Growing Power Vertical Farm

A Major Qualifying Project
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for the
degree of Bachelor of Science

by

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Report Submitted to:

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Abstract

This project is part of the 2015 Architectural Engineering Institute Student Competition. The team was challenged to propose a new design for a 5-story vertical farm located at 5500 W. Silver Spring Drive in Milwaukee, Wisconsin. The team focused on the architectural, structural and building systems integration design, in addition to a complete project management plan. Through sustainable and innovative solutions, the team provided an integrative, cost efficient and energy saving design for the urban commercial farm.

Acknowledgements

Our team would like to thank key individuals for their help and support throughout the duration of our project. Without the guidance and continued support we would not have achieved the level of success that we had. We would like to thank Professors Leonard Albano, Leffi Cewe-Malloy, and Kenneth Elovitz, who were invaluable to our project. They were always able to provide insight to our project and their hard work, encouragement and time commitment were unparalleled.

We would like to thank the Architectural Engineering Institute for hosting this Student Competition and for allowing us this great opportunity to test our skills and further explore the various fields that the competition offered. We would also like to thank Growing Power Inc. for the opportunity to create an alternative design for their vertical farm facility. In addition, we would also like to express our gratitude towards other WPI community members who took the time to assist us with our project and answer our questions. We appreciate Professor Milosh Puchovsky's assistance with the fire protection and building code questions. We also want to thank Maria Del Lourdes Gómez and Sergio Alvarez for their constant assistance with *Revit* and *Navisworks* modeling.

Capstone Design Statement

This Major Qualifying Project demonstrates the application of academic coursework to realistic engineering practices. The use of engineering theory and practice was a key factor in the development of this project. The capstone design requirement of the MQP was met through the proposal of an alternate design of the Green Power Vertical Farm located at 5500 W. Silver Spring Drive in Milwaukee, Wisconsin. The new design focuses on the architectural, structural, and building systems integration of the facility along with a construction project management plan. The main goal of the project was to achieve a sustainable, innovative and cost beneficial solution for this building. Throughout the design process realistic constraints were considered in various aspects of the project, including economics, constructability, social impact, environmental and sustainability, and safety and politics. These considerations are described in greater detail below.

Economic

Two major economic considerations were taken into the account of this project. First, the team's conceptual estimate and design development estimate provided a detailed budget for the completion of the project. This estimation process applied value engineering in order to select the materials and building components that would perform according to the needs of the project and, at the same time, lower the overall initial cost. Second, the Life Cycle Cost analysis of the interior lighting fixtures allowed quantification of the reduction in energy consumption and the savings of utility costs over a 25 year period.

Constructability

The site for the vertical farm is located in a suburban residential area; therefore the project management plan was directed at minimizing the effects of a construction project on the surroundings. The development of the site plan layout allocated spaces to different purposes in the building and reduced the interference between activities that will take place on site. Also, the team opted for a Design Build project delivery method contract because it will accelerate the project design and construction phases. Another measurement taken in order to reduce the project duration was the selection of pre-cast panels for the building enclosure that decreases the installation time. In addition, the construction schedule takes into consideration the increase of working crews to reduce construction time for enclosing the building before the winter season.

Social Impact

A primary project guideline and goal set by the group was to abide by and create a design that exemplified the vision of Growing Power Inc. Growing Power as an organization has the primary goal of providing sustainable, healthy, high quality and affordable food to people of all communities. The organization also hopes to teach the everyday person the appropriate methods of growing this food on their own. The vertical farm itself is designed to be a community center, for people to buy this sustainable food grown on site, take classes to learn more about the process of growing this food, and provide space to host large scale community events. This vertical farm is completely open to the community it serves to do with as they wish. Beyond the immediate Milwaukee community, this vertical farm hopes to be an exemplar for other farms to be built and service various communities around the country in the years to come.

Environmental and Sustainability

The new design for Growing Power Inc. vertical farm incorporates environmental and sustainability elements that can qualify towards LEED Silver accreditation. The design incorporates a rain catchment system that uses water collection to supply the building demands for the growing area irrigation. It also provides LED lamps and a HVAC system that are controlled by areas and reduce the energy consumption of the building. In addition, the design incorporates a market area with two demonstration aquaponic tanks. This space will support Growing Power's mission as it serves as a hub for the community to learn about sustainable food production.

Safety and Political

The safety and political considerations were comprised throughout several aspect of the project. One of them was safety during construction. Through the site plan developed, the effects of the construction project on the surroundings were minimized by placing chain link fences around the perimeter of the property during the construction phase. The plan also separated the construction area from the existing buildings and adjacent dwelling, and included 4 gates allowing regulated access to all areas in the property. In addition, the *International Building Code*® 2012 Edition and the *Milwaukee Commercial Building Code 2011 Edition* were applied during the design. This provided the required means of egress, the type of construction, the building's allowable height and area, and the need of an automatic sprinkler system. Specified by these aforementioned codes, *ASCE 7-10* was utilized for a majority of structural analysis. Strength, stiffness, and stability were three main criteria checked when designing the facility.

Licensure Statement

Professional licensure, which was first made a law in 1907 for Wyoming, is a measure to protect the public health, safety, and welfare. Prior to this first measure, engineers could work without proof of competency. Currently, every state regulates engineering practices by allowing only PE's the authority to "sign and seal engineering plans and offer their services to the public" (NSPE). It is often referred to as the "seal" or "stamp" and signifies possessing the credentials that can earn the trust of a client.

To obtain a PE seal, engineers first need to prove their competency through several steps. Listed below are steps toward this licensure according to the National Society of Professional Engineers (NSPE):

-Earn a four-year degree in engineering from an accredited engineering program

-Pass the Fundamentals of Engineering (FE) exam

-Complete four years of progressive engineering experience under a PE

-Pass the Principles and Practice of Engineering (PE) exam

As mentioned, the professional engineer assigned to a project is responsible for the public's health, safety, and welfare. Beneficial to the engineer, only a professional engineer may prepare, sign, seal and submit engineering plans and drawings to a public authority for approval, or to seal engineering work for public and private clients. State governments and an increasing number of universities are requiring engineers and professors to have a PE to teach the practice.

Distinguishing oneself is the ultimate achievement of a PE. With this distinction comes responsibility and the PE is ultimately responsible for all effects their work has on the public, incurring a strict obedience to ethical standards. Consulting, creating one's own company, and serving the public directly are all benefits that becoming licensed create.

This MQP is directly related to professional practice. Architectural drawings and their coordination with the structural systems is an important procedure in professional practice. This MQP consisted of both architectural and structural teams, who through integration, produced a facility at a near professional level. For a project like this one, a professional engineer would be required to approve and stamp the structural drawings before distribution.

Principle Responsibilities

The group's project comprised the architectural, structural and integrative components of the vertical farm design. Throughout the structural focus of the project, all team members were involved in the design of the structure and integration with the architectural features and other systems in the building. Background research of systems and materials was performed by all members of this team. Also, the *Revit* modeling and the production of drawings were cooperatively carried out. In addition, the primary responsibilities or contributions were broken down based on each of the team members' strengths, interests, and experience.

Veronica Rivero Gorrin, an Architectural Engineering major with a concentration in structural systems, contributed primarily towards the electrical and plumbing analysis and calculations of the systems, including the lighting design. She was also primarily responsible for the glazing system selection and ensuring the design adhered to the relevant codes and regulations. Austin Holliday, an Architectural Engineering major with a concentration in structural systems, contributed primarily to the design of the building's mechanical systems for the growing and non-growing areas. He was also responsible for the building envelope and helped significantly with the design of the architectural floor plan layouts. Juan Parra, a Civil Engineering major with concentration construction project management, was primarily responsible for the development of the project's project management plan. His work focused in the creation of the project's site plan layout, cost estimates, schedule, and *Navisworks* 4D construction simulation. Also, he was responsible for the selection and integration of the greenhouse systems. William Michalski, a Civil Engineering major with a structural concentration, was the primary designer of gravity framing, performing load calculations and structural analysis. He was also responsible for adhering structural work to codes and regulations. Jose Andrade, a Civil Engineering major with a structural concentration, was the primary designer of the greenhouse structures. He also maintained integration of these structures with the architectural requirements.

Executive Summary

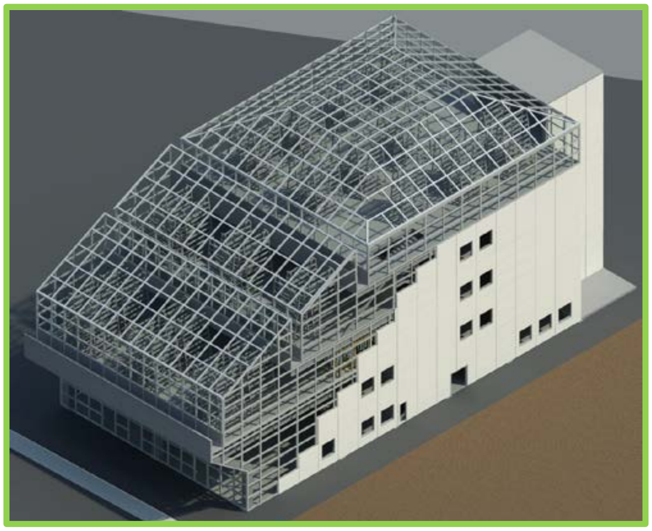
The American Society of Civil Engineers (ASCE) organizes an annual Architectural Engineering Student Competition, in which students are challenged to create an integrated and innovative design for different types of buildings. The 2015 competition addressed the design of a 50,000ft^2 vertical farm building located in Milwaukee. The competition provided five focus areas, to which the team chose two: the building systems integration and the structural systems.

The building was designed for Growing Power Inc., a national nonprofit organization dedicated to the growing, processing, and marketing of healthy, high quality foods for communities across the country. The entity's main goal for this building was to create a space that would inspire the community to build sustainable food systems that are equitable and ecologically sound. Therefore, the MQP team found *Impact* to be a suitable name to represent the project and the design team. The name embodies the effect that the learning experience of this urban farm will provide to the community.

Impact's multidisciplinary team was composed of two Architectural Engineers, two Civil Engineers with structural design concentrations, and one Civil Engineer with a construction project management concentration. Each member contributed with their knowledge and different background skills to develop the design. To efficiently address the challenge presented by Growing Power Inc., *Impact* determined its project goals:

- Design a vertical farm building that meets the vision of Growing Power Inc.
- Develop innovative and original solutions that incorporate environmentally-friendly and efficient features into the design.
- Provide a cost efficient system that can be easily adapted to different locations in the United States, such as Miami.
- Present a solution that integrates all of the building's systems into a fully functional vertical farm and greenhouse space.
- Optimize all major high performance attributes of the building including energy conservation, safety, structural and material durability, accessibility, cost efficiency, growing productivity, sustainability, functionality, and operability.

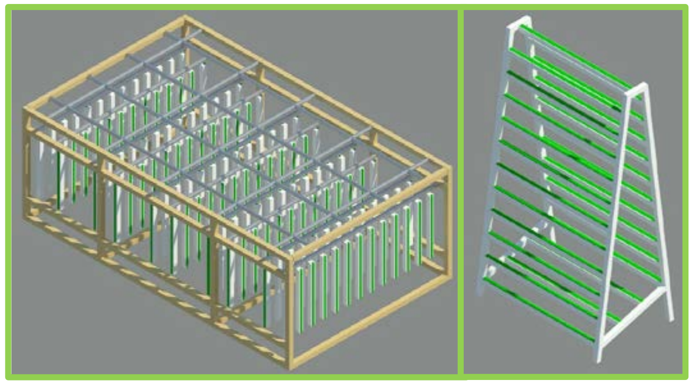
In order to fulfill these goals, the team designed a five story building and basement consisting of approximately 51,000 total square feet, and a footprint of approximately 70 feet by 150 feet. The architectural design is characterized by three exterior inclined columns that reach to the third floor. In addition, it provides an ascending step back structure that exposes each of the growing areas to direct sunlight. The structural system was a traditional steel gravity frame structure with CMU shear walls and steel truss frame lateral systems. The column layout limited interior columns to compliment the architectural usage requirements.



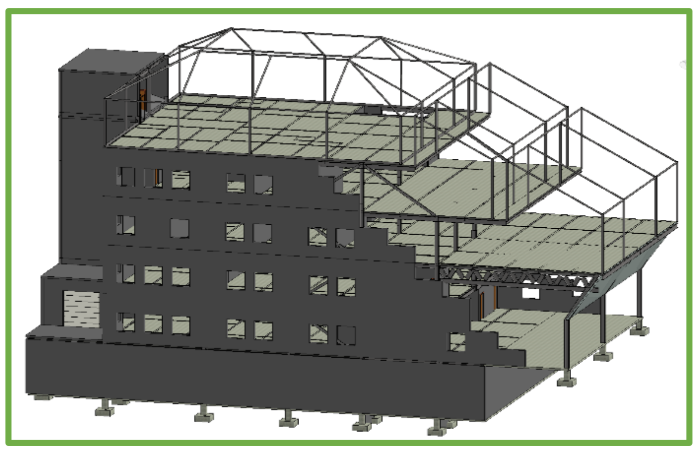
In addition, through the integration of the fire protection, building envelope, mechanical, electrical, plumbing and structural systems, *Impact* developed a series of selections. The main features of the design are provided below:

- A design that provides a 567 ft2 **larger growing area** condensed into just the three top levels
- A market area serving as a **community learning hub** through the display of two aquaponic demonstration tanks.
- A **decrease of the basement area** to create a slab on grade that would support the large weight of the aquaponic demonstration tanks.
- An **occupant capacity** increase of the second floor assembly area from 463 to 600 occupants.
- A **precast panel** system that improves the project's constructability and adaptability to other sites
- A **building envelope** system composed of precast panels and double pane low-e glazing that minimizes the heating and cooling load.

- A self-sufficient **water source heat pump** that supplies both heating and cooling to the different building zones.
- A **LED lighting** design that reduces lighting energy consumption by 45%.
- A **regenerative elevator** that saves one third of the electric consumption produced by commonly used elevator.



