ -	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ -	$ 154,774.86	$ (154,774.86)	$ (18,014,184.19)
188	$ -	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ -	$ 154,774.86	$ (154,774.86)	$ (18,168,959.05)
189	$ -	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ -	$ 154,774.86	$ (154,774.86)	$ (18,323,733.91)
190	$ -	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ -	$ 154,774.86	$ (154,774.86)	$ (18,478,508.77)
191	$ -	$ 40,448.63	$ -	$ 154,774.86	$ -	$ -	$ -	$ 154,774.86	$ (154,774.86)	$ (18,633,283.63)
192	$ -	$ 40,448.63	$ -	$ 154,774.86	$ 134,586.83	$ 28,314.04	$ -	$ 317,675.73	$ (317,675.73)	$ (18,950,959.36)
193	$ 4,137,575.08	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ 4,137,575.08	$ 157,870.36	$ 3,979,704.73	$ (14,971,254.64)
194	$ -	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ -	$ 157,870.36	$ (157,870.36)	$ (15,129,124.99)
195	$ -	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ -	$ 157,870.36	$ (157,870.36)	$ (15,286,995.35)
196	$ -	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ -	$ 157,870.36	$ (157,870.36)	$ (15,444,865.70)
197	$ -	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ -	$ 157,870.36	$ (157,870.36)	$ (15,602,736.06)
198	$ -	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ -	$ 157,870.36	$ (157,870.36)	$ (15,760,606.42)
199	$ -	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ -	$ 157,870.36	$ (157,870.36)	$ (15,918,476.77)
200	$ -	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ -	$ 157,870.36	$ (157,870.36)	$ (16,076,347.13)
201	$ -	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ -	$ 157,870.36	$ (157,870.36)	$ (16,234,217.48)
202	$ -	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ -	$ 157,870.36	$ (157,870.36)	$ (16,392,087.84)
203	$ -	$ 40,785.70	$ -	$ 157,870.36	$ -	$ -	$ -	$ 157,870.36	$ (157,870.36)	$ (16,549,958.20)
204	$ -	$ 40,785.70	$ -	$ 157,870.36	$ 137,278.57	$ 28,549.99	$ -	$ 323,698.92	$ (323,698.92)	$ (16,873,657.12)
205	$ 4,261,702.34	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ 4,261,702.34	$ 161,027.76	$ 4,100,674.57	$ (12,772,982.54)
206	$ -	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ -	$ 161,027.76	$ (161,027.76)	$ (12,934,010.31)
207	$ -	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ -	$ 161,027.76	$ (161,027.76)	$ (13,095,038.07)
208	$ -	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ -	$ 161,027.76	$ (161,027.76)	$ (13,256,065.83)
209	$ -	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ -	$ 161,027.76	$ (161,027.76)	$ (13,417,093.60)
210	$ -	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ -	$ 161,027.76	$ (161,027.76)	$ (13,578,121.36)
211	$ -	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ -	$ 161,027.76	$ (161,027.76)	$ (13,739,149.12)
212	$ -	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ -	$ 161,027.76	$ (161,027.76)	$ (13,900,176.89)
213	$ -	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ -	$ 161,027.76	$ (161,027.76)	$ (14,061,204.65)
214	$ -	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ -	$ 161,027.76	$ (161,027.76)	$ (14,222,232.41)
215	$ -	$ 41,125.58	$ -	$ 161,027.76	$ -	$ -	$ -	$ 161,027.76	$ (161,027.76)	$ (14,383,260.18)
216	$ -	$ 41,125.58	$ -	$ 161,027.76	$ 140,024.14	$ 28,787.91	$ -	$ 329,839.81	$ (329,839.81)	$ (14,713,099.99)
217	$ 4,389,553.41	$ 41,468.30	$ -	$ 164,248.32	$ -	$ -	$ 4,389,553.41	$ 164,248.32	$ 4,225,305.09	$ (10,487,794.90)
218	$ -	$ 41,468.30	$ -	$ 164,248.32	$ -	$ -	$ -	$ 164,248.32	$ (164,248.32)	$ (10,652,043.22)
219	$ -	$ 41,468.30	$ -	$ 164,248.32	$ -	$ -	$ -	$ 164,248.32	$ (164,248.32)	$ (10,816,291.54)
220	$ -	$ 41,468.30	$ -	$ 164,248.32	$ -	$ -	$ -	$ 164,248.32	$ (164,248.32)	$ (10,980,539.86)
221	$ -	$ 41,468.30	$ -	$ 164,248.32	$ -	$ -	$ -	$ 164,248.32	$ (164,248.32)	$ (11,144,788.18)
222	$ -	$ 41,468.30	$ -	$ 164,248.32	$ -	$ -	$ -	$ 164,248.32	$ (164,248.32)	$ (11,309,036.50)
223	$ -	$ 41,468.30	$ -	$ 164,248.32	$ -	$ -	$ -	$ 164,248.32	$ (164,248.32)	$ (11,473,284.81)
224	$ -	$ 41,468.30	$ -	$ 164,248.32	$ -	$ -	$ -	$ 164,248.32	$ (164,248.32)	$ (11,637,533.13)

225	-	41,468.30	-	164,248.32	-	-	-	164,248.32	(164,248.32)	(11,801,781.45)
226	-	41,468.30	-	164,248.32	-	-	-	164,248.32	(164,248.32)	(11,966,029.77)
227	-	41,468.30	-	164,248.32	-	-	-	164,248.32	(164,248.32)	(12,130,278.09)
228	-	41,468.30	-	164,248.32	142,824.62	29,027.81	-	336,100.75	(336,100.75)	(12,466,378.84)
229	4,521,240.01	41,813.87	-	167,533.28	-	-	4,521,240.01	167,533.28	4,353,706.72	(8,112,672.12)
230	-	41,813.87	-	167,533.28	-	-	-	167,533.28	(167,533.28)	(8,280,205.40)
231	-	41,813.87	-	167,533.28	-	-	-	167,533.28	(167,533.28)	(8,447,738.69)
232	-	41,813.87	-	167,533.28	-	-	-	167,533.28	(167,533.28)	(8,615,271.97)
233	-	41,813.87	-	167,533.28	-	-	-	167,533.28	(167,533.28)	(8,782,805.26)
234	-	41,813.87	-	167,533.28	-	-	-	167,533.28	(167,533.28)	(8,950,338.54)
235	-	41,813.87	-	167,533.28	-	-	-	167,533.28	(167,533.28)	(9,117,871.83)
236	-	41,813.87	-	167,533.28	-	-	-	167,533.28	(167,533.28)	(9,285,405.11)
237	-	41,813.87	-	167,533.28	-	-	-	167,533.28	(167,533.28)	(9,452,938.40)
238	-	41,813.87	-	167,533.28	-	-	-	167,533.28	(167,533.28)	(9,620,471.68)
239	-	41,813.87	-	167,533.28	-	-	-	167,533.28	(167,533.28)	(9,788,004.97)
240	-	41,813.87	-	167,533.28	145,681.12	29,269.71	-	342,484.11	(342,484.11)	(10,130,489.07)
241	4,656,877.21	42,162.32	-	170,883.95	-	-	4,656,877.21	170,883.95	4,485,993.26	(5,644,495.82)
242	-	42,162.32	-	170,883.95	-	-	-	170,883.95	(170,883.95)	(5,815,379.77)
243	-	42,162.32	-	170,883.95	-	-	-	170,883.95	(170,883.95)	(5,986,263.72)
244	-	42,162.32	-	170,883.95	-	-	-	170,883.95	(170,883.95)	(6,157,147.67)
245	-	42,162.32	-	170,883.95	-	-	-	170,883.95	(170,883.95)	(6,328,031.62)
246	-	42,162.32	-	170,883.95	-	-	-	170,883.95	(170,883.95)	(6,498,915.57)
247	-	42,162.32	-	170,883.95	-	-	-	170,883.95	(170,883.95)	(6,669,799.52)
248	-	42,162.32	-	170,883.95	-	-	-	170,883.95	(170,883.95)	(6,840,683.47)
249	-	42,162.32	-	170,883.95	-	-	-	170,883.95	(170,883.95)	(7,011,567.42)
250	-	42,162.32	-	170,883.95	-	-	-	170,883.95	(170,883.95)	(7,182,451.37)
251	-	42,162.32	-	170,883.95	-	-	-	170,883.95	(170,883.95)	(7,353,335.32)
252	-	42,162.32	-	170,883.95	148,594.74	29,513.62	-	348,992.31	(348,992.31)	(7,702,327.63)
253	4,796,583.52	42,513.67	-	174,301.63	-	-	4,796,583.52	174,301.63	4,622,281.89	(3,080,045.74)
254	-	42,513.67	-	174,301.63	-	-	-	174,301.63	(174,301.63)	(3,254,347.37)
255	-	42,513.67	-	174,301.63	-	-	-	174,301.63	(174,301.63)	(3,428,649.00)
256	-	42,513.67	-	174,301.63	-	-	-	174,301.63	(174,301.63)	(3,602,950.63)
257	-	42,513.67	-	174,301.63	-	-	-	174,301.63	(174,301.63)	(3,777,252.26)
258	-	42,513.67	-	174,301.63	-	-	-	174,301.63	(174,301.63)	(3,951,553.89)
259	-	42,513.67	-	174,301.63	-	-	-	174,301.63	(174,301.63)	(4,125,855.52)
260	-	42,513.67	-	174,301.63	-	-	-	174,301.63	(174,301.63)	(4,300,157.15)
261	-	42,513.67	-	174,301.63	-	-	-	174,301.63	(174,301.63)	(4,474,458.78)
262	-	42,513.67	-	174,301.63	-	-	-	174,301.63	(174,301.63)	(4,648,760.41)
263	-	42,513.67	-	174,301.63	-	-	-	174,301.63	(174,301.63)	(4,823,062.04)
264	-	42,513.67	-	174,301.63	151,566.63	29,759.57	-	355,627.83	(355,627.83)	(5,178,689.87)
265	4,940,481.03	42,867.95	-	177,787.66	-	-	4,940,481.03	177,787.66	4,762,693.37	(415,996.50)
266	-	42,867.95	-	177,787.66	-	-	-	177,787.66	(177,787.66)	(593,784.16)
267	-	42,867.95	-	177,787.66	-	-	-	177,787.66	(177,787.66)	(771,571.82)
268	-	42,867.95	-	177,787.66	-	-	-	177,787.66	(177,787.66)	(949,359.49)
269	-	42,867.95	-	177,787.66	-	-	-	177,787.66	(177,787.66)	(1,127,147.15)
270	-	42,867.95	-	177,787.66	-	-	-	177,787.66	(177,787.66)	(1,304,934.81)
271	-	42,867.95	-	177,787.66	-	-	-	177,787.66	(177,787.66)	(1,482,722.47)
272	-	42,867.95	-	177,787.66	-	-	-	177,787.66	(177,787.66)	(1,660,510.13)
273	-	42,867.95	-	177,787.66	-	-	-	177,787.66	(177,787.66)	(1,838,297.80)
274	-	42,867.95	-	177,787.66	-	-	-	177,787.66	(177,787.66)	(2,016,085.46)
275	-	42,867.95	-	177,787.66	-	-	-	177,787.66	(177,787.66)	(2,193,873.12)
276	-	42,867.95	-	177,787.66	154,597.97	30,007.56	-	362,393.19	(362,393.19)	(2,556,266.31)
277	5,088,695.46	43,225.18	-	181,343.42	-	-	5,088,695.46	181,343.42	4,907,352.04	2,351,085.73
278	-	43,225.18	-	181,343.42	-	-	-	181,343.42	(181,343.42)	2,169,742.32
279	-	43,225.18	-	181,343.42	-	-	-	181,343.42	(181,343.42)	1,988,398.90
280	-	43,225.18	-	181,343.42	-	-	-	181,343.42	(181,343.42)	1,807,055.48
281	-	43,225.18	-	181,343.42	-	-	-	181,343.42	(181,343.42)	1,625,712.07
282	-	43,225.18	-	181,343.42	-	-	-	181,343.42	(181,343.42)	1,444,368.65
283	-	43,225.18	-	181,343.42	-	-	-	181,343.42	(181,343.42)	1,263,025.24
284	-	43,225.18	-	181,343.42	-	-	-	181,343.42	(181,343.42)	1,081,681.82
285	-	43,225.18	-	181,343.42	-	-	-	181,343.42	(181,343.42)	900,338.41
286	-	43,225.18	-	181,343.42	-	-	-	181,343.42	(181,343.42)	718,994.99
287	-	43,225.18	-	181,343.42	-	-	-	181,343.42	(181,343.42)	537,651.58
288	-	43,225.18	-	181,343.42	157,689.93	30,257.63	-	369,290.97	(369,290.97)	168,360.61
289	5,241,356.32	43,585.39	-	184,970.28	-	-	5,241,356.32	184,970.28	5,056,386.04	5,224,746.65
290	-	43,585.39	-	184,970.28	-	-	-	184,970.28	(184,970.28)	5,039,776.36
291	-	43,585.39	-	184,970.28	-	-	-	184,970.28	(184,970.28)	4,854,806.08
292	-	43,585.39	-	184,970.28	-	-	-	184,970.28	(184,970.28)	4,669,835.80
293	-	43,585.39	-	184,970.28	-	-	-	184,970.28	(184,970.28)	4,484,865.51
294	-	43,585.39	-	184,970.28	-	-	-	184,970.28	(184,970.28)	4,299,895.23
295	-	43,585.39	-	184,970.28	-	-	-	184,970.28	(184,970.28)	4,114,924.95
296	-	43,585.39	-	184,970.28	-	-	-	184,970.28	(184,970.28)	3,929,954.66
297	-	43,585.39	-	184,970.28	-	-	-	184,970.28	(184,970.28)	3,744,984.38
298	-	43,585.39	-	184,970.28	-	-	-	184,970.28	(184,970.28)	3,560,014.09
299	-	43,585.39	-	184,970.28	-	-	-	184,970.28	(184,970.28)	3,375,043.81
300	-	43,585.39	-	184,970.28	160,843.72	30,509.77	-	376,323.78	(376,323.78)	2,998,720.03
301	5,398,597.01	43,948.60	-	188,669.69	-	-	5,398,597.01	188,669.69	5,209,927.32	8,208,647.35
302	-	43,948.60	-	188,669.69	-	-	-	188,669.69	(188,669.69)	8,019,977.66

303	$ -	$ 43,948.60	$ -	$ 188,669.69	$ -	$ -	$ -	$ 188,669.69	$ (188,669.69)	$ 7,831,307.97
304	$ -	$ 43,948.60	$ -	$ 188,669.69	$ -	$ -	$ -	$ 188,669.69	$ (188,669.69)	$ 7,642,638.28
305	$ -	$ 43,948.60	$ -	$ 188,669.69	$ -	$ -	$ -	$ 188,669.69	$ (188,669.69)	$ 7,453,968.60
306	$ -	$ 43,948.60	$ -	$ 188,669.69	$ -	$ -	$ -	$ 188,669.69	$ (188,669.69)	$ 7,265,298.91
307	$ -	$ 43,948.60	$ -	$ 188,669.69	$ -	$ -	$ -	$ 188,669.69	$ (188,669.69)	$ 7,076,629.22
308	$ -	$ 43,948.60	$ -	$ 188,669.69	$ -	$ -	$ -	$ 188,669.69	$ (188,669.69)	$ 6,887,959.53
309	$ -	$ 43,948.60	$ -	$ 188,669.69	$ -	$ -	$ -	$ 188,669.69	$ (188,669.69)	$ 6,699,289.84
310	$ -	$ 43,948.60	$ -	$ 188,669.69	$ -	$ -	$ -	$ 188,669.69	$ (188,669.69)	$ 6,510,620.15
311	$ -	$ 43,948.60	$ -	$ 188,669.69	$ -	$ -	$ -	$ 188,669.69	$ (188,669.69)	$ 6,321,950.46
312	$ -	$ 43,948.60	$ -	$ 188,669.69	$ 164,060.60	$ 30,764.02	$ -	$ 383,494.31	$ (383,494.31)	$ 5,938,456.15
313	$ 5,560,554.92	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ 5,560,554.92	$ 192,443.08	$ 5,368,111.84	$ 11,306,567.99
314	$ -	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ -	$ 192,443.08	$ (192,443.08)	$ 11,114,124.91
315	$ -	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ -	$ 192,443.08	$ (192,443.08)	$ 10,921,681.82
316	$ -	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ -	$ 192,443.08	$ (192,443.08)	$ 10,729,238.74
317	$ -	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ -	$ 192,443.08	$ (192,443.08)	$ 10,536,795.66
318	$ -	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ -	$ 192,443.08	$ (192,443.08)	$ 10,344,352.57
319	$ -	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ -	$ 192,443.08	$ (192,443.08)	$ 10,151,909.49
320	$ -	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ -	$ 192,443.08	$ (192,443.08)	$ 9,959,466.41
321	$ -	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ -	$ 192,443.08	$ (192,443.08)	$ 9,767,023.32
322	$ -	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ -	$ 192,443.08	$ (192,443.08)	$ 9,574,580.24
323	$ -	$ 44,314.84	$ -	$ 192,443.08	$ -	$ -	$ -	$ 192,443.08	$ (192,443.08)	$ 9,382,137.16
324	$ -	$ 44,314.84	$ -	$ 192,443.08	$ 167,341.81	$ 31,020.39	$ -	$ 390,805.28	$ (390,805.28)	$ 8,991,331.87
325	$ 5,727,371.57	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ 5,727,371.57	$ 196,291.94	$ 5,531,079.63	$ 14,522,411.50
326	$ -	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ -	$ 196,291.94	$ (196,291.94)	$ 14,326,119.56
327	$ -	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ -	$ 196,291.94	$ (196,291.94)	$ 14,129,827.61
328	$ -	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ -	$ 196,291.94	$ (196,291.94)	$ 13,933,535.67
329	$ -	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ -	$ 196,291.94	$ (196,291.94)	$ 13,737,243.72
330	$ -	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ -	$ 196,291.94	$ (196,291.94)	$ 13,540,951.78
331	$ -	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ -	$ 196,291.94	$ (196,291.94)	$ 13,344,659.83
332	$ -	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ -	$ 196,291.94	$ (196,291.94)	$ 13,148,367.89
333	$ -	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ -	$ 196,291.94	$ (196,291.94)	$ 12,952,075.94
334	$ -	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ -	$ 196,291.94	$ (196,291.94)	$ 12,755,784.00
335	$ -	$ 44,684.13	$ -	$ 196,291.94	$ -	$ -	$ -	$ 196,291.94	$ (196,291.94)	$ 12,559,492.05
336	$ -	$ 44,684.13	$ -	$ 196,291.94	$ 170,688.65	$ 31,278.89	$ -	$ 398,259.48	$ (398,259.48)	$ 12,161,232.57
337	$ 5,899,192.72	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ 5,899,192.72	$ 200,217.78	$ 5,698,974.94	$ 17,860,207.50
338	$ -	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ -	$ 200,217.78	$ (200,217.78)	$ 17,659,989.72
339	$ -	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ -	$ 200,217.78	$ (200,217.78)	$ 17,459,771.94
340	$ -	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ -	$ 200,217.78	$ (200,217.78)	$ 17,259,554.15
341	$ -	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ -	$ 200,217.78	$ (200,217.78)	$ 17,059,336.37
342	$ -	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ -	$ 200,217.78	$ (200,217.78)	$ 16,859,118.59
343	$ -	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ -	$ 200,217.78	$ (200,217.78)	$ 16,658,900.80
344	$ -	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ -	$ 200,217.78	$ (200,217.78)	$ 16,458,683.02
345	$ -	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ -	$ 200,217.78	$ (200,217.78)	$ 16,258,465.23
346	$ -	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ -	$ 200,217.78	$ (200,217.78)	$ 16,058,247.45
347	$ -	$ 45,056.50	$ -	$ 200,217.78	$ -	$ -	$ -	$ 200,217.78	$ (200,217.78)	$ 15,858,029.67
348	$ -	$ 45,056.50	$ -	$ 200,217.78	$ 174,102.42	$ 31,539.55	$ -	$ 405,859.75	$ (405,859.75)	$ 15,452,169.91
349	$ 6,076,168.50	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ 6,076,168.50	$ 204,222.14	$ 5,871,946.36	$ 21,324,116.27
350	$ -	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ -	$ 204,222.14	$ (204,222.14)	$ 21,119,894.13
351	$ -	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ -	$ 204,222.14	$ (204,222.14)	$ 20,915,672.00
352	$ -	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ -	$ 204,222.14	$ (204,222.14)	$ 20,711,449.86
353	$ -	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ -	$ 204,222.14	$ (204,222.14)	$ 20,507,227.72
354	$ -	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ -	$ 204,222.14	$ (204,222.14)	$ 20,303,005.58
355	$ -	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ -	$ 204,222.14	$ (204,222.14)	$ 20,098,783.44
356	$ -	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ -	$ 204,222.14	$ (204,222.14)	$ 19,894,561.30
357	$ -	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ -	$ 204,222.14	$ (204,222.14)	$ 19,690,339.16
358	$ -	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ -	$ 204,222.14	$ (204,222.14)	$ 19,486,117.02
359	$ -	$ 45,431.97	$ -	$ 204,222.14	$ -	$ -	$ -	$ 204,222.14	$ (204,222.14)	$ 19,281,894.88
360	$ -	$ 45,431.97	$ -	$ 204,222.14	$ 177,584.47	$ 31,802.38	$ -	$ 413,608.99	$ (413,608.99)	$ 18,868,285.89
361	$ 6,258,453.56	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ 6,258,453.56	$ 208,306.58	$ 6,050,146.97	$ 24,918,432.87
362	$ -	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ -	$ 208,306.58	$ (208,306.58)	$ 24,710,126.28
363	$ -	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ -	$ 208,306.58	$ (208,306.58)	$ 24,501,819.70
364	$ -	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ -	$ 208,306.58	$ (208,306.58)	$ 24,293,513.12
365	$ -	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ -	$ 208,306.58	$ (208,306.58)	$ 24,085,206.54
366	$ -	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ -	$ 208,306.58	$ (208,306.58)	$ 23,876,899.96
367	$ -	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ -	$ 208,306.58	$ (208,306.58)	$ 23,668,593.37
368	$ -	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ -	$ 208,306.58	$ (208,306.58)	$ 23,460,286.79
369	$ -	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ -	$ 208,306.58	$ (208,306.58)	$ 23,251,980.21
370	$ -	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ -	$ 208,306.58	$ (208,306.58)	$ 23,043,673.63
371	$ -	$ 45,810.57	$ -	$ 208,306.58	$ -	$ -	$ -	$ 208,306.58	$ (208,306.58)	$ 22,835,367.04
372	$ -	$ 45,810.57	$ -	$ 208,306.58	$ 181,136.16	$ 32,067.40	$ -	$ 421,510.14	$ (421,510.14)	$ 22,413,856.90
373	$ 6,446,207.16	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ 6,446,207.16	$ 212,472.71	$ 6,233,734.45	$ 28,647,591.35
374	$ -	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ -	$ 212,472.71	$ (212,472.71)	$ 28,435,118.64
375	$ -	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ -	$ 212,472.71	$ (212,472.71)	$ 28,222,645.93
376	$ -	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ -	$ 212,472.71	$ (212,472.71)	$ 28,010,173.21
377	$ -	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ -	$ 212,472.71	$ (212,472.71)	$ 27,797,700.50
378	$ -	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ -	$ 212,472.71	$ (212,472.71)	$ 27,585,227.78
379	$ -	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ -	$ 212,472.71	$ (212,472.71)	$ 27,372,755.07
380	$ -	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ -	$ 212,472.71	$ (212,472.71)	$ 27,160,282.36

381	$ -	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ -	$ 212,472.71	$ (212,472.71)	$ 26,947,809.64
382	$ -	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ -	$ 212,472.71	$ (212,472.71)	$ 26,735,336.93
383	$ -	$ 46,192.32	$ -	$ 212,472.71	$ -	$ -	$ -	$ 212,472.71	$ (212,472.71)	$ 26,522,864.22
384	$ -	$ 46,192.32	$ -	$ 212,472.71	$ 184,758.88	$ 32,334.63	$ -	$ 429,566.22	$ (429,566.22)	$ 26,093,297.99
385	$ 6,639,593.38	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ 6,639,593.38	$ 216,722.17	$ 6,422,871.21	$ 32,516,169.20
386	$ -	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ -	$ 216,722.17	$ (216,722.17)	$ 32,299,447.03
387	$ -	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ -	$ 216,722.17	$ (216,722.17)	$ 32,082,724.87
388	$ -	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ -	$ 216,722.17	$ (216,722.17)	$ 31,866,002.70
389	$ -	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ -	$ 216,722.17	$ (216,722.17)	$ 31,649,280.53
390	$ -	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ -	$ 216,722.17	$ (216,722.17)	$ 31,432,558.36
391	$ -	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ -	$ 216,722.17	$ (216,722.17)	$ 31,215,836.19
392	$ -	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ -	$ 216,722.17	$ (216,722.17)	$ 30,999,114.03
393	$ -	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ -	$ 216,722.17	$ (216,722.17)	$ 30,782,391.86
394	$ -	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ -	$ 216,722.17	$ (216,722.17)	$ 30,565,669.69
395	$ -	$ 46,577.26	$ -	$ 216,722.17	$ -	$ -	$ -	$ 216,722.17	$ (216,722.17)	$ 30,348,947.52
396	$ -	$ 46,577.26	$ -	$ 216,722.17	$ 188,454.06	$ 32,604.08	$ -	$ 437,780.31	$ (437,780.31)	$ 29,911,167.21
397	$ 6,838,781.18	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ 6,838,781.18	$ 221,056.61	$ 6,617,724.57	$ 36,528,891.78
398	$ -	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ -	$ 221,056.61	$ (221,056.61)	$ 36,307,835.17
399	$ -	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ -	$ 221,056.61	$ (221,056.61)	$ 36,086,778.56
400	$ -	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ -	$ 221,056.61	$ (221,056.61)	$ 35,865,721.94
401	$ -	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ -	$ 221,056.61	$ (221,056.61)	$ 35,644,665.33
402	$ -	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ -	$ 221,056.61	$ (221,056.61)	$ 35,423,608.72
403	$ -	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ -	$ 221,056.61	$ (221,056.61)	$ 35,202,552.11
404	$ -	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ -	$ 221,056.61	$ (221,056.61)	$ 34,981,495.50
405	$ -	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ -	$ 221,056.61	$ (221,056.61)	$ 34,760,438.89
406	$ -	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ -	$ 221,056.61	$ (221,056.61)	$ 34,539,382.27
407	$ -	$ 46,965.40	$ -	$ 221,056.61	$ -	$ -	$ -	$ 221,056.61	$ (221,056.61)	$ 34,318,325.66
408	$ -	$ 46,965.40	$ -	$ 221,056.61	$ 192,223.14	$ 32,875.78	$ -	$ 446,155.54	$ (446,155.54)	$ 33,872,170.13
409	$ 7,043,944.61	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ 7,043,944.61	$ 225,477.74	$ 6,818,466.87	$ 40,690,637.00
410	$ -	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ -	$ 225,477.74	$ (225,477.74)	$ 40,465,159.25
411	$ -	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ -	$ 225,477.74	$ (225,477.74)	$ 40,239,681.51
412	$ -	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ -	$ 225,477.74	$ (225,477.74)	$ 40,014,203.77
413	$ -	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ -	$ 225,477.74	$ (225,477.74)	$ 39,788,726.02
414	$ -	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ -	$ 225,477.74	$ (225,477.74)	$ 39,563,248.28
415	$ -	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ -	$ 225,477.74	$ (225,477.74)	$ 39,337,770.54
416	$ -	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ -	$ 225,477.74	$ (225,477.74)	$ 39,112,292.79
417	$ -	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ -	$ 225,477.74	$ (225,477.74)	$ 38,886,815.05
418	$ -	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ -	$ 225,477.74	$ (225,477.74)	$ 38,661,337.31
419	$ -	$ 47,356.78	$ -	$ 225,477.74	$ -	$ -	$ -	$ 225,477.74	$ (225,477.74)	$ 38,435,859.56
420	$ -	$ 47,356.78	$ -	$ 225,477.74	$ 196,067.60	$ 33,149.75	$ -	$ 454,695.10	$ (454,695.10)	$ 37,981,164.47
421	$ 7,255,262.95	$ 47,751.42	$ -	$ 229,987.30	$ -	$ -	$ 7,255,262.95	$ 229,987.30	$ 7,025,275.65	$ 45,006,440.12