- A **greenhouse system** composed of vertical and rotating growing towers that allow more plants to be grown in a smaller area, increasing the yield of saleable product.
- A **lighting control** system that provides the amount of artificial light required for each specific crop type.
- A **site plan layout** that minimizes the effect of the construction project on the surroundings and the interference between activities that will take place on site
- A **4D virtual construction simulation** that incorporates the schedule into a 3D model of the project.
- A detailed **cost estimate and construction schedule** that account for all the work required to complete the project.



- A series of **open-web steel truss joists** to open the market area atrium space.
- A **stainless steel HSS framing system** for the greenhouses which serve as dual-functioning structural members and glazing framing.
- A structural design utilizing **cantilevers** to further eliminate columns from the floorplan.

Throughout the achievement of *Impact's* goals, the MQP vertical farm design exemplifies the beliefs of Growing Power Inc. creating a high performance community center to teach and grow sustainable food systems. By taking a comprehensive approach by using Building Information Modelling (BIM), which included multiple software applications to maintain integrative collaboration and communication between disciplines, we were able to design a new building that is not only architecturally pleasing and structurally stable but maintains the purpose and mission of Growing Power.

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1. Introduction

The American Society of Civil Engineers (ASCE) organizes an annual Architectural Engineering Student Competition. Through this project, students are challenged to integrate all of the engineering systems with the architectural design, develop a construction management plan and collaborate in a multi-disciplinary team to enhance the building's high performance. Participants are also encouraged to apply knowledge and skills gained from their different backgrounds, and develop innovative and original solutions for the project.

Since the competition requires student teams to integrate the various systems and construction process of the building, it focuses on five main categories: integrated design, structural design, mechanical design, electrical design and construction management. However, through this project the team focused its efforts in two areas: the building systems integration and the structural systems.

1.1 The Challenge

The design challenge for the 2015 Architectural Engineering Student Competition is a five-story with a basement urban commercial farm. The facility, located at 5500 W. Silver Spring Drive in Milwaukee, Wisconsin, consists of approximately 50,000 total square feet. The solutions to this project will aid Growing Power's mission.

Growing Power is a national, nonprofit organization dedicated to the growing, processing and marketing of healthy, high quality foods to communities across the country. The Growing Power organization has been established for 20 plus years, built on the goal; "to grow food, to grow minds, and to grow community" (Growing Power Inc., 2015). The organization has manifested their goal through the creation and operation of community food centers and food systems located in Milwaukee and Chicago. These food centers grow healthy sustainable food but more importantly grow minds within the community, by educating local farmers and youth through hands on workshops. The workshops encompass topics such as aquaponics, urban and rural farming, compost systems, renewable energies, year-round greenhouse production, and community project design among other subjects. Through the years Growing Power has grown exponentially which has prompted construction of the world's first working urban farm. The urban farm accommodates the space demands for more food production, classes, meal preparation and offices, while also being the exemplar of everything the Growing Power Organization represents.

One of the main goals of this building was to integrate it with the community and assist the owner with its mission. Therefore, besides the production of plants, vegetables, and herbs in the greenhouse spaces, the building includes spaces dedicated to the education of the community. Some of these rooms include educational classrooms, conference rooms, demonstration kitchen, food processing and storage, freezers and loading docks. In addition, an indoor retail space and an outdoor market for selling products to the community are also be part of this initiative to teach the community about sustainable urban food production.

Another essential aspect of the project was sustainability and energy efficiency. Not only did the greenhouse system and building envelope play a major role in achieving this goal, but the team had to achieve the integrated performance of all other aspects such as the lighting and mechanical systems, and the hydroponic system to help satisfy this goal. Other high performance attributes that were optimized during the design process were safety, building security, material durability, accessibility, cost-benefit, productivity, functionality and operational considerations.

A very important characteristic of this project was proposing a design that could be implemented and adapted to other urban areas across the United States. This design is to serve as a prototype for future projects and initiative in other areas, making it essential to achieving this goal.

Lastly, as the team focused on the structural area, making it imperative to provide an innovative solution that properly integrates with the architectural layout and the other systems present in the building. In addition, its cost, adaptability and alternative materials were explored throughout the design.

1.2 Team Goals

As the team gathered a better understating of the project, a set of specific goals to achieve during the design process were created. Below, these goals are presented:

1. To use this experience as a learning tool to advance each member's knowledge in innovative and sustainable designs.
2. To design a vertical farm facility that meets the vision of Growing Power Inc., which is to "inspire communities to build sustainable food systems that are equitable and ecologically sound".
3. To develop innovative and original solutions that incorporate environmentally-friendly features that will serve as a role model for other designers
4. To provide a cost efficient system that can be easily adapted to other locations in the United States
5. To present a solution that integrates all of the building's systems into a fully functional vertical farm and greenhouse space
6. To optimize all major high performance attributes of the building, including energy conservation, environment, safety, building security, structural and material durability,

accessibility, cost-benefit, productivity, sustainability, functionality and operational considerations.

7. By project's end, to develop a narrative description of our thought-process, by thoroughly documenting our decision-making processes.
8. By the project's end, to create a 3D *Revit* model of the design, with its corresponding construction schedule and cost estimate.

2. Literature Review

This section provides a background understanding on the topics pertaining to our project. It starts with a broad outlook on the origin of urban farms and description of current vertical farm projects, followed by a description of the Growing Power organization. Then the elements of greenhouses and the components and requirements of an aquaponic system are detailed, followed by an overview of high performance building systems that will help reduce energy consumption and gas emissions from the building. Finally, construction project management and life cycle cost analysis background is given.

2.1 ZFarming

Due to some of the challenges the world is facing today, such as climate change, equitable economies and health concerns, urban agriculture has started to grow in the last years. Through this time, different methods of urban agriculture have developed and most recently the term Zfarming has emerged. This term, which stands for Zero-Acreage Farming, describes "all types of urban agriculture characterized by the non-use of farmland or open space" (Dierich et. al. 2013). The central idea is to establish a small-scale resource of saving systems, where you can use and recycle resources derived from synergies between agriculture and buildings. The types of applications include rooftop gardens (or rooftop farms), rooftop greenhouses, indoor farms, edible green walls and vertical greenhouses (or vertical farms).

As an initiative to provide sustainable food production, it incorporates the three principles of sustainability: Environmental, Social, and Economic. In the environmental aspect, Zfarming looks to provide an integrated production of building systems that can contribute to the reduction in demand for water and energy resources, as well as reduce any waste produced. Meanwhile, on the social dimension, the approach can contribute to improving the community's food security, and provide a multifunctional space for the community to use. Lastly, it can also offer advantages on the economic front, including strengthening the local economy and new opportunities for sales and marketing in the area (Dierich et. al. 2013).

Vertical Farms

Dickson Despoimer, an ecologist at Columbia University, introduced the concept of vertical farms in 1999. He suggests that food should be grown all-year long in high-rise urban buildings, reducing the use of carbon-emitting transportation for fruit and vegetables. Also, "vertical farms aim to avoid the problems inherent in growing food crops in drought-and-disease-prone fields, many hundreds of kilometres from the population centres in which they will be consumed" (Marks, 2014)

Urban vertical farms look into the possibility of growing food continuously 24 hours a day, 365 days a year in an environment that will protect the crops from unpredictable and harmful weather. There are several advantages of building and producing crops within urban vertical farms such as: reduced water consumption through the reuse of water collected from the indoor environment; the elimination of pesticides, fertilizers or herbicides; drastically reduced dependence on fossil fuels; and job opportunities for urban residents.

2.2 Greenhouses

A greenhouse is an indoor space designed for the growth of plants in order to protect them against excessive cold or heat. Therefore, as the main focus of the vertical farm is to provide food growth, greenhouses become essential to this type of project. There are several aspects that need to be considered when designing a greenhouse space, all of which will be discussed in this section.

2.2.1 Materials

Greenhouses have existed since the 17th century, when they were built out of brick and timber and did not have much window space. However, through the centuries, as materials became less expensive, the availability of different types of heating evolved and the advances in science and technology, its original design evolved.

Today, one of the most important elements of a greenhouse space is its glazing system. Glazing allows day light to enter the spaces, as well as permits solar heat into the structure. Through the years, the material that characterizes the glazing of a greenhouse has been glass. This material not only achieves the function of glazing very well, but it is very durable; not combustible; and provides very low expansion or contraction with changing temperatures. Also with the technological advancements, new types of glass with additional layers or coats that improve insulation and reduce the heat loss have been developed (Smith, 2003).

Nevertheless, there are other types of glazing materials that are currently available. One of them is polycarbonate, a rigid plastic material. The use of this material can be seen in Netherlands, where GE's Lexan ZigZag sheet double-wall polycarbonate roofing panel is been used for an experimental greenhouse. According to GE, their product "raises light transmission levels above those of single glass, especially during non-peak hours/seasons, while ensuring outstanding insulation to retain heat." Its insulation properties are similar to those of double-wall glass, where the material can retain 45% more heat than single glass and provide energy saving up to 40%. GE also states that this material provides resistance to UV light on the exterior, has anti-condensation properties and is 50% lighter than glass (GE Plastics, 2006).

Figure 1 Lexan ZigZag Polycarbonate, in Netherlands (GE Plastics, 2006).

In addition to glazing and day light, it is important to take into account that a greenhouse is a wet and moist environment. Therefore, it is important to carefully select the materials that will offer resistance to these conditions. The most recommended option for the structural portion of the space is sealed concrete. Other moisture resistant materials offered are rubber mats to let the water flow, and aluminum or structural plastic resistant to UV for the plant benches.

2.2.2 Lighting

Light is an essential component of a greenhouse. Most plant needs light for the photosynthesis process to take place and thus allow them to grow. Therefore, when a greenhouse space is designed, it is very important to take into account day lighting and any supplementary lights needed to ensure sufficient growth of the plants in the greenhouse area.

Day Lighting

Day lighting involves using naturally available sunlight to compensate for artificial lighting and energy consumption. In the case of a greenhouse, it not only helps to reduce the energy usage, but is also needed by the plants in order to grow. Therefore, to guarantee the maximum available sunlight in this space there are several aspects that need to be taken into account.

The first one is the location of the greenhouse. This space should not only be located toward the exterior of the building, but its orientation will also influence the presence of day light in the space. The sunlight is easiest to control on the north and south facades. During the summer, most of the solar gain will be provided by the east and west, meanwhile in the winter, when the solar gain is needed at its most, its majority falls on the south end (Nicolow, 2004). Therefore, in the northern hemisphere, the best orientation is south, even though southeast and southwest are also acceptable (Biehle, 2006).

Another important aspect needed to harvest as much sunlight as possible is to understand its path. Each site has a precise location of the sun at a given time, which helps understand the areas where more light can be gained (Nicolow, 2004). This analysis can also assist in determining the areas where too much sun or glare might cause a problem. Trying to gain as much daylight as possible can increase the cooling load and affect the growth of sensitive plants, leading to the need of shading in some cases. Some of the options used are aluminum slats or mesh, ultraviolet resistant fabric or typical window shades. Also there are motorized shades that function with daylight sensors to determine the light present in the room and the need for shades (Biehle, 2006).

Supplementary Lighting

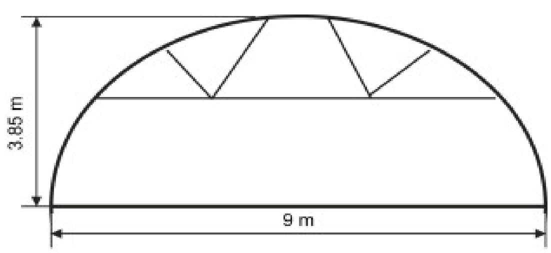
No matter how good the day lighting design of a space is, the actual penetration of light will always be influenced by external factors. For example, it might be a cloudy day or simply the winter, when daylighting is shorter. Therefore, greenhouses cannot take this for granted and many times supplementary lighting is used to compensate for insufficient day lighting (Ciolkisz, 2010).

Traditionally, fluorescent and incandescent lights were used as supplementary lighting in greenhouse spaces. However, they were then replaced by metal halide and high pressure sodium. The reasons for this change mainly relied on their ratio of total radiant flux emitted in comparison with the lower power they consume. Other advantages argued are also their extended bulb longevity, their easier handling and longer maintenance of light output (Clark and Devine).

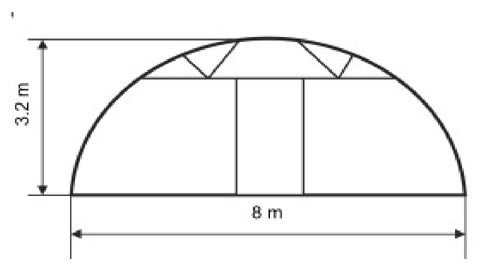
Today, with the development of light emitting diodes (LED) and their low energy consumption, this technology has also been introduced into the growth of plants and vegetables. It has been discovered that the wavelength has a major effect in the growth process of plants, as only lights of certain wavelengths are needed, while others are not effective. Research studies indicate that one of the most effective combinations is the one of red and blue LEDs. In regards with the red light, it has been discovered that the "interchange between the presence of red light (bright) and the absence of red light (dark) makes phytochromes affect plants by causing the stems and leaves of the plants to grow" (Chang, Hong, Ying, 2013). Meanwhile the blue light affects the growth of plants, the absorption of nutrients, the growth of sturdy stems and the phototropism of plants. However, some studies have also been made in regards to green light. Even though this wavelength band affects the "formation of carotone and intensifies the metabolism of carbohydrates and nitrites" (Chang, Hong, Ying, 2013), it has no significant effect of growth patterns and only on the coloring of the leaves. Therefore, many studies are currently being conducted to discover any additional solutions to enhance, and possibly shorten, the cultivation cycle to improve the food production in greenhouses.