APPENDIX B: Boring Logs and Soil Profiles



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Project Name & Location: Proposed West Student Housing Bucknell University, East Buffalo Township Union County, Pennsylvania	**Boring No:** B-1 **Ground Surface Elevation:** +/- 486.0'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 15, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 15, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 10.7'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/15/22	10.7'	Dry	0

		Soil Sampling Data			Rock Coring Data				
	Material Description & Remarks	No.	Depth Interval (Feet)	Spoon Blows Per 6 Inches	Run No.	Depth Interval (Feet)	Recovery (Feet)	RQD (feet)	NOTES
0.0' to 0.4'	Brown topsoil - moist	1	0.0'- 2.0'	3-4-4-4					Continuous sampling to 7.3'
0.4' to 6.5'	Brown clayey silt w/ a little sand & limestone gravel – moist – soft to med. stiff	2 3	2.0'- 4.0' 4.0'- 6.0'	4-4-3-2 5-2-2-3					No groundwater encountered
6.5' to 7.5'	Grey highly weathered limestone – moist – dense to v. dense	4 5	6.0'- 7.3' 8.0'- 9.6'	3-30-50/0.3 6-3-52-50/0.1					Spoon refusals at 7.3' and 9.6'
7.5' to 9.0'	Brown clayey silt w/ limestone gravel – highly decomposed limestone – wet - soft								Auger refusal at 10.7'
9.0' to 10.7'	Grey highly weathered limestone – dry – v. dense								End of boring at 10.7'

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Project Name & Location: Proposed West Student Housing Bucknell University, East Buffalo Township Union County, Pennsylvania	**Boring No:** B-2 **Ground Surface Elevation:** +/- 491.0'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 15, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 15, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 15.8'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/15/22	15.8'	Dry	0

		Soil Sampling Data			Rock Coring Data				
	Material Description & Remarks	**No.**	**Depth Interval (Feet)**	**Spoon Blows Per 6 Inches**	**Run No.**	**Depth Interval (Feet)**	**Recovery (Feet)**	**RQD (feet)**	**NOTES**
0.0' to 0.3'	Brown topsoil - moist	1	0.0'- 2.0'	2-3-4-4					Continuous sampling of overburden
0.3' to 0.7'	Brown sandy silt w/ a little clay – moist - loose	2 3	2.0'- 4.0' 4.0'- 6.0'	4-4-7-9 5-7-7-9					
0.7' to 7.5'	Brown clayey silt w/ a little sand & limestone gravel – moist – med. stiff to stiff	4 5	6.0'-8.0' 8.0'- 10.0'	4-4-5-7 4-8-8-23					No groundwater encountered
7.5' to 9.5'	Brown sandy silt w/ weathered limestone gravel – v. moist – med. dense	6 7	10.0'- 12.0' 12.0'- 13.8'	10-22-25-31 25-44-48-50/0.3					Spoon refusals at 13.8' and 15.8'
9.5' to 15.8'	Brown sandy silt/silty sand and decomposed limestone gravel – moist to v. moist – dense to v. dense	8	14.0'- 15.8'	5-20-22-50/0.3					Auger refusal at 15.8'
									End of boring at 15.8'

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Project Name & Location: Proposed West Student Housing, Bucknell University, East Buffalo Township, Union County, Pennsylvania	**Boring No:** B-3 **Ground Surface Elevation:** +/- 482.0'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University, Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 14, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 14, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 22.0'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/14/22	22.0'	Dry	0

		Soil Sampling Data			Rock Coring Data				
	Material Description & Remarks	No.	Depth Interval (Feet)	Spoon Blows Per 6 Inches	Run No.	Depth Interval (Feet)	Recovery (Feet)	RQD (feet)	NOTES
0.0' to 2.5'	Brown topsoil mixed w/ silt & sand - moist	1	0.0'- 2.0'	2-4-4-3					Continuous sampling of overburden
2.5' to 10.0'	Brown & grey clayey silt w/ a little sand – moist – med. stiff to v. stiff	2 3	2.0'- 4.0' 4.0'- 6.0'	3-4-6-6 10-7-8-7					
		4 5	6.0'-8.0' 8.0'- 10.0'	7-9-12-14 4-9-12-16					No groundwater encountered
10.0' to 12.0'	Brown clayey silt w/ some sand & weathered limestone gravel – moist – med. dense	6 7	10.0'- 12.0' 12.0'- 14.0'	5-7-11-13 10-9-9-10					No durable bedrock encountered
12.0' to 14.0'	Brown clayey silt w/ some sand – moist – v. stiff	8 9	14.0'- 16.0' 16.0'- 18.0'	5-4-5-6 5-4-4-11					
14.0' to 20.5'	Brown clayey sandy silt w/ some weathered limestone gravel – moist – med. stiff to stiff	10 11	18.0'- 20.0' 20.0'- 22.0'	3-7-6-8 6-33-15-16					Advanced augers to 18.0'
20.5' to 22.0'	Grey highly weathered/ decomposed limestone – moist – med. dense to dense								End of boring at 22.0'

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Project Name & Location: Proposed West Student Housing, Bucknell University, East Buffalo Township, Union County, Pennsylvania	**Boring No:** B-4 **Ground Surface Elevation:** +/- 489.0'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University, Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 15, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 15, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 16.5'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/15/22	16.5'	Dry	0

	Material Description & Remarks	Soil Sampling Data			Rock Coring Data				
		No.	Depth Interval (Feet)	Spoon Blows Per 6 Inches	Run No.	Depth Interval (Feet)	Recovery (Feet)	RQD (feet)	NOTES
0.0' to 6.5'	Brown topsoil mixed w/ brown silt & sand – moist – loose to med. dense	1	0.0'- 2.0'	2-3-3-4					Continuous sampling of overburden
6.5' to 9.0'	Brown clayey silt w/ fine limestone gravel – moist – stiff to v. stiff	2 3	2.0'- 4.0' 4.0'- 6.0'	5-4-4-5 5-5-6-9					
9.0' to 11.0'	Brown sandy silt – decomposed limestone gravel – moist – med. dense	4 5	6.0'-8.0' 8.0'- 10.0'	6-11-9-12 4-7-10-11					No groundwater encountered
11.0' to 14.0'	Brown clayey silt w/ some sand & decomposed limestone gravel – moist to v. moist – med. stiff to stiff	6 7	10.0'- 12.0' 12.0'- 14.0'	6-6-3-4 4-5-7-12					
14.0' to 16.0'	Brown sandy silt and decomposed limestone gravel – moist – med. dense	8 9	14.0'- 16.0' 16.0'- 16.3'	9-10-11-19 50/0.3					Spoon refusal at 16.3'
16.0' to 16.3'	Brown highly weathered limestone – moist – v. dense								Auger refusal at 16.5'
									End of boring at 16.5'

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Project Name & Location: Proposed West Student Housing Bucknell University, East Buffalo Township Union County, Pennsylvania	**Boring No:** B-5 **Ground Surface Elevation:** +/- 493.0'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 15, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 15, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 8.0'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/15/22	8.0'	Dry	0

		Soil Sampling Data			Rock Coring Data				
	Material Description & Remarks	No.	Depth Interval (Feet)	Spoon Blows Per 6 Inches	Run No.	Depth Interval (Feet)	Recovery (Feet)	RQD (feet)	NOTES
0.0' to 0.2'	Brown topsoil - moist	1	0.0'- 2.0'	1-2-3-6					Continuous sampling of overburden
0.2' to 1.5'	Brown clayey silt w/ a little fine gravel – moist – soft	2 3	2.0'- 4.0' 4.0'- 6.0'	5-6-6-6 4-4-4-3					No groundwater encountered
1.5' to 7.5'	Brown clayey silt and decomposed limestone gravel – moist – stiff/loose	4	6.0'- 7.7'	3-6-5-50/0.2					Spoon refusal at 7.2'
7.5' to 8.0'	Grey highly weathered limestone – moist – v. dense								Auger refusal at 8.0'
									End of boring at 8.0'

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Project Name & Location: Proposed West Student Housing Bucknell University, East Buffalo Township Union County, Pennsylvania	**Boring No:** B-6 **Ground Surface Elevation:** +/- 492.5'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 15, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 15, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 14.1'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/15/22	14.1'	Caved/Dry at 10.5'	0

		Soil Sampling Data			Rock Coring Data				
	Material Description & Remarks	No.	Depth Interval (Feet)	Spoon Blows Per 6 Inches	Run No.	Depth Interval (Feet)	Recovery (Feet)	RQD (feet)	NOTES
0.0' to 0.4'	Brown topsoil – moist	1	0.0'- 2.0'	2-5-4-5					Continuous sampling of overburden
0.4' to 4.5'	Brown clayey silt w/ a little fine gravel – moist – med. stiff	2 3	2.0'- 4.0' 4.0'- 6.0'	5-3-6-7 5-6-10-13					
4.5' to 8.0'	Brown clayey sandy silt w/ limestone gravel – moist – med. dense	4 5	6.0'-8.0' 8.0'- 10.0'	10-13-14-16 5-3-4-4					No groundwater encountered
8.0' to 14.0'	Brown clayey silt w/ a little sand & decomposed limestone gravel – moist to v. moist – v. soft to soft	6 7	10.0'- 12.0' 12.0'- 14.0'	1-2-1-3 3-2-3-10					Difficult augering 13.5' to 14.0'
14.0' to 14.1'	Grey weathered limestone – moist – v. dense								Auger refusal at 14.1' – 0.1' long core of limestone in augers
									End of boring at 14.1'

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Project Name & Location: Proposed West Student Housing, Bucknell University, East Buffalo Township, Union County, Pennsylvania	**Boring No:** B-7 **Ground Surface Elevation:** +/- 487.0'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University, Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 14, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 14, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 17.5'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/14/22	17.5'	Caved/Dry at 12.5'	0

	Material Description & Remarks	Soil Sampling Data: No.	Depth Interval (Feet)	Spoon Blows Per 6 Inches	Rock Coring Data: Run No.	Depth Interval (Feet)	Recovery (Feet)	RQD (feet)	NOTES
0.0' to 0.6'	Brown topsoil – moist	1	0.0'- 2.0'	2-2-4-3					Continuous sampling of overburden
0.6' to 1.5'	Fill: Brown silty sand/sandy silt w/ some gravel – moist – v. loose	2 3	2.0'- 4.0' 4.0'- 6.0'	4-4-6-7 3-4-5-6					
1.5' to 6.0'	Brown clayey silt w/ some sand – little gravel – moist – med. stiff	4 5	6.0'-8.0' 8.0'- 10.0'	5-5-5-5 5-6-6-7					No groundwater encountered
6.0' to 11.5'	Brown sandy silt w/ some decomposed limestone gravel – moist to v. moist - loose	6 7	10.0'- 12.0' 12.0'- 14.0'	3-3-4-16 2-5-16-11					Spoon refusal at 17.1'
11.5' to 13.0'	Brown silty sand & limestone gravel – dry - dense	8 9	14.0'- 16.0' 16.0'- 17.1'	5-13-18-15 7-24-50/0.1					Auger refusal at 17.5'
13.0' to 17.5'	Brown highly weathered/ decomposed limestone – relic bedding structure – dry – med. dense to v. dense								End of boring at 17.5'

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Project Name & Location: Proposed West Student Housing Bucknell University, East Buffalo Township Union County, Pennsylvania	**Boring No:** B-8 **Ground Surface Elevation:** +/- 493.0'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 14, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 14, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 15.5'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/14/22	15.5'	Caved/Dry at 9.0'	0

		Soil Sampling Data			Rock Coring Data				
	Material Description & Remarks	No.	Depth Interval (Feet)	Spoon Blows Per 6 Inches	Run No.	Depth Interval (Feet)	Recovery (Feet)	RQD (feet)	NOTES
0.0' to 0.4'	Brown topsoil – moist	1	0.0'- 2.0'	2-3-4-5					Continuous sampling of overburden
0.4' to 8.0'	Fill: Brown fine sandy silt w/ some clay and decomposed limestone gravel – moist – loose to med. dense	2 3	2.0'- 4.0' 4.0'- 6.0'	5-6-6-6 4-3-3-5					No groundwater encountered
8.0' to 12.0'	Brown clayey silt w/ some sand – moist soft/loose to med. stiff/loose	4 5	6.0'-8.0' 8.0'- 10.0'	2-3-4-6 3-2-3-3					
12.0' to 15.5'	Grey highly weathered/ decomposed limestone dry to moist – med. dense to v. dense	6 7	10.0'- 12.0' 12.0'- 13.3'	3-5-5-3 14-56-50/0.3					Spoon refusal at 13.3' Auger refusal at 15.5'
									End of boring at 15.5'

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Project Name & Location: Proposed West Student Housing Bucknell University, East Buffalo Township Union County, Pennsylvania	**Boring No:** B-9 **Ground Surface Elevation:** +/- 491.5'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 14, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 14, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 18.5'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/14/22	18.5'	Caved/Dry at 14.8'	0

	Material Description & Remarks	Soil Sampling Data: No.	Depth Interval (Feet)	Spoon Blows Per 6 Inches	Rock Coring Data: Run No.	Depth Interval (Feet)	Recovery (Feet)	RQD (feet)	NOTES
0.0' to 0.4'	Brown topsoil – moist	1	0.0'- 2.0'	3-3-4-4					Continuous sampling of overburden
0.4' to 2.0'	Fill: Brown clayey silt w/ a little organic material – moist – med. stiff	2 3	2.0'- 4.0' 4.0'- 6.0'	3-3-9-8 10-6-6-6					
2.0' to 6.0'	Brown clayey sandy silt w/ some decomposed limestone gravel – moist – med. stiff to stiff	4 5	6.0'-8.0' 8.0'- 10.0'	6-5-6-6 3-3-5-5					Soil wet from 6.0' to 8.0'
6.0' to 8.0'	Brown clayey silt w/ a little fine gravel – wet – soft to med. stiff	6 7	10.0'- 12.0' 12.0'- 14.0'	3-3-3-3 2-2-2-2					WOH = weight of hammer
8.0' to 17.0'	Brown, dark brown & grey silty sand w/ highly decomposed limestone gravel – v. moist to wet – v. soft to med. stiff	8 9	14.0'- 16.0' 16.0'- 17.6'	2-1-WOH-1 1-1-16-50/0.1					Spoon refusal at 17.6' Auger refusal at 18.5'
17.0' to 18.5'	Grey highly weathered limestone – dry – v. dense								End of boring at 18.5'

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Project Name & Location: Proposed West Student Housing Bucknell University, East Buffalo Township Union County, Pennsylvania	**Boring No:** B-10 **Ground Surface Elevation:** +/- 490.5'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 14, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 14, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 23.7'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/14/22	23.7'	Caved/Dry at 15.0'	0

	Material Description & Remarks	Soil Sampling Data: No.	Depth Interval (Feet)	Spoon Blows Per 6 Inches	Rock Coring Data: Run No.	Depth Interval (Feet)	Recovery (Feet)	RQD (feet)	NOTES
0.0' to 0.4'	Brown topsoil – moist	1	0.0'- 2.0'	2-3-3-4					Continuous sampling of overburden
0.4' to 1.5'	Fill: Brown sandy clayey silt w/ some cinders – loose/ med. stiff	2 3	2.0'- 4.0' 4.0'- 6.0'	4-6-4-6 12-8-8-10					
1.5' to 7.0'	Dark brown & grey clayey silt w/ a little sand – moist – med. stiff to stiff	4 5	6.0'-8.0' 8.0'- 10.0'	7-8-12-12 4-9-13-15					
7.0' to 14.0'	Dark brown & brown clayey sandy clayey silt w/ decomposed limestone gravel – moist to v. moist – stiff to v. stiff	6 7	10.0'- 12.0' 12.0'- 14.0'	8-8-7-6 10-9-7-6					
14.0' to 21.0'	Brown sandy silt w/ a little clay and fine decomposed limestone gravel – moist to v. moist – v. loose to loose/ v. soft to soft	8 9	14.0'- 16.0' 16.0'- 18.0'	1-1-1-2 1-2-1-2					Advanced augers to 22.0'
21.0' to 23.0'	Brown clayey silt – moist to v. moist - stiff	10 11	18.0'- 20.0' 20.0'- 22.0'	2-3-2-4 3-3-4-5					Spoon refusal at 23.7'
23.0' to 23.7'	Grey weathered limestone – moist – dense to v. dense	12	22.0'- 23.7'	6-8-22-50/0.2					End of boring at 23.7'

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Project Name & Location: Proposed West Student Housing Bucknell University, East Buffalo Township Union County, Pennsylvania	**Boring No:** B-11 **Ground Surface Elevation:** +/- 485.0'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 15, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 15, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 10.0'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/15/22	10.0'	Caved/Dry at 8.0'	0

		Soil Sampling Data			Rock Coring Data				
	Material Description & Remarks	**No.**	**Depth Interval (Feet)**	**Spoon Blows Per 6 Inches**	**Run No.**	**Depth Interval (Feet)**	**Recovery (Feet)**	**RQD (feet)**	**NOTES**
0.0' to 0.4'	Brown topsoil - moist	1	0.0'- 2.0'	1-2-3-3					Continuous sampling of overburden
0.4' to 4.5'	Fill: Brown sandy silt w/ some coarse sandstone gravel and cinders – moist - loose	2 3	2.0'- 4.0' 4.0'- 6.0'	3-4-2-5 3-16-15-14					May be pushing cobble ahead of spoon Sample Nos. 3 and 4
4.5' to 10.0'	Brown clayey silt w/ a little sand and fine gravel – moist - hard	4 5	6.0'- 8.0' 8.0'- 10.0'	10-14-15-22 6-10-14-24					Advanced augers to 8.0'
									End of boring at 10.0'

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Project Name & Location: Proposed West Student Housing Bucknell University, East Buffalo Township Union County, Pennsylvania	**Boring No:** B-12 **Ground Surface Elevation:** +/- 486.0'
Project No.: 22-02-10990	**Sheet** 1 **of** 1
Client: Bucknell University Lewisburg, Pennsylvania	**Boring Location:** As Shown on Plan
Date Started: March 15, 2022	**Casing:** 3.25" I.D. HSA
Date Completed: : March 15, 2022	**Casing Hammer Weight:**
Total Boring Depth (ft): 10.0'	**Casing Hammer Drop:**
Driller & Drilling Co.: Eichelbergers, Inc.	**Spoon Sampler O.D. X I.D.:** 2.00"
Drilling Rig Model & No.: Dietrich D50 Track	**Sampling Hammer Weight:** 140 pounds
Weather: Clear - Mild	**Sampling Hammer Drop:** 30"
	Core Bit Type & Size: NQ2-2"

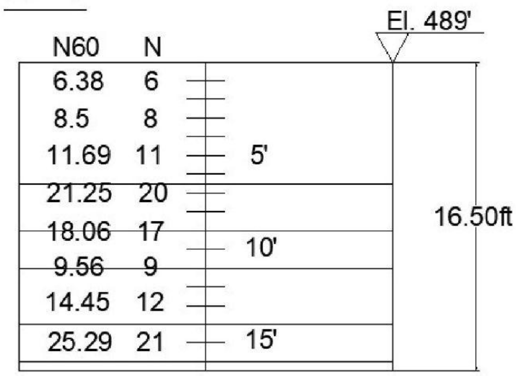
Drilling Progress & Ground Water Data

Date	Depth Reached	Depth to Water	Hour
3/15/22	10.0'	Caved/Dry at 3.0'	0

		Soil Sampling Data			Rock Coring Data				
	Material Description & Remarks	**No.**	**Depth Interval (Feet)**	**Spoon Blows Per 6 Inches**	**Run No.**	**Depth Interval (Feet)**	**Recovery (Feet)**	**RQD (feet)**	**NOTES**
0.0' to 0.3'	Brown topsoil - moist	1	0.0'- 2.0'	2-3-4-6					Continuous sampling of overburden
0.3' to 1.5'	Fill: Brown sandy silt/ silty sand w/ some cinders – moist – med. stiff	2 3	2.0'- 4.0' 4.0'- 6.0'	7-5-4-6 3-4-7-12					Advanced augers to 8.0'
1.5' to 4.0'	Brown clayey silt w/ a little sand – moist – med. stiff	4 5	6.0'- 8.0' 8.0'- 10.0'	5-8-9-9 10-8-10-11					Sample No. 5 wet 9.5' to 10.0'
4.0' to 10.0'	Brown and dark brown silty sand – moist to v. moist – loose to med. dense								End of boring at 10.0'

Multi-Story Residential Building: Boring Log B-4 SPT Values

B-4



$N_1 := 6$

$N_2 := 8$

$N_3 := 11$

$N_4 := 20$

$N_5 := 17$

$N_6 := 9$

$N_7 := 12$

$N_8 := 21$

Hammer Efficiency: $\eta_h := 85$

assuming automatic hammer based on rig model.

Borehole Diameter Correction:
$\eta_b := 1$ assuming standard borehole diameter

Sampler Liner Correction: $\eta_s := 1$

assuming standard sampler (no liner)

Rod Length Correction:
$\eta_{R1} := 0.75$ (up to 13 feet)

$\eta_{R2} := 0.85$ (13- 20 feet)

Converting N to N60 Values

$$N60_1 := N_1 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 6.375$$

$$N60_2 := N_2 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 8.5$$

$$N60_3 := N_3 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 11.6875$$

$$N60_4 := N_4 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 21.25$$

$$N60_5 := N_5 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 18.0625$$

$$N60_6 := N_6 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 9.5625$$

$$N60_7 := N_7 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R2} = 14.45$$

$$N60_8 := N_8 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R2} = 25.2875$$

Finding a Normalized Blow Count, denoted by $N_{1.60}$

Overburden Correction Factor C_N using Liao and Whitman (1986):

Atmospheric Pressure: $p_a := 1.06 \frac{\text{tonf}}{\text{ft}^2}$

Standard Overburden Pressure: $\sigma'_{vo} := 1 \frac{\text{tonf}}{\text{ft}^2}$

Overburden Correction Factor $C_N := \sqrt{\frac{p_a}{\sigma'_{vo}}} = 1.0296$

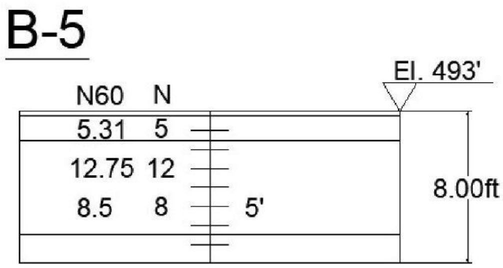
Normalized Blow Count at embedment depth of foundation: $N_{1.60} := C_N \cdot N60_3 = 12.033$

Estimating Friction Angle of Soil from Normalized Blow Count (graphically estimated by Pect et. al (1974) but approximated by Wolff (1989):

$\phi' := 27.1 + 0.3 \cdot N_{1.60} - 0.00054 \cdot \left(N_{1.60}\right)^2 = 30.6317$ (in Degrees)

Estimating unit weight for a cohesionless soil:

$\gamma_{moist} := 107 + 0.95 \cdot N60_3 = 118.1031$ (lb/ft^3)



$N_1 := 5$

$N_2 := 12$

$N_3 := 8$

Hammer Efficiency: $\eta_h := 85$
assuming automatic hammer based on rig model.

Borehole Diameter Correction:
$\eta_b := 1$ assuming standard borehole diameter

Sampler Liner Correction: $\eta_s := 1$
assuming standard sampler (no liner)

Rod Length Correction:
$\eta_{R1} := 0.75$ (up to 13 feet)
$\eta_{R2} := 0.85$ (13- 20 feet)

Converting N to N60 Values

$$N60_1 := N_1 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 5.3125$$

$$N60_2 := N_2 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 12.75$$

$$N60_3 := N_3 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 8.5$$

Finding a Normalized Blow Count, denoted by $N_{1.60}$
Overburden Correction Factor C_N using Liao and Whitman (1986):

Atmospheric Pressure: $p_a := 1.06 \ \frac{\text{tonf}}{\text{ft}^2}$

Standard Overburden Pressure: $\sigma'_{vo} := 1 \ \frac{\text{tonf}}{\text{ft}^2}$

Overburden Correction Factor $C_N := \sqrt{\frac{p_a}{\sigma'_{vo}}} = 1.0296$

Normalized Blow Count at embedment depth of foundation: $N_{1.60} := C_N \cdot N60_3 = 8.7513$

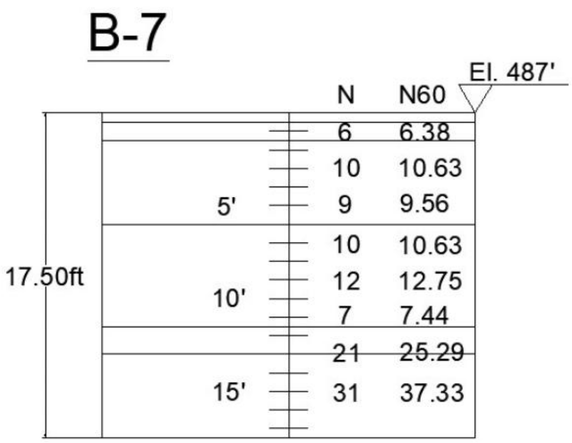
Estimating Friction Angle of Soil from Normalized Blow Count (graphically estimated by Pect et. al (1974) but approximated by Wolff (1989):

$$\phi' := 27.1 + 0.3 \cdot N_{1.60} - 0.00054 \cdot \left(N_{1.60}\right)^2 = 29.684 \text{ (deg)}$$

Estimating unit weight for a cohesionless soil:

$$\gamma_{moist} := 107 + 0.95 \cdot N60_3 = 115.075 \text{ (lb/ft^3)}$$

Multi-Story Residential Building: Boring Log B-7 SPT Values



$N_1 := 6$

$N_2 := 10$

$N_3 := 9$

$N_4 := 10$

$N_5 := 12$

$N_6 := 7$

$N_7 := 21$

$N_8 := 31$

Hammer Efficiency: $\eta_h := 85$
assuming automatic hammer based on rig model.

Borehole Diameter Correction:
$\eta_b := 1$ assuming standard borehole diameter

Sampler Liner Correction: $\eta_s := 1$
assuming standard sampler (no liner)

Rod Length Correction:
$\eta_{R1} := 0.75$ (up to 13 feet)
$\eta_{R2} := 0.85$ (13- 20 feet)

Converting N to N60 Values

$$N60_1 := N_1 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 6.375$$

$$N60_2 := N_2 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 10.625$$

$$N60_3 := N_3 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 9.5625$$

$$N60_4 := N_4 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 10.625$$

$$N60_5 := N_5 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 12.75$$

$$N60_6 := N_6 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 7.4375$$

$$N60_7 := N_7 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R2} = 25.2875$$

$$N60_8 := N_8 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R2} = 37.3292$$

Finding a Normalized Blow Count, denoted by $N_{1.60}$

Overburden Correction Factor C_n using Liao and Whitman (1986):

Atmospheric Pressure: $p_a := 1.06 \frac{\text{tonf}}{\text{ft}^2}$

Standard Overburden Pressure: $\sigma'_{vo} := 1 \frac{\text{tonf}}{\text{ft}^2}$

Overburden Correction Factor: $C_N := \sqrt{\frac{p_a}{\sigma'_{vo}}} = 1.0296$

Normalized Blow Count at embedment depth of foundation: $N_{1.60} := C_N \cdot N60_3 = 9.8452$

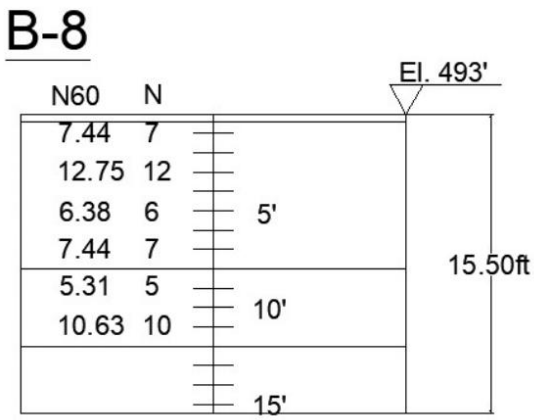
Estimating Friction Angle of Soil from Normalized Blow Count (graphically estimated by Pect et. al (1974) but approximated by Wolff (1989):

$\phi' := 27.1 + 0.3 \cdot N_{1.60} - 0.00054 \cdot \left(N_{1.60}\right)^2 = 30.0012$ (degrees)

Estimating unit weight for a cohesionless soil:

$\gamma := 107 + 0.95 \cdot N60_3 = 116.0844$ (lb/ft^3)

Multi-Story Residential Building: Boring Log B-8 SPT Values



$N_1 := 7$

$N_2 := 12$

$N_3 := 6$

$N_4 := 7$

$N_5 := 5$

$N_6 := 10$

Hammer Efficiency: $\eta_h := 85$

assuming automatic hammer based on rig model.

Borehole Diameter Correction:
$\eta_b := 1$ assuming standard borehole diameter

Sampler Liner Correction: $\eta_s := 1$

assuming standard sampler (no liner)

Rod Length Correction:
$\eta_{R1} := 0.75$ (up to 13 feet)

$\eta_{R2} := 0.85$ (13- 20 feet)

Converting N to N60 Values

$$N60_1 := N_1 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 7.4375$$

$$N60_2 := N_2 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 12.75$$

$$N60_3 := N_3 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 6.375$$

$$N60_4 := N_4 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 7.4375$$

$$N60_5 := N_5 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 5.3125$$

$$N60_6 := N_6 \cdot \frac{\eta_h}{60} \cdot \eta_b \cdot \eta_s \cdot \eta_{R1} = 10.625$$

Finding a Normalized Blow Count, denoted by $N_{1.60}$

Overburden Correction Factor C_N using Liao and Whitman (1986):

Atmospheric Pressure: $p_a := 1.06 \frac{\text{tonf}}{\text{ft}^2}$

Standard Overburden Pressure: $\sigma'_{vo} := 1 \frac{\text{tonf}}{\text{ft}^2}$

Overburden Correction Factor $C_N := \sqrt{\frac{p_a}{\sigma'_{vo}}} = 1.0296$

Normalized Blow Count at embedment depth of foundation: $N_{1.60} := C_N \cdot N60_3$

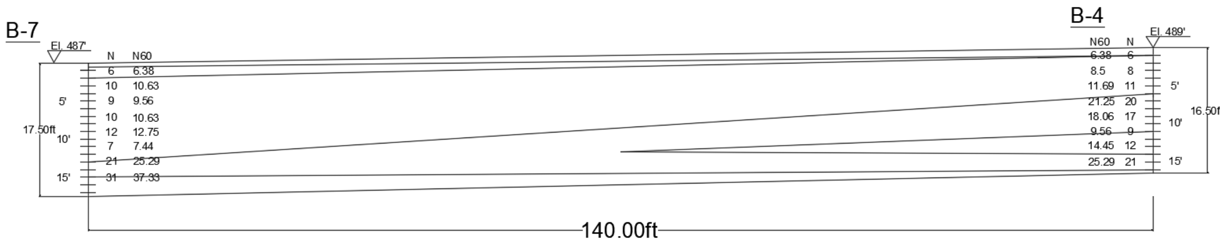
Estimating Friction Angle of Soil from Normalized Blow Count (graphically estimated by Pect et. al (1974) but approximated by Wolff (1989):

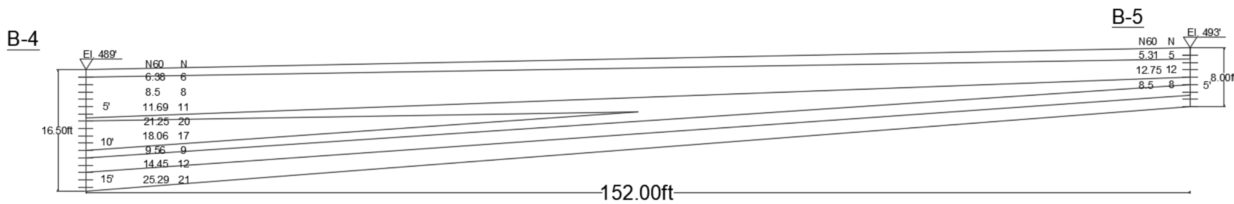
$\phi' := 27.1 + 0.3 \cdot N_{1.60} - 0.00054 \cdot \left(N_{1.60}\right)^2 = 29.0458$ (deg)

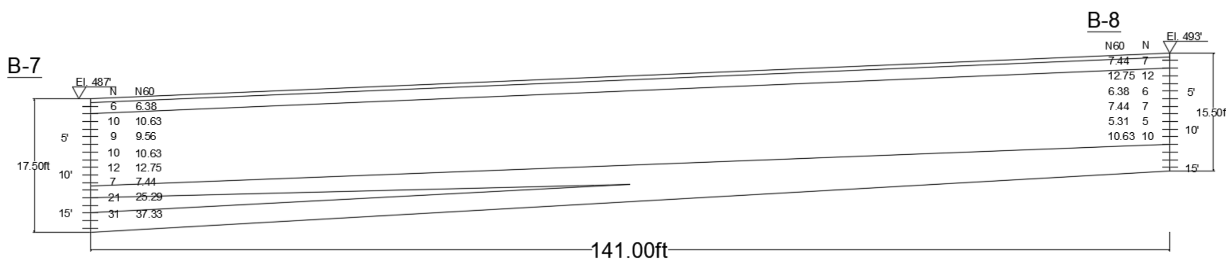
Estimating unit weight for a cohesionless soil:

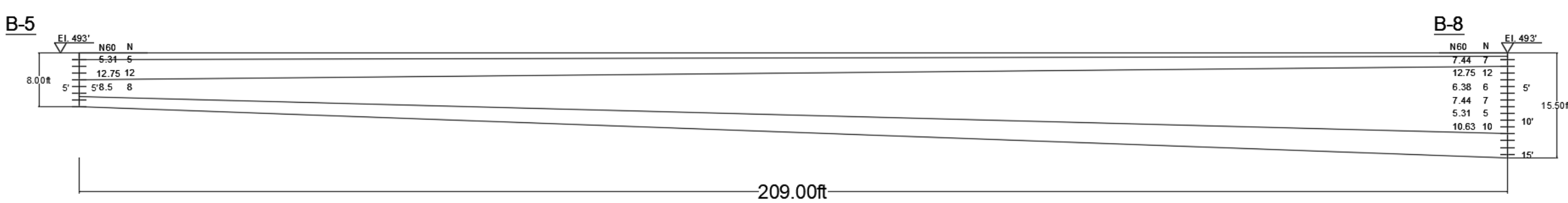
$\gamma_{moist} := 107 + 0.95 \cdot N60_3 = 113.0562$ (lb/ft^3)

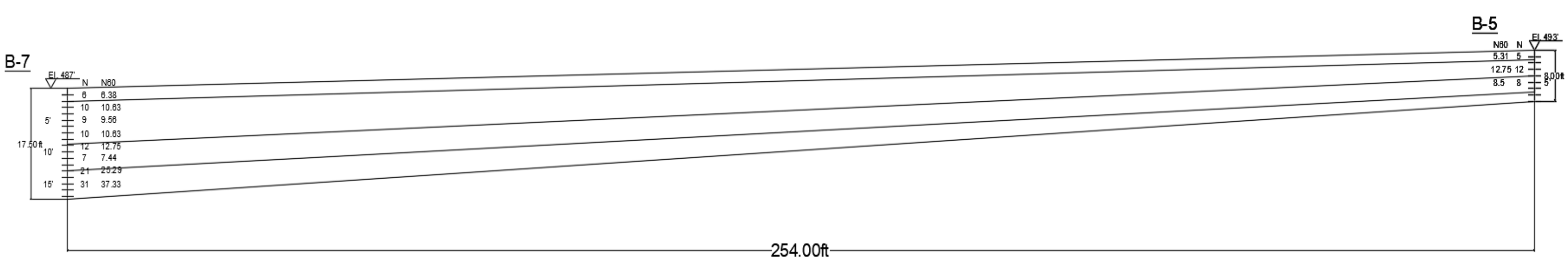
Soil Profiles For Relevant Boring Locations on Site:

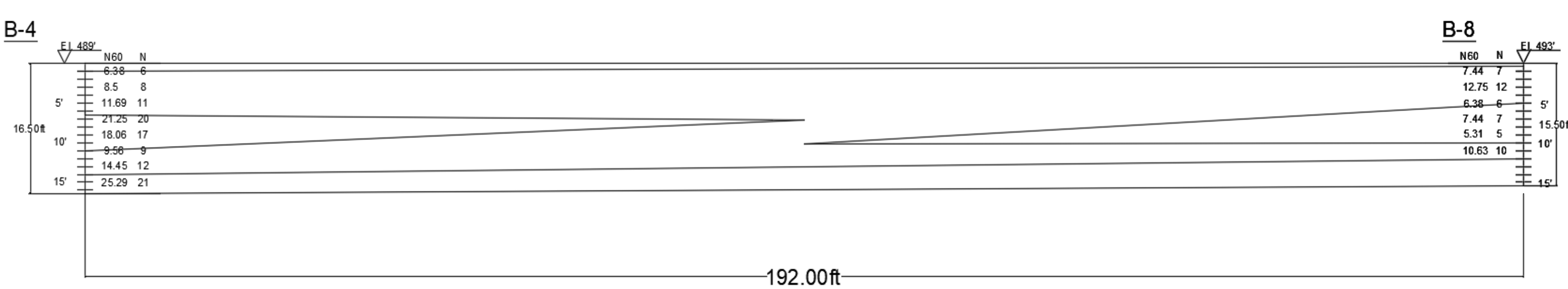












APPENDIX C: Relevant ordinances

- §400. General Requirements.
  - §400.1 All proposed uses should comply with the "Development Standards" contained in this Chapter. (Ordinance 293, January 22, 2007)
  - §400.2 All proposed uses shall comply with the applicable "Performance Standards" contained in this Chapter. Ordinance 293, January 22, 2007)
  - §400.3 All proposed uses shall comply with all other applicable Federal, State, County and Municipal Statutes, Regulations and Ordinances. Ordinance 293, January 22, 2007)
  - §400.4 All multifamily and nonresidential uses shall comply with the provisions of the East Buffalo Township Subdivision and Land Development Ordinance. (As Amended by Ordinance 369, adopted November 10, 2014)
- §407. Bucknell University (B-U).
  - §407.1 Permitted Uses
    - (b) University Owned or Operated Student Housing
  - §407.5 Maximum Height Requirements
    - (a) No structure, except as provided in this Chapter shall exceed 60 feet above the existing natural grade. (As amended by Ordinance 218, April 12, 1999; Ordinance 293, January 22, 2007)
  - §407.7 Minimum Setbacks
    - (a) Front Yard - 75 feet from the centerline of any public road or 50 feet from the edge of any public right of way, whichever is greater

APPENDIX D: Superstructure Calculations

Building Square - Foot Estimates

Measurements From South-Campus Apartments

- 4, 10ft x 12 ft rooms = 480 ft^2
- Kitchen, common area, and hallways = 450 ft^2
- Bathroom area = 144 ft^2

Total sq-ft of one apartment = 1194 ft^2 ≈ 1200 ft^2

Two Main Alternatives: 4 Story vs. 8 story

4 Story

- 20 apartments on floors 2,3,4
- 10 on floor 1 + common space

Each Floor Size

20 apartments x 1200 ft^2 = 24,000 ft^2

Assuming 80% of floor space is apartments:

each floor = 30,000 ft^2

Total Building sq-ft: $\boxed{120{,}000\ ft^2}$

8 Story

- 10 apartments on floors 2-8
- 0 apartments on floor 1; only Common space

Each Floor Size

10 apartments x 1200 ft^2 = 12,000 ft^2

Assuming 80% of floor space is apartments:

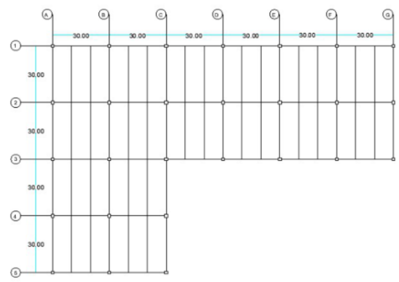
each floor = 30,000 ft^2

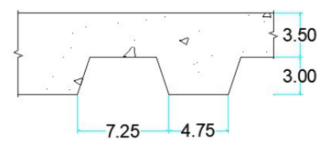
Total Building sq-ft: $\boxed{120{,}000\ ft^2}$

Roof Beam Design:

Multi-Story Residential Building: Beam Design Supporting Roof

Plan Supporting Roof:





Assumptions: composite floor decking, the beam is braced by the deck, deck flutes run parallel to the beams, deck is lightweight concrete $f'_c := 3$ ksi and the studs have a diameter , $d_{stud} := 0.75$ in with yield strength, $F_{ystud} := 65$ ksi , depth of concrete $Y_{conc} := 6.5$ in , $E_{steel} := 29000$ ksi

Loads:

Live Load $L_l := 20$ psf

Dead Load $L_d := 25$ psf

Snow Load $L_s := 61$ psf

Trib width, $w_{tr} := 10$ ft

Beam length, $L := 30$ ft

Center-center span, $s_c := 10$ ft

Distance to edge of slab, $d_{edge\_left} := 10$ ft

$d_{edge\_right} := 170$ ft

$A_t := w_{tr} \cdot 30\ \text{ft} = 300\ \text{ft}^2$

Reducing the Live Load:

$$L_{lr} := L_l \cdot \left(0.25 + \frac{15}{\sqrt{2 \cdot 300}}\right) = 17.2474\ \text{psf}$$

Factored Load Effects:

$w_d := w_{tr} \cdot L_d = 0.25$ ft ksf

$w_l := w_{tr} \cdot L_{lr} = 0.1725$ ft ksf

$w_s := w_{tr} \cdot L_s = 0.61$ ft ksf

$w_{u1} := 1.2 \cdot w_d + 1.6 \cdot w_l + 0.3 \cdot w_s = 0.759$ ft ksf

$w_{u2} := 1.2 \cdot w_d + 1.0 \cdot w_s + 1 \cdot w_l = 1.0825$ ft ksf

$w_u := \max\left(\left[\, w_{u1} \;\; w_{u2} \,\right]\right) = 1.0825$ ft ksf

$$M_u := \frac{w_u \cdot L^2}{8} = 121.7784\ \text{kip ft}$$

$$V_u := \frac{w_u \cdot L}{2} = 16.2371\ \text{kip}$$

Wet Concrete Load Effects (factoring the weight to account for uncertainty and incidental live load when drying):

$w_{wc} := 1.2 \cdot w_d = 0.3$ ft ksf

$$M_{wc} := \frac{w_{wc} \cdot L^2}{8} = 33.75\ \text{kip ft}$$

$$V_{wc} := \frac{w_{wc} \cdot L}{2} = 4.5\ \text{kip}$$

Selecting a Shape to Try Using Table $3-19$**:**

Estimating depth of steel shape: $d := \frac{L}{24} = 15\ in$

Estimating Y2 (assuming a is equal to 1; $a := 1\ in$):

$Y2 := Y_{conc} - \frac{a}{2} = 6\ in$

Identifying Shapes to Use:
W14x22; ϕbMn-> 191 kip-ft , ΣQn-> 81.1 kip
W16x26; ϕbMn-> 252 kip-ft , ΣQn->96 kip
W18x35; ϕbMn->372 kip-ft , ΣQn->129 kip

Try W14x22 $\phi M_n := 191\ kip\ ft$;

$\Sigma Q_n := 81.1\ kip$ $I := 199\ in^4$

Effective width: $b_e := \min\left(\left[\frac{L}{8}\cdot 2\quad \frac{s_c}{2}\cdot 2\quad \frac{L}{8}+\frac{s_c}{2}\quad \frac{L}{8}+d_{edge\_left}\quad \frac{s_c}{2}+d_{edge\_left}\quad \frac{L}{8}+d_{edge\_right}\quad \frac{s_c}{2}+d_{edge\_right}\right]\right)$

$b_e = 90\ in$

Detemining the Number of Studs and ΣQn:
Using Table $3-21$ of the AISC Steel Design Manual
Light-weight Concrete $f'c := 3\ ksi$;
Deck is Parallel;
$d_{stud} = 0.75\ in$;

Nominal Rib Height: $h_r := 3\ in$

Average Width of Concrete Rib: $w_r := 4.75\ in$

$\frac{w_r}{h_r} = 1.5833$ > 1.5, so $Q_n := 17.1\ kip$ per stud

Required Number of Studs $\frac{\Sigma Q_n}{Q_n} = 4.7427$ studs

Try 12 studs, now $\Sigma Q_n := Q_n \cdot 12 = 205.2\ kip$

Checking if spacing of studs satisfy requirements from AISC Manual Section I8.2d
$s_{min} := 6 \cdot d_{stud} = 4.5\ in$

$s_{max} := \min\left(\left[8 \cdot Y_{conc}\quad 36\ in\right]\right) = 36\ in$

$s := \frac{L}{12} = 30\ in$ which falls within the max and min

Computing a:

$a := \frac{\Sigma Q_n}{0.85 \cdot f'_c \cdot b_e} = 0.8941\ in$

Computing Y2:

$Y2 := Y_{conc} - \frac{a}{2} = 6.0529\ in$

Reading ϕMn from Table $3-19$**:**
$\Sigma Q_n = 205.2\ kip$; $Y2 = 6.0529\ in$

Since it falls between the values on the chart, using the most conservative approach of ΣQn = 199 kip and the Y2 depth as 6 in, the ΦMn =255 k-ft >Mu =122 k-ft (OK)

Check Shear Capacity from Table $3-2$**:**
For a W14x22 ΦVn =94.5 kips > Vu =16.24 kips (OK)

Check Beam under Wet Concrete Load:
For a W14x22 ΦMn =ΦMp = 125 kip-ft > 33.75 k-ft (OK)

Compute Required Camber:

$$\delta_{wc} := \frac{5 \cdot w_{wc} \cdot L^{4}}{384 \cdot E_{steel} \cdot I} = 0.9474 \text{ in}$$

Lived Load Deflection:

$$\delta_{L} := \frac{5 \cdot w_{l} \cdot L^{4}}{384 \cdot E_{steel} \cdot I} = 0.5447 \text{ in}$$

Permitted Live Load Deflection:

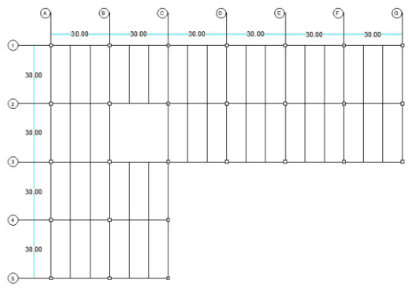
$$\delta_{L.perm} := \frac{L}{360} = 1 \text{ in}$$

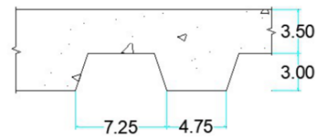
Section	W14x22					
Criteria	units	Design Value		Required		Check
Strength	kip-ft	ϕM_n	255	M_u	122	Good
Shear Capacity	kip	ϕV	94.5	V_u	16.24	Good
Studs	-	N	12	N_{min}	5	Good
Stud Spacing	in	s	30	s_{min}	4.5	Good
				s_{max}	36	
Deflection	in	δ_L	0.54	δ_{permit}	1	Good

Floor 1-8 Beam Design:

Multi-Story Residential Building: Typical Beam on Floors $1-8$

Plan Supporting Floor 1-8:





Assumptions: composite floor decking, the beam is braced by the deck, deck flutes run parallel to the beams, deck is lightweight concrete $f'_c := 3\ \text{ksi}$ and the studs have a diameter , $d_{stud} := 0.75\ \text{in}$ with yield strength, $F_{ystud} := 65\ \text{ksi}$, depth of concrete $Y_{conc} := 6.5\ \text{in}$, $E_{steel} := 29000\ \text{ksi}$

Loads:

Live Load $L_l := 100\ \text{psf}$

Dead Load $L_d := 25\ \text{psf}$

Trib width, $w_{tr} := 10\ \text{ft}$

Beam length, $L := 30\ \text{ft}$

Center-center span, $s_c := 10\ \text{ft}$

Distance to edge of slab, $d_{edge\_left} := 10\ \text{ft}$

$d_{edge\_right} := 170\ \text{ft}$

$A_t := w_{tr} \cdot 30\ \text{ft} = 300\ \text{ft}^2$

Reducing the Live Load:

$$L_{lr} := L_l \cdot \left(0.25 + \frac{15}{\sqrt{2 \cdot 300}}\right) = 86.2372\ \text{psf}$$

Factored Load Effects:

$w_d := w_{tr} \cdot L_d = 0.25\ \text{ft ksf}$

$w_l := w_{tr} \cdot L_{lr} = 0.8624\ \text{ft ksf}$

$w_{ul} := 1.2 \cdot w_d + 1.6 \cdot w_l = 1.6798\ \text{ft ksf}$

$$M_u := \frac{w_{ul} \cdot L^2}{8} = 188.977\ \text{kip ft}$$

$$V_u := \frac{w_{ul} \cdot L}{2} = 25.1969\ \text{kip}$$

Wet Concrete Load Effects (factoring the weight to account for uncertainty and incidental live load when drying):

$w_{wc} := 1.2 \cdot w_d = 0.3\ \text{ft ksf}$

$$M_{wc} := \frac{w_{wc} \cdot L^2}{8} = 33.75\ \text{kip ft}$$

$$V_{wc} := \frac{w_{wc} \cdot L}{2} = 4.5\ \text{kip}$$

Selecting a Shape to Try Using Table $3-19$**:**

Estimating depth of steel shape: $d := \frac{L}{24} = 15\ in$

Estimating Y2 (assuming a is equal to 1; $a := 1\ in$):

$Y2 := Y_{conc} - \frac{a}{2} = 6\ in$

Identifying Shapes to Use:
W14x22; ϕbMn-> 191 kip-ft , ΣQn-> 81.1 kip
W16x26; ϕbMn-> 252 kip-ft , ΣQn->96 kip ****DOES NOT MEET h/tw LIMIT FOR SHEAR****
W16x45; ϕbMn->372 kip-ft , ΣQn->129 kip

Try W16x45 $\phi M_n := 454\ kip\ ft$; $\Sigma Q_n := 166\ kip$

$I := 586\ in^4$

Effective width: $b_e := \min\left(\left[\frac{L}{8} \cdot 2 \quad \frac{s_c}{2} \cdot 2 \quad \frac{L}{8} + \frac{s_c}{2} \quad \frac{L}{8} + d_{edge\_left} \quad \frac{s_c}{2} + d_{edge\_left} \quad \frac{L}{8} + d_{edge\_right} \quad \frac{s_c}{2} + d_{edge\_right}\right]\right)$

$b_e = 90\ in$

Detemining the Number of Studs and ΣQn:
Using Table $3-21$ of the AISC Steel Design Manual
Light-weight Concrete $f'c := 3\ ksi$;
Deck is Parallel;
$d_{stud} = 0.75\ in$;

Nominal Rib Height: $h_r := 3\ in$

Average Width of Concrete Rib: $w_r := 4.75\ in$

$\frac{w_r}{h_r} = 1.5833$ > 1.5, so $Q_n := 17.1\ kip$ per stud

Required Number of Studs $\frac{\Sigma Q_n}{Q_n} = 9.7076$ studs

Try 12 studs, now $\Sigma Q_n := Q_n \cdot 12 = 205.2\ kip$

Checking if spacing of studs satisfy requirements from AISC Manual Section I8.2d
$s_{min} := 6 \cdot d_{stud} = 4.5\ in$

$s_{max} := \min\left(\left[8 \cdot Y_{conc} \quad 36\ in\right]\right) = 36\ in$

$s := \frac{L}{12} = 30\ in$ which falls within the max and min

Computing a:

$a := \frac{\Sigma Q_n}{0.85 \cdot f'_c \cdot b_e} = 0.8941\ in$

Computing Y2:

$Y2 := Y_{conc} - \frac{a}{2} = 6.0529\ in$

Reading ϕMn from Table $3-19$**:**
$\Sigma Q_n = 205.2\ kip$; $Y2 = 6.0529\ in$

Since it falls between the values on the chart, using the most conservative approach of ΣQn = 166 kip and the Y2 depth as 6 in, ΦMn =486 k-ft >Mu =189 k-ft (OK)

Check Shear Capacity from Table $3-2$**:**
For a W16x45 ΦVn 167 kips > Vu =25.2 kips (OK)

Check Beam under Wet Concrete Load:
For a W16x45 ΦMn =ΦMp = 309 kip-ft > 33.75 k-ft (OK)

Compute Required Camber:

$$\delta_{wc} := \frac{5 \cdot w_{wc} \cdot L^{4}}{384 \cdot E_{steel} \cdot I} = 0.3217 \text{ in}$$

Live Load Deflection:

$$\delta_{L} := \frac{5 \cdot w_{l} \cdot L^{4}}{384 \cdot E_{steel} \cdot I} = 0.9248 \text{ in}$$

Permitted Live Load Deflection

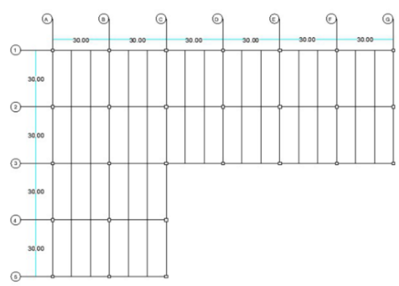
$$\delta_{L.perm} := \frac{L}{360} = 1 \text{ in}$$