2.2.3 Structures

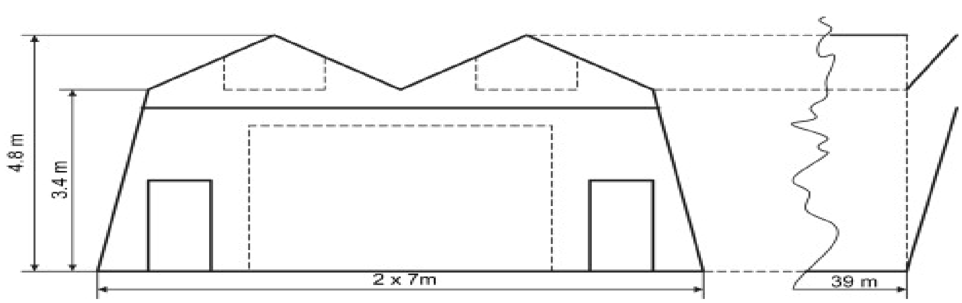
Another aspect of a greenhouse design is the form of its structure. Today, there is a variety of shapes for greenhouse construction. From a conventional span roof (A-shaped), to a single slope roof, to a curvilinear one. Each of these structures not only affects the aesthetic look of the building, but also influences the energy consumption of the greenhouse. In 2009, Djevic and Dimitrijevic, published their paper "Energy consumption for different greenhouse constructions". This article presents their research, in which four types of greenhouse structures and their energy usage were investigated. The four structures can be seen in the figures below.



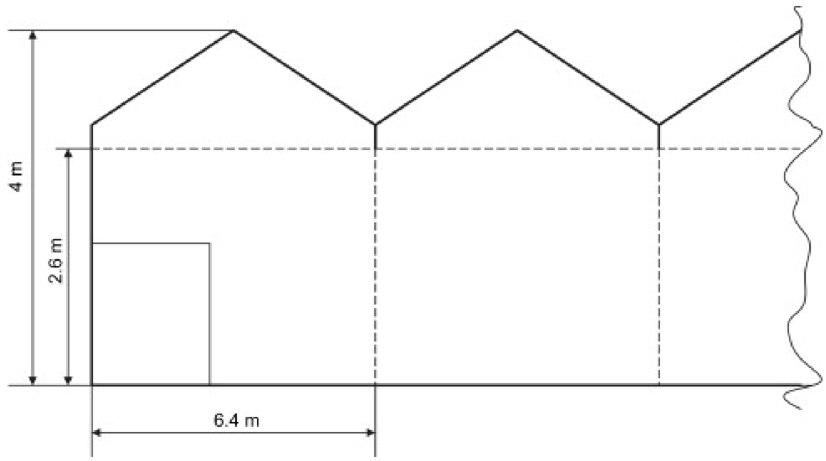
(a) 9x58 m Tunnel



(b) 8x25m Tunnel



(c) 14x39 m Gutter-connected



(d)20x6.4 Multi-span

Figure 2 Types of Greenhouse Structures (Djevic and Dimitrijevic 2009).

When the research was completed, they determined that most of the energy consumption in the building was caused by the heating. Also their results showed that the energy efficiency of the multi-span greenhouse was the highest with a percentage close to 28%. Meanwhile, it was followed by gutter-connected greenhouse (22%), the bigger tunnel structure (17%) and lastly the smaller tunnel (15%). The energy efficiency was based on the lettuce production output in comparison to the energy input into the system. With their results, they concluded that the higher the volume, the lower energy consumption the structure had, meaning that energy efficiency can be higher with larger greenhouses (Djevic and Dimitrijevic, 2009).

2.2.4 Cooling, Heating and Ventilation

As previously mentioned, the shape of the structure affects the energy consumption of the space. Therefore, another main aspect that would influence this usage is the heating, cooling and ventilation of the room. These three elements are essential in the design of a greenhouse since one of the main objectives of this space is to provide an appropriate environment for the plants to grow.

During the day, plants are heated by the sun, meanwhile as the night falls or during very cold days, the temperature decreases and can cause plants to freeze. Therefore, there is a variety of options in regards with the cooling and heating system that are used in greenhouses today. Some of these options range from the traditional systems such as hot water or steam heating to more innovative options. Some of the systems the team has studied will be explained with more detail in a further section (Biehle, 2006).

Similarly happens with fresh air as it needs to be constantly ventilated, especially during very hot days. Greenhouses are characterized by having natural ventilation that constantly provides the plants with fresh air. One of the most common systems used are vent panels in the roof that can be manually opened to allow fresh air. Today, with the existence of automated vents, there is the possibility to control the temperature inside with thermostatically automated devices. Another option to consider is an automatic ventilating fan system controlled by a thermostat (Biehle, 2006).

2.2.5 Water Supply and Drainage

The last aspect mentioned in this background specific to greenhouses is water. Besides light, water is another essential element for plants to carry on the photosynthesis. Today this system can be either manual or automated. In the case of this project, a hydroponic system will be incorporated to the greenhouse. Lastly, it is also important to take into account the way in which the water will leave the greenhouse. Therefore, a drainage system needs to be incorporated to the greenhouse space. A very common solution for the drainage system is to build a sloped floor (Biehle, 2006).

2.3 Hydroponic System

Hydroponics is a method of growing plants without the use of soil. Instead a hydroponic system grows plants in an inert system such as peat, gravel, sand or water, and uses a specifically calculated nutrient solution containing all the essential nutrients the plants need to grow (Resh, 1995). Hydroponics has several advantages over its traditional soil culture counterpart including, more efficient nutrition regulation, efficient use of water and fertilizers, low cost of sterilization, increased crop yield and no weeds. The system does have a few drawbacks including a high initial capital cost but this money can be reimbursed through the efficient use and configuration of the specific system.

2.3.1 Aquaponics

The Growing Power vertical farm will implement a closed-loop aquaponic system where fish waste fertilizes hydroponically grown plants whiles the plants naturally filter the water for reuse by the fish. An aquaponic system is a recirculating system of hydroponics where plants grow in conjunction with fish, usually tilapia. Aquaponic systems consist of fish rearing tanks, a suspended solids removal component, a biofilter, a hydroponic component, where the plants grow in a soilless culture, a sump tank and sometimes a container with secondary crops, depending on the system.

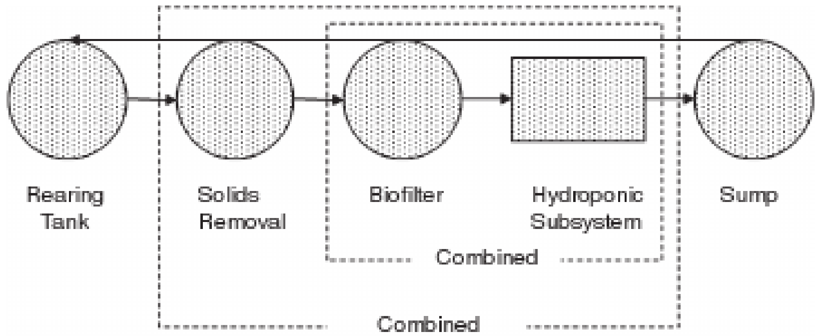


Figure 3 General Aquaponic System Configuration (Tidwell, 2012).

The fish, located in rearing tanks, excrete organic waste into the water, this water is then treated with bacteria to remove the nitrite and ammonia considered toxic to the fish. Nitrite is the byproduct of this wastewater treatment, as nitrite is one of the preferred nutrients for plant growth (Tidwell, 2012). The nitrite from fish waste, is the nutritional equivalent of the hydroponic nutrient solutions found in most hydroponic systems used to fertilize plants. Plants retain the nutrients from this organic waste and naturally filter the water as it flows through the system, decreasing the need to discharge this wastewater into the environment. At that point the water is clean enough to be recycled back into the fish-rearing tank to be reused by the system, reducing the operating cost of the system. If the water is sufficiently filtered by the plant roots, there is no need for a biofilter, which is a major capital expense in aquaponic systems. This recirculated water will still have accumulated organic waste that wasn't filtered (Tidwell, 2012). This water will be dumped into the sump tank before going back into the rearing tanks where the organic matter is broken down further. In an integrated aquaponic system this final wastewater can be channeled into a container of secondary aquatic crops such as algae or seaweed, which provides food for the fish.

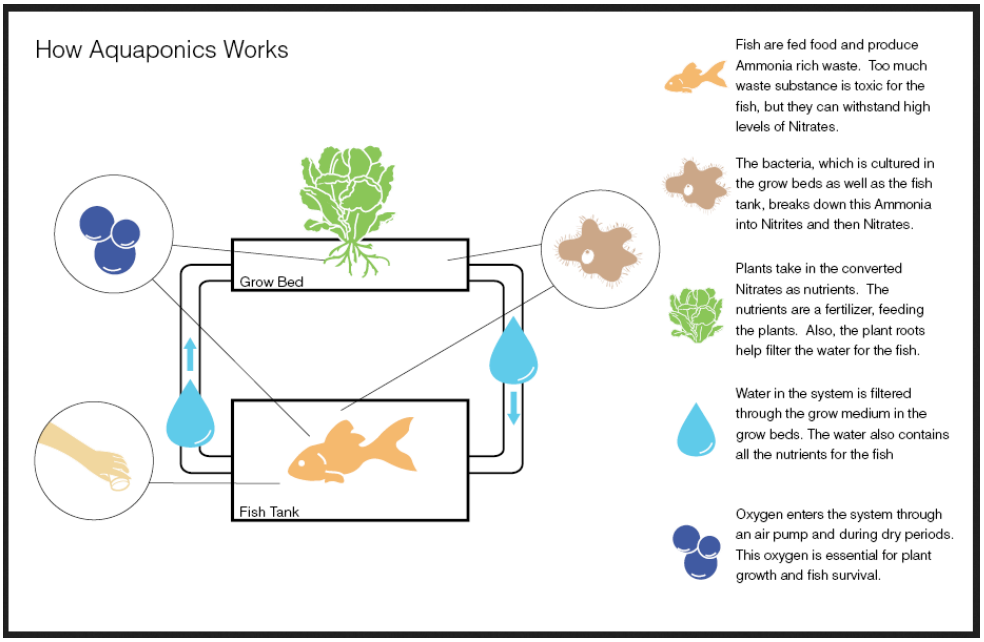


Figure 4 Aquaponic System Summary (Aquaponics Ideas Online).

One major disadvantage is that aquaponics emphasizes plant culture over fish production. The ratio of plant growing areas to fish rearing area is normally 7:3. This ratio has to be carefully balanced to keep the nutrient levels of the plants consistent because the efficiency of the biofilter will diminish over time (Tidwell, 2012). The aquaponic system also requires a large capital investment and a substantial amount of energy to keep the system running.

2.3.2 Construction Materials

Construction materials for aquaponic systems are chosen based on minimizing the impact on the health of the fish and plants within the system. It has been found that fiberglass is the best material for the rearing, sump and filter tanks because of its durability and nontoxicity (Tidwell, 2012). Concrete is a common alternative with a lower price tag, though it lacks the flexibility inherent in fiberglass construction. For the hydroponic plant containers, extruded polyethylene is preferred to makeshift plant containers made of PVC piping. The sizing of materials is proportional to the amount of fish being raised, which determines the size of the solid waste removal component. Another important construction consideration is the ratio of plant growing area to the daily fish feeding area.

2.3.3 Vegetable Selection

Aquaponic system vegetables are selected based on producing the highest level of income per unit area per unit time. Under these guidelines culinary herbs such as basil cilantro, chives, and parsley are considered some of the best choices (Tidwell, 2012). Herbs tend to grow quickly and have high market prices creating a higher income than other possible crops. Leafy greens such as cabbage and pak choi are also preferred options because of their short growing periods.

2.4 High Performance Buildings

A high performance building can be formally defined as a building "that integrates, and optimizes on a life-cycle basis all major high performance attributes, including energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality and operational considerations"(Energy Independence and Security Act, 2007). The component interactions of different building systems must be planned and designed by an integrated team of professionals including owners, engineers and architects. From the building's conception, this project team must consider cost effective energy minimization, as one of their main goals. Common technological advances found in many high performance buildings include: efficient thermal envelopes, plant irrigation, advanced glazing, trombe walls, photovoltaic systems, day lighting, ground source heat pumps, passive solar design, and renewable energy sources.

2.4.1 Renewable Energy

One of the attributes of high performance buildings is providing alternative sources of energy that have a lower impact on the environment. Today, these renewable resources can be found in various forms such as solar energy harvesting and hydropower.

Solar

The sun is a huge source of which energy can be harvested because solar energy is infinite. Harvesting the sun's energy can be used to power small-scale and large-scale buildings. The suns energy can't be harvested unless Photovoltaic (PV) cells are integrated. PV systems are expensive at first but the return on investment makes the purchase worthwhile. Solar panels work extremely well with establishments that are in obscure locations because that avoids the extension of an electric power grid from the nearest main line. Placing the panels can be done in an open field or on the roof of the building, so long as the panels are exposed to the sun. However, some disadvantages of solar panels is that it is impacted by the weather especially in places where the weather is very unpredictable. Another downside of solar panels is that the sun is not out for 24 hours so that limits the amount of energy collected especially in the colder parts of the year. Below is a picture on how PV works.

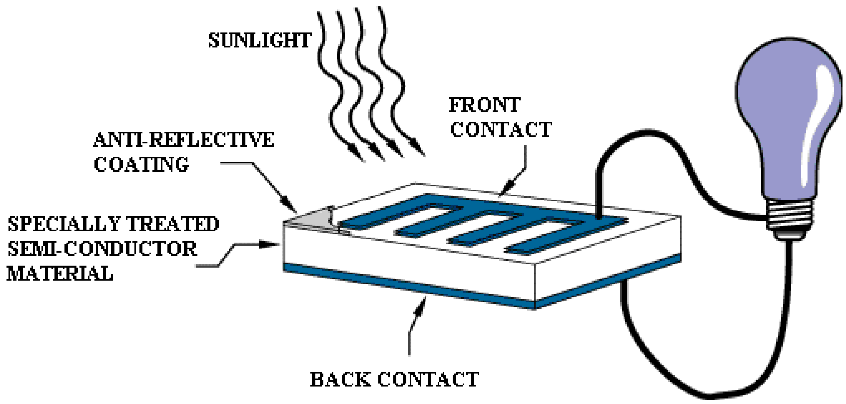


Figure 5 Solar PV Function (NASA).

2.4.2 Irrigation

Along with harvested rainwater being a source of water for irrigation so can grey water. Grey water is water that comes from sinks, showers, baths and other appliances. The most common use to get rid of grey water is irrigation. When it comes to irrigation, it is important that the plants are not over and under watered. This can be regulated by installing a rain sensor or a moisture sensor. Rain sensors sense rainfall and when a certain amount of rain is detected, the irrigation system shuts down. The soil moisture sensors detect the moisture in the soil at the root and are more accurate than rain sensors. Rain sensors are easier to maintain and are less expensive but the moisture sensors outperform them. The accuracy the soil moisture sensors have in detecting the amount of water plants are receiving leads to saving water and money. Below a moisture sensor (left) and rain sensor (right) can be seen.

Figure 6 Moisture sensor (left), Rain sensor (right) (Rain Bird).

Rain Water Harvesting

Natural occurrences can be taken advantage of in order to save on things such as water, energy and money. Rain water huge when it comes to recycling because water is an essential to the human population. Rain water can easily be harvested and stored for later use for things such as plant, crop, or landscape irrigation, appliances that require water, and potential can even be used for drinking water since the rain is clean. However, if harvested water is intended for drinking purposes, it would be crucial for the recycled water to run through a filtration system. Harvested rain water reduces demand on existing water supply, and reduces run-off, erosion, and contamination of surface water and it also reduces flooding.

Rain harvest systems range in sizes, the larger they are, the more water can be stored but at a higher cost. The system is made up of a catchment surface, conveyance system, storage, distribution, and treatment and an example can be seen below. Systems are meant to save the owner money but it does come expensive at first so it is a long term investment.

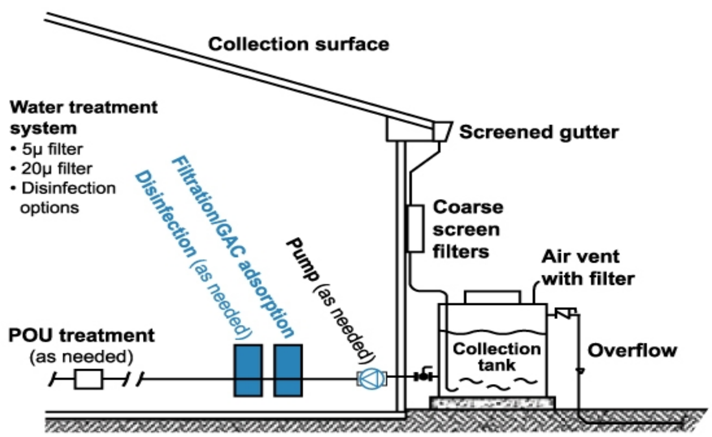


Figure 7 Rain Harvesting System Example (Sweet Water).

Some disadvantages of rainwater systems is that the return on investment will be impacted based on the amount of rainfall which is why the location is important. These systems require constant maintenance because they face algae growth and animal infestation such as insects and rodents. The collection surface of the system is very exposed and that is what the rain impacts first and the proceeds to run off to be collected. When the water makes contact with the surface, it runs the risk of collecting chemicals, dirt and animal droppings. This can be resolved by installing a filtration system to make the water safer.

2.4.3 High-Performance Building Facades

There are many sustainable façade systems that utilize advanced technology to achieve reduction in building energy consumption, reducing solar glare, etc. A chart outlining the pros and cons chart of the different façade options is shown in Appendix A (Aksamija, 2013).

Double Skin Facades

Double skin facade systems consist of two glazed layers with an air space in between. This airspace can either be mechanically or naturally ventilated in a way that makes sense for the building's size and orientation. Natural ventilation is preferred for areas with cold climates, and mechanical ventilation is optimal for hotter climates (Aksamija, 2013). Natural ventilation occurs through the stack effect as hot air rises above the cold air within the air space until it is dispersed through an opening near the top of the exterior layer. Double skin façade systems can be implemented across a wide range of building components from single windows to large multi-story continuous façades. Though double skin facades are a larger investment from the outset than single skin facades they also provide many benefits over the building's lifecycle such as wind-load protection, reduced glare and improved acoustic performance (Aksamija, 2013). Additionally, double skin facades are ideal for cold climates as opposed to single skin facades. The air gap between the two layers works as a thermal barrier and wider gaps provide better insulation, though the hot air stored in this gap must be ventilated in the summer so the building does not overheat.

2.4.4 Heating & Cooling

There are various technologies that reduce the carbon footprint and energy consumption of the heating, ventilating and air conditioning (HVAC) system. Some of them are explained in the following section.

Trombe Walls

Trombe walls are used to provide steady passive solar heat to buildings throughout the day. The walls are normally one-foot thick masonry walls faced with a dark, heat absorbing material on their exterior. A single or double pane of glass that creates a small insulating air film fronts this heat-absorbing material. Sunlight passes through the glass and gets absorbed onto the dark surface, and then is slowly conducted through the masonry. The heat will take eight to ten hours to reach the interior of the building, so rooms are passively heated after the sun has gone down (Torcellini, 2004). To ensure that heat reaches the interior of the space, conductive material such as concrete is placed on the interior of the trombe walls. Trombe walls can supply essentially 20% of annual heating loads making them a highly effective passive heating solution (Torcellini, 2004). Certain drawbacks to the trombe wall system do exist. The system can overheat in the summer months when solar heating isn't necessary. Having engineered overhangs that shade the trombe walls from the sun, although the overhangs don't always account for the low sunrays that are present in the early mornings and late afternoons, can counteract overheating.

Water Source Heat Pump

A WSHP is a highly adaptable and energy efficient mechanical system. A general diagram of the system can be seen below in Figure 8. The system employs units of varying size, based on their tonnage, distributed throughout the building, to create different zones connected through a water distribution loop. The water distribution loop serving the heat pumps is connected to a boiler unit that adds heat to the system and a cooling tower that rejects heat from the system. These components allow different zones to be concurrently heating, or cooling or completely shut off at any given time. The units that need heat will extract the heat from the distribution loop and the units that don't will reject heat back into the loop. In this way the system is constantly recovering heat that is rejected and acts self-sufficiently, saving power. The system is controlled through the use of thermostats placed in each individual zone.

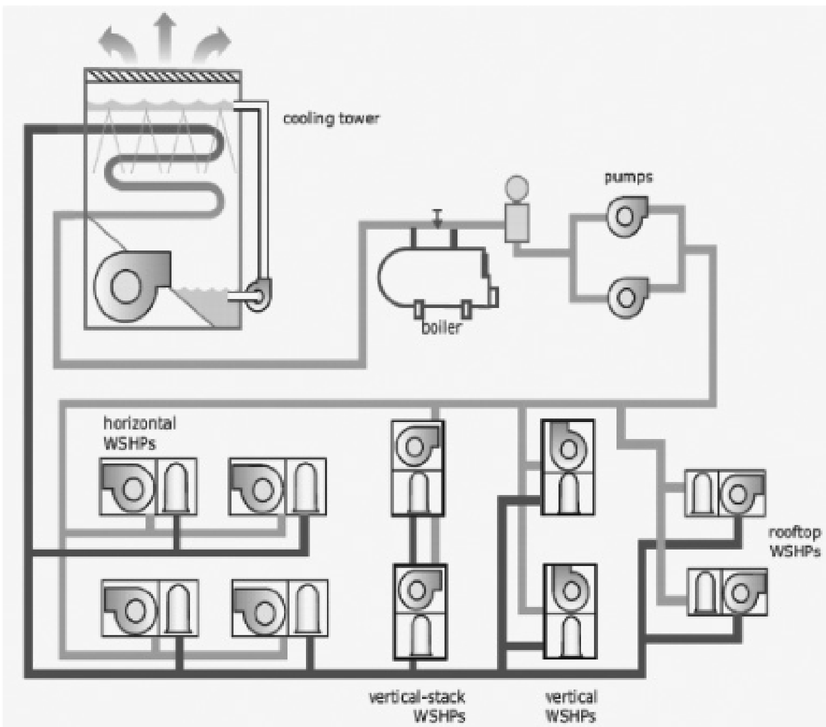


Figure 8 WSHP Layout (Trane Product Catalog 2013).

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Ground Source Heat Pump

A heat pump is a device that transfers the trace amount of heat from a colder fluid to a warmer fluid. The larger the temperature difference is between the two fluids the less efficient the heat pump will be. Groundwater heat pumps are the oldest form of the ground-source heat pump systems as they were first implemented in the late 1940’s (Rafferty, 2008). Ground source heat pumps provide a clean method for heating buildings through the use of the renewable energy stored in the ground. Heat within the ground stays nearly the same year round, being cooler than air in the summer, and warmer than air in the winter providing heating and cooling for buildings (Rafferty, 2008). The only energy used in a ground pump heat system is the electricity to power the pumps. Also ground source heat pumps can operate with considerably less water flow than the average water source closed loop heat pump. Ground source heat pumps are generally known as the most energy efficient, environmentally clean, and cost effective heating and cooling system available (Valizade, 2013).

A ground source heating system works by first removing heat from the earth by extracting ground water into an open loop system or circulating an antifreeze refrigerant solution in a closed loop system. This water, or refrigerant fluid is then circulated through the water-source heat pump, which has an almost universal design. The main components of a water source heat pump include: a compressor, refrigerant-to-water heat exchanger (condenser), refrigerant-to-air heat exchanger (evaporator), refrigerant expansion devices and refrigerant-reversing valve. This heat pump system works the same way as a refrigerator when it is cooling and works in the opposite way during heating (Rafferty, 2008). The heat pump consists of an evaporator to extract heat from the water in the ground loop, a compressor to compress the gaseous refrigerant to the temperature needed, and a condenser to feed the heat to a hot water tank. The heat from the pump can then be distributed through a classic duct system. The ground loop is essentially a buried piping network containing ground water or antifreeze, depending on the type of loop, which is circulated in the pipes and picks up heat from the earth. There are many different types of loops that will be expounded upon below.

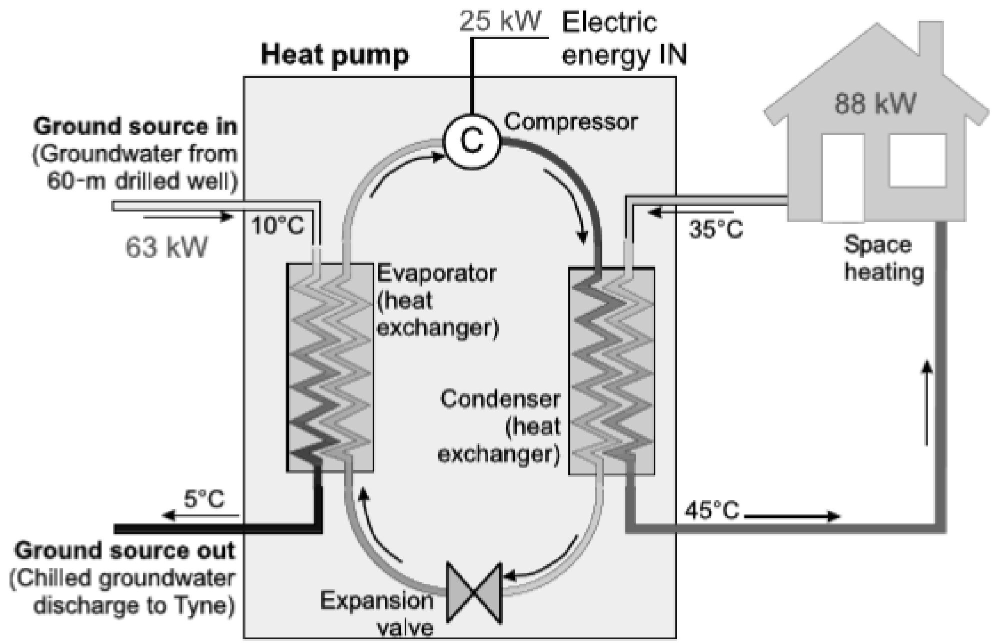


Figure 9 Heat Pump for an Open Loop Ground Source Heat Pump (Valizade 2013).

Closed Loop Systems

Closed loop systems consist of heat exchanging pipes that are placed underground horizontal or vertical. The piping loop is filled with a heat carrying fluid, usually a refrigerant that transports the heat from the ground directly to the heat pump. This system is separated from the groundwater and soil by the walls of the pipe, hence being called a closed system.

Horizontal Loop

A horizontal loop system is one where its heat exchangers are placed horizontally in a shallow trench. Since the trench is quite shallow in comparison to other ground source heat pumps, the horizontal loop system is the least expensive to install (Valizade, 2013). There are also a myriad of options for installation so the system is more flexible than most. Unfortunately this type of system requires a large surface footprint because the trench has to be wide. The ground temperature is also a problem at it is prone to fluctuate more when the heat exchangers are at such a shallow depth (Rafferty, 2008).

Spiral Loop

A spiral loop system consists of pipe laid out in a spiral horizontal loop configuration. This type of system requires more piping than a basic horizontal loop, but less trenching which lowers the installation cost. These types of systems are associated with sites that don't have land area requirements as a limiting factor. This type of system is also subject to seasonal temperature fluctuations because the spiral loops trench is shallow.

Vertical Loop

The heat exchangers are configured vertically when there are land area restrictions on the site. This system requires less total pipe length and thus requires the least amount of pumping energy of the different closed loop systems. With the boreholes that pipes are placed so deep, 75 to 300 feet, the ground temperatures will not fluctuate with the weather. With the boring holes being so deep heavy drilling equipment is required increasing the cost of installation.

Open Loop Systems

Open loop systems differ from closed systems in that they use the local groundwater supply as a direct heat transfer fluid as opposed to using a refrigerant fluid within a closed loop. Because the open loop system uptakes local groundwater there are many regulatory issues and system factors that need to be considered. Ground water flow rate is paramount as it informs the design of the entire system, because a stronger flow rate decreases the power necessary for pumping and increases the efficiency of the entire system (Rafferty, 2008). The flow rate must be carefully considered, however, because there is a maximum flow rate that produces the optimum efficiency for the system that shouldn't be surpassed. This optimal flow can be calculated by dividing the cooling capacity of the system by the sum of the heat pump power, loop pump power, and well pump power.