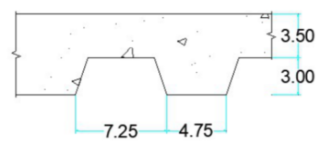
Section	W16x45					
Criteria	**units**	**Design Value**		**Required**		**Check**
Strength	kip-ft	ϕM_n	486	M_u	189	**Good**
Shear Capacity	kip	ϕV	167	V_u	25.2	**Good**
Studs	-	N	12	N_{min}	5	**Good**
Stud Spacing	in	s	30	s_{min}	4.5	**Good**
				s_{max}	36	
Deflection	in	δ_L	0.92	δ_{permit}	1	**Good**

Roof Girder Design:

Multi-Story Residential Building: Roof Girder

Plan Supporting Roof:





Assumptions: composite floor decking, the beam is braced by the deck, deck flutes run parallel to the beams, deck is lightweight concrete $f'_c := 3\ \text{ksi}$ and the studs have a diameter , $d_{stud} := 0.75\ \text{in}$ with yield strength, $F_{ystud} := 65\ \text{ksi}$, depth of concrete $Y_{conc} := 6.5\ \text{in}$, $E_{steel} := 29000\ \text{ksi}$

<u>Loads:</u>

Live Load $L_l := 20\ \text{psf}$

Dead Load $L_d := 25\ \text{psf}$

Snow Load $L_s := 61\ \text{psf}$

Trib width, $w_{tr} := 30\ \text{ft}$

Beam length, $L := 30\ \text{ft}$

Center-center span, $s_c := 10\ \text{ft}$

Distance to edge of slab, $d_{edge\_left} := 10\ \text{ft}$

$d_{edge\_right} := 170\ \text{ft}$

$A_t := w_{tr} \cdot L = 900\ \text{ft}^2$

<u>Reducing the Live Load:</u>

$$L_{lr} := L_l \cdot \left(0.25 + \frac{15}{\sqrt{2 \cdot 450}}\right) = 15\ \text{psf}$$

<u>Factored Load Effects:</u>

$w_d := w_{tr} \cdot L_d = 0.75\ \text{ft ksf}$

$w_l := w_{tr} \cdot L_{lr} = 0.45\ \text{ft ksf}$

$w_s := w_{tr} \cdot L_s = 1.83\ \text{ft ksf}$

$w_{u1} := 1.2 \cdot w_d + 1.6 \cdot w_l + 0.3 \cdot w_s = 2.169\ \text{ft ksf}$

$w_{u2} := 1.2 \cdot w_d + 1.0 \cdot w_s + 1 \cdot w_l = 3.18\ \text{ft ksf}$

$w_u := \max\left(\left[\, w_{u1} \;\; w_{u2} \,\right]\right) = 3.18\ \text{ft ksf}$

$$M_u := \frac{w_u \cdot L^2}{8} = 357.75\ \text{kip ft}$$

$$V_u := \frac{w_u \cdot L}{2} = 47.7\ \text{kip}$$

<u>Wet Concrete Load Effects</u> <u>(factoring the weight to account for uncertainty and incidental live load when drying):</u>

$w_{wc} := 1.2 \cdot w_d = 0.9\ \text{ft ksf}$

$$M_{wc} := \frac{w_{wc} \cdot L^2}{8} = 101.25\ \text{kip ft}$$

$$V_{wc} := \frac{w_{wc} \cdot L}{2} = 13.5\ \text{kip}$$

Selecting a Shape to Try Using Table $3-19$**:**

Estimating depth of steel shape: $d := \frac{L}{24} = 15\ in$

Estimating Y2 (assuming a is equal to 1; $a := 1\ in$):

$Y2 := Y_{conc} - \frac{a}{2} = 6\ in$

Identifying Shapes to Use:
W14x22; ϕbMn-> 191 kip-ft , ΣQn-> 81.1 kip
W16x31; ϕbMn-> 304 kip-ft , ΣQn->114 kip
W18x35; ϕbMn->372 kip-ft , ΣQn->129 kip

Try W18x35 $\phi M_n := 372\ kip\ ft$; $\Sigma Q_n := 129\ kip$

$I := 510\ in^4$

Effective width: $b_e := \min\left(\left[\frac{L}{8} \cdot 2 \quad \frac{s_c}{2} \cdot 2 \quad \frac{L}{8} + \frac{s_c}{2} \quad \frac{L}{8} + d_{edge\_left} \quad \frac{s_c}{2} + d_{edge\_left} \quad \frac{L}{8} + d_{edge\_right} \quad \frac{s_c}{2} + d_{edge\_right}\right]\right)$

$b_e = 90\ in$

Detemining the Number of Studs and ΣQn:
Using Table $3-21$ of the AISC Steel Design Manual
Light-weight Concrete $f'c := 3\ ksi$;
Deck is Parallel;
$d_{stud} = 0.75\ in$;

Nominal Rib Height: $h_r := 3\ in$

Average Width of Concrete Rib: $w_r := 4.75\ in$

$\frac{w_r}{h_r} = 1.5833$ > 1.5, so $Q_n := 17.1\ kip$ per stud

Required Number of Studs $\frac{\Sigma Q_n}{Q_n} = 7.5439$ studs

Try 12 studs, now $\Sigma Q_n := Q_n \cdot 12 = 205.2\ kip$

Checking if spacing of studs satisfy requirements from AISC Manual Section I8.2d
$s_{min} := 6 \cdot d_{stud} = 4.5\ in$

$s_{max} := \min\left(\left[8 \cdot Y_{conc} \quad 36\ in\right]\right) = 36\ in$

$s := \frac{L}{12} = 30\ in$ which falls within the max and min

Computing a:

$a := \frac{\Sigma Q_n}{0.85 \cdot f'_c \cdot b_e} = 0.8941\ in$

Computing Y2:

$Y2 := Y_{conc} - \frac{a}{2} = 6.0529\ in$

Reading ϕMn from Table $3-19$**:**
$\Sigma Q_n = 205.2\ kip$; $Y2 = 6.0529\ in$

Since it falls between the values on the chart, using the most conservative approach of ΣQn = 194 kip and the Y2 depth as 6 in, the ΦMn =419 k-ft >Mu =358 k-ft (OK)

Check Shear Capacity from Table $3-2$**:**
For a W18x35 ΦVn =159 kips > Vu =47.7 kips (OK)

Check Beam under Wet Concrete Load:
For a W18x35 ΦMn =ΦMp = 249 kip-ft > 101.25 k-ft (OK)

Compute Required Camber:

$$\delta_{wc} := \frac{5 \cdot w_{wc} \cdot L^4}{384 \cdot E_{steel} \cdot I} = 1.109 \text{ in}$$

Live Load Deflection:

$$\delta_L := \frac{5 \cdot w_l \cdot L^4}{384 \cdot E_{steel} \cdot I} = 0.5545 \text{ in}$$

Permitted Live Load Deflection:

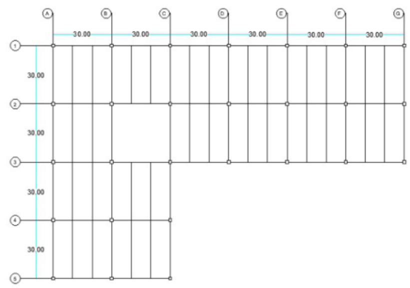
$$\delta_{L.perm} := \frac{L}{360} = 1 \text{ in}$$

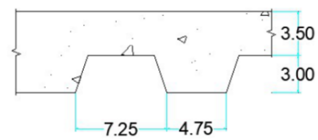
Section	W18x35					
Criteria	**units**	**Design Value**		**Required**		**Check**
Strength	kip-ft	**ϕM_n**	419	**M_u**	357.75	**Good**
Shear Capacity	kip	**ϕV**	159	**V_u**	47.7	**Good**
Studs	-	**N**	12	**N_{min}**	5	**Good**
Stud Spacing	in	**s**	30	**s_{min}**	4.5	**Good**
				s_{max}	36	
Deflection	in	**δ_L**	0.55	**δ_{permit}**	1	**Good**

Floor 1-8 Typical Interior Girder Design:

Multi-Story Residential Building: "Floor 1-8" Typical Interior Girder Design

Plan Supporting Floor 1-8:





Assumptions: composite floor decking, the beam is braced by the deck, deck flutes run parallel to the beams, deck is lightweight concrete $f'_c := 3\ \text{ksi}$ and the studs have a diameter , $d_{stud} := 0.75\ \text{in}$ with yield strength, $F_{ystud} := 65\ \text{ksi}$, depth of concrete $Y_{conc} := 6.5\ \text{in}$, $E_{steel} := 29000\ \text{ksi}$

Loads:

Live Load $L_l := 100\ \text{psf}$

Dead Load $L_d := 25\ \text{psf}$

Trib width, $w_{tr} := 30\ \text{ft}$

Beam length, $L := 30\ \text{ft}$

Center-center span, $s_c := 10\ \text{ft}$

Distance to edge of slab, $d_{edge\_left} := 10\ \text{ft}$

$d_{edge\_right} := 170\ \text{ft}$

$A_t := w_{tr} \cdot L = 900\ \text{ft}^2$

Reducing the Live Load:

$$L_{lr} := L_l \cdot \left(0.25 + \frac{15}{\sqrt{2 \cdot 450}}\right) = 75\ \text{psf}$$

Factored Load Effects:

$w_d := w_{tr} \cdot L_d = 0.75\ \text{ft ksf}$

$w_l := w_{tr} \cdot L_{lr} = 2.25\ \text{ft ksf}$

$w_u := 1.2 \cdot w_d + 1.6 \cdot w_l = 4.5\ \text{ft ksf}$

$$M_u := \frac{w_u \cdot L^2}{8} = 506.25\ \text{kip ft}$$

$$V_u := \frac{w_u \cdot L}{2} = 67.5\ \text{kip}$$

Wet Concrete Load Effects (factoring the weight to account for uncertainty and incidental live load when drying):

$w_{wc} := 1.2 \cdot w_d = 0.9\ \text{ft ksf}$

$$M_{wc} := \frac{w_{wc} \cdot L^2}{8} = 101.25\ \text{kip ft}$$

$$V_{wc} := \frac{w_{wc} \cdot L}{2} = 13.5\ \text{kip}$$

Selecting a Shape to Try Using Table $3-19$**:**

Estimating depth of steel shape: $d := \frac{L}{24} = 15\ in$

Estimating Y2 (assuming a is equal to 1; $a := 1\ in$):

$Y2 := Y_{conc} - \frac{a}{2} = 6\ in$

Identifying Shapes to Use:
W16x31; ϕbMn-> 304 kip-ft , ΣQn->114 kip
W18x50; ϕbMn->550 kip-ft , ΣQn->184 kip
W21x73; ϕbMn->921 kip-ft , ΣQn->269 kip

Try W21x73 $\phi M_n := 921\ kip\ ft$; $\Sigma Q_n := 269\ kip$

$I := 1600\ in^4$

Effective width: $b_e := \min\left(\left[\frac{L}{8} \cdot 2\ \ \frac{s_c}{2} \cdot 2\ \ \frac{L}{8} + \frac{s_c}{2}\ \ \frac{L}{8} + d_{edge\_left}\ \ \frac{s_c}{2} + d_{edge\_left}\ \ \frac{L}{8} + d_{edge\_right}\ \ \frac{s_c}{2} + d_{edge\_right}\right]\right)$

$b_e = 90\ in$

Detemining the Number of Studs and ΣQn:
Using Table $3-21$ of the AISC Steel Design Manual
Light-weight Concrete $f'c := 3\ ksi$;
Deck is Parallel;
$d_{stud} = 0.75\ in$;

Nominal Rib Height: $h_r := 3\ in$

Average Width of Concrete Rib: $w_r := 4.75\ in$

$\frac{w_r}{h_r} = 1.5833$ > 1.5, so $Q_n := 17.1\ kip$ per stud

Required Number of Studs $\frac{\Sigma Q_n}{Q_n} = 15.731$ studs

Try 16 studs, now $\Sigma Q_n := Q_n \cdot 16 = 273.6\ kip$

Checking if spacing of studs satisfy requirements from AISC Manual Section I8.2d
$s_{min} := 6 \cdot d_{stud} = 4.5\ in$

$s_{max} := \min\left(\left[8 \cdot Y_{conc}\ \ 36\ in\right]\right) = 36\ in$

$s := \frac{L}{16} = 22.5\ in$ which falls within the max and min

Computing a:

$a := \frac{\Sigma Q_n}{0.85 \cdot f'_c \cdot b_e} = 1.1922\ in$

Computing Y2:

$Y2 := Y_{conc} - \frac{a}{2} = 5.9039\ in$

Reading ϕMn from Table $3-19$**:**
$\Sigma Q_n = 273.6\ kip$; $Y2 = 5.9039\ in$

Since it falls between the values on the chart, using the most conservative approach of ΣQn = 269 kip and the Y2 depth as 6 in, the ΦMn 921 k-ft >Mu =506.25 k-ft (OK)

Check Shear Capacity from Table $3-2$**:**
For a W21x73 ΦVn =289 kips > Vu =67.5 kips (OK)

Check Beam under Wet Concrete Load:
For a W21x73 ΦMn =ΦMp = 645 kip-ft > 101.25 k-ft (OK)

Compute Required Camber:

$$\delta_{wc} := \frac{5 \cdot w_{wc} \cdot L^4}{384 \cdot E_{steel} \cdot I} = 0.3535 \text{ in}$$

Live Load Deflection:

$$\delta_L := \frac{5 \cdot w_l \cdot L^4}{384 \cdot E_{steel} \cdot I} = 0.8838 \text{ in}$$

Permitted Live Load Deflection:

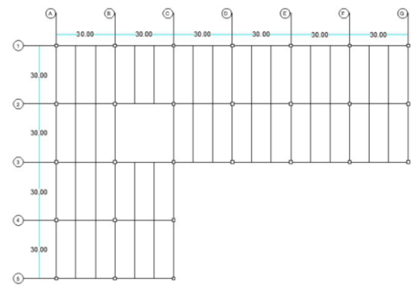
$$\delta_{L.perm} := \frac{L}{360} = 1 \text{ in}$$

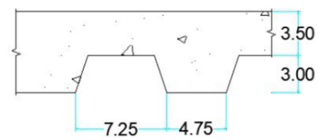
Section	W21x73					
Criteria	**units**	**Design Value**		**Required**		**Check**
Strength	kip-ft	**ϕMn**	921	**Mu**	506.25	**Good**
Shear Capacity	kip	**ϕV**	289	**Vu**	67.5	**Good**
Studs	-	**N**	16	**Nmin**	15	**Good**
Stud Spacing	in	**s**	22.5	**smin**	4.5	**Good**
				smax	36	
Deflection	in	**δL**	0.88	**δpermit**	1	**Good**

Floor 1-8 Elevator Girder Design:

Multi-Story Residential Building: "Floor 1-8" Elevator Girder Design

Plan Supporting Floor 1-8:





Assumptions: composite floor decking, the beam is braced by the deck, deck flutes run parallel to the beams, deck is lightweight concrete $f'_c := 3\ \text{ksi}$ and the studs have a diameter , $d_{stud} := 0.75\ \text{in}$ with yield strength, $F_{ystud} := 65\ \text{ksi}$, depth of concrete $Y_{conc} := 6.5\ \text{in}$, $E_{steel} := 29000\ \text{ksi}$

Loads:

Live Load $L_l := 100\ \text{psf}$

Dead Load $L_d := 25\ \text{psf}$

Trib width, $w_{tr} := 15\ \text{ft}$

Beam length, $L := 30\ \text{ft}$

Center-center span, $s_c := 10\ \text{ft}$

Distance to edge of slab, $d_{edge\_left} := 10\ \text{ft}$

$d_{edge\_right} := 170\ \text{ft}$

$A_t := w_{tr} \cdot L = 450\ \text{ft}^2$

Reducing the Live Load:

$L_{lr} := L_l \cdot \left(0.25 + \frac{15}{\sqrt{2 \cdot 450}}\right) = 75\ \text{psf}$

Factored Load Effects:

$w_d := w_{tr} \cdot L_d = 0.375\ \text{ft ksf}$

$w_l := w_{tr} \cdot L_{lr} = 1.125\ \text{ft ksf}$

$w_u := 1.2 \cdot w_d + 1.6 \cdot w_l = 2.25\ \text{ft ksf}$

$M_u := \frac{w_u \cdot L^2}{8} = 253.125\ \text{kip ft}$

$V_u := \frac{w_u \cdot L}{2} = 33.75\ \text{kip}$

Wet Concrete Load Effects (factoring the weight to account for uncertainty and incidental live load when drying):

$w_{wc} := 1.2 \cdot w_d = 0.45\ \text{ft ksf}$

$M_{wc} := \frac{w_{wc} \cdot L^2}{8} = 50.625\ \text{kip ft}$

$V_{wc} := \frac{w_{wc} \cdot L}{2} = 6.75\ \text{kip}$

Selecting a Shape to Try Using Table 3 − 19:

Estimating depth of steel shape: $d := \frac{L}{24} = 15\ in$

Estimating Y2 (assuming a is equal to 1; $a := 1\ in$):

$Y2 := Y_{conc} - \frac{a}{2} = 6\ in$

Identifying Shapes to Use:
W16x31; ϕbMn-> 304 kip-ft , ΣQn->114 kip
W18x35; ϕbMn->372 kip-ft , ΣQn->129 kip
W18x50; ϕbMn->550 kip-ft , ΣQn->184 kip

Try W18x50 $\phi M_n := 550\ kip\ ft$; $\Sigma Q_n := 184\ kip$

$I := 800\ in^4$

Effective width: $b_e := \min\left(\left[\frac{L}{8} \cdot 2\ \ \frac{s_c}{2} \cdot 2\ \ \frac{L}{8} + \frac{s_c}{2}\ \ \frac{L}{8} + d_{edge\_left}\ \ \frac{s_c}{2} + d_{edge\_left}\ \ \frac{L}{8} + d_{edge\_right}\ \ \frac{s_c}{2} + d_{edge\_right}\right]\right)$

$b_e = 90\ in$

Detemining the Number of Studs and ΣQn:
Using Table 3 − 21 of the AISC Steel Design Manual
Light-weight Concrete $f'c := 3\ ksi$;
Deck is Parallel;
$d_{stud} = 0.75\ in$;

Nominal Rib Height: $h_r := 3\ in$

Average Width of Concrete Rib: $w_r := 4.75\ in$

$\frac{w_r}{h_r} = 1.5833$ > 1.5, so $Q_n := 17.1\ kip$ per stud

Required Number of Studs $\frac{\Sigma Q_n}{Q_n} = 10.7602$ studs

Try 12 studs, now $\Sigma Q_n := Q_n \cdot 12 = 205.2\ kip$

Checking if spacing of studs satisfy requirements from AISC Manual Section I8.2d
$s_{min} := 6 \cdot d_{stud} = 4.5\ in$

$s_{max} := \min\left(\left[8 \cdot Y_{conc}\ \ 36\ in\right]\right) = 36\ in$

$s := \frac{L}{12} = 30\ in$ which falls within the max and min

Computing a:

$a := \frac{\Sigma Q_n}{0.85 \cdot f'_c \cdot b_e} = 0.8941\ in$

Computing Y2:

$Y2 := Y_{conc} - \frac{a}{2} = 6.0529\ in$

Reading ϕMn from Table 3 − 19:
$\Sigma Q_n = 205.2\ kip$; $Y2 = 6.0529\ in$

Since it falls between the values on the chart, using the most conservative approach of ΣQn = 184 kip and the Y2 depth as 6 in, the ΦMn =550 k-ft >Mu =253.13 k-ft (OK)

Check Shear Capacity from Table 3 − 2:
For a W18x50 ΦVn =192 kips > Vu =33.75 kips (OK)

Check Beam under Wet Concrete Load:
For a W18x50 ΦMn =ΦMp = 249 kip-ft > 50.63 k-ft (OK)

Compute Required Camber:

$$\delta_{wc} := \frac{5 \cdot w_{wc} \cdot L^4}{384 \cdot E_{steel} \cdot I} = 0.3535 \text{ in}$$

Live Load Deflection:

$$\delta_L := \frac{5 \cdot w_l \cdot L^4}{384 \cdot E_{steel} \cdot I} = 0.8838 \text{ in}$$

Permitted Live Load Deflection:

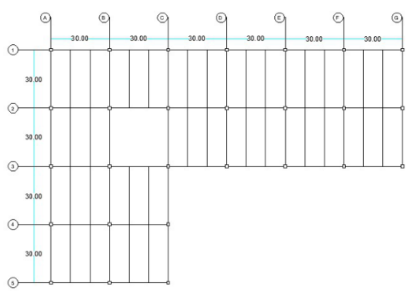
$$\delta_{L.perm} := \frac{L}{360} = 1 \text{ in}$$

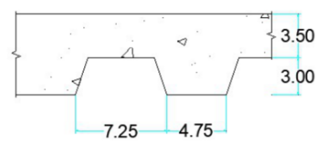
Section	W18x50					
Criteria	**units**	**Design Value**		**Required**		**Check**
Strength	kip-ft	**ϕM_n**	550	**M_u**	253.13	**Good**
Shear Capacity	kip	**ϕV**	192	**V_u**	33.75	**Good**
Studs	-	**N**	12	**N_{min}**	5	**Good**
Stud Spacing	in	**s**	30	**s_{min}**	4.5	**Good**
				s_{max}	36	
Deflection	in	**δ_L**	0.88	**δ_{permit}**	1	**Good**

Floor 1-8 Exterior Girder Design:

Multi-Story Residential Building: "Floor 1-8" Exterior Girder Design

Plan Supporting Floor 1-8:





Assumptions: composite floor decking, the beam is braced by the deck, deck flutes run parallel to the beams, deck is lightweight concrete $f'_c := 3\ \text{ksi}$ and the studs have a diameter , $d_{stud} := 0.75\ \text{in}$ with yield strength, $F_{ystud} := 65\ \text{ksi}$, depth of concrete $Y_{conc} := 6.5\ \text{in}$, $E_{steel} := 29000\ \text{ksi}$

Loads:

Live Load $L_l := 100\ \text{psf}$

Dead Load $L_d := 25\ \text{psf}$

Exterior Wall Load $L_{wall} := 40\ \text{psf}$

Trib width, $w_{tr} := 15\ \text{ft}$

Beam length, $L := 30\ \text{ft}$

Center-center span, $s_c := 10\ \text{ft}$

Distance to edge of slab, $d_{edge\_left} := 10\ \text{ft}$

$d_{edge\_right} := 170\ \text{ft}$

$A_t := w_{tr} \cdot L = 450\ \text{ft}^2$

Reducing the Live Load:

$$L_{lr} := L_l \cdot \left(0.25 + \frac{15}{\sqrt{2 \cdot 450}}\right) = 75\ \text{psf}$$

Factored Load Effects:

$w_d := w_{tr} \cdot \left(L_d + L_{wall}\right) = 0.975\ \text{ft ksf}$

$w_l := w_{tr} \cdot L_{lr} = 1.125\ \text{ft ksf}$

$w_u := 1.2 \cdot w_d + 1.6 \cdot w_l = 2.97\ \text{ft ksf}$

$$M_u := \frac{w_u \cdot L^2}{8} = 334.125\ \text{kip ft}$$

$$V_u := \frac{w_u \cdot L}{2} = 44.55\ \text{kip}$$

Wet Concrete Load Effects (factoring the weight to account for uncertainty and incidental live load when drying):

$w_{wc} := 1.2 \cdot w_d = 1.17\ \text{ft ksf}$

$$M_{wc} := \frac{w_{wc} \cdot L^2}{8} = 131.625\ \text{kip ft}$$

$$V_{wc} := \frac{w_{wc} \cdot L}{2} = 17.55\ \text{kip}$$

Selecting a Shape to Try Using Table $3-19$**:**

Estimating depth of steel shape: $d := \frac{L}{24} = 15\ in$

Estimating Y2 (assuming a is equal to 1; $a := 1\ in$):

$Y2 := Y_{conc} - \frac{a}{2} = 6\ in$

Identifying Shapes to Use:
W16x31; ϕbMn-> 304 kip-ft , ΣQn->114 kip
W18x35; ϕbMn->372 kip-ft , ΣQn->129 kip
W18x50; ϕbMn->550 kip-ft , ΣQn->184 kip

Try W18x50 $\phi M_n := 550\ kip\ ft$; $\Sigma Q_n := 184\ kip$

$I := 800\ in^4$

Effective width: $b_e := \min\left(\left[\frac{L}{8} \cdot 2\quad \frac{s_c}{2} \cdot 2\quad \frac{L}{8} + \frac{s_c}{2}\quad \frac{L}{8} + d_{edge\_left}\quad \frac{s_c}{2} + d_{edge\_left}\quad \frac{L}{8} + d_{edge\_right}\quad \frac{s_c}{2} + d_{edge\_right}\right]\right)$

$b_e = 90\ in$

Detemining the Number of Studs and ΣQn:
Using Table $3-21$ of the AISC Steel Design Manual
Light-weight Concrete $f'c := 3\ ksi$;
Deck is Parallel;
$d_{stud} = 0.75\ in$;

Nominal Rib Height: $h_r := 3\ in$

Average Width of Concrete Rib: $w_r := 4.75\ in$

$\frac{w_r}{h_r} = 1.5833$ > 1.5, so $Q_n := 17.1\ kip$ per stud

Required Number of Studs $\frac{\Sigma Q_n}{Q_n} = 10.7602$ studs

Try 12 studs, now $\Sigma Q_n := Q_n \cdot 12 = 205.2\ kip$

Checking if spacing of studs satisfy requirements from AISC Manual Section I8.2d
$s_{min} := 6 \cdot d_{stud} = 4.5\ in$

$s_{max} := \min\left(\left[8 \cdot Y_{conc}\quad 36\ in\right]\right) = 36\ in$

$s := \frac{L}{12} = 30\ in$ which falls within the max and min

Computing a:

$a := \frac{\Sigma Q_n}{0.85 \cdot f'_c \cdot b_e} = 0.8941\ in$

Computing Y2:

$Y2 := Y_{conc} - \frac{a}{2} = 6.0529\ in$

Reading ϕMn from Table $3-19$**:**
$\Sigma Q_n = 205.2\ kip$; $Y2 = 6.0529\ in$

Since it falls between the values on the chart, using the most conservative approach of ΣQn = 184 kip and the Y2 depth as 6 in, the ΦMn =550 k-ft >Mu =334.13 k-ft (OK)

Check Shear Capacity from Table $3-2$**:**
For a W18x50 ΦVn =192 kips > Vu =44.55 kips (OK)

Check Beam under Wet Concrete Load:
For a W18x50 ΦMn =ΦMp = 249 kip-ft > 131.63 k-ft (OK)

Compute Required Camber:

$$\delta_{wc} := \frac{5 \cdot w_{wc} \cdot L^4}{384 \cdot E_{steel} \cdot I} = 0.9191 \text{ in}$$

Live Load Deflection:

$$\delta_L := \frac{5 \cdot w_l \cdot L^4}{384 \cdot E_{steel} \cdot I} = 0.8838 \text{ in}$$

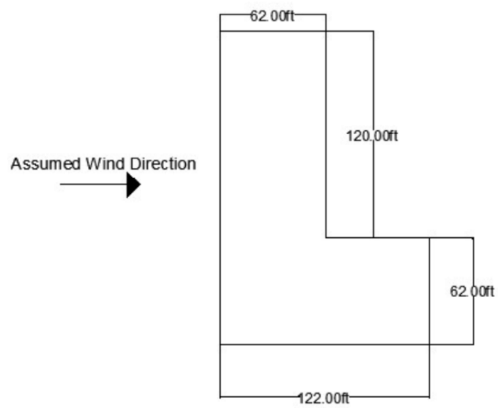
Permitted Live Load Deflection:

$$\delta_{L.perm} := \frac{L}{360} = 1 \text{ in}$$

Section	W18x50					
Criteria	units	Design Value		Required		Check
Strength	kip-ft	ϕM_n	550	M_u	334.13	Good
Shear Capacity	kip	ϕV	192	V_u	44.55	Good
Studs	-	N	12	N_{min}	5	Good
Stud Spacing	in	s	30	s_{min}	4.5	Good
				s_{max}	36	
Deflection	in	δ_L	0.88	δ_{permit}	1	Good