When using an open water system, one must consider the quality and availability of the local groundwater. Open systems require an ample amount of water, which can be a problem if there are stringent local water resource regulations. Water discharge can be another major issue, but there are two options for discharge. The water can be recycled using an injection well or water can discharged into another body in what is called a surface system (Rafferty, 2008). An injection well is more complex and costly but is not subject to strict local water regulations because the water is recycled and the aquifer the water is taken from is not affected. Surface discharge systems are simpler, less expensive, but require another water body such as a lake or river to take the discharged water, and there are many regulatory issues that come with this. The surface system requires the most water for pumping, and thus requires the greatest pumping energy. On the other hand the surface system can be integrated with a system that already pumps water on site like an irrigation system (Rafferty, 2008). Other factors to consider include: well pump control, water well design, heat exchanger selection, and production/injection well separation.

2.5 Structural Systems

A multi-use facility such as the vertical farm presents multiple structural design challenges. An educational facility lends itself to open spaces and visuals of the operating systems. The operating systems of the hydroponic growth system are complex and will stretch between several floors, connecting many rooms. With this connection between spaces, integration of the structure with the systems is crucial. To do this, structural systems that could aid in the design were investigated.

2.5.1 Hollow Steel Sections vs. Wide Flange

In regards to structural columns, there are two options for investigation: hollow structural sections (HSS) and wide flange (WF) sections. Moving forward, the advantages and disadvantages have to be weighed in order to decide which of the two will be the best fit for the vertical farm project.

According to steel fabricator Atlas Connection's website, architecturally HSS is a more commonly used column approach, making it more appealing for exposed structural elements due to the higher quality surface finish. It is cost-effective as well, when compared to other building materials, and does not require a large amount of maintenance since it "resists dry rot, mildew, and pests" (Atlas). For engineering, some advantages, according to Atlas' website, are: HSS has a higher resistance to torsional loading and has less resistance to air and water flow. HSS is stated to be "suited for compression column applications" (Atlas) and to have greater design properties about both axes in regards to moment of inertia, section modulus and radius of gyration. Since these members are hollow, it allows for concrete to be poured into the empty space as this helps fire resistance. HSS members are easier to erect and is generally cheaper to ship since they do not weigh as much as wide flange members.

However, a huge disadvantage to HSS is that it cannot be used as a girder because it is more likely to fail due to its hollow center. This is why wide flange sections are the appropriate pieces for horizontal girder usage in order to create areas that will support heavy loads on floors and roofs.

For horizontal members, the primary advantage to the wide flange section is that it allows for distribution of load spread throughout an area. This means that it can support a larger or wider structure with less risk of failure. Wide flange beams resist larger moments due to larger loads and require less material than a square HSS beam of equal strength, making them more efficient. Wide flange beams are surely the best choice for horizontal members. They are easily connected to HSS structural columns and have been in use for a long time.

2.5.2 Concrete vs. Steel

An analysis of steel and concrete and their best uses is an important step to justify our ultimate decision of which material or combination of materials the design uses. Areas of safety, cost, material availability, scheduling, and design possibilities outline the comparison. Both materials are great for construction and have been taken advantage of for various infrastructural means.

Safety

Buildings' cores are often vertical shafts of multi-foot thick reinforced concrete. This core can handle fire and terrorist attacks and endure high temperatures for a sustained period of time without a decrease in structural integrity. Concrete's material properties aid in its safety as weight, mass and strength defend cast-in-placed concrete structures from high wind loads of more than 200 miles per hour (62 Madsen). Concrete is not a ductile material inherently, but "the performance of any building during an earthquake is largely a function of design rather than the material used in construction" (62 Madsen).

Steel is safe just as well. The addition of passive fire protection, raises the temperatures that structural steel can sustain before experiencing its softening and melting characteristics with high temperatures. Steel is a ductile material, lending itself ideal for seismic zones and high wind environments. Steel framing can bend without breaking, absorbing significant quantities of energy in either event.

Cost

Both concrete and steel prices have risen since the turn of the century. Initially, concrete costs seem more appealing but looking at the overall impact on project costs, steel is viable. A cost incentive for high-rise concrete structures is the return on investment through property insurance deductions. Insurance companies report that "owners and developers of a Class-A, cast-in-place reinforced concrete-framed office tower with a concrete core and wider egress stairs will save nearly 25 percent annually on the cost of property insurance" (63 Madsen).

The decision of materials based on cost proves to be on a project-by-project basis. Concrete can be placed to great heights without a crane, but to know at what height concrete serves to be more beneficial is determined at the time of design.

Material Availability

Recently, a shortage of cement, the primary binding ingredient used in concrete has affected the industry. Concrete is a normally a consistent and reliable material, so when availability is damaged, the domestic production capacity is risen without hesitation. Instead of importing cement supplies, relying on domestic transport is the main way to minimize cost.

Steel's availability is different; the United States in 2004 could produce 6 million tons of structural steel per year, covering the 4 million tons used in that very same year (63 Madsen). The steel industry in the United States has dropped as to follow the demand trends of the industry. The infrastructure and material needed to ramp production has remained, lowering the lead times for procurement.

Construction Scheduling

When in the construction industry, time equals money. The sooner a project can be completed and tenants move in, the happier the client. In most cases, concrete building can be built faster. Typically, a 2-day cycle is the norm for large cast-in-place projects. This labor-intensive operation, pouring up to 20,000 square feet of floor space every 2 days can rise one floor every other day (64 Madsen).

Steel's competitive feature for scheduling is its ability to be fabricated off-site. Increased quality and a reduction in on-site time and construction is the future of the industry. An ever-accelerating progress, building information modeling (BIM) has enabled integration of design through fabrication, sometimes "literally compressing the steel portion of the schedule of projects by 40 or 50 percent" (64 Madsen).

Design Possibilities

In high rises, cast-in-place concrete is demanded because of the lower floor-to-floor heights is yields. Increased rental space means more income from tenants and in the case of the Trump International Hotel and Tower, by switching from steel to concrete added two stories to the 1,125-foot building (64, Madsen). Floorplates of great spans reaching 45 feet are desired because of their uninterrupted physical presence towards occupants. In addition to its volume reductions for strength, it can form to any shape, and is architecturally appealing.

Advancements in steel design have mitigated the large floor depth expectations normally accompanying steel design. Girder slab, staggered truss, and castellated beam construction have made this possible (64, Madsen). Long spans of column free space, meaning open-bay footprints are a result of steel construction. Concentric braced framing using steel is a great potential. This, in addition, to a ridged frame mitigates bending actions of columns and girders by web members resisting lateral shear. The flexibility to meet design challenges lends its self to steel.

Sustainability

Historically, concrete has been the more environmentally friendly option towards building materials. The close proximity and availability of the materials needed for cement production (rocks, limestone, and clay) lend itself to this sustainable reputation. Transport during the concrete production process as well as CO2 emissions during cement production are additional concerns. Transport and electricity account for nearly 25% of the CO2 emissions in concrete production (Sakai, 2000).

Steel is an appealing material for sustainability reasons. Steel is very durable and highly recyclable. Because it can be recycled, a significant amount of steel used for new buildings today is recycled, instead of raw materials. After the life cycle, a steel framed building can be dismantled, with an ability to recycle 66% of the steel (Emerson, 2005). The reduction in natural resources mined and used is highly sought after in any manufacturing industry.

2.5.3 Lateral Force Resisting Systems

Shear Walls

The two main functions of a shear wall for the structural system of a building are stiffness and strength. Lateral loads such as earthquake and wind loads produce shear which the wall is designed to handle. Floors and their structural beams often rest on shear walls. Mitigating lateral movement, a shear wall increases their stiffness at the end connections. When designing shear walls, not only do these functions need to be designed for, connections at the bases for sliding resistance as well as uplift resistance should be considered. When uplift forces act positively over the gravity monotomic load of the wall, hold down anchors should be used. A traditional placement strategy for shear walls is equal length shear walls placed symmetrically on all four exterior walls. When using shear walls in a multi-story building it is crucial to align them vertically otherwise the loads should be traced. Aspect ratios of the height to width often govern design. A wider and shorter wall is more stable than a short and tall wall.

Lateral loads shift in opposing directions, also known as cyclic loading. A shear wall's end vertical pieces will ultimately experience tension and compression due to this alternating force. A variety of materials can be used for a shear wall; most commonly lumber shear walls are used in wood construction for residential purposes in the Northeast. CMU, steel and aluminum shear wall designs are also specified when their use is most beneficial to the project.

Braced Frames

An alternative to shear walls, but a solution to lateral loads is bracing. Lateral steel bracing on each level of a multi-story building can have similar mitigating effects of several shear walls throughout the floor. Seen in Figure 10, cyclic loading can produce compression and tension effects in LFRS members, so each condition needs to be designed for.

Figure 10 Single Diagonal Bracing in Tension and Compression.

2.5.4 Greenhouses

Using the Growers Supply division of FarmTek, common industry standards were gathered for greenhouse components. Specifically, using the Elite Educator Greenhouse, frames are triple-galvanized structural steel for corrosion resistance, with 8mm Twin-Wall Polycarbonate. This material is clear, UV resistant and twelve times lighter than glass. Growers Supply also states that "8 mm Twin-Wall Polycarbonate will not develop a film after long exposure to sunlight…". A 14' Wide x 48' Long Greenhouse of this model has an approximate weight of 4,500lbs. Knowing this weight per greenhouse area serves as a basis for rough structural outlines. Although these greenhouses are not the exact dimensions that will be used for the project, their components and materials that have become popular can be used.

In addition to the main structure of the greenhouses, live loads should be considered: hydroponic plant troughs, heat lamps, growing lamps, walkways, vents, fans, cooling equipment, and organic material. Mechanical lines of transfer such as electrical lines and plumbing tubes will need weight bearing points as well. One method that proves advantageous to approaching this structural design is to use the greenhouse solar envelope as a shell only. By doing this, the interior equipment of the greenhouses will need to be floor mounted. Eliminating hanging structures will lend itself to designing the building structure only, as the greenhouse shell is self-supporting. The only additional loads to self-weight will be External live loads such as snow and wind loads.

2.5.5 Structural Glass

The application of glass to the vertical farmhouse project is appealing, in regards to the architectural renderings provided by Growing Power and the AEI competition. Glass has drifted from traditional use, such as domestic windows, to a much larger scale, as in high rise buildings. When designing the glass to be used for this project, the dimensions are a significant factor in determining its lateral and vertical capacities. Installing glass on this project will have various positive impacts on the operation of the facility, both externally and internally. Externally, glass is now used to make buildings look sleek despite it being something brittle and simple. In addition to the greenhouses, it will give people walking outside a better view of what is taking place inside, which may spark some curiosity and push them to explore the facility further.

Internally, selecting structural glass allows for an abundance of sunlight to enter the facility which is essential, especially with the growing areas all consisting of glass as an encasement. Plants need sunlight in order to survive however, overexposure to sunlight can ruin them and production. Plant protection is crucial, therefore a shade or shutter system should be installed to be utilized to block out the sun after the plants have received enough sunlight. Although the shades stop sunlight from entering the building it is still making contact with the glass. With the installation of structural glass we have the opportunity to apply a transparent photovoltaic system to the glass. This will allow for solar energy to be harvested even when sunlight is being exposed to the vegetation inside of the growing area and when it is being blocked off.

Glass is one of the most useful materials in the world. Few manufactured substances add as much to modern living as does glass. According to 'corrosiondoctors.org', glass is much more resistant to corrosion than most materials; it is easy to think of it as corrosion-proof. Glass is used for various purposes such as: food storage, storage or preservation of a liquid or drink, and traditional domestic glass use for windows. Aside from storage, glass can be used for protection which is the case for windows on buildings, houses and cars. This glass protects the internal contents from the conditions on the opposite side of the glass. Glass on buildings, or windows, is subject to wind loads as well as its self-weight applied to seismic forces.

According to Steve W. Martin, Professor of Materials Science and Engineering at Iowa State University, glass can be stronger than steel, or more fragile than paper. Most glass is transparent, but glass can also be colored to any desired shade. He also mentions that glass can be made to take different shapes potentially making it more architecturally appealing, but the vertical farm is going to use flat glass for the greenhouse roofs and its encasement.

The application of structural glass has been purely for windows but has now taken a more modern direction and is being used more to compliment the building and giving it the state-of-the-art look. For example, Apple stores, are known for their huge glass pane entrance that gives it a sleek modern look that lures in potential customers who walk by. This is the same effect that we want the vertical farmhouse project to have (Martin, 2001).

2.6 Project Management

Construction project management can be defined as "the art and science of coordinating people, equipment, materials, money, and schedules to complete a specified project on time and within approved cost". (Oberlander, 2000). Every construction project needs to have a well-defined scope with a detailed schedule and cost estimate. The project manager as well as other entities involved in the project need to work closely to ensure that the project will be finished on time and on budget (Oberlander, 2000).

Cost Analysis

One of the major concerns in the construction business is the finance and the money flow in a specific project. The prediction of the project cost as well as the forecast to balance the money spent throughout its execution is determinant. The accuracy of the cost estimate will affect the completion of the project as well as the expected money to be spent during the building's construction.

Project Cost Estimation

An estimate of the cost of a construction project is the probable and expected cost of that job as computed from plans and specifications. There are several approaches and methods to produce an estimate. There are different estimate classes and types. The Estimate Classes typically refer to the level of pricing detail or the type of services priced in the estimate. The Estimate Types are defined by the level project documentation and development, therefore the accuracy of the estimate increase as the design drawings and drawings are developed. A description of the most common Classes and Types of estimates is provided below.

Estimate Classes:

Class A

- Provides a detailed breakdown of materials, labor and equipment.
- The pricing details exact unit prices for each construction element.
- It is often performed with less than 100% complete documents.

Class B

- Uses building component format and composite unit pricing
- Can be performed at any stage of the design process
- It is commonly used in Construction Management projects.

Class C:

- Uses historical data for pricing, usually square foot costs.

- Drawings are not usually available at this point. The project is only defined orally or in written documents.
- Usually used to provide early opinions of probable outcome of more detailed estimate.

Class D:

- Pricing data is related to providing services such as consulting work, professional services contracts, design phase services, etc.
- The fee proposal is included in this class.