Wind Pressure Calculation:

Multi-Story Residential Building: Wind Pressure Calculation



*Following ASCE $7-22$ Table $27.2-1$ "Steps to Determine MWFRS Wind Loads for Enclosed, Partially Enclosed, Partially Open, and Open Buildings, of All Heights

$L := 182$ feet

$B := 122$ feet

Wind Speed: $V := 119$ mph
Wind-Direction Factor: $K_d := 0.85$

Exposure Category: C
Topographic Factor: $K_{zt} := 1$

Ground Elevation Factor: $K_e := 1$

Gust- Effect Factor: $G := 0.85$
Enclosure Class: Enclosed
Internal Pressure Coefficient: $GC_{pi} := 0.18$

$GC_{pi2} := -0.18$

Velocity Pressure Exposure Coefficient: $K_z := 1.31$

$K_h := K_z = 1.31$

Velocity Pressure: $q_z := 0.00256 \cdot K_z \cdot K_{zt} \cdot K_e \cdot V^2 = 47.4903$ (mph)

$q_h := q_z$

External Pressure Coefficient:

Wall: windward wall: $C_{p1} := 0.8$

Leeward Wall: $\frac{L}{B} = 1.4918$ so use $C_{p2} := -0.3$

Side: $C_{p3} := -0.7$

Roof: Windward: $C_{p4} := -0.9$

Leeward: $C_{p5} := -0.18$

Wind Pressure on Each Side:
Wall:
Windward Wall: $P_1 := q_z \cdot K_d \cdot G \cdot C_{p1} - q_z \cdot K_d \cdot GC_{pi} = 20.1834$ psf

Leeward Wall: $P_2 := q_h \cdot K_d \cdot G \cdot C_{p2} - q_h \cdot K_d \cdot GC_{pi2} = -3.0275$ psf

Sidewall: $P_3 := q_h \cdot K_d \cdot G \cdot C_{p3} - q_h \cdot K_d \cdot GC_{pi2} = -16.7522$ psf

Roof:
Windward: $P_4 := q_h \cdot K_d \cdot G \cdot C_{p4} - q_h \cdot K_d \cdot GC_{pi2} = -23.6146$ psf

Leeward: $P_5 := q_h \cdot K_d \cdot G \cdot C_{p5} - q_h \cdot K_d \cdot GC_{pi2} = 1.0899$ psf

Column Design:

Column Design

Demands - 1st and 2nd Story - Interior Columns

Unfactored Loads
Floor
Floor Dead Load $D_{floor} := 25\ \text{psf}$

Floor Live Load $L_{floor} := 20\ \text{psf}$

Roof
Roof Dead Load $D_{roof} := 20\ \text{psf}$

Roof Live Load $L_{roof} := 61\ \text{psf}$

Tributary Area
Floors
Tributary width $w_{trib} := 30\ \text{ft}$

Tributary length $l_{trib} := 30.75\ \text{ft}$

1st Floor Tributary Area $A_{t.levelx} := 7 \cdot w_{trib} \cdot l_{trib} = 6458\ \text{ft}^2$

Roof

roof Tributary Area $A_{t.roof} := w_{trib} \cdot l_{trib} = 922.5\ \text{ft}^2$

Live Load Reduction (LLR)
Floor
$L_o := L_{floor} = 20\ \text{psf}$

$K_{LL} := 4$

$$L := L_o \cdot \left(0.25 + \frac{15}{\sqrt{K_{LL} \cdot A_{t.levelx} \cdot \frac{1}{\text{ft}^2}}} \right) = 6.87\ \text{psf}$$

Roof
$L_o := L_{roof} = 61\ \text{psf}$

$R_1 := 0.6$

$R_2 := 1$

$L_{roof} := L_o \cdot R_1 \cdot R_2 = 36.6\ \text{psf}$

Factored Loads
$P_D := D_{floor} \cdot A_{t.levelx} + D_{roof} \cdot A_{t.roof} = 179.89\ \text{kip}$

$P_L := L_{floor} \cdot A_{t.levelx} = 129.15\ \text{kip}$

$P_{Lr} := L_{roof} \cdot A_{t.roof} = 33.7635\ \text{kip}$

$P_u := 1.2 \cdot P_D + 1.6 \cdot P_L + 0.5 \cdot P_{Lr} = 439\ \text{kip}$ (Load Combination 2 controls)

Try
W10x49 ϕcPn = 471 kip
W12x53 ϕcPn = 502 kip
W14x61 ϕcPn = 571 kip

where KLx = KLy = 14ft

Demands - 1st and 2nd Story - Exterior Columns

Unfactored Loads
Floor
Floor Dead Load $D_{floor} := 25\ psf$

Floor Live Load $L_{floor} := 20\ psf$

Roof
Roof Dead Load $D_{roof} := 20\ psf$

Roof Live Load $L_{roof} := 61\ psf$

Wall
Exterior Wall Dead Load $D_{wall} := 22\ psf$

Tributary Area
Floors

Tributary width $w_{trib} := \frac{30}{2}\ ft$

Tributary length $l_{trib} := 30.75\ ft$

Per Level Tributary Area $A_{t.level} := w_{trib} \cdot l_{trib} = 461.25\ ft^2$

1st Floor Tributary Area $A_{t.levelx} := 7 \cdot w_{trib} \cdot l_{trib} = 3229\ ft^2$

Walls
$storyheight := 14\ ft$
$storynumber := 8$
$height_{trib} := storyheight \cdot storynumber = 112\ ft$

wall Tributary Area $A_{t.wall} := w_{trib} \cdot height_{trib} = 1680\ ft^2$

Roof

roof Tributary Area $A_{t.roof} := w_{trib} \cdot l_{trib} = 461.25\ ft^2$

Live Load Reduction (LLR)
Floor
$L_o := L_{floor} = 20\ psf$
$K_{LL} := 4$

$$L := L_o \cdot \left(0.25 + \frac{15}{\sqrt{K_{LL} \cdot A_{t.levelx} \cdot \frac{1}{ft^2}}} \right) = 7.64\ psf$$

Roof
$L_o := L_{roof} = 61\ psf$
$R_1 := 0.6$
$R_2 := 1$
$L_{roof} := L_o \cdot R_1 \cdot R_2 = 36.6\ psf$

Factored Loads
$P_D := D_{floor} \cdot A_{t.levelx} + D_{roof} \cdot A_{t.roof} + D_{wall} \cdot A_{t.wall} = 126.90\ kip$
$P_L := L_{floor} \cdot A_{t.levelx} = 64.575\ kip$
$P_{Lr} := L_{roof} \cdot A_{t.roof} = 16.8817\ kip$

$P_u := 1.2 \cdot P_D + 1.6 \cdot P_L + 0.5 \cdot P_{Lr} = 264\ kip$ (Load Combination 2 controls)

Demands - 3rd and 4th Story - Interior Columns

Unfactored Loads
Floor
Floor Dead Load $D_{floor} := 25\ psf$

Floor Live Load $L_{floor} := 20\ psf$

Roof
Roof Dead Load $D_{roof} := 20\ psf$

Roof Live Load $L_{roof} := 61\ psf$

Tributary Area
Floors
Tributary width $w_{trib} := 30\ ft$

Tributary length $l_{trib} := 30.75\ ft$

3rd Floor Tributary Area $A_{t.levelx} := 5 \cdot w_{trib} \cdot l_{trib} = 4612\ ft^2$

Roof

roof Tributary Area $A_{t.roof} := w_{trib} \cdot l_{trib} = 922.5\ ft^2$

Live Load Reduction (LLR)
Floor
$L_o := L_{floor} = 20\ psf$

$K_{LL} := 4$

$$L := L_o \cdot \left(0.25 + \frac{15}{\sqrt{K_{LL} \cdot A_{t.levelx} \cdot \frac{1}{ft^2}}} \right) = 7.21\ psf$$

Roof
$L_o := L_{roof} = 61\ psf$

$R_1 := 0.6$

$R_2 := 1$

$L_{roof} := L_o \cdot R_1 \cdot R_2 = 36.6\ psf$

Factored Loads
$P_D := D_{floor} \cdot A_{t.levelx} + D_{roof} \cdot A_{t.roof} = 133.76\ kip$

$P_L := L_{floor} \cdot A_{t.levelx} = 92.25\ kip$

$P_{Lr} := L_{roof} \cdot A_{t.roof} = 33.7635\ kip$

$P_u := 1.2 \cdot P_D + 1.6 \cdot P_L + 0.5 \cdot P_{Lr} = 325\ kip$ (Load Combination 2 controls)

Try
W10x45 ϕcPn = 359 kip
W12x45 ϕcPn = 343 kip
W14x48 ϕcPn = 360 kip

Demands - 3rd and 4th Story - Exterior Columns

Unfactored Loads

Floor

Floor Dead Load $D_{floor} := 25\ \text{psf}$

Floor Live Load $L_{floor} := 20\ \text{psf}$

Roof

Roof Dead Load $D_{roof} := 20\ \text{psf}$

Roof Live Load $L_{roof} := 61\ \text{psf}$

Wall

Exterior Wall Dead Load $D_{wall} := 22\ \text{psf}$

Tributary Area

Floors

Tributary width $w_{trib} := \frac{30}{2}\ \text{ft}$

Tributary length $l_{trib} := 30.75\ \text{ft}$

Per Level Tributary Area $A_{t.level} := w_{trib} \cdot l_{trib} = 461.25\ \text{ft}^2$

3rd Floor Tributary Area $A_{t.levelx} := 5 \cdot w_{trib} \cdot l_{trib} = 2306\ \text{ft}^2$

Walls

$storyheight := 14\ \text{ft}$

$storynumber := 6$

$height_{trib} := storyheight \cdot storynumber = 84\ \text{ft}$

wall Tributary Area $A_{t.wall} := w_{trib} \cdot height_{trib} = 1260\ \text{ft}^2$

Roof

roof Tributary Area $A_{t.roof} := w_{trib} \cdot l_{trib} = 461.25\ \text{ft}^2$

Live Load Reduction (LLR)

Floor

$L_o := L_{floor} = 20\ \text{psf}$

$K_{LL} := 4$

$$L := L_o \cdot \left(0.25 + \frac{15}{\sqrt{K_{LL} \cdot A_{t.levelx} \cdot \frac{1}{\text{ft}^2}}}\right) = 8.12\ \text{psf}$$

Roof

$L_o := L_{roof} = 61\ \text{psf}$

$R_1 := 0.6$

$R_2 := 1$

$L_{roof} := L_o \cdot R_1 \cdot R_2 = 36.6\ \text{psf}$

Factored Loads

$P_D := D_{floor} \cdot A_{t.levelx} + D_{roof} \cdot A_{t.roof} + D_{wall} \cdot A_{t.wall} = 94.601\ \text{kip}$

$P_L := L_{floor} \cdot A_{t.levelx} = 46.125\ \text{kip}$

$P_{Lr} := L_{roof} \cdot A_{t.roof} = 16.8817\ \text{kip}$

$P_u := 1.2 \cdot P_D + 1.6 \cdot P_L + 0.5 \cdot P_{Lr} = 196\ \text{kip}$ (Load Combination 2 controls)

Demands - 5th and 6th Story - Interior Columns

Unfactored Loads

Floor

Floor Dead Load $D_{floor} := 25\ psf$

Floor Live Load $L_{floor} := 20\ psf$

Roof

Roof Dead Load $D_{roof} := 20\ psf$

Roof Live Load $L_{roof} := 61\ psf$

Tributary Area

Floors

Tributary width $w_{trib} := 30\ ft$

Tributary length $l_{trib} := 30.75\ ft$

5th Floor Tributary Area $A_{t.levelx} := 3 \cdot w_{trib} \cdot l_{trib} = 2768\ ft^2$

Roof

roof Tributary Area $A_{t.roof} := w_{trib} \cdot l_{trib} = 922.5\ ft^2$

Live Load Reduction (LLR)

Floor

$L_o := L_{floor} = 20\ psf$

$K_{LL} := 4$

$$L := L_o \cdot \left(0.25 + \frac{15}{\sqrt{K_{LL} \cdot A_{t.levelx} \cdot \frac{1}{ft^2}}} \right) = 7.85\ psf$$

Roof

$L_o := L_{roof} = 61\ psf$

$R_1 := 0.6$

$R_2 := 1$

$L_{roof} := L_o \cdot R_1 \cdot R_2 = 36.6\ psf$

Factored Loads

$P_D := D_{floor} \cdot A_{t.levelx} + D_{roof} \cdot A_{t.roof} = 87.637\ kip$

$P_L := L_{floor} \cdot A_{t.levelx} = 55.35\ kip$

$P_{Lr} := L_{roof} \cdot A_{t.roof} = 33.7635\ kip$

$P_u := 1.2 \cdot P_D + 1.6 \cdot P_L + 0.5 \cdot P_{Lr} = 211\ kip$ (Load Combination 2 controls)

Try

W10x33 ϕcPn = 253 kip

W12x40 ϕcPn = 304 kip

W14x48 ϕcPn = 360 kip

Demands - 5th and 6th Story - Exterior Columns

Unfactored Loads
Floor
Floor Dead Load $D_{floor} := 25\ psf$

Floor Live Load $L_{floor} := 20\ psf$

Roof
Roof Dead Load $D_{roof} := 20\ psf$

Roof Live Load $L_{roof} := 61\ psf$

Wall
Exterior Wall Dead Load $D_{wall} := 22\ psf$

Tributary Area
Floors

Tributary width $w_{trib} := \frac{30}{2}\ ft$

Tributary length $l_{trib} := 30.75\ ft$

Per Level Tributary Area $A_{t.level} := w_{trib} \cdot l_{trib} = 461.25\ ft^2$

5th Floor Tributary Area $A_{t.levelx} := 5 \cdot w_{trib} \cdot l_{trib} = 2306\ ft^2$

Walls
$storyheight := 14\ ft$
$storynumber := 4$
$height_{trib} := storyheight \cdot storynumber = 56\ ft$

wall Tributary Area $A_{t.wall} := w_{trib} \cdot height_{trib} = 840\ ft^2$

Roof
roof Tributary Area $A_{t.roof} := w_{trib} \cdot l_{trib} = 461.25\ ft^2$

Live Load Reduction (LLR)
Floor
$L_o := L_{floor} = 20\ psf$
$K_{LL} := 4$

$$L := L_o \cdot \left(0.25 + \frac{15}{\sqrt{K_{LL} \cdot A_{t.levelx} \cdot \frac{1}{ft^2}}}\right) = 8.12\ psf$$

Roof
$L_o := L_{roof} = 61\ psf$
$R_1 := 0.6$
$R_2 := 1$
$L_{roof} := L_o \cdot R_1 \cdot R_2 = 36.6\ psf$

Factored Loads
$P_D := D_{floor} \cdot A_{t.levelx} + D_{roof} \cdot A_{t.roof} + D_{wall} \cdot A_{t.wall} = 85.361\ kip$
$P_L := L_{floor} \cdot A_{t.levelx} = 46.125\ kip$
$P_{Lr} := L_{roof} \cdot A_{t.roof} = 16.8817\ kip$

$P_u := 1.2 \cdot P_D + 1.6 \cdot P_L + 0.5 \cdot P_{Lr} = 185\ kip$ (Load Combination 2 controls)

Demands - 7th and 8th Story - Interior Columns

Unfactored Loads

Floor

Floor Dead Load $D_{floor} := 25 \text{ psf}$

Floor Live Load $L_{floor} := 20 \text{ psf}$

Roof

Roof Dead Load $D_{roof} := 20 \text{ psf}$

Roof Live Load $L_{roof} := 61 \text{ psf}$

Tributary Area

Floors

Tributary width $w_{trib} := 30 \text{ ft}$

Tributary length $l_{trib} := 30.75 \text{ ft}$

7th Floor Tributary Area $A_{t.levelx} := 1 \cdot w_{trib} \cdot l_{trib} = 922.5 \text{ ft}^2$

Roof

roof Tributary Area $A_{t.roof} := w_{trib} \cdot l_{trib} = 922.5 \text{ ft}^2$

Live Load Reduction (LLR)

Floor

$L_o := L_{floor} = 20 \text{ psf}$

$K_{LL} := 4$

$$L := L_o \cdot \left(0.25 + \frac{15}{\sqrt{K_{LL} \cdot A_{t.levelx} \cdot \frac{1}{\text{ft}^2}}} \right) = 9.94 \text{ psf}$$

Roof

$L_o := L_{roof} = 61 \text{ psf}$

$R_1 := 0.6$

$R_2 := 1$

$L_{roof} := L_o \cdot R_1 \cdot R_2 = 36.6 \text{ psf}$

Factored Loads

$P_D := D_{floor} \cdot A_{t.levelx} + D_{roof} \cdot A_{t.roof} = 41.512 \text{ kip}$

$P_L := L_{floor} \cdot A_{t.levelx} = 18.45 \text{ kip}$

$P_{Lr} := L_{roof} \cdot A_{t.roof} = 33.7635 \text{ kip}$

$P_u := 1.2 \cdot P_D + 1.6 \cdot P_L + 0.5 \cdot P_{Lr} = 96 \text{ kip}$ (Load Combination 2 controls)

Try

W10x33 ϕcPn = 253 kip

W12x40 ϕcPn = 304 kip

W14x48 ϕcPn = 360 kip

Demands - 7th and 8th Story - Exterior Columns

Unfactored Loads
Floor
Floor Dead Load $D_{floor} := 25\ psf$

Floor Live Load $L_{floor} := 20\ psf$

Roof
Roof Dead Load $D_{roof} := 20\ psf$

Roof Live Load $L_{roof} := 61\ psf$

Wall
Exterior Wall Dead Load $D_{wall} := 22\ psf$

Tributary Area
Floors

Tributary width $w_{trib} := \frac{30}{2}\ ft$

Tributary length $l_{trib} := 30.75\ ft$

Per Level Tributary Area $A_{t.level} := w_{trib} \cdot l_{trib} = 461.25\ ft^2$

7th Floor Tributary Area $A_{t.levelx} := 1 \cdot w_{trib} \cdot l_{trib} = 461.2\ ft^2$

Walls
$storyheight := 14\ ft$
$storynumber := 2$
$height_{trib} := storyheight \cdot storynumber = 28\ ft$

wall Tributary Area $A_{t.wall} := w_{trib} \cdot height_{trib} = 420\ ft^2$

Roof
roof Tributary Area $A_{t.roof} := w_{trib} \cdot l_{trib} = 461.25\ ft^2$

Live Load Reduction (LLR)
Floor
$L_o := L_{floor} = 20\ psf$
$K_{LL} := 4$

$$L := L_o \cdot \left(0.25 + \frac{15}{\sqrt{K_{LL} \cdot A_{t.levelx} \cdot \frac{1}{ft^2}}} \right) = 11.98\ psf$$

Roof
$L_o := L_{roof} = 61\ psf$
$R_1 := 0.6$
$R_2 := 1$
$L_{roof} := L_o \cdot R_1 \cdot R_2 = 36.6\ psf$

Factored Loads
$P_D := D_{floor} \cdot A_{t.levelx} + D_{roof} \cdot A_{t.roof} + D_{wall} \cdot A_{t.wall} = 29.996\ kip$
$P_L := L_{floor} \cdot A_{t.levelx} = 9.225\ kip$
$P_{Lr} := L_{roof} \cdot A_{t.roof} = 16.8817\ kip$

$P_u := 1.2 \cdot P_D + 1.6 \cdot P_L + 0.5 \cdot P_{Lr} = 59\ kip$ (Load Combination 2 controls)

Moment Connections:

Moment Connections Design Column-Beam

$M_u := 189 \text{ ft kip}$

$V_u := 25.2 \text{ kip}$

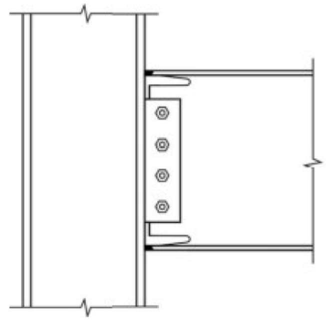
A992 steel

$F_y := 50 \text{ ksi}$

A325-N bolts

$F_u := 58 \text{ ksi}$

E70 electrodes



Step 1 Properties

Beam: W16x35

$d_{beam} := 16.1 \text{ in}$

$b_{f.beam} := 7.04 \text{ in}$

$t_{w.beam} := 0.345 \text{ in}$

$Z_{beam} := 82.3 \text{ in}^3$

Column: W12x53

$d_{column} := 12.1 \text{ in}$

$b_{f.column} := 10 \text{ in}$

$t_{w.column} := 0.345 \text{ in}$

$Z_{column} := 77.9 \text{ in}^3$

Step 2 check flexural strength of beam

$\phi_1 := 0.9$

$F_y := 50 \text{ ksi}$

$M_n := F_y \cdot Z_{beam} = 342.9167 \text{ ft kip}$

$\phi_1 \cdot M_n = 308.625 \text{ ft kip}$

Step 3 Design the flange-to-column weld

Use complete joint penetration (CPJ) groove weld and E70 electrodes

Step 4 Design the web plate

$\phi r_n := 17.9 \text{ kip}$

$n_{notrounded} := \frac{V_u}{\phi r_n} = 1.4078$

$n := 2$

$s := 3 \text{ in}$

plate thickness try

$t := \frac{3}{8} \text{ in}$

$l_{ev} := 1.5 \text{ in}$ end distances

$l := \left(2 \cdot l_{ev} + s \cdot (n - 1)\right) = 6 \text{ in}$

$d_h := \frac{3}{4} \text{ in}$

$t = \frac{3}{8} \text{ in}$

Step 5 Determine the bolt bearing strength

$l_c := l_{ev} - \frac{1}{2} \cdot d_h = 1.125\ \text{in}$

$2 \cdot \frac{3}{4} = 1.5$

so tearout controls over bearing and the bolt nomincal strength is

$R_n := 1.2 \cdot l_c \cdot t \cdot F_u = 29.3625\ \text{kip}$

$\phi_2 := 0.75$

$\phi_2 \cdot R_n = 22.0219\ \text{kip}$

$l_c := s - d_h + \frac{1}{16}\ \text{in} = 2.3125\ \text{in}$

so bearing will control over tearout
nominal strength in

$R_n := 2.4 \cdot d_h \cdot t \cdot F_u = 39.15\ \text{kip}$

$\phi_2 \cdot R_n = 29.3625\ \text{kip}$

since this is greater than the design shear rupture strength, shear rupture will control for these bolts also so

$\phi R_n := 3 \cdot \phi r_n = 53.7\ \text{kip}$

$V_u = 25.2\ \text{kip}$

Good

Step 6 Check the plate for shear yield

$F_{y.plate} := 36\ \text{ksi}$

$\phi_{plate} := 1$

$A_{gv} := t \cdot l = 2.25\ \text{in}^2$

$V_n := 0.6 \cdot F_{y.plate} \cdot A_{gv} = 48.6\ \text{kip}$

$\phi_{plate} \cdot V_n = 48.6\ \text{kip}$

$V_u = 25.2\ \text{kip}$

Good

Step 7 Check the plate for shear rupture

$A_{nv} := t \cdot \left(l - n \cdot \left(d_h + \frac{1\ \text{in}}{16} \right) \right) = 1.6406\ \text{in}^2$

$\phi V_n := 0.75 \cdot 0.6 \cdot F_u \cdot A_{gv} = 58.725\ \text{kip}$

$V_u = 25.2\ \text{kip}$

Good

Step 8 Check block shear of the plate. First calculate the areas

$A_{nt} := \left(l_{ev} - \frac{1}{2} \cdot \left(d_h + \frac{1}{16}\ \text{in} \right) \right) \cdot t_{w.beam} = 0.3773\ \text{in}^2$

$A_{gv.2} := l \cdot t_{w.beam} = 2.07\ \text{in}^2$

$A_{nv.2} := t_{w.beam} \cdot \left(l - (n - 0.5) \cdot \left(d_h + \frac{1}{16}\ \text{in} \right) \right) = 1.6495\ \text{in}^2$

$F_u \cdot A_{nt} = 21.8859\ \text{kip}$

select least strength from shear yield and shear rupture

$0.6 \cdot F_{y.plate} \cdot A_{gv.2} = 44.712\ \text{kip}$

$0.6 \cdot F_u \cdot A_{nv.2} = 57.4037\ \text{kip}$

$\phi R_{n.block} := 0.75 \cdot \left(0.6 \cdot F_{y.plate} \cdot A_{gv.2} + F_u \cdot A_{nt} \right) = 49.9485\ \text{kip}$

$V_u = 25.2\ \text{kip}$

Good

Step 9 Select the plate-to-column weld

Assume fillet weld on each side of the plate with weld design strength of 1.392 kips per $\frac{1}{16}$ in

$$D := \frac{V_u}{2 \cdot 1.392\ \text{kip} \cdot 12} = 0.7543$$

Step 10 Develop the final design

$n = 2$

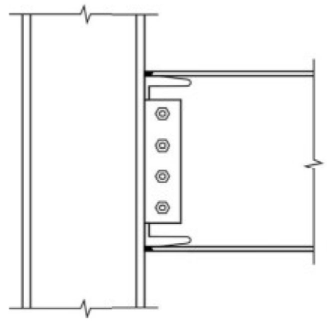
$d_h = 0.75$ in

$t = 0.375$ in

$l = 6$ in

so use two $\frac{3}{4}$ in A325-N bolts in a 3 / 8 x 1 / 2 x 6" plate

Moment Connections Design Column-ExteriorGirder/ElevaterGirder



$M_u := 334\ ft\ kip$

$V_u := 45\ kip$

A992 steel

$F_y := 50\ ksi$

A325-N bolts

$F_u := 58\ ksi$

E70 electrodes

Step 1 Properties

Beam: W18x50

$d_{beam} := 18\ in$

$b_{f.beam} := 7.5\ in$

$t_{w.beam} := 0.355\ in$

$Z_{beam} := 101\ in^3$

Column: W12x53

$d_{column} := 12.1\ in$

$b_{f.column} := 10\ in$

$t_{w.column} := 0.345\ in$

$Z_{column} := 77.9\ in^3$

Step 2 check flexural strength of beam

$\phi_1 := 0.9$

$F_y := 50\ ksi$

$M_n := F_y \cdot Z_{beam} = 420.8333\ ft\ kip$

$\phi_1 \cdot M_n = 378.75\ ft\ kip$

Step 3 Design the flange-to-column weld

Use complete joint penetration (CPJ) groove weld and E70 electrodes

Step 4 Design the web plate

$\phi r_n := 17.9\ kip$

$$n_{notrounded} := \frac{V_u}{\phi r_n} = 2.514$$

$n := 3$

so required minimum of 3 bolts

bolt spacing = 3in

$s := 3\ in$

end distances = 1.5in

plate thickness try

$t := \frac{3}{8}\ in$

$l_{ev} := 1.5\ in$

$l := \left(2 \cdot l_{ev} + s \cdot (n - 1)\right) = 9\ in$

$d_h := \frac{3}{4}\ \text{in}$

t = $\frac{3}{8}\ \text{in}$

Step 5 Determine the bolt bearing strength

$l_c := l_{ev} - \frac{1}{2} \cdot d_h = 1.125\ \text{in}$

$2 \cdot \frac{3}{4} = 1.5$

so tearout controls over bearing and the bolt nomincal strength is

$R_n := 1.2 \cdot l_c \cdot t \cdot F_u = 29.3625\ \text{kip}$

$\phi_2 := 0.75$

$\phi_2 \cdot R_n = 22.0219\ \text{kip}$

$l_c := s - d_h + \frac{1}{16}\ \text{in} = 2.3125\ \text{in}$

so bearing will control over tearout
nominal strength in

$R_n := 2.4 \cdot d_h \cdot t \cdot F_u = 39.15\ \text{kip}$

$\phi_2 \cdot R_n = 29.3625\ \text{kip}$

since this is greater than the design shear rupture strength, shear rupture will control for these bolts also
so