(Zarenski, 2015)

Estimate Types:

Parametric:

- Usually used for sales presentations and early project conception
- Design drawings and documentation are not available
- Historical cost data is used in order to obtain a ranging estimate
- It has an accuracy of ±20%

Conceptual:

- It is considered to be the project's initial estimate
- All the subsequent estimates are compared to this type of estimate
- Based on conceptual drawings and documents
- Uses building component format.
- It has an accuracy of ±15%

Schematic Design:

- Based on schematic level documents
- Uses building component format
- Less conceptualizing is required
- It has an accuracy of ±5-10%

Design Development:

- Based on design development documents
- At this point the design is reviewed and approved by the client
- It has an accuracy of ±5%

Construction Documents:

- Based on construction documents which detail all the information required to bid, purchase, and construct.
- Usually follows under Class A or B

- It is not typically performed unless required by the client

Bid Package:

- It is the most detail estimate
- Based on design development or construction documents
- The scope growth is defined and identifies changes made since previous design stage
- Used to compare with trade contractor proposal

(Zarenski, 2015)

Expense Subdivisions

The cost estimation process starts by identifying the different expenses present in the cost of an item of work. The unit price of an item of work encompasses the cost for material, labor, and equipment. A description of these expenses subdivisions is provided below.

1. Material: The conformation on a list of materials is known as the "takeoff". The takeoff process involves the quantification of material used to build a project. This process is performed using spreadsheets and building component schedules.
2. Labor: In order to estimate the amount of labor needed, the takeoff information is used. The length of time (labor hours or crews per day) required to do a certain item of work is calculated using productivity rates.
3. Equipment: Certain items of work require the use of equipment in order to be completed. The cost for equipment use is normally estimated by the amount of labor hours or days it will be used.
4. Overhead and Profit: This type of expense includes all general office and other labor costs that are not considered as direct productive labor on the project. Overhead costs include rents, insurances, taxes, legal expenses, etc. Overhead and profit costs are usually estimated to be 10% and 15% of the unit price cost of an item of work.

(Atkinson, 1999)

Life Cycle Cost Analysis

The Life Cycle Cost (LCC) Analysis can be defined as "a method for assessing the total cost of facility ownership. It takes into account all costs of acquiring, owning, and disposing of a building or building system over a period of time." (Life Cycle Cost Analysis (LCCA), 2010). LCC uses economic evaluation techniques to determine the total cost of owning and operating a building over a period of time. This approach can be used in any type of building and is helpful at the time of making decisions about the construction process or sustainable improvements to a building. "Life Cycle Cost is an increasingly used technique for sustainable construction analyses to compare high efficiency construction materials, systems, and designs that with traditional alternatives that initially may be less expensive but have a higher operational and maintenance costs" (Halpin and Senior, 2011).

A LCC analysis is a cradle-to-grave analysis of a building; therefore, a highly important aspect of this analysis is the energy consumed during the different phases of the building's life span. "Sustainable or 'green' construction centers on the efficient use of resources that create and support the built environment. The efficient use of energy, such as the electricity required to run a home, is a key aspect of sustainable construction, especially during the occupancy phase of a building's life cycle" (Halpin and Senior, 2011). The operations and maintenance costs of a building are considerable as compared to the initial investment costs. Sustainable features included in the design of a building have to be evaluated to be economically viable because they represent an incremented investment at the time of construction but might represent significant savings during the operation phase.

Identifying the main components of a LCC analysis is important in order to understand if the inclusion of sustainable or high performance features, systems, or designs will be cost effective. The initial, replacement, operating, maintenance, and disposal costs are subjected to evaluation when comparing two different systems that will provide the same service. This evaluation is crucial because a particular system might have a lower initial cost, but might end up having a greater overall cost, than a high efficiency system because of the maintenance or even replacement needs during the life span of the building.

The LLC analysis of a building depends on a thorough understanding of the time value of money. It considers the time and cost of borrowing money as a construction resource. The biggest challenge during this analysis is the transformation of future cost to present worth and vice versa.

2.7 Code & Standards

When a building is designed, it must comply with the applicable codes and standards for that area. These documents will provide the limitations and constraints that the design might satisfy. In Milwaukee, both the *International Building Code* and the local code apply. In addition, the Florida codes will also be included in this section to study the constraints of the second site.

2.7.1 International Building Code

The *International Building Code® (IBC®)*is "a model building code that provides minimum requirements to safeguard the public health, safety and general welfare of the occupants of new and existing buildings and structures" (*International Building Code®*, 2012). This code is published every three years by the International Code Council (ICC)® and addresses "structural strength, means of egress, sanitation, adequate lighting and ventilation, accessibility, energy conservation and life safety" of buildings, facilities and systems, both new and existing. It also restricts the area and height based on use and construction materials. The code establishes minimum regulations of the different prescriptive and/or performance specifications that the building systems must meet. Therefore for the purpose of this project, the team studied the 2012 Edition of the *IBC®* which is the latest version published to this date.

Use & Occupancy Classification

In accordance with the *International Building Code®* 2012 Edition, a building should be classified in respect to its use and occupancy, which determines the purpose for which the building, or part of it, is intended to be used. Identifying these characteristics in the early stages of the project is very important as they will help determine the minimum expected structural load, the type of structure, the fire-resistance rating and any additional safety measures needed for this building. The 2012 edition on *IBC®* provides a list of ten classifications and sub classifications. However, for the purpose of this project, the team only studied five of the classifications, which pertained to the building design. These groups are the following:

- Group A (Assembly): this group includes spaces dedicated to the gathering of persons. Uses for this type of space include civic, social or religious functions; recreation, food or drink consumption; and awaiting transportation area. The assembly group is classified in various subsections, including group A-3, which contains areas such as community, lecture and exhibitions halls.

- Group B (Business): this group represents spaces that are used for office, professional or service-type transactions. Some of the most common examples are educational occupancies for students above 12th grade, training and skill development not within a school or academic program, professional services, post offices, among others.

- Group F (Factory Industrial): this group consists of spaces that are used for assembling, disassembling, fabricating, finishing, manufacturing, packaging, repair and processing operations. In the case of F-2, it comprises low-hazard uses that involve the fabrication or manufacturing of noncombustible materials which do not involve a significant fire hazard. Some of the uses for F-2 spaces are beverages, ice, brick and masonry, foundries, among others.

- Group M (Mercantile): this group describes those spaces whose purpose is to display and sale merchandise, as well as involved the stocks of goods, wares or merchandise incidental. One of its most common examples are markets.

- Group S (Storage): as their name implies, these spaces are used for storage that are not classified as hazardous. According to S-2 classification (Low-hazard Storage), some of its uses are for food products, food in noncombustible containers, fresh fruits and vegetables in non-plastic trays or containers, among others.

Types of Construction

Another classification provided by the 2012 Edition of the *International Building Code®* is the types of construction. This categorization divides a building into one of five types depending on the fire-resistance rating of its structure. Some of the elements taken into account for this classification are: the primary structural frame, interior and exterior bearing walls, interior and exterior nonbearing walls, and floor and roof construction and associates secondary members. The classification of construction types is outlined in the following table.

Table 1 Construction Type Classification

IBC Type of Construction	
Type of Construction	Materials
I & II	All Non Combustible
III	Exterior - Non Combustible Interior - any material permitted by this code
IV (Heavy Timber)	Exterior - Non Combustible Interior - Solid or laminated wood without concealed spaces
V	Exterior and Interior – any material permitted by this code

All construction must be categorized in one of five construction type categories. This categorization is determined by the height and area limitations of the construction and the construction materials being used. Every component of the structure such as exit/ access corridors, shear walls, floors, etc., has a minimum fire resistance rating (hours). Construction types I and II are noncombustible, in type III the exterior walls are noncombustible and the interior is made of any material allowed by the code. Type IV is heavy timber where the exterior walls are noncombustible and the interior components are made of solid or laminated wood. In type V construction the structural elements are made of any material permitted by the code. There is 3-hour, 2-hour, and 1-hour noncombustible construction, which requires a respective fireproof rating for its structural members. There is also unprotected noncombustible construction, which has no additional fire-resistive requirements for its structural members (Iano, Allen, 2012).

The urban farm design provided to the team had a Type IIA Construction with separated uses. Separated occupancy uses demand fire resistance rating requirements for walls, door, and any other opening between the different occupancies within the building. In separated occupancy there is added fire protection within the building. This allows for larger building areas and larger ceiling heights, though the different occupancies must conform to their individual height and area requirements. Type IIA Construction is protected noncombustible construction with one hour fire resistive rating for exterior walls, structural frames, floors, ceilings and roof structures.

Building Height and Area Limitation

The code establishes that when a structure contains various occupancy groups, it should comply with the provisions in regards to mixed use and occupancy. In this section, it is established that accessory occupancies "shall not occupy more than 10 percent of the building area of the story in which they are located" (*International Building Code*®, 2012). It also determines that the allowable building area and height will be limited by the one corresponding to the main occupancy.

If the occupancy classification exceeds the 10% and is not considered a separated occupancy by section 508.4 of the *IBC*®, they are considered nonseparated occupancies. According to section 508.3.1, the most restrictive provisions that apply to nonseparated occupancies shall apply to the total nonseparated area. (*International Building Code*®, 2012)

In addition to the height and area limitations, mixed use and occupancy provisions of the *IBC*® code also take into account if the occupancies are separated or not. According to this code, a building is considered as separate if these conditions are met:

1. "The buildings are separated with a *horizontal assembly* having a *fire-resistance rating* of not less than 3 hours.

2. The building below the *horizontal assembly* is not greater than one *story above grade plane*.

3. The building below the *horizontal assembly* is of Type IA construction.

4. *Shaft*, *stairway*, *ramp* and escalator enclosures through the *horizontal assembly* shall have not less than a 2-hour *fire-resistance rating* with opening protectives in accordance with Section 716.5. "

(*International Building Code®*, 2012)

Means of Egress

Egress systems are meant to provide occupants with access to the exit in case of emergency in the quickest and safest way possible. Egress systems most often consist of an exit access corridor, an exit, and an exit discharge. The exit access can be any pathway that leads to an exit such as a ramp, hallway, corridor, unenclosed stairway etc. This exit pathway must be clearly marked and easy to follow. The exit itself is the protected portion of the system permitting access to the exterior of the building, usually in the form of a fire-protected stairway with a minimum width based on occupancy load (Iano, Allen, 2012). All exits must be within fire resistant rated assemblies that are continuous until they reach the exterior. When there is more than one exit in an area, these two exits must be remote enough from each other that they do not simultaneously become unsafe. The exit discharge leads occupants to a public way along the exterior or another safe area. The *International Building Code* does make exception for discharges to take occupants through open areas at the ground floor such as lobbies.

Structural Designs

Chapter 16 of *IBC* entitled Structural Designs was the most used literature for the design. The local building code is the legal code of record but for Milwaukee it adopted a majority of the *IBC*. Steel has been chosen as the main material of construction, so code applicable to steel design was analyzed more in depth.

2.7.2 Milwaukee Local Building Code

It is crucial not only that the building follows *IBC* code, but that any more stringent local codes are followed as well. The 2014 Wisconsin Commercial Building Code released September 1st is the most recent applicable reference.

Some substantial improvements are in foundations and loading, where Wisconsin uses alternative phrasing and mandates specific formulas. The most concentration by Wisconsin in improving the *IBC* was added to the fire protection measures. Nearly half of all addendums are fire protection rated, whether plumbing, electrical, or material specific.

2.8 Project Location

The project site location influences the design of the building. It can be influenced by factors such as the exterior temperatures, the hours of daylight, to the availability of water, and even the architectural aspects of the area. Since the project is located in Milwaukee, with a potential relocation to Miami, some of these factors were investigated to serve as reference during the design process.

2.8.1 Milwaukee Background

The city of Milwaukee, Wisconsin is located on the southeastern coast of the state adjacent to Lake Michigan. Milwaukee originally belonged to the Potawatomi Native American tribe until French traders acquired the land. Through the years many different groups populated the land, but none more influential than a group of Germans that came to the city in 1848. These Germans were forced to leave their homeland after their rebellion had failed. The Germans brought their customs and greatly impacted the culture and history of Milwaukee by introducing musical societies and theaters to the city. These new additions bolstered the culture and intellectual life of the city leading to the population more than doubling in 1850 and 1851 (Cities of the US, 2009). Now Milwaukee is established as a metropolitan and cultural epicenter for the upper Midwest of the United States. The city has an area of approximately 96 square miles and stands 581 feet above sea level. Milwaukee's dominant economic sectors include wholesale and retail trade, tourism, manufacturing, and services. Additionally Milwaukee is dubbed the "city of festivals" as it boasts many large-scale cultural and ethnic festivals, parades, and concerts year round. The general aesthetic of the city itself is also varied, with multiple architectural styles, old and new, such as Greek revival, Flemish Renaissance, and Indian Saracenic. In summary Milwaukee is an eclectic city with a broad range of aesthetic and cultural qualities.

Climate

Milwaukee has a humid continental climate with hot summers, but no dry season. A continental climate is generally characterized by having a wide range of temperatures. Averages for temperature, rainfall and snowfall for Milwaukee can be seen in Table 2. The temperature fluctuates over the course of the year, but range between 0°F - 90°F. The warm season lasts from May through September, and the cold season is November through March. As the hours of sunlight in Table 4 demonstrates the length of the day changes greatly over the course of the year with the shortest day, of nine hours, in mid-December and the longest day, of 15 hours, in mid-June. The cloud cover in Milwaukee is moderate with clearer skies more prevalent than cloudy skies. In terms of precipitation, actual rainfall mostly occurs in the warm season while light snowfall dominates the cold season. This light snowfall adds up to about 47 inches annually. Winds in Milwaukee range from 2 mph to 19 mph and rarely reach what is considered a strong breeze of 27 mph.

Table 2 Milwaukee Climate Data January - June

Milwaukee Climate Data (January - June)						
Month	Jan	Feb	Mar	Apr	May	Jun
Average High °F	29	33	42	54	65	75
Average High °F	16	19	28	37	47	57
Average Precipitation (in.)	1.77	1.65	2.28	3.54	3.39	3.9
Average Snowfall (in.)	15	10	7	2	0	0

Table 3 Milwaukee Climate Data July- December

Milwaukee Climate Data (July - December)						
Month	Jul	Aug	Sep	Oct	Nov	Dec
Average High °F	80	78	71	59	47	33
Average Low °F	64	63	55	43	30	20
Average Precipitation (in.)	3.66	3.98	3.19	2.64	2.36	2.05
Average Snowfall (in.)	0	0	0	0	2	11

Table 4 Milwaukee Daylight

	Hours of Daylight	Altitude of Noon Sun
Summer Solstice	14	74 Degrees
Winter Solstice	9	28 Degrees

2.8.2 Miami Background

The city of Miami, Florida is located on the southeastern Atlantic coast. Early Native American settlers known as the “Tequestas” originally occupied the territory now known as Miami. The Spanish then took over this area and tried to convert the “Tequestas” to Christianity but failed as the majority of the tribe died because of diseases brought from Europe. In the 1700's it was occupied by other Native American groups that emigrated due to the United States land expansion. Then in 1819 it was purchased from Spain and ceded to the United States. Later on, it became larger and important to commerce when the railroads reached the city. The city has evolved over the years, with multicultural influences due to the great amount of immigrants it has received, and it is considered the "Gateway to the Americas". The city continuously grew with vision on global economies; it has become headquarters for many multi-national companies and financial institutions. Miami is a major center and a leader in finance, commerce, culture, media, entertainment, arts, and international trade. (City of Miami History, 2014).

Climate

Miami's coastal location, sea-level elevation, and proximity to the Tropic of Cancer shape its climate to be tropical monsoon. Also known as tropical wet climate, it is free of extremes in temperature, with long, warm summers and abundant rainfall followed by a mild, dry winter. The average annual temperature is 77.05°F while the averages for winter and summer are 69.9°F and 84.2°F respectively. (Climate Miami – Florida, 2014). Humidity levels usually vary from 86 to 89 percent during the day. Even though hurricane season is defined from June 1st through November 30th, hurricanes usually affect the area form mid-August through the end of September. (Miami: Geography and Climate, 2009). In terms of precipitation, rainfall occurs on an average of 128 days of the year, and there is no snow precipitation in this area, adding up to an annual average precipitation of 61.93 in. Also, as noted in the tables below, the total annual exposure to sunshine in Miami is 2903 hours. (Climate Miami – Florida, 2014). Over the past 60 years, winds in Miami range from a monthly average of 7.9 mph to 10.5 mph and the annual average is 9.2 mph. Even though the wind speed averages are not considerable high, the presence of hurricanes increases the wind speed to over 75 mph when they affect the city. (Stern, 1999).

Table 5 Miami Climate Data, January - June

Month	Jan	Feb	Mar	Apr	May	Jun
Average High °F	76	78	80	83	87	89
Average Low °F	60	62	65	68	73	76
Average Precipitation (in.)	1.61	2.24	2.99	3.15	5.35	9.69
Hours of Sunshine	222	227	266	275	280	251
Wind Speed (mph)	9.4	10	10.4	10.5	9.5	83

(Climate Miami – Florida, 2014)

Table 6 Miami Climate Data, July-December

Month	Jul	Aug	Sep	Oct	Nov	Dec
Average High °F	91	91	89	86	82	78
Average Low °F	77	77	76	74	68	63
Average Precipitation (in.)	6,5	8,9	9,84	6.34	3.27	2.05
Hours of Sunshine	267	263	216	215	212	209
Wind Speed (mph)	7.9	7.9	8.1	9.2	9.6	9.1

(Climate Miami – Florida, 2014)

2.9 Existing Design

The team reviewed the competition documents provided by the Architectural Engineering Institute Student Competition Committee. By analyzing these rules and drawings, a preliminary review, and a detailed analysis of the structure were made. In addition, the team worked on narrowing down some of the possible options regarding the researched systems.

2.9.1 Review of Existing Design

Initially, the first area of focus was the competition drawings supplied by the Architectural Engineering Institute Student Competition Committee. *Impact* looked at the spaces present and the functions of the structure and future purposes. There were several requirements that impact the systems; the architectural and structural design.

On the basement level there is a large open space used for storage. This will be an area to focus on the structural analysis because of the large unimpeded area. The coolers and freezer on this level along with any elevator equipment should not represent many issues for the steel frame design because the equipment is supported by the slab on grade.

The first floor serves as a market and loading area in the rear. Its intention as a lobby makes it an open and welcoming area, which will need to be considered for both the architectural and structural design. Another important aspect of this floor is that it displays one of the main features of the building: its aquaponic system. Having four fish tanks, and considering their large structural load, analysis is required around its vicinity potentially requiring extra support.

The second floor has an assembly space, characterized by a large area with additional breakout walls. These are considered partition walls and not load bearing. Therefore, from a structural layout, the space will need to be seen as entirely open. Also, on the plan east side of the second floor is the first growing area, which has an area of 2,772 sf.

The third and fourth floors are similar in regards to their structural design. They offer more growing areas, as well as classrooms, and offices. These spaces are mainly characterized for not having large openings or heavy equipment. Meanwhile, specific architectural design usages were noticed for each floor: the third floor focuses on the community, with a demo kitchen and classrooms as previously stated, and the fourth floor houses Growing Power offices.

Lastly, the fifth floor consists of a 2,011 sf growing area, a reception area, lobby, and office spaces. The project will focus on assessing the appropriate loads, as well as the efficient performance of the building systems, including heating, cooling, water, and electric, among others. Also during this analysis, it was noticed that the building has height above grade of 79'8. Therefore, in accordance to the 2012 *IBC*® code the current design is considered a high-rise building as it has an "occupied floor located more than 75 feet (22.86 m) above the lowest level of fire department vehicle access (*International Building Code*®, 2012).

2.9.2 Structural Analysis

In addition to identifying the purpose of the spaces, the existing structural system and materials were analyzed. The plans presented to us by Growing Power Inc. and The Kubala Washatko Architects, Inc. show a mainly concrete structure. The designers utilized steel to frame the conveying system in the green houses and commercial glass for the roofs and exterior walls. Flooring was 12-inch pre-cast concrete plank with 2-inch topping. Their framing layout is traditional stacked columns extending up to the top floor from the basement. One unique feature is the structure for the fifth floor green house. There is a mid-span column along the sides of the greenhouse. This does not line up with the columns in the structure below so the designers used a large transfer beam to distribute the large load to two continuous columns extending down to the basement. This may have been a solution to roof loads on the glazing of the greenhouse. It may have proved important to have this column for roof loads, but not essential to extend down the structure multiple floors. To avoid this in the alternative design, bay areas will be designed with an integrated approach with greenhouses and code requirements.

2.9.3 Initial Thoughts for an Alternative Design

When deciding which system to use for the vertical farm it is important to consider the location of the structure. Due to the greenhouse spaces, humidity will be high in certain areas of the structure and sunlight will be taken advantage of along with the prevalence of water and moisture. Therefore, wood is not appealing for the super structure knowing that an alternative location will be in Florida. Termites limit the wood construction industry in Florida (Termite Protection, 2006). Location has narrowed down potential materials to concrete and/or steel.

The need of the project is the second criteria that will influence our design decision. We need to choose an inspiration that would guide us throughout the duration of project. This anchor aids in the success of many projects. Some areas of importance we explored were: build time, thermal needs, punch outs, and long spans or openings. Framing for greenhouses are generally aluminum because of the lightness and non-corrosive properties of the material. However, concrete and aluminum do not interact well together, as there is a tendency to form corrosion in the aluminum and cause cracks to the concrete. Connections between concrete and aluminum can be investigated but because of the small number of inconveniences this causes, alternatives are better. Structural glass is another element that we were interested in using, and to frame this, steel is the best option. Another benefit to steel is the design of moment frames which allow standardization and personalization of each room. When learning about Blu Homes Inc. and their company philosophy from Professional Engineer Paul Kassabian, the advantages of integration were highlighted. A concrete foundation structure of footings with pilings and a steel column and frame structure may be the best option because of the long spans that steel acts well for.

2.10 Research Compilation

A compilation of research that was performed but not incorporated into the design can be found in Appendix B. This includes structural fireproofing as well as hydropower.

3. Methodology

The following section shows the procedure and design processes of the various building systems to be put into the final design. Design approaches vary between the architectural, systems integration, structural and project management disciplines as different criteria were developed in order to select the most appropriated solutions. The design processes for each of the systems are explained in the section below. These methodological processes are detailed in the following order

- Architectural Layout,
- Fire Protection,
- Building Envelope,
- Greenhouse,
- Mechanical,
- Electrical,
- Plumbing,
- Structure
- Project Planning and Delivery Method
- Site Plan Layout
- Cost Analysis
- Project Schedule
- Building Information Modeling.

3.1 Architectural Design

A well-executed architectural design is paramount as it creates the usable spaces for the occupants and, if done correctly, lays out room adjacencies that provide an efficient flow for occupants on each individual floor.

3.1.1 Overall Building Architecture Review of Existing Design

The group started by reviewing the overall building architecture of the existing design by looking over the elevation drawings given. The original building includes five stories plus a basement, creating an overall building height of 79' 8" from grade. The first floor building footprint measures out to approximately 10027.6 ft^2 and the total building area is 53,000 ft^2. The primary components of the architectural design are the four growing areas located on the second, third, fourth and fifth floors. These growing areas create a side building profile of ascending steps.

3.1.2 Architectural Layout

The Growing Power Vertical Farm is meant to be a community center where people can purchase and learn how to grow sustainable foods. The building itself is meant to be inviting and easy for the general public to navigate. The original architectural layout is competent in its approach towards these goals, thus the layout did not need to be changed significantly to achieve a design *Impact* and Growing Power would be proud of. Upon a quick initial review of all the floor plans, the group noticed that spaces that only require limited public access are on the top floors and spaces that require the most public access are near the base. The uses of each floor can be seen in Figure 11. Ideally there shouldn't be much of a public presence near the growing areas, as their occupancy type is F-2 (factory industrial) with an occupancy load factor of 100. Additionally a large amount usable space will be taken up by growing systems. Additionally the growing areas are the building's primary source of income and should not be tampered with by the general public. Complementary spaces are placed adjacent to one another on the same floor, providing occupants with an easy to follow path from activity to activity, and decreasing chances of congestion or getting lost. This is demonstrated in the preliminary reviews of each floor.

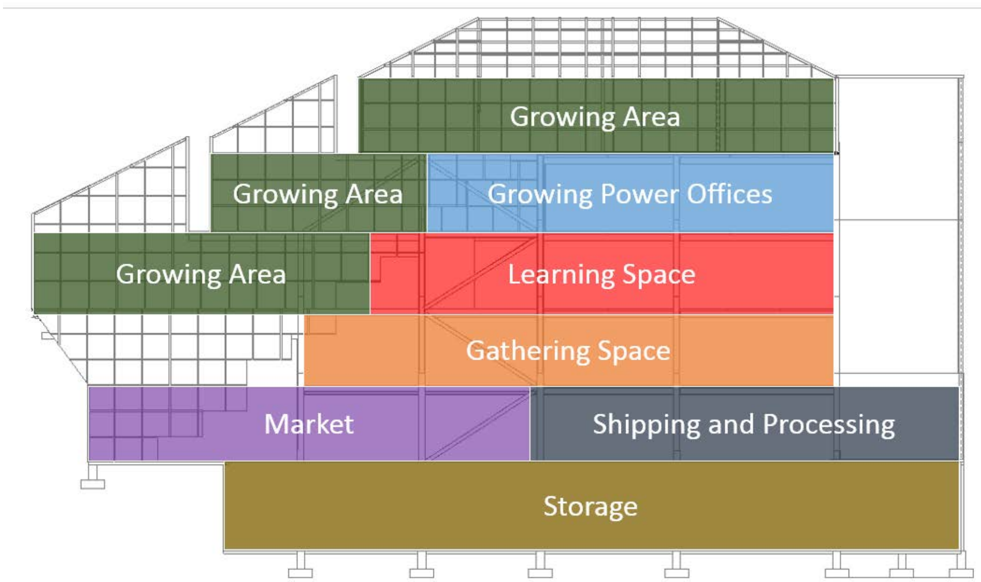


Figure 11 Building Uses by Floor.

Upon recognition that the majority of the spaces would be located in the same area as the original design, AutoCAD schematics of floor plans were created to fit within the dimension of the new design. Rooms were placed with areas on each floor and the team made many small alterations to the room placement and areas to make sure the following criteria was followed throughout the design process.

- The use of each space must be retained
- Each space must have the same area or more than the original design
- The architectural layout must be complimentary to the goals and vision of Growing Power Inc.

3.2 Systems Integration

A major component of the project was the integration of its systems, including fire protection, building envelope, and the mechanical, electrical and plumbing (MEP) systems. In addition, the integration also included the way in which these systems were incorporated between the growing areas and the remaining spaces in the building. To carry out the selection of each of these systems, the team followed three steps:

1. Developed criteria for choosing a system
2. Collected, evaluated and calculated data
3. Gathered solutions and analyzed the options

(1) In A-term, the team developed a set of criteria or goals for each system to achieve. (2) After the criteria were established, the data needed to fully understand the criteria for each system was collected, evaluated and/or calculated, depending on the information required. (3) With the information obtained and the research that had been made through the project, the team gathered and analyzed each of the possible options, until a final system selection was made.

3.2.1 Fire Protection

One of the first areas in which the team focused was fire protection. The team established the following criteria at the beginning of the project:

- Prioritize tenants' safety
- Operational integration with other systems
- Comply with Building Codes

In order to accomplish these criteria, the *International Building Code*® 2012 Edition and the Milwaukee Commercial Building Code 2011 Edition the provisions were applied throughout the design of the vertical farm. By utilizing these codes, a series of steps were followed to provide a compliant design. These steps or areas of focus were occupancy classification, type of construction, allowable height and area, and means of egress.

Occupancy Classification

During the design of the floor plan layouts, each of the spaces were identified based on their occupancy classification, as described in Chapter 3 of the *IBC*®. Throughout the building a total of five different occupancy types were determined: Storage (S-2), Mercantile (M), Business (B), Assembly (A-3), and Factory Industrial (F-2). Due to the mixed occupancy, the total area of each space was quantified and the building's main occupancy was determined. Defining the main occupancy served to later establish the allowable height and area of the building. The area percentages by occupancy can be seen in the Table 7, where factory industrial (F-2) is considered the main occupancy. Business (B) and Assembly (A-3) classifications will be considered as nonseparated occupancies, as they exceed the 10% of accessory occupancies. This requires the most restrictive provision of each occupancy to apply for the building height and area.