$\phi R_n := 3 \cdot \phi r_n = 53.7\ \text{kip}$

$V_u = 45\ \text{kip}$

Good

Step 6 Check the plate for shear yield

$F_{y.plate} := 36\ \text{ksi}$

$\phi_{plate} := 1$

$A_{gv} := t \cdot l = 3.375\ \text{in}^2$

$V_n := 0.6 \cdot F_{y.plate} \cdot A_{gv} = 72.9\ \text{kip}$

$\phi_{plate} \cdot V_n = 72.9\ \text{kip}$

$V_u = 45\ \text{kip}$

Good

Step 7 Check the plate for shear rupture

$A_{nv} := t \cdot \left(l - n \cdot \left(d_h + \frac{1\ \text{in}}{16} \right) \right) = 2.4609\ \text{in}^2$

$\phi V_n := 0.75 \cdot 0.6 \cdot F_u \cdot A_{gv} = 88.0875\ \text{kip}$

$V_u = 45\ \text{kip}$

Good

Step 8 Check block shear of the plate. First calculate the areas

$A_{nt} := \left(l_{ev} - \frac{1}{2} \cdot \left(d_h + \frac{1}{16}\ \text{in} \right) \right) \cdot t_{w.beam} = 0.3883\ \text{in}^2$

$A_{gv.2} := l \cdot t_{w.beam} = 3.195\ \text{in}^2$

$A_{nv.2} := t_{w.beam} \cdot \left(l - (n - 0.5) \cdot \left(d_h + \frac{1}{16}\ \text{in} \right) \right) = 2.4739\ \text{in}^2$

$F_u \cdot A_{nt} = 22.5203\ \text{kip}$

select least strength from shear yield and shear rupture

$0.6 \cdot F_{y.plate} \cdot A_{gv.2} = 69.012\ \text{kip}$

$0.6 \cdot F_u \cdot A_{nv.2} = 86.0919 \text{ kip}$

$\phi R_{n.block} := 0.75 \cdot \left(0.6 \cdot F_{y.plate} \cdot A_{gv.2} + F_u \cdot A_{nt}\right) = 68.6492 \text{ kip}$

$V_u = 45 \text{ kip}$

Step 9 Select the plate-to-column weld

Assume fillet weld on each side of the plate with weld design strength of 1.392 kips per $\frac{1}{16}$ in

$$D := \frac{V_u}{2 \cdot 1.392 \text{ kip} \cdot 12} = 1.347$$

Step 10 Develop the final design

so use three $\frac{3}{4}$ in A325-N bolts in a 3 / 8 x 1 / 2 x 9" plate

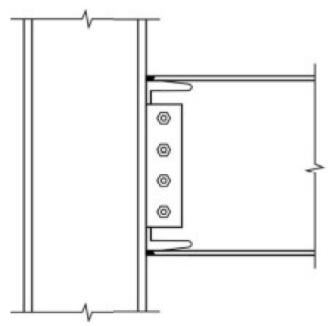
Moment Connections Design Column-InteriorGirder

$M_u := 506\ ft\ kip$

$V_u := 68\ kip$

A992 steel

$F_y := 50\ ksi$



A325-N bolts

$F_u := 58\ ksi$

E70 electrodes

Step 1 Properties

Beam: W21x73

$d_{beam} := 21.2\ in$

$b_{f.beam} := 8.3\ in$

$t_{w.beam} := 0.455\ in$

$Z_{beam} := 172\ in^3$

Column: W12x53

$d_{column} := 12.1\ in$

$b_{f.column} := 10\ in$

$t_{w.column} := 0.345\ in$

$Z_{column} := 77.9\ in^3$

Step 2 check flexural strength of beam

$\phi_1 := 0.9$

$F_y := 50\ ksi$

$M_n := F_y \cdot Z_{beam} = 716.6667\ ft\ kip$

$\phi_1 \cdot M_n = 645\ ft\ kip$

Step 3 Design the flange-to-column weld

Use complete joint penetration (CPJ) groove weld and E70 electrodes

Step 4 Design the web plate

$\phi r_n := 17.9\ kip$

$n_{notrounded} := \dfrac{V_u}{\phi r_n} = 3.7989$

$n := 4$

$s := 3\ in$

plate thickness try

$t := \dfrac{3}{8}\ in$

$l_{ev} := 1.5\ in$ end distances

$l := \left(2 \cdot l_{ev} + s \cdot (n-1)\right) = 12\ in$

$d_h := \dfrac{3}{4}\ in$

$t = \dfrac{3}{8}\ in$

Step 5 Determine the bolt bearing strength

$l_c := l_{ev} - \frac{1}{2} \cdot d_h = 1.125 \text{ in}$

$2 \cdot \frac{3}{4} = 1.5$

so tearout controls over bearing and the bolt nomincal strength is

$R_n := 1.2 \cdot l_c \cdot t \cdot F_u = 29.3625 \text{ kip}$

$\phi_2 := 0.75$

$\phi_2 \cdot R_n = 22.0219 \text{ kip}$

$l_c := s - d_h + \frac{1}{16} \text{ in} = 2.3125 \text{ in}$

so bearing will control over tearout
nominal strength in

$R_n := 2.4 \cdot d_h \cdot t \cdot F_u = 39.15 \text{ kip}$

$\phi_2 \cdot R_n = 29.3625 \text{ kip}$

since this is greater than the design shear rupture strength, shear rupture will control for these bolts also so

$\phi R_n := 3 \cdot \phi r_n = 53.7 \text{ kip}$

$V_u = 68 \text{ kip}$

Good

Step 6 Check the plate for shear yield

$F_{y.plate} := 36 \text{ ksi}$

$\phi_{plate} := 1$

$A_{gv} := t \cdot l = 4.5 \text{ in}^2$

$V_n := 0.6 \cdot F_{y.plate} \cdot A_{gv} = 97.2 \text{ kip}$

$\phi_{plate} \cdot V_n = 97.2 \text{ kip}$

$V_u = 68 \text{ kip}$

Good

Step 7 Check the plate for shear rupture

$A_{nv} := t \cdot \left(l - n \cdot \left(d_h + \frac{1 \text{ in}}{16} \right) \right) = 3.2812 \text{ in}^2$

$\phi V_n := 0.75 \cdot 0.6 \cdot F_u \cdot A_{gv} = 117.45 \text{ kip}$

$V_u = 68 \text{ kip}$

Good

Step 8 Check block shear of the plate. First calculate the areas

$A_{nt} := \left(l_{ev} - \frac{1}{2} \cdot \left(d_h + \frac{1}{16} \text{ in} \right) \right) \cdot t_{w.beam} = 0.4977 \text{ in}^2$

$A_{gv.2} := l \cdot t_{w.beam} = 5.46 \text{ in}^2$

$A_{nv.2} := t_{w.beam} \cdot \left(l - (n - 0.5) \cdot \left(d_h + \frac{1}{16} \text{ in} \right) \right) = 4.1661 \text{ in}^2$

$F_u \cdot A_{nt} = 28.8641 \text{ kip}$

select least strength from shear yield and shear rupture

$0.6 \cdot F_{y.plate} \cdot A_{gv.2} = 117.936 \text{ kip}$

$0.6 \cdot F_u \cdot A_{nv.2} = 144.9801 \text{ kip}$

$\phi R_{n.block} := 0.75 \cdot \left(0.6 \cdot F_{y.plate} \cdot A_{gv.2} + F_u \cdot A_{nt} \right) = 110.1 \text{ kip}$

$V_u = 68 \text{ kip}$

Step 9 Select the plate-to-column weld

Assume fillet weld on each side of the plate with weld design strength of 1.392 kips per $\frac{1}{16}$ in

$$D := \frac{V_u}{2 \cdot 1.392 \text{ kip} \cdot 12} = 2.0354$$

Step 10 Develop the final design

$n = 4$

$d_h = 0.75$ in

$t = 0.375$ in

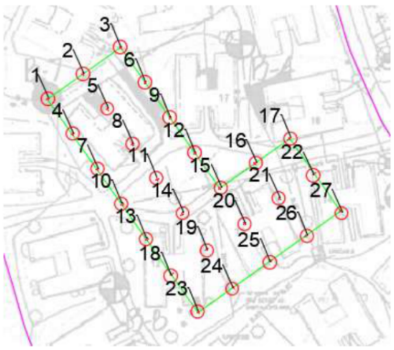
$l = 12$ in

so use four $\frac{3}{4}$ in A325-N bolts in a 3 / 8 x 1 / 2 x 12" plate

APPENDIX E: Substructure Design

Initial Design: Not Accounting for Settlement

Multi-Story Residential Building: Design of Foundation 1



Given the description of the soil from the boring logs (fine to medium sand, silty or clayey medium to coarse sand that is medium to compact), Naval Facilities Engineering Command recommends an allowable bearing pressure of 2.5 tons/ sqft

Assumptions:
*The embeddment depth is 3 feet; $D_f := 3\ \text{ft}$

*The unit weight of the concrete foundation is 150 lb/cubic foot; $\gamma_{conc} := 150\ \frac{\text{lb}}{\text{ft}^3}$

*The spread footing is square, such that dimensions B equals L
*The soil profile is fairly homogeneous with sub-horizontal layers
*Weight for final foundation element of 2% of the axial load in column

Soil Properties: $\phi := 30\ °$ $c := 0\ \text{ksf}$; $\gamma := 108\ \frac{\text{psf}}{\text{ft}}$

Preliminary Design of Base: $P := 343\ \text{kip}$ $V := 1.51\ \text{kip}$

$q_{allow} := 2.5\ \frac{\text{tonf}}{\text{ft}^2}$

$Q_{app.net} := P \cdot 1.02 = 349.86\ \text{kip}$

$A := \frac{Q_{app.net}}{q_{allow}} = 69.972\ \text{ft}^2$

so $B := 8.5\ \text{ft}$ and $L := 8.5\ \text{ft}$ such that

$A := B \cdot L = 72.25\ \text{ft}^2$

Checking that the Dimensions are satisfactory:

Load Inclination: $\alpha := \text{atan}\left(\frac{V}{P}\right) = 0.2522\ °$

Eccentricity: $e := 0$
Effective Width: $B' := B - 2 \cdot e = 8.5\ \text{ft}$
Effective Length: $L' := L - 2 \cdot e = 8.5\ \text{ft}$
Since the Water Table is not located near the base of the foundation, there is no effect on the ultimate bearing capacity

Bearing Capacity Factors: $N_c := 30.2$; $N_q := 18.5$; $N_\gamma := 22.5$ (Used Vesic's Approach);
Correction Factors:

Shape Factors: $N_\phi := \left(\tan\left(45\ ° + \frac{\phi}{2}\right)\right)^2 = 3$

$s_c := 1 + 0.2 \cdot \frac{B'}{L'} \cdot N_\phi = 1.6$

$s_q := 1 + 0.1 \cdot \frac{B'}{L'} \cdot N_\phi = 1.3$

$s_\gamma := s_q = 1.3$

Depth Factors:

$$d_c := 1 + 0.2 \cdot \frac{D_f}{B'} \cdot \sqrt{N_\phi} = 1.1223$$

$$d_q := 1 + 0.1 \cdot \frac{D_f}{B'} \cdot \sqrt{N_\phi} = 1.0611$$

$$d_\gamma := d_q = 1.0611$$

Inclination Factors:

$$i_c := \left(1 - \frac{\alpha}{90\,°}\right)^2 = 0.9944$$

$$i_q := i_c = 0.9944$$

$$i_\gamma := \left(1 - \frac{\alpha}{\phi}\right) = 0.9916$$

Ultimate Bearing Capacity:

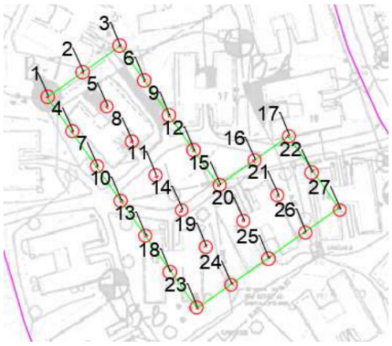
$$q_{ult} := s_c \cdot d_c \cdot i_c \cdot c \cdot N_c + s_q \cdot d_q \cdot i_q \cdot \gamma \cdot D_f \cdot N_q + s_\gamma \cdot d_\gamma \cdot i_\gamma \cdot 0.5 \cdot B' \cdot \gamma \cdot N_\gamma = 22.349\ \mathrm{ksf}$$

$$q_{ult.net} := q_{ult} - \gamma \cdot D_f = 22.025\ \mathrm{ksf}$$

$$q_{app.net} := \frac{Q_{app.net}}{B' \cdot L'} = 4.8424\ \mathrm{ksf}$$

$$FS := \frac{q_{ult.net}}{q_{app.net}} = 4.5484$$

Multi-Story Residential Building: Design of Foundation 3



Given the description of the soil from the boring logs (fine to medium sand, silty or clayey medium to coarse sand that is medium to compact), Naval Facilities Engineering Command recommends an allowable bearing pressure of 2.5 tons/ sqft

Assumptions:
*The embeddment depth is 3 feet; $D_f := 3\ \mathrm{ft}$

*The unit weight of the concrete foundation is 150 lb/cubic foot; $\gamma_{conc} := 150\ \dfrac{\mathrm{lb}}{\mathrm{ft}^3}$

*The spread footing is square, such that dimensions B equals L
*The soil profile is fairly homogeneous with sub-horizontal layers
*Weight for final foundation element of 2% of the axial load in column
*Unfactored axial load from column design is 343 kips

Soil Properties: $\phi := 31\ °$ $c := 0\ \mathrm{ksf}$; $\gamma := 109.6\ \dfrac{\mathrm{psf}}{\mathrm{ft}}$

Preliminary Design of Base: $P := 343\ \mathrm{kip}$ $V := 0.48\ \mathrm{kip}$

$$q_{allow} := 2.5\ \frac{\mathrm{tonf}}{\mathrm{ft}^2}$$

$$Q_{app.net} := P \cdot 1.02 = 349.86\ \mathrm{kip}$$

$$A := \frac{Q_{app.net}}{q_{allow}} = 69.972\ \mathrm{ft}^2$$

so $B := 8.5\ \mathrm{ft}$ and $L := 8.5\ \mathrm{ft}$ such that

$$A := B \cdot L = 72.25\ \mathrm{ft}^2$$

Checking that the Dimensions are satisfactory:

Load Inclination: $\alpha := \mathrm{atan}\left(\dfrac{V}{P}\right) = 0.0802\ °$

Eccentricity: $e := 0$
Effective Width: $B' := B - 2 \cdot e = 8.5\ \mathrm{ft}$
Effective Length: $L' := L - 2 \cdot e = 8.5\ \mathrm{ft}$
Since the Water Table is not located near the base of the foundation, there is no effect on the ultimate bearing capacity

Bearing Capacity Factors: $N_c := 30.2$; $N_q := 18.5$; $N_\gamma := 22.5$ (Used Vesic's Approach);

Correction Factors:

Shape Factors: $N_{\phi} := \left(\tan\left(45° + \frac{\phi}{2}\right)\right)^2 = 3.124$

$s_c := 1 + 0.2 \cdot \frac{B'}{L'} \cdot N_{\phi} = 1.6248$

$s_q := 1 + 0.1 \cdot \frac{B'}{L'} \cdot N_{\phi} = 1.3124$

$s_{\gamma} := s_q = 1.3124$

Depth Factors:

$d_c := 1 + 0.2 \cdot \frac{D_f}{B'} \cdot \sqrt{N_{\phi}} = 1.1248$

$d_q := 1 + 0.1 \cdot \frac{D_f}{B'} \cdot \sqrt{N_{\phi}} = 1.0624$

$d_{\gamma} := d_q = 1.0624$

Inclination Factors:

$i_c := \left(1 - \frac{\alpha}{90°}\right)^2 = 0.9982$

$i_q := i_c = 0.9982$

$i_{\gamma} := \left(1 - \frac{\alpha}{\phi}\right) = 0.9974$

Ultimate Bearing Capacity:

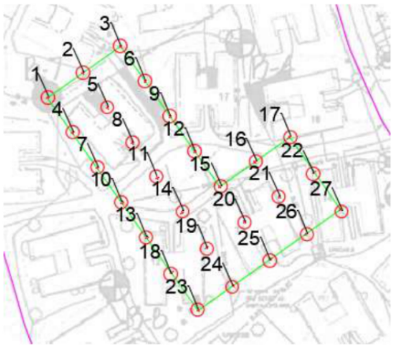
$q_{ult} := s_c \cdot d_c \cdot i_c \cdot c \cdot N_c + s_q \cdot d_q \cdot i_q \cdot \gamma \cdot D_f \cdot N_q + s_{\gamma} \cdot d_{\gamma} \cdot i_{\gamma} \cdot 0.5 \cdot B' \cdot \gamma \cdot N_{\gamma} = 23.0409 \text{ ksf}$

$q_{ult.net} := q_{ult} - \gamma \cdot D_f = 22.7121 \text{ ksf}$

$q_{app.net} := \frac{Q_{app.net}}{B' \cdot L'} = 4.8424 \text{ ksf}$

$FS := \frac{q_{ult.net}}{q_{app.net}} = 4.6903$

Multi-Story Residential Building: Design of Foundation 23



Given the description of the soil from the boring logs (fine to medium sand, silty or clayey medium to coarse sand that is medium to compact), Naval Facilities Engineering Command recommends an allowable bearing pressure of 2.5 tons/ sqft

Assumptions:
*The embeddment depth is 3 feet; $D_f := 3\ \text{ft}$

*The unit weight of the concrete foundation is 150 lb/cubic foot; $\gamma_{conc} := 150\ \frac{\text{lb}}{\text{ft}^3}$

*The spread footing is square, such that dimensions B equals L
*The soil profile is fairly homogeneous with sub-horizontal layers
*Weight for final foundation element of 2% of the axial load in column

Soil Properties: $\phi := 29\ °$ $c := 0\ \text{ksf}$; $\gamma := 106\ \frac{\text{psf}}{\text{ft}}$

Preliminary Design of Base: $P := 343\ \text{kip}$ $V := 1.51\ \text{kip}$

$q_{allow} := 2.5\ \frac{\text{tonf}}{\text{ft}^2}$

$Q_{app.net} := P \cdot 1.02 = 349.86\ \text{kip}$

$A := \frac{Q_{app.net}}{q_{allow}} = 69.972\ \text{ft}^2$

so $B := 8.5\ \text{ft}$ and $L := 8.5\ \text{ft}$ such that

$A := B \cdot L = 72.25\ \text{ft}^2$

Checking that the Dimensions are satisfactory:

Load Inclination: $\alpha := \operatorname{atan}\left(\frac{V}{P}\right) = 0.2522\ °$

Eccentricity: $e := 0$
Effective Width: $B' := B - 2 \cdot e = 8.5\ \text{ft}$
Effective Length: $L' := L - 2 \cdot e = 8.5\ \text{ft}$
Since the Water Table is not located near the base of the foundation, there is no effect on the ultimate bearing capacity

Bearing Capacity Factors: $N_c := 27.9$; $N_q := 16.5$; $N_\gamma := 19.4$ (Used Vesic's Approach);

Correction Factors:

Shape Factors: $N_{\phi} := \left(\tan\left(45° + \frac{\phi}{2}\right)\right)^2 = 2.8821$

$s_c := 1 + 0.2 \cdot \frac{B'}{L'} \cdot N_{\phi} = 1.5764$

$s_q := 1 + 0.1 \cdot \frac{B'}{L'} \cdot N_{\phi} = 1.2882$

$s_{\gamma} := s_q = 1.2882$

Depth Factors:

$d_c := 1 + 0.2 \cdot \frac{D_f}{B'} \cdot \sqrt{N_{\phi}} = 1.1198$

$d_q := 1 + 0.1 \cdot \frac{D_f}{B'} \cdot \sqrt{N_{\phi}} = 1.0599$

$d_{\gamma} := d_q = 1.0599$

Inclination Factors:

$i_c := \left(1 - \frac{\alpha}{90°}\right)^2 = 0.9944$

$i_q := i_c = 0.9944$

$i_{\gamma} := \left(1 - \frac{\alpha}{\phi}\right) = 0.9913$

Ultimate Bearing Capacity:

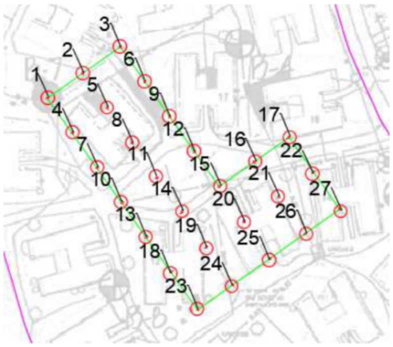
$q_{ult} := s_c \cdot d_c \cdot i_c \cdot c \cdot N_c + s_q \cdot d_q \cdot i_q \cdot \gamma \cdot D_f \cdot N_q + s_{\gamma} \cdot d_{\gamma} \cdot i_{\gamma} \cdot 0.5 \cdot B' \cdot \gamma \cdot N_{\gamma} = 18.9534 \text{ ksf}$

$q_{ult.net} := q_{ult} - \gamma \cdot D_f = 18.6354 \text{ ksf}$

$q_{app.net} := \frac{Q_{app.net}}{B' \cdot L'} = 4.8424 \text{ ksf}$

$FS := \frac{q_{ult.net}}{q_{app.net}} = 3.8484$

Multi-Story Residential Building: Design of Foundation 27



Given the description of the soil from the boring logs (fine to medium sand, silty or clayey medium to coarse sand that is medium to compact), Naval Facilities Engineering Command recommends an allowable bearing pressure of 2.5 tons/ sqft

Assumptions:

*The embeddment depth is 3 feet; $D_f := 3 \text{ ft}$

*The unit weight of the concrete foundation is 150 lb/cubic foot; $\gamma_{conc} := 150 \frac{\text{lb}}{\text{ft}^3}$

*The spread footing is square, such that dimensions B equals L

*The soil profile is fairly homogeneous with sub-horizontal layers

*Weight for final foundation element of 2% of the axial load in column

Soil Properties: $\phi := 29\ °$ $c := 0 \text{ ksf}$; $\gamma := 107.5 \frac{\text{psf}}{\text{ft}}$

Preliminary Design of Base: $P := 343 \text{ kip}$ $V := 0.48 \text{ kip}$

$q_{allow} := 2.5 \frac{\text{tonf}}{\text{ft}^2}$

$Q_{app.net} := P \cdot 1.02 = 349.86 \text{ kip}$

$A := \frac{Q_{app.net}}{q_{allow}} = 69.972 \text{ ft}^2$

so $B := 8.5 \text{ ft}$ and $L := 8.5 \text{ ft}$ such that

$A := B \cdot L = 72.25 \text{ ft}^2$

Checking that the Dimensions are satisfactory:

Load Inclination: $\alpha := \operatorname{atan}\left(\frac{V}{P}\right) = 0.0802\ °$

Eccentricity: $e := 0$

Effective Width: $B' := B - 2 \cdot e = 8.5 \text{ ft}$

Effective Length: $L' := L - 2 \cdot e = 8.5 \text{ ft}$

Since the Water Table is not located near the base of the foundation, there is no effect on the ultimate bearing capacity

Bearing Capacity Factors: $N_c := 27.9$; $N_q := 16.5$; $N_\gamma := 19.4$ (Used Vesic's Approach);

Correction Factors:

Shape Factors: $N_\phi := \left(\tan\left(45\ ° + \frac{\phi}{2}\right)\right)^2 = 2.8821$

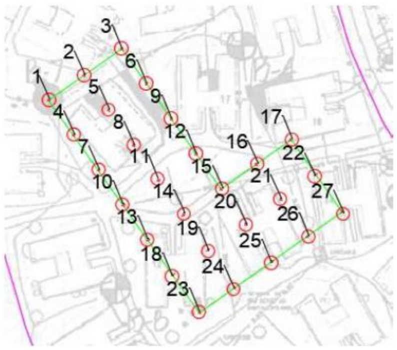
$s_c := 1 + 0.2 \cdot \frac{B'}{L'} \cdot N_\phi = 1.5764$

$s_q := 1 + 0.1 \cdot \frac{B'}{L'} \cdot N_\phi = 1.2882$

$s_\gamma := s_q = 1.2882$

Final Design: Incorporating Settlement and Bearing Capacity

Multi-Story Residential Building: Design of Foundation 1



Given the description of the soil from the boring logs (fine to medium sand, silty or clayey medium to coarse sand that is medium to compact), Naval Facilities Engineering Command recommends an allowable bearing pressure of 2.5 tons/ sqft

Assumptions:
*The embeddment depth is 3 feet; $D_f := 3\ \text{ft}$

*The unit weight of the concrete foundation is 150 lb/cubic foot; $\gamma_{conc} := 150\ \dfrac{\text{lbf}}{\text{ft}^3}$

*The spread footing is square, such that dimensions B equals L
*The soil profile is fairly homogeneous with sub-horizontal layers
*Weight for final foundation element of 2% of the axial load in column

Soil Properties: $\phi := 30\ °$ $c := 0\ \text{ksf}$; $\gamma := 116\ \dfrac{\text{psf}}{\text{ft}}$

Preliminary Design of Base: $P := 343\ \text{kip}$ $V := 1.51\ \text{kip}$

$$q_{allow} := 2.5\ \frac{\text{tonf}}{\text{ft}^2}$$

$$Q_{app.net} := P \cdot 1.02 = 349.86\ \text{kip}$$

$$A := \frac{Q_{app.net}}{q_{allow}} = 69.972\ \text{ft}^2$$

so $B := 12\ \text{ft}$ and $L := 12\ \text{ft}$ such that

$$A := B \cdot L = 144\ \text{ft}^2$$

Checking that the Dimensions are satisfactory:

Load Inclination: $\alpha := \operatorname{atan}\left(\dfrac{V}{P}\right) = 0.2522\ °$

Eccentricity: $e := \dfrac{V \cdot D_f}{P} = 0.0132\ \text{ft}$

Effective Width: $B' := B - 2 \cdot e = 11.9736\ \text{ft}$
Effective Length: $L' := L - 2 \cdot e = 11.9736\ \text{ft}$
Since the Water Table is not located near the base of the foundation, there is no effect on the ultimate bearing capacity

Bearing Capacity Factors: $N_c := 30.2$; $N_q := 18.5$; $N_\gamma := 22.5$ (Used Vesic's Approach);

Correction Factors:

Shape Factors: $N_\phi := \left(\tan\left(45\ ° + \dfrac{\phi}{2}\right)\right)^2 = 3$

$$s_c := 1 + 0.2 \cdot \frac{B'}{L'} \cdot N_\phi = 1.6$$

$$s_q := 1 + 0.1 \cdot \frac{B'}{L'} \cdot N_\phi = 1.3$$

$s_\gamma := s_q = 1.3$

Depth Factors:

$$d_c := 1 + 0.2 \cdot \frac{D_f}{B'} \cdot \sqrt{N_\phi} = 1.0868$$

$$d_q := 1 + 0.1 \cdot \frac{D_f}{B'} \cdot \sqrt{N_\phi} = 1.0434$$

$$d_\gamma := d_q = 1.0434$$

Inclination Factors:

$$i_c := \left(1 - \frac{\alpha}{90\ °}\right)^2 = 0.9944$$

$$i_q := i_c = 0.9944$$

$$i_\gamma := \left(1 - \frac{\alpha}{\phi}\right) = 0.9916$$

Ultimate Bearing Capacity:

$$q_{ult} := s_c \cdot d_c \cdot i_c \cdot c \cdot N_c + s_q \cdot d_q \cdot i_q \cdot \gamma \cdot D_f \cdot N_q + s_\gamma \cdot d_\gamma \cdot i_\gamma \cdot 0.5 \cdot B' \cdot \gamma \cdot N_\gamma = 29.7002\ \text{ksf}$$

$$q_{ult.net} := q_{ult} - \gamma \cdot D_f = 29.3522\ \text{ksf}$$

$$q_{app.net} := \frac{P}{B' \cdot L'} + \frac{\gamma_{conc} \cdot B' \cdot L' \cdot D_f}{B' \cdot L'} = 2.8425\ \text{ksf}$$

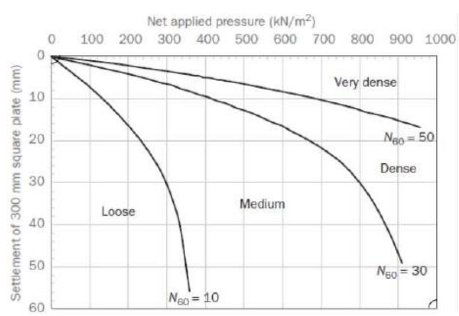
$$FS := \frac{q_{ult.net}}{q_{app.net}} = 10.3263$$

Checking for Settlement using Terzaghi and Peck's (1967) Method:

$$q_{app.net} = 136.098\ \text{kPa}$$

$$N_{60} := 9.56$$

Using this interactive chart from Sivakugan 2021:

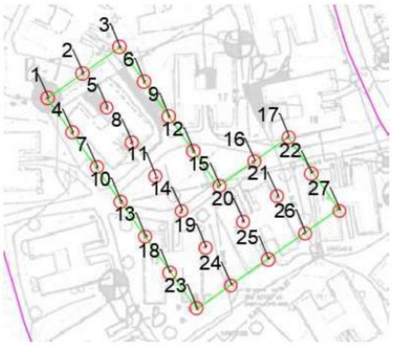


$$s_{plate} := 10\ \text{mm}$$

$$s_{footing} := s_{plate} \cdot \left(\frac{2 \cdot B}{B}\right)^2 \cdot \left(1 - \frac{1}{3} \cdot \frac{D_f}{B}\right) = 36.6667\ \text{mm}$$

Which is less than the maximum allowable settlement described by O'Brien (2013)~ 40 mm for sands

Multi-Story Residential Building: Design of Foundation 3



Given the description of the soil from the boring logs (fine to medium sand, silty or clayey medium to coarse sand that is medium to compact), Naval Facilities Engineering Command recommends an allowable bearing pressure of 2.5 tons/ sqft

Assumptions:
*The embeddment depth is 3 feet; $D_f := 3\ \text{ft}$

*The unit weight of the concrete foundation is 150 lb/cubic foot; $\gamma_{conc} := 150\ \frac{\text{lbf}}{\text{ft}^3}$

*The spread footing is square, such that dimensions B equals L
*The soil profile is fairly homogeneous with sub-horizontal layers
*Weight for final foundation element of 2% of the axial load in column
*Unfactored axial load from column design is 343 kips

Soil Properties: $\phi := 31\ °$ $c := 0\ \text{ksf}$; $\gamma := 118.1\ \frac{\text{psf}}{\text{ft}}$

Preliminary Design of Base: $P := 343\ \text{kip}$ $V := 0.48\ \text{kip}$

$q_{allow} := 2.5\ \frac{\text{tonf}}{\text{ft}^2}$

$Q_{app.net} := P \cdot 1.02 = 349.86\ \text{kip}$

$A := \frac{Q_{app.net}}{q_{allow}} = 69.972\ \text{ft}^2$

so $B := 12\ \text{ft}$ and $L := 12\ \text{ft}$ such that

$A := B \cdot L = 144\ \text{ft}^2$

Checking that the Dimensions are satisfactory:

Load Inclination: $\alpha := \text{atan}\left(\frac{V}{P}\right) = 0.0802\ °$

Eccentricity: $e := \frac{V \cdot D_f}{P} = 0.0042\ \text{ft}$

Effective Width: $B' := B - 2 \cdot e = 11.9916\ \text{ft}$
Effective Length: $L' := L - 2 \cdot e = 11.9916\ \text{ft}$
Since the Water Table is not located near the base of the foundation, there is no effect on the ultimate bearing capacity

Bearing Capacity Factors: $N_c := 30.2$; $N_q := 18.5$; $N_\gamma := 22.5$ (Used Vesic's Approach);

Correction Factors:

Shape Factors: $N_\phi := \left(\tan\left(45° + \frac{\phi}{2}\right)\right)^2 = 3.124$

$s_c := 1 + 0.2 \cdot \frac{B'}{L'} \cdot N_\phi = 1.6248$

$s_q := 1 + 0.1 \cdot \frac{B'}{L'} \cdot N_\phi = 1.3124$

$s_\gamma := s_q = 1.3124$

Depth Factors:

$d_c := 1 + 0.2 \cdot \frac{D_f}{B'} \cdot \sqrt{N_\phi} = 1.0884$

$d_q := 1 + 0.1 \cdot \frac{D_f}{B'} \cdot \sqrt{N_\phi} = 1.0442$

$d_\gamma := d_q = 1.0442$

Inclination Factors:

$i_c := \left(1 - \frac{\alpha}{90°}\right)^2 = 0.9982$

$i_q := i_c = 0.9982$

$i_\gamma := \left(1 - \frac{\alpha}{\phi}\right) = 0.9974$

Ultimate Bearing Capacity:

$q_{ult} := s_c \cdot d_c \cdot i_c \cdot c \cdot N_c + s_q \cdot d_q \cdot i_q \cdot \gamma \cdot D_f \cdot N_q + s_\gamma \cdot d_\gamma \cdot i_\gamma \cdot 0.5 \cdot B' \cdot \gamma \cdot N_\gamma = 30.7444 \text{ ksf}$

$q_{ult.net} := q_{ult} - \gamma \cdot D_f = 30.3901 \text{ ksf}$

$q_{app.net} := \frac{P}{B' \cdot L'} + \frac{\gamma_{conc} \cdot B' \cdot L' \cdot D_f}{B' \cdot L'} = 2.8353 \text{ ksf}$

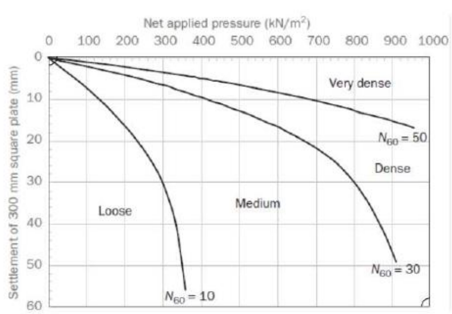
$FS := \frac{q_{ult.net}}{q_{app.net}} = 10.7185$

Checking for Settlement using Terzaghi and Peck's (1967) Method:

$q_{app.net} = 135.754 \text{ kPa}$

$N_{60} := 11.69$

Using this interactive chart from Sivakugan 2021:

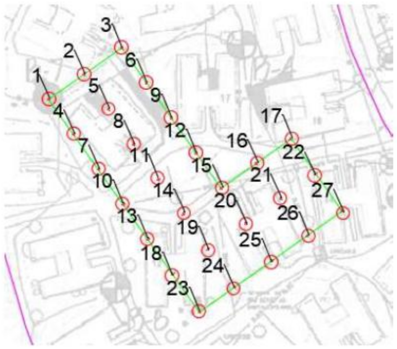


$s_{plate} := 8 \text{ mm}$

$s_{footing} := s_{plate} \cdot \left(\frac{2 \cdot B}{B}\right)^2 \cdot \left(1 - \frac{1}{3} \cdot \frac{D_f}{B}\right) = 29.3333 \text{ mm}$

Which is less than the maximum allowable settlement described by O'Brien (2013) ~40 mm for sands

Multi-Story Residential Building: Design of Foundation 23



Given the description of the soil from the boring logs (fine to medium sand, silty or clayey medium to coarse sand that is medium to compact), Naval Facilities Engineering Command recommends an allowable bearing pressure of 2.5 tons/ sqft

Assumptions:
*The embeddment depth is 3 feet; $D_f := 3\ \text{ft}$

*The unit weight of the concrete foundation is 150 lb/cubic foot; $\gamma_{conc} := 150\ \dfrac{\text{lbf}}{\text{ft}^3}$

*The spread footing is square, such that dimensions B equals L
*The soil profile is fairly homogeneous with sub-horizontal layers
*Weight for final foundation element of 2% of the axial load in column

Soil Properties: $\phi := 29\ °$ $c := 0\ \text{ksf}$; $\gamma := 113.1\ \dfrac{\text{psf}}{\text{ft}}$

Preliminary Design of Base: $P := 343\ \text{kip}$ $V := 1.51\ \text{kip}$

$q_{allow} := 2.5\ \dfrac{\text{tonf}}{\text{ft}^2}$

$Q_{app.net} := P \cdot 1.02 = 349.86\ \text{kip}$

$A := \dfrac{Q_{app.net}}{q_{allow}} = 69.972\ \text{ft}^2$

so $B := 12\ \text{ft}$ and $L := 12\ \text{ft}$ such that

$A := B \cdot L = 144\ \text{ft}^2$

Checking that the Dimensions are satisfactory:

Load Inclination: $\alpha := \text{atan}\left(\dfrac{V}{P}\right) = 0.2522\ °$

Eccentricity: $e := \dfrac{V \cdot D_f}{P} = 0.0132\ \text{ft}$

Effective Width: $B' := B - 2 \cdot e = 11.9736\ \text{ft}$
Effective Length: $L' := L - 2 \cdot e = 11.9736\ \text{ft}$
Since the Water Table is not located near the base of the foundation, there is no effect on the ultimate bearing capacity

Bearing Capacity Factors: $N_c := 27.9$; $N_q := 16.5$; $N_\gamma := 19.4$ (Used Vesic's Approach);

Correction Factors:

Shape Factors: $N_\phi := \left(\tan\left(45° + \frac{\phi}{2}\right)\right)^2 = 2.8821$

$s_c := 1 + 0.2 \cdot \frac{B'}{L'} \cdot N_\phi = 1.5764$

$s_q := 1 + 0.1 \cdot \frac{B'}{L'} \cdot N_\phi = 1.2882$

$s_\gamma := s_q = 1.2882$

Depth Factors:

$d_c := 1 + 0.2 \cdot \frac{D_f}{B'} \cdot \sqrt{N_\phi} = 1.0851$

$d_q := 1 + 0.1 \cdot \frac{D_f}{B'} \cdot \sqrt{N_\phi} = 1.0425$

$d_\gamma := d_q = 1.0425$

Inclination Factors:

$i_c := \left(1 - \frac{\alpha}{90°}\right)^2 = 0.9944$

$i_q := i_c = 0.9944$

$i_\gamma := \left(1 - \frac{\alpha}{\phi}\right) = 0.9913$

Ultimate Bearing Capacity:

$q_{ult} := s_c \cdot d_c \cdot i_c \cdot c \cdot N_c + s_q \cdot d_q \cdot i_q \cdot \gamma \cdot D_f \cdot N_q + s_\gamma \cdot d_\gamma \cdot i_\gamma \cdot 0.5 \cdot B' \cdot \gamma \cdot N_\gamma = 24.9647 \text{ ksf}$

$q_{ult.net} := q_{ult} - \gamma \cdot D_f = 24.6254 \text{ ksf}$

$q_{app.net} := \frac{P}{B' \cdot L'} + \frac{\gamma_{conc} \cdot B' \cdot L' \cdot D_f}{B' \cdot L'} = 2.8425 \text{ ksf}$

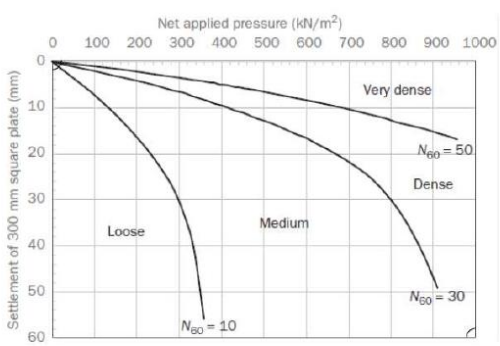
$FS := \frac{q_{ult.net}}{q_{app.net}} = 8.6634$

Checking for Settlement using Terzaghi and Peck's (1967) Method:

$q_{app.net} = 136.098 \text{ kPa}$

$N_{60} := 10.38$

Using this interactive chart from Sivakugan 2021:

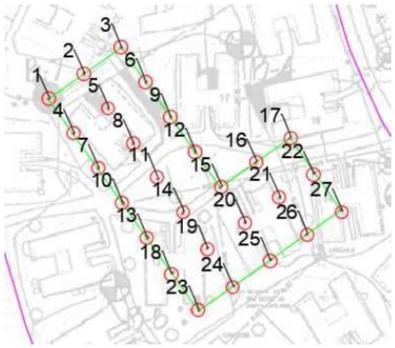


$s_{plate} := 9 \text{ mm}$

$s_{footing} := s_{plate} \cdot \left(\frac{2 \cdot B}{B}\right)^2 \cdot \left(1 - \frac{1}{3} \cdot \frac{D_f}{B}\right) = 33 \text{ mm}$

Which is less than the maximum allowable settlement described by O'Brien (2013) ~40 mm for sands

Multi-Story Residential Building: Design of Foundation 27



Given the description of the soil from the boring logs (fine to medium sand, silty or clayey medium to coarse sand that is medium to compact), Naval Facilities Engineering Command recommends an allowable bearing pressure of 2.5 tons/ sqft

Assumptions:
*The embeddment depth is 3 feet; $D_f := 3\ \text{ft}$

*The unit weight of the concrete foundation is 150 lb/cubic foot; $\gamma_{conc} := 150\ \dfrac{\text{lbf}}{\text{ft}^3}$

*The spread footing is square, such that dimensions B equals L
*The soil profile is fairly homogeneous with sub-horizontal layers
*Weight for final foundation element of 2% of the axial load in column

Soil Properties: $\phi := 29\ °$ $c := 0\ \text{ksf}$; $\gamma := 115.1\ \dfrac{\text{psf}}{\text{ft}}$

Preliminary Design of Base: $P := 343\ \text{kip}$ $V := 0.48\ \text{kip}$

$$q_{allow} := 2.5\ \frac{\text{tonf}}{\text{ft}^2}$$

$$Q_{app.net} := P \cdot 1.02 = 349.86\ \text{kip}$$

$$A := \frac{Q_{app.net}}{q_{allow}} = 69.972\ \text{ft}^2$$

so $B := 12\ \text{ft}$ and $L := 12\ \text{ft}$ such that

$$A := B \cdot L = 144\ \text{ft}^2$$

Checking that the Dimensions are satisfactory:

Load Inclination: $\alpha := \text{atan}\left(\dfrac{V}{P}\right) = 0.0802\ °$

Eccentricity: $e := \dfrac{V \cdot D_f}{P} = 0.0042\ \text{ft}$

Effective Width: $B' := B - 2 \cdot e = 11.9916\ \text{ft}$
Effective Length: $L' := L - 2 \cdot e = 11.9916\ \text{ft}$
Since the Water Table is not located near the base of the foundation, there is no effect on the ultimate bearing capacity

Bearing Capacity Factors: $N_c := 27.9$; $N_q := 16.5$; $N_\gamma := 19.4$ (Used Vesic's Approach);

Correction Factors:

Shape Factors: $N_\phi := \left(\tan\left(45\ ° + \dfrac{\phi}{2}\right)\right)^2 = 2.8821$

$$s_c := 1 + 0.2 \cdot \frac{B'}{L'} \cdot N_\phi = 1.5764$$

$$s_q := 1 + 0.1 \cdot \frac{B'}{L'} \cdot N_\phi = 1.2882$$

$s_\gamma := s_q = 1.2882$

Depth Factors:

$d_c := 1 + 0.2 \cdot \frac{D_f}{B'} \cdot \sqrt{N_\phi} = 1.0849$

$d_q := 1 + 0.1 \cdot \frac{D_f}{B'} \cdot \sqrt{N_\phi} = 1.0425$

$d_\gamma := d_q = 1.0425$

Inclination Factors:

$i_c := \left(1 - \frac{\alpha}{90\ °}\right)^2 = 0.9982$

$i_q := i_c = 0.9982$

$i_\gamma := \left(1 - \frac{\alpha}{\phi}\right) = 0.9972$

Ultimate Bearing Capacity:

$q_{ult} := s_c \cdot d_c \cdot i_c \cdot c \cdot N_c + s_q \cdot d_q \cdot i_q \cdot \gamma \cdot D_f \cdot N_q + s_\gamma \cdot d_\gamma \cdot i_\gamma \cdot 0.5 \cdot B' \cdot \gamma \cdot N_\gamma = 25.5672\ \text{ksf}$

$q_{ult.net} := q_{ult} - \gamma \cdot D_f = 25.2219\ \text{ksf}$

$q_{app.net} := \frac{P}{B' \cdot L'} + \frac{\gamma_{conc} \cdot B' \cdot L' \cdot D_f}{B' \cdot L'} = 2.8353\ \text{ksf}$

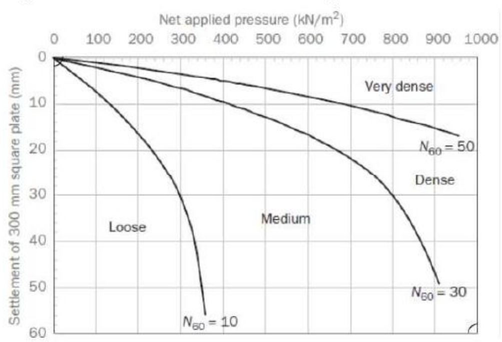
$FS := \frac{q_{ult.net}}{q_{app.net}} = 8.8957$

Checking for Settlement using Terzaghi and Peck's (1967) Method:

$q_{app.net} = 135.754\ \text{kPa}$

$N_{60} := 9.5$

Using this interactive chart from Sivakugan 2021:



$s_{plate} := 10\ \text{mm}$

$s_{footing} := s_{plate} \cdot \left(\frac{2 \cdot B}{B}\right)^2 \cdot \left(1 - \frac{1}{3} \cdot \frac{D_f}{B}\right) = 36.6667\ \text{mm}$

Which is less than the maximum allowable settlement described by O'Brien (2013) ~40 mm for sands

APPENDIX F: Sustainability Profile Calculations

Material weight calculations:

TOTAL STEEL (lbs):	1,077,486

Beams

Size:	W16x45
lb/ft:	45
ft/member:	30
total members:	402
total weight (lb):	**542700**

Girders

Size:	W18x50
lb/ft:	50
ft/member:	30
total members:	176
total weight (lb):	**264000**

Columns

Size:	W12x72
lb/ft:	72
ft/member:	14
total members:	216
total weight (lb):	**217728**

Moment Frame

Size:	W14x22
lb/ft:	22
ft/member:	33
total members:	16
total weight (lb):	**11616**

Roof

Size:	W16x45
lb/ft:	22
ft/member:	30
total members:	0
total weight (lb):	**0**

Connections/Misc.

% of member wieght:	4.00%
bolts/fasteners (lbs):	**41441.76**

TOTAL CONCRETE: (ft^3)	2,138	

Decking

deck height:	3.5	in
deck total area:	120000	sqft
rib width:	5	in
rib depth:	3	in
rib length 1:	120	ft
total ribs length 2:	90	
rib length 2:	60	ft
total ribs length 2:	195	ribs
total deck volume:	1,296	cy
total rib volume:	694	cy
total concrete volume:	1,383	cy

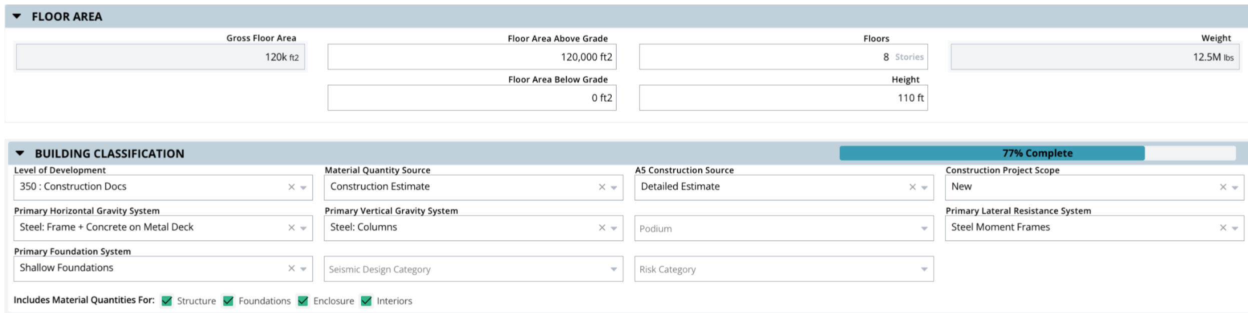
Foundation

footing width:	7	ft
footing length:	7	ft
footing depth:	3	ft
footing volume:	5.44	cy
total footings:	27	
total foundation volume:	147	cy

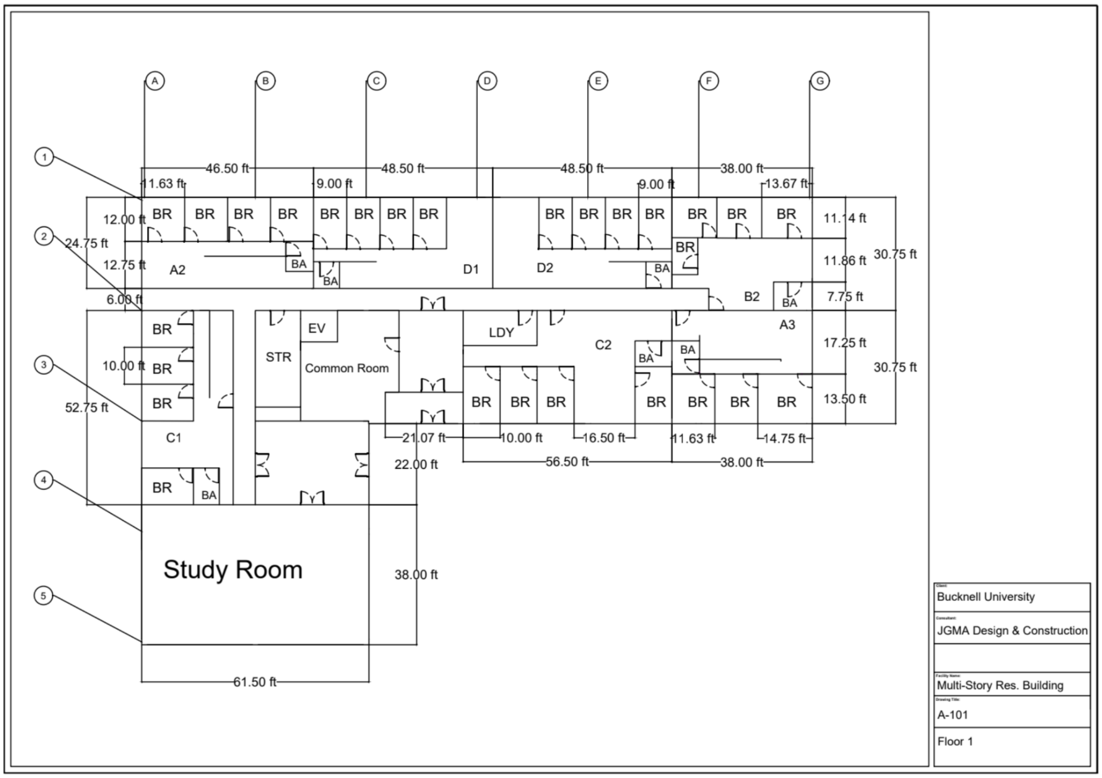
Individual material components for embodied carbon footprint analysis:

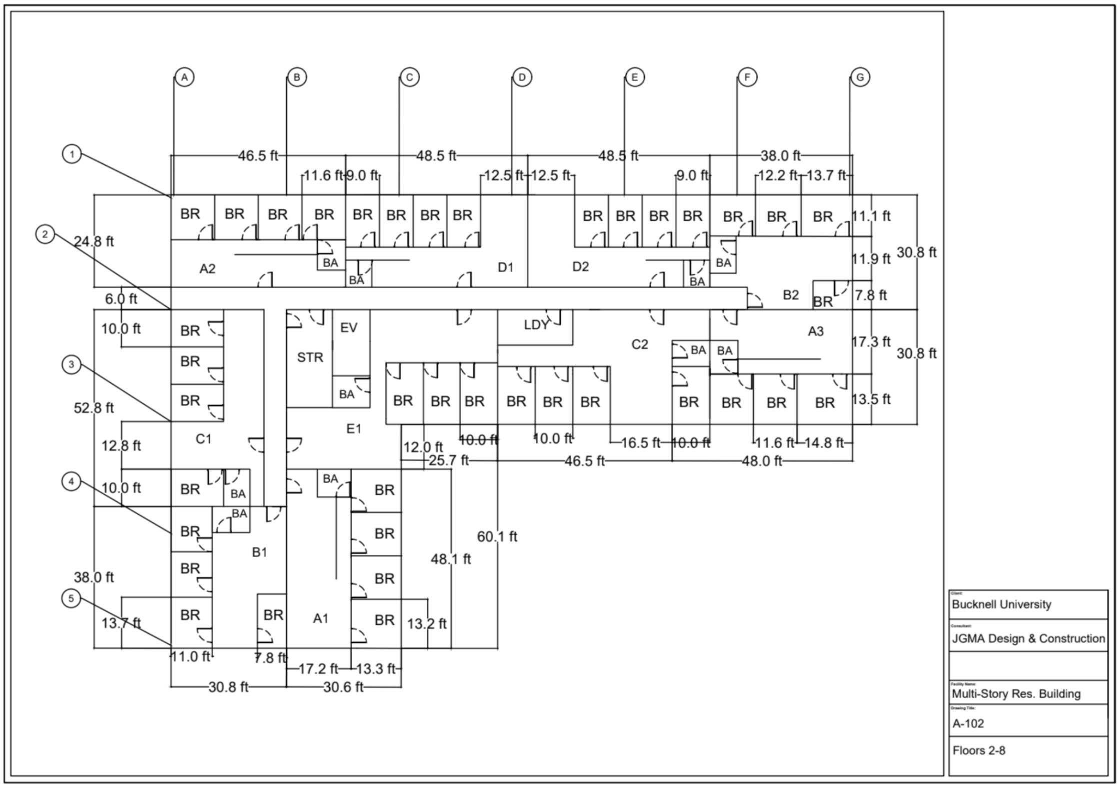
NAME	QUANTITY	UNIT	Collection / Selected (5/30) *	Achievable
Substructure				36.1k kgCO2e
Foundations				36.1k kgCO2e
Slab on grade reinforcing steel	36,750	lbs	RebarSteel: Compliance - BuyCleanCalifornia2022; ...	10.4k kgCO2e
Concrete foundation	145	yd3	ReadyMix: Strength @28d = 4000 psi; CO2 Cured - ...	25.6k kgCO2e
Shell				1.16M kgCO2e
Superstructure				867k kgCO2e
Concrete composite beam	600	yd3	ReadyMix: Strength @28d = 4000 psi; CO2 Cured - ...	106k kgCO2e
Frame reinforcing steel	1,075,000	lbs	HotRolledSections: Jurisdiction - USA; GWP ≤ 882 k...	423k kgCO2e
Slab on deck concrete	1,200	yd3	ReadyMix: Strength @28d = 4000 psi; Lightweight -...	292k kgCO2e
Slab on deck reinforcing steel	162,500	lbs	RebarSteel: Compliance - BuyCleanCalifornia2022; ...	46.1k kgCO2e
Exterior Enclosure				226k kgCO2e
Glazed curtain wall	12,741	ft2	InsulatingGlazingUnits	65.8k kgCO2e
CMU wall	300	yd3	CMU	62.9k kgCO2e
Gypsum board	67.1	1000 ft2	Gypsum: Jurisdiction - USA; Type X - Yes; ⅝" - Yes;	16.2k kgCO2e
Metal stud	40,000	lbs	ColdFormedSteel	35.5k kgCO2e
Mineral Wool Insulation	23,247.6	ft2 RSI	BoardInsulation: Mineral Wool - Yes; Wall & Gener...	5.17k kgCO2e
Fiberglass bat insulation	43,084.5	ft2 RSI	BlanketInsulation	4.24k kgCO2e
PIR board insulation	7,661.1	ft2 RSI	BoardInsulation: Polyiso (iso) - Yes;	1.72k kgCO2e
Plywood	300	ft3	SheathingPanels	1.47k kgCO2e
Paint	43,205	kg	PaintingAndCoating	9.53k kgCO2e
Reinforcing bar	73,628	lbs	RebarSteel: Plant Straight-line Distance ≤ 500 mi;	23k kgCO2e
Interiors				196k kgCO2e
Interior Construction				150k kgCO2e
Metal stud	50,874	lbs	ColdFormedSteel	47.6k kgCO2e
Gypsum boards	393.5	1000 ft2	Gypsum: Plant Straight-line Distance ≤ 1000 miles; ...	88.5k kgCO2e
Acoustic insulation	62,874.3	ft2 RSI	BoardInsulation: Mineral Wool - Yes; Wall & Gener...	13.8k kgCO2e
Interior Finishes				45.8k kgCO2e
Paint	22,700	kg	PaintingAndCoating	5.02k kgCO2e
Carpet	6,252	ft2	Carpet: Plant Straight-line Distance ≤ 1000 miles; C...	9.98k kgCO2e
Tile	6,252	ft2	EPDs Multi-Material	
Hard flooring	50,016	ft2	ResilientFlooring: Other Tile - Yes; LVT - Yes; Thickn...	28.2k kgCO2e
Flooring underlayment	1,042	ft3	SheathingPanels	2.65k kgCO2e

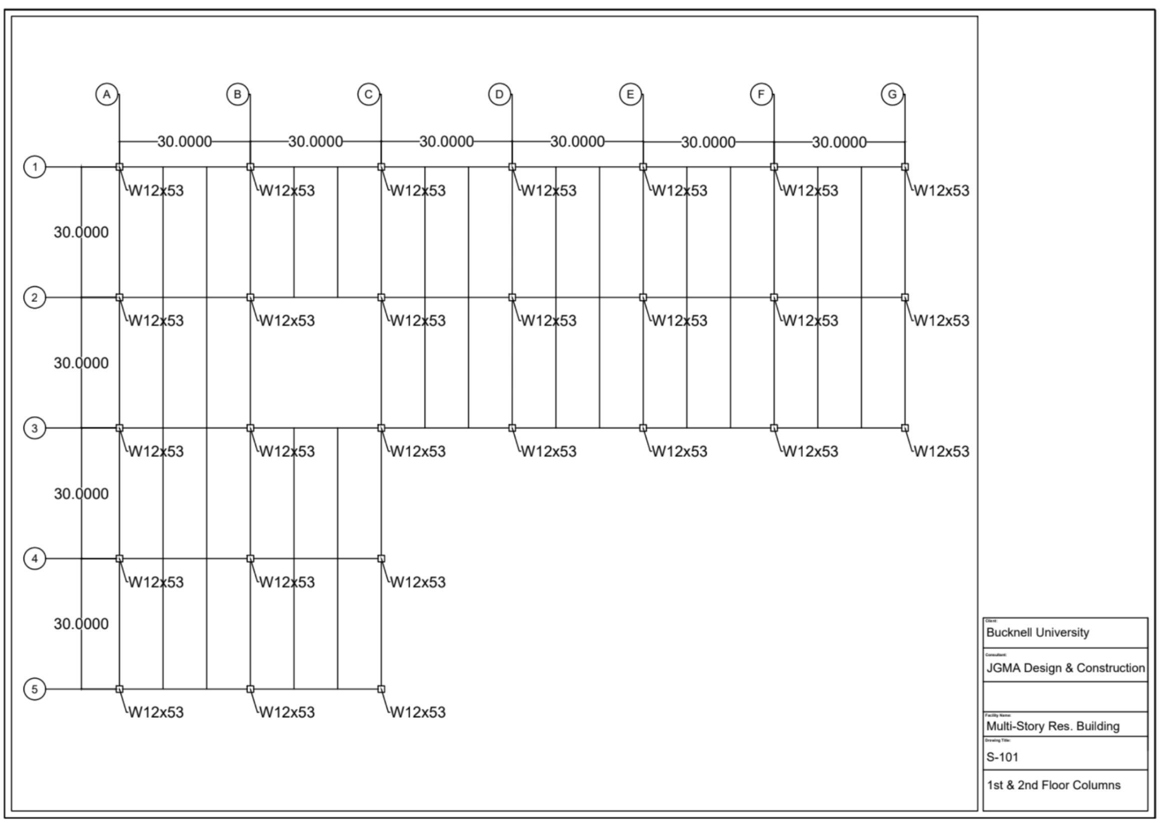
Building classification specifications for embodied carbon footprint analysis:

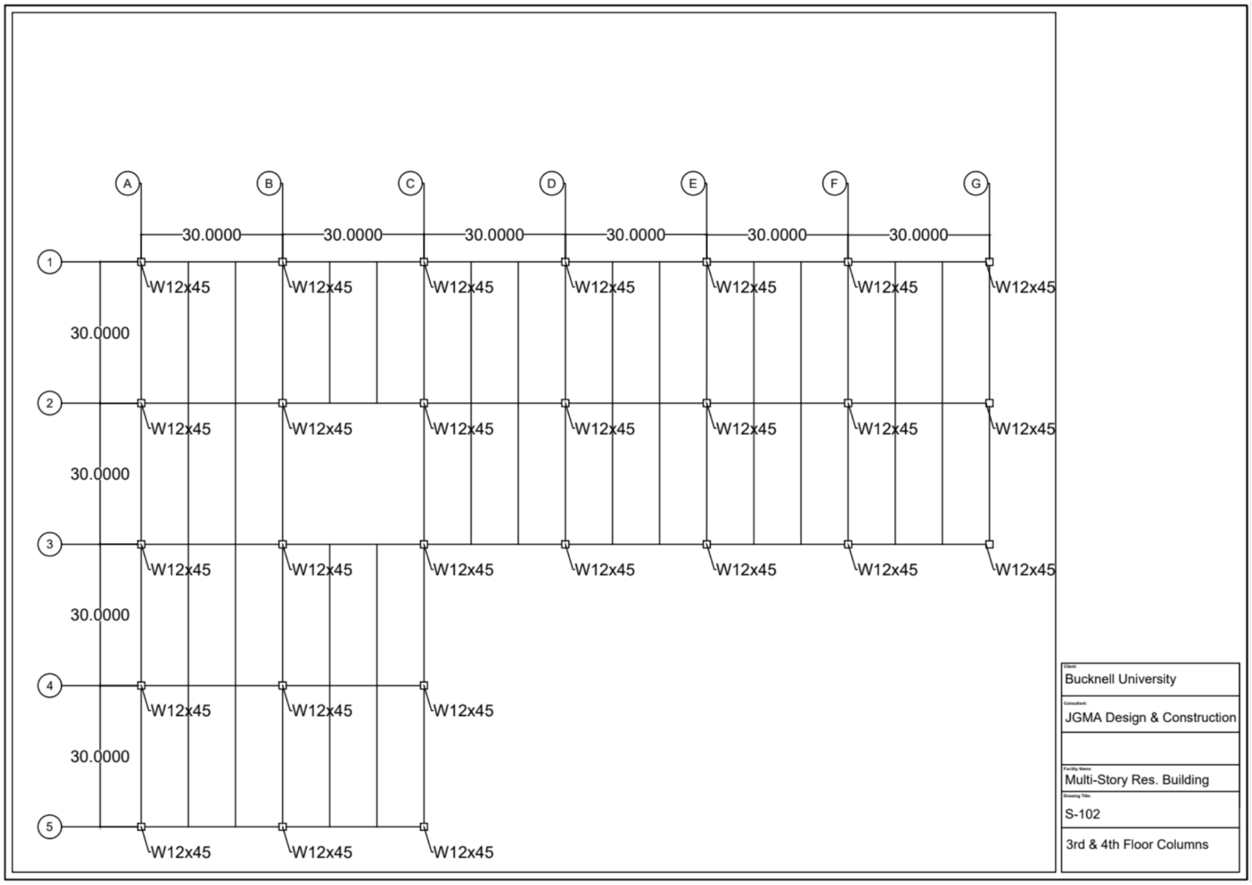


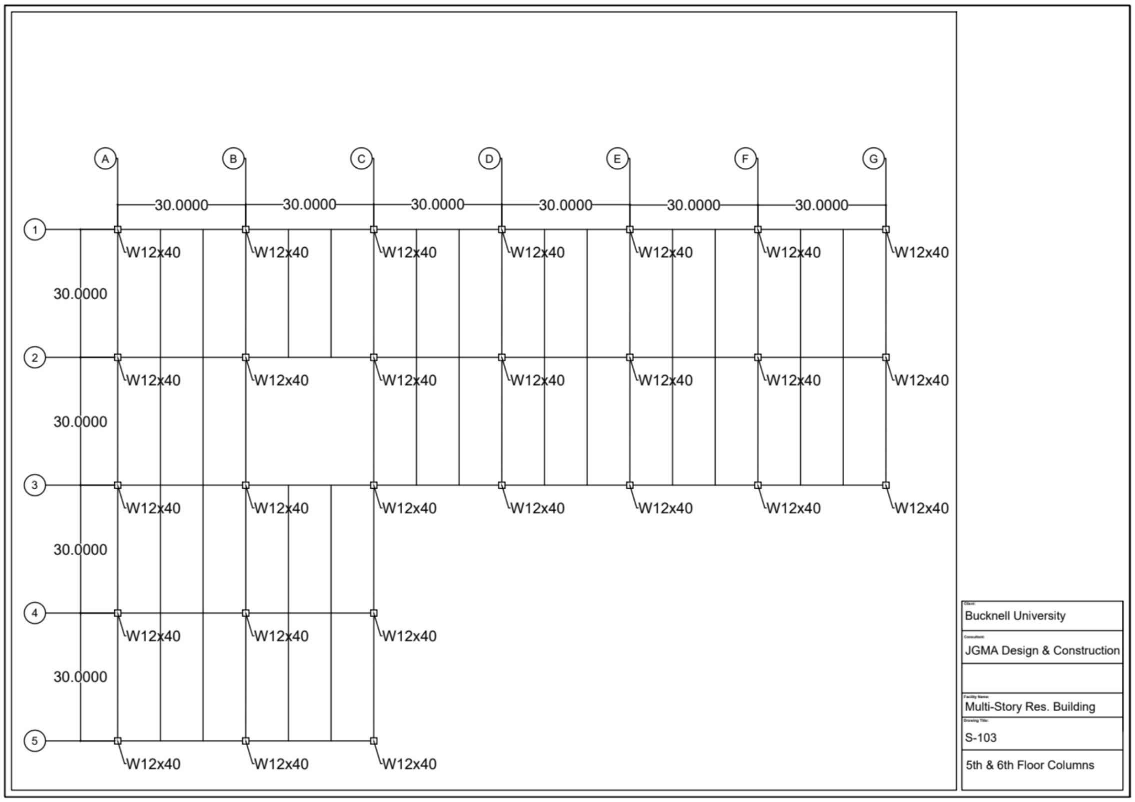
APPENDIX G: AutoCAD Design Drawings Package

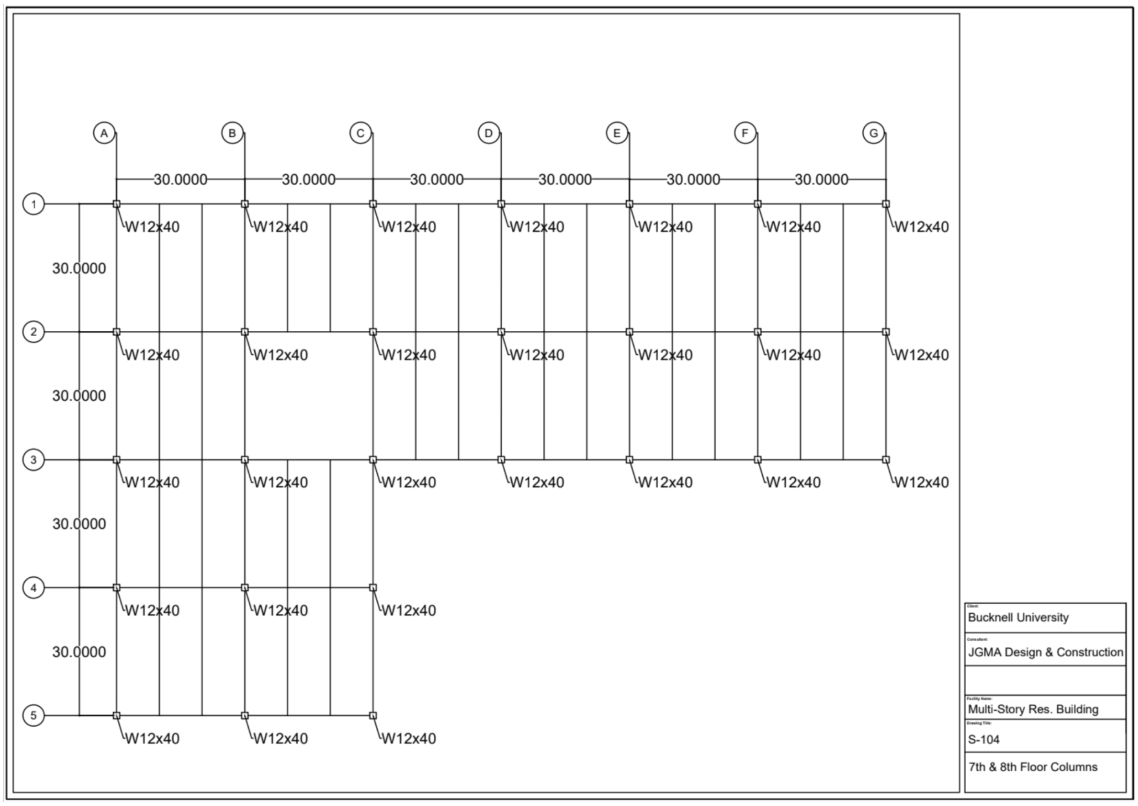


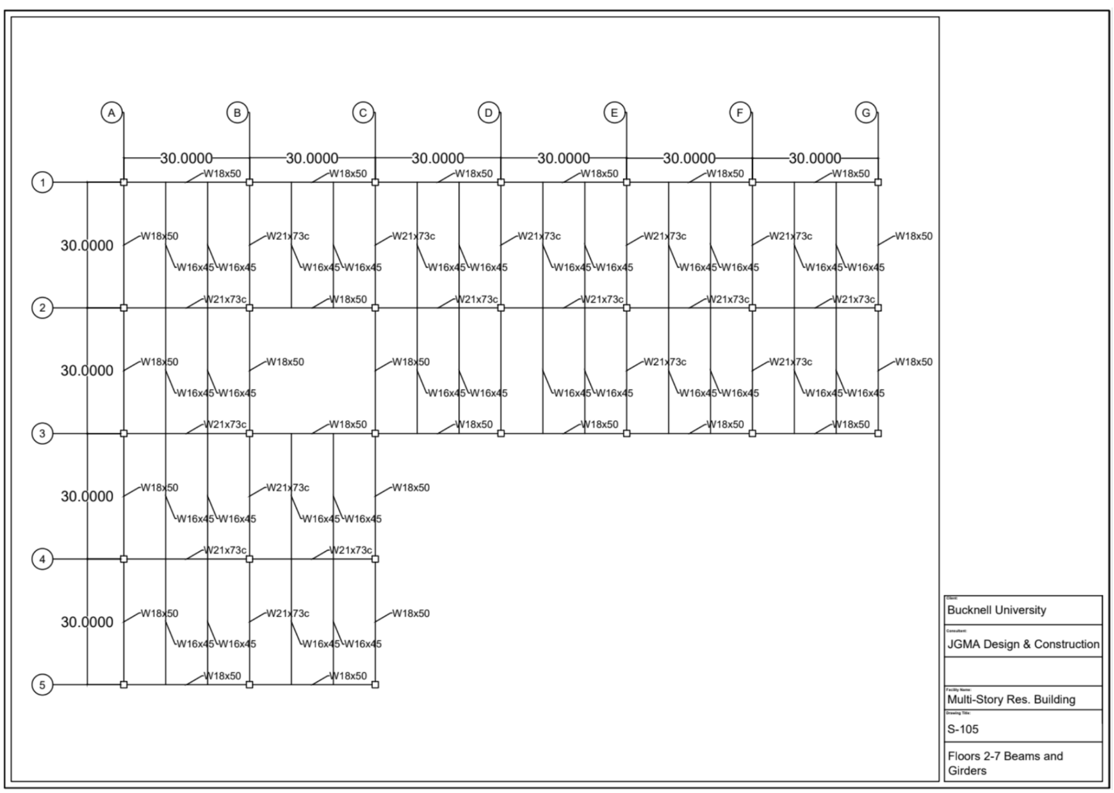

A
B
C
D
E
F
G
1
2
3
4
5
46.5 ft
48.5 ft
48.5 ft
38.0 ft
11.6 ft
9.0 ft
12.5 ft
12.5 ft
9.0 ft
12.2 ft
13.7 ft
BR
BA
A2
D1
D2
B2
A3
C2
C1
B1
A1
E1
EV
STR
LDY
24.8 ft
6.0 ft
10.0 ft
52.8 ft
12.8 ft
10.0 ft
38.0 ft
13.7 ft
11.1 ft
11.9 ft
30.8 ft
7.8 ft
17.3 ft
30.8 ft
13.5 ft
12.0 ft
10.0 ft
10.0 ft
16.5 ft
10.0 ft
11.6 ft
14.8 ft
25.7 ft
46.5 ft
48.0 ft
60.1 ft
48.1 ft
13.2 ft
11.0 ft
7.8 ft
17.2 ft
13.3 ft
30.8 ft
30.6 ft
Bucknell University
JGMA Design & Construction
Multi-Story Res. Building
A-102
Floors 2-8


A
B
C
D
E
F
G
1
2
3
4
5
30.0000
W12x53
Bucknell University
JGMA Design & Construction
Multi-Story Res. Building
S-101
1st & 2nd Floor Columns


A
B
C
D
E
F
G
1
2
3
4
5
30.0000
W12x45
Bucknell University
JGMA Design & Construction
Multi-Story Res. Building
S-102
3rd & 4th Floor Columns

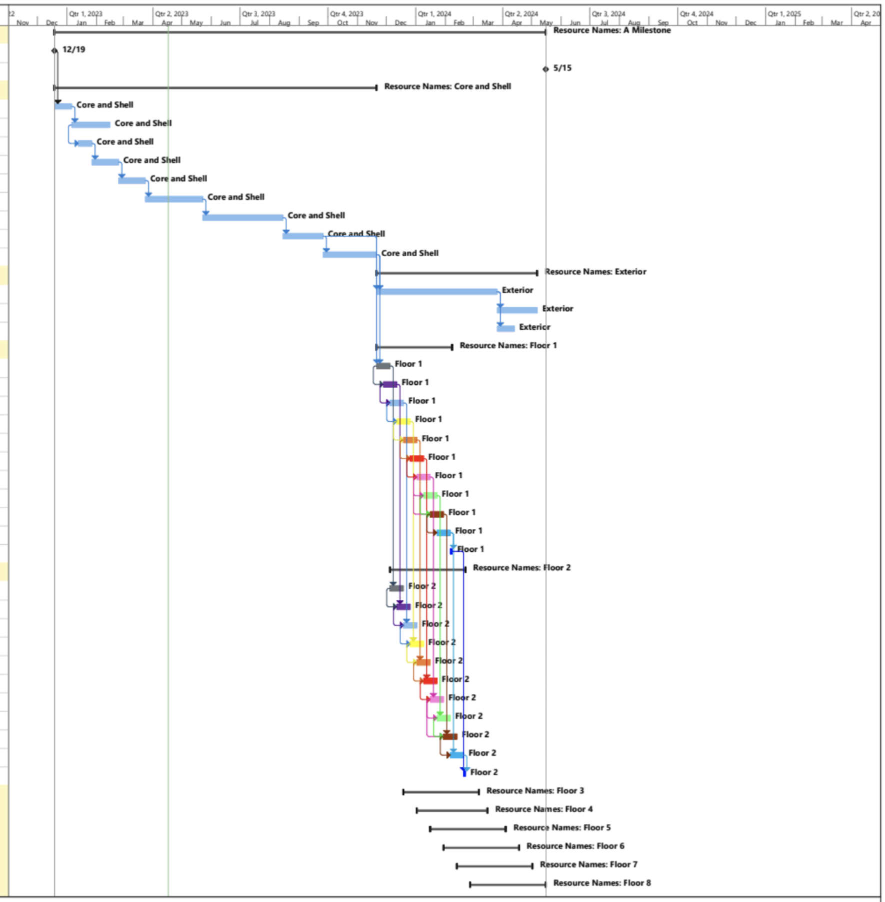

A
B
C
D
E
F
G
1
2
3
4
5
30.0000
W12x40
Bucknell University
JGMA Design & Construction
Multi-Story Res. Building
S-103
5th & 6th Floor Columns


A
B
C
D
E
F
G
1
2
3
4
5
30.0000
W12x40
Bucknell University
JGMA Design & Construction
Multi-Story Res. Building
S-104
7th & 8th Floor Columns


A
B
C
D
E
F
G
1
2
3
4
5
30.0000
W18x50
W21x73c
W16x45
Bucknell University
JGMA Design & Construction
Multi-Story Res. Building
S-105
Floors 2-7 Beams and Girders

APPENDIX H: Full Project Schedule

ID	Task Mode	Task Name	Start	Finish
		Resource Names: A Milestone	**Mon 12/19/2**	**Wed 5/15/24**
1		Notice To Proceed	Mon 12/19/2	Mon 12/19/22
76		Project Complete	Wed 5/15/24	Wed 5/15/24
		Resource Names: Core and Shell	**Mon 12/19/2**	**Mon 11/20/23**
2		Excavation	Mon 12/19/2	Thu 1/5/23
3		Foundation	Fri 1/6/23	Tue 2/14/23
4		Underslab Utilities	Fri 1/13/23	Thu 1/26/23
5		Backfill/Slab on Grade	Fri 1/27/23	Thu 2/23/23
6		Steel Erection	Fri 2/24/23	Thu 3/23/23
7		Concrete Pouring	Fri 3/24/23	Mon 5/22/23
8		Exterior Walls	Tue 5/23/23	Mon 8/14/23
9		Exterior Sheathing	Tue 8/15/23	Mon 9/25/23
77		Doors and Windows	Tue 9/26/23	Mon 11/20/23
		Resource Names: Exterior	**Tue 11/21/2**	**Mon 5/6/24**
42		Masonry	Tue 11/21/23	Mon 3/25/24
59		Exterior Finishes	Tue 3/26/24	Mon 5/6/24
101		Landscaping	Tue 3/26/24	Fri 4/12/24
		Resource Names: Floor 1	**Tue 11/21/2**	**Wed 2/7/24**
10		Floor 1 - Framing	Tue 11/21/23	Mon 12/4/23
34		Floor 1 - Plumbing Rough-In	Tue 11/28/23	Mon 12/11/23
18		Floor 1 - Rough-In	Tue 12/5/23	Mon 12/18/23
26		Floor 1 - Electrical Rough-In	Tue 12/12/23	Mon 12/25/23
50		Floor 1 - Insulation	Tue 12/19/23	Mon 1/1/24
58		Floor 1 - Drywall	Tue 12/26/23	Mon 1/8/24
67		Floor 1 - Millwork	Tue 1/2/24	Mon 1/15/24
75		Floor 1 - Finsh MEP	Tue 1/9/24	Mon 1/22/24
85		Floor 1 - Flooring Install	Tue 1/16/24	Mon 1/29/24
93		Floor 1 - Painting	Tue 1/23/24	Mon 2/5/24
100		Floor 1 - Cleaning	Tue 2/6/24	Wed 2/7/24
		Resource Names: Floor 2	**Tue 12/5/23**	**Wed 2/21/24**
11		Floor 2 - Framing	Tue 12/5/23	Mon 12/18/23
35		Floor 2 - Plumbing Rough-In	Tue 12/12/23	Mon 12/25/23
19		Floor 2 - HVAC Rough-In	Tue 12/19/23	Mon 1/1/24
27		Floor 2 - Electrical Rough-In	Tue 12/26/23	Mon 1/8/24
49		Floor 2 - Insulation	Tue 1/2/24	Mon 1/15/24
57		Floor 2 - Drywall	Tue 1/9/24	Mon 1/22/24
66		Floor 2 - Millwork	Tue 1/16/24	Mon 1/29/24
74		Floor 2 - Finsh MEP	Tue 1/23/24	Mon 2/5/24
84		Floor 2 - Flooring Install	Tue 1/30/24	Mon 2/12/24
92		Floor 2 - Painting	Tue 2/6/24	Mon 2/19/24
99		Floor 2 - Cleaning	Tue 2/20/24	Wed 2/21/24
		Resource Names: Floor 3	**Tue 12/19/2**	**Wed 3/6/24**
		Resource Names: Floor 4	**Tue 1/2/24**	**Fri 3/15/24**
		Resource Names: Floor 5	**Tue 1/16/24**	**Wed 4/3/24**
		Resource Names: Floor 6	**Tue 1/30/24**	**Wed 4/17/24**
		Resource Names: Floor 7	**Tue 2/13/24**	**Wed 5/1/24**
		Resource Names: Floor 8	**Tue 2/27/24**	**Wed 5/15/24**



Project: Multi-Story Building Pr
Date: Mon 4/17/23

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

Page 1