Table 7 Percentage of Spaces

Percentage of Spaces		
Occupancy Classification	Area (ft^2)	% of Total Area
Assembly (A-3)	6850.11	14%
Business (B)	11493	23%
Factory Industrial (F-2)	17991.5	37%
Mercantile (M)	4277	9%
Storage (S-2)	8604	17%
Total	49214.61	100%

Allowable Height & Area

Before determining the total height and area allowed by the *IBC*®, the type of construction of the facility was established. In order to make this selection, the structural materials and numbers of stories in the design were determined.

The team members collaborated among each other to come up with the selection of a steel structure. Therefore, Type I and II construction were evaluated. According to Chapter 6, Section 602.2 of the *IBC*®, both types require building elements composed of noncombustible materials, such as masonry, concrete and steel, building elements. Some of these elements include the primary structural frame, the bearing walls, the nonbearing walls and the floor and roof construction, a category in which steel was in. However, due to its lower fire-resistance rating requirement for these building elements, Type II was selected over Type I.

Even though *Impact* wanted to reduce the fire-resistance rating of the elements and reduce the costs of fire proofing the structure, the design was constrained by the five stories above grade. As seen in the Table 8, which was taken from Table 503 of the *IBC*®, the allowable height for an F-2 building is five stories for Type IIA (1 hour fire resistance) and 3 stories for Type IIB (0 hour fire resistance). A decision for Type IIA construction was made, where a total height of 65 feet and a maximum allowable area per story of 37,500 ft^2, satisfied the building requirements. Also, the 1-hour fire-resistance-rated construction of Type IIA can be substituted with the addition of an approved automatic sprinkler system.

Table 8 IBC Requirements

IBC Requirements		
IBC Requirement	TYPE IIA	TYPE IIB
Fire Resistance Rating (hours)	1	0
Number of Stories	5	3
Number of Stories with Sprinklers	6	4
Area (sqft)	37,500	23,000
Area with Sprinklers (sqft)	112,500	69,000

On the other hand, *Impact* wanted to avoid the building's classification as a high-rise, which would have incurred additional considerations and costs to its construction. These additional features would have included: a higher category seismic requirements in regards to lateral members and foundation, a full smoke control and fire alarm system, a standby power system for the fire detection devices and the elevator, and an impact resistant level 2 materials for enclosures of the exit stairways and elevator hoistway, among others. As defined by the *International Building Code*®, a High-Rise is "a building with an occupied floor located more than 75 feet above the lowest level of fire department vehicle access". In the case of our design, this 75 feet limit represents the height between the first floor and the floor of the fifth floor. As it can be observed in Figure 12, the design selected uses a height of 13 feet from floor-to-floor to the exception of the basement. This provided a 10 feet floor-to-ceiling height and 3 feet of plenum space for the structural and MEP systems. In the case of the basement, the ceiling height was designed for 15 feet, since the coolers and freezers will have condenser units above their panels that will require additional space in the ceiling.

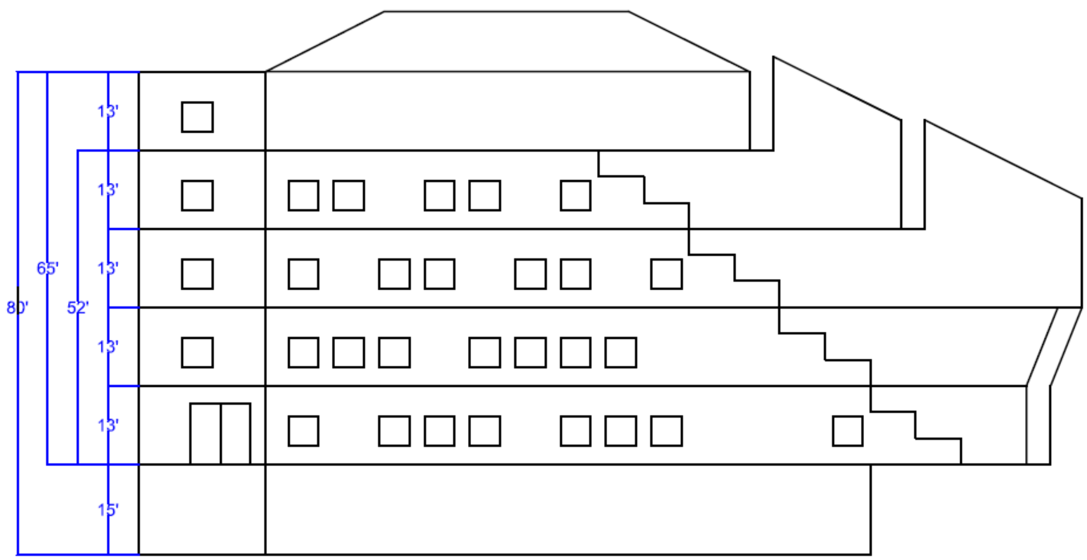


Figure 12 West Elevation Building Height.

Means of Egress

The third step that the team took in regards to the fire protection system was calculating the egress capacity needed in each floor. First, the total occupant load per floor was calculated, based on the occupancy classifications previously identified. By using the function and occupant load factor of Chapter 10 Table 1004.1.2 of the *IBC*®, the occupant load for each of the different occupancy groups each floor was determined. For floors with multiple occupancy types, the occupant loads were added to obtain the total occupant load per floor. This can be seen in Table 9.

Table 9 Occupancy Load Calculations

Occupancy Load Calculation					
Occupancy Classification	Occupant Load Factor (*IBC* Table 1004.1.2)	Gross or Net	Area (ft^2)	Occupant Load	Total Occupant Load per Floor
Basement					
S-2	300	gross	8604	29	29
First Floor					
M	30	gross	4277	143	197
F-2	100	gross	5452	55	
Second Floor					
A-3	7	net	5466.81	781	781
Third Floor					
B	100	gross	6438	64	99
F-2	100	gross	3500	35	
Fourth Floor					
B	100	gross	5055	51	79
F-2	100	gross	2883	29	
Fifth Floor					
F-2	100	gross	6156.5	62	62

After the total occupant loads per floor were calculated, the means of egress for each floor were determined. Based on the means of egress capacity factors given in Chapter 10 Section 1005 of the *IBC*®, Table 10 was developed to determine the minimum size of each component. A capacity factor of 0.3 inches per occupant was used for the stairs, while a capacity of 0.2 inches per occupant was used to determine the corridor and doorways sizes.

Table 10 Means of Egress Required

Means of Egress Required			
	Occupant Load	Stairs (ft)	Corridor and Doorways (ft)
Basement	29	0.7	0.5
First Floor	197	4.9	3.3
Second Floor	781	19.5	13.0
Third Floor	99	2.5	1.7
Fourth Floor	79	2.0	1.3
Fifth Floor	62	1.6	1.0
Total	1247	19.5	13.0

Lastly, the egress capacities obtained for the stairs and the corridor and doorways were verified with the dimensions determined during the floor plan layout. In case that the dimensions of the design were smaller than those required, and the means of egress was revised and increased to comply with the code.

3.2.2 Building Envelope

Building envelopes are an integral part to the building's design as they interact with almost all of the building's systems. There are many factors envelopes must address including energy efficiency, indoor air quality, thermal comfort and overall performance of the enclosure to control air leakage, vapor diffusion and heat transfer. These envelopes accomplish this by being equipped with layers that control the transmittance of air, water, vapor, and thermal between the interior and exterior of the building. Additionally when designing the envelope one must consider cost effectiveness and functionality within the climatic zone in which the building is located.

Upon initial review of the existing design the group found no explicit information concerning the building envelope. The building is located in Milwaukee, Wisconsin in the 6A climate zone (cold-humid) and requires a minimum wall R-value of 15.62 per the International Energy Conservation Code, Chapter 4: Commercial Energy Efficiency, Section C402 Building Envelope Requirements. The building appeared to be skin-load dominant because most of the occupied rooms had exterior walls that could cause significant heat transmittance through exterior surfaces. Thus the heating and cooling loads are largely determined by the building envelope instead the internal heat gain of the people and equipment.

After this review the group came up with the following system criteria for the building envelope:

- Integrate with the architectural layout and glazing to provide the most aesthetically pleasing and functional design
- Reduce heating and cooling loads for the mechanical system
- Construct and maintain easily for possible modular applications
- Adapt to other locations within the United States

Based on the exterior architectural design and the adaptability to other sites, the team decided early on to use precast panels. Precast panels make the construction process easier and can be delivered to any site or location premade. After this selection was made, the team proceeded to determine the size of the panels that would fit within the design, be easy to transport, and erect on site. The group experimented with various panel sizes using the Auto CAD elevations created during the conceptual design phase. Panel sizes were configured in ways that made the most sense for the ascending stepped design.

In addition to sizing the panels, the team also placed the windows. The team wanted to blend the windows appearance with the façade, and minimize the amount of windows due to the already high amount of glazing present in the growing areas to lessen unnecessary solar heat gain. As found in *International Building Code*, it is required that the total area of windows in a room must represent at least 8% of the room's floor area in square feet. Therefore, after trying various designs of windows that worked with the existing paneling system, the team was able to comply with the minimum requirement in all the spaces needed by using 25 ft^2 windows. The bottom sill of these windows is located 3 feet above the floor, as can be seen in the Figure 13.

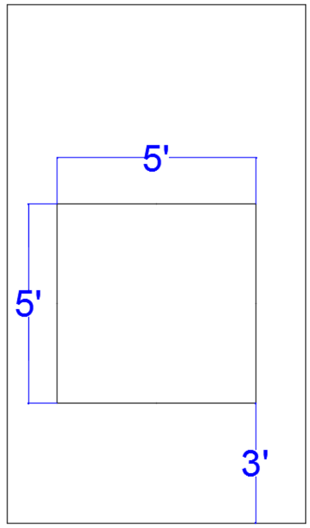


Figure 13 Window Size.

After sizing the panels the group looked into the thermal properties of the different panel layers. These layers were analyzed and catalogued to make sure the panel design was feasible for the building type and the climatic zone. The proposed panel layers, wall areas and glazing areas were put into a COMCheck code compliance report, which can be seen in Appendix C. Upon the initial compliance check it was found that the proposed panel would not reach the minimum requirements of a building located in Milwaukee so an additional layer insulation was added. The panel's overall weight was catalogued to comply with the structural system in place.

Growing Area Glazing

In order to select the glazing system covering the growing area, *Impact* researched and evaluated various glazing products in the market and commonly used in greenhouse spaces. The properties of these alternatives were compared to those provided by clear glass. When searching the different systems, the team focused on three factors and considered solutions for both the Milwaukee and the Miami location:

- Thermal Performance – due to the 25,000 ft^2 of glazing needed provided by the architectural, it was crucial for the high performance of the building that this part of the façade has a low U-value.
- Visible Light – since the main purpose of the growing area was to maximize plants growth, it was very important that the glazing system allowed the appropriate light to enter into the space. During photosynthesis, plants use the waves that follow under the visible light spectrum range, making this visible light transmittance one of parameters for the team to look into.

- Solar Heat Gain Coefficient (SHGC) - the team also considered the percentage of solar radiation admitted through the glazing system. The lower the light transmitted, the less the heat gain in the room was. Therefore, the team searched for a lower SHGC coefficient that would reduce the cooling load during the summer and avoid the overheating of the space.

3.2.3 Greenhouse Systems

The team investigated the hydroponic and aquaponics systems used in different projects throughout the world in order to determine the type of system that would be included in our proposed design. The team focused its efforts in finding hydroponics systems that would be suitable for the space conditions and limitations present in the greenhouse areas.

Existing greenhouse system

Impact investigated the hydroponic and aquaponics systems used in different projects throughout the world in order to determine the type of system that would be included in our proposed design. The team focused its efforts in finding hydroponics systems that would be suitable for the space conditions and limitations present in the greenhouse areas.

Existing greenhouse system

The existing design has an Overhead Plant Tray Conveying System, which includes a conveyor system that rotates the trays (also referred to as baskets) where the plants are grown. A company called VertiCrop developed this type of system. Figure 14 shows a side view of the VertiCrop system. The company states that this system can "provide up to 20 times the yield of normal field crops, while using 8% of the water typically required for soil farming" (Growing with VertiCrop, 2011)

Figure 14 VertiCrop conveyor system.

(Growing with VertiCrop, 2011) (Vertical Farming on Rise for Urban Food Supply, 2010)

Omega Garden - Volkgarden Rotatory Garden

Impact also investigated the system used at the Green Spirit Farms located in New Buffalo, Michigan. The system used is called Volkgarden Rotatory Garden and was developed by Omega Garden. The system has a cylindrical shape, where plants are placed in the interior face of the shaft and rotate around an artificial lighting fixture that is placed in the center of the shaft. This system delivers water to the plants by placing a water-feeding fixture through which the growing media passes, allowing this media to absorb the amount of water needed (Grow with Omega, 2014). Figure 15 shows a schematic drawing and a picture of the system.

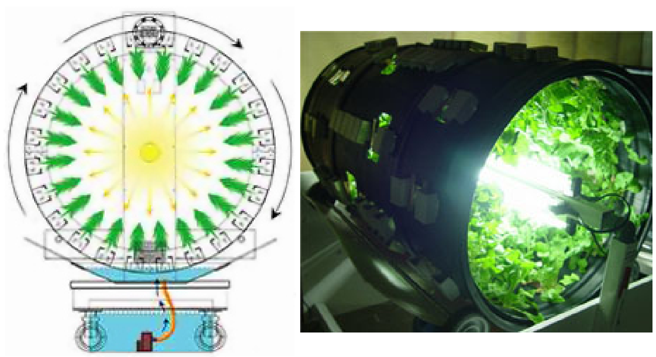


Figure 15 Volksgarder Rotary garden (Volksgarden garden 2014).

Sky Greens – A-Go-Gro system

The Sky Greens vertical farm implemented the use of 120 vertical farming systems, called "A-Go-Gro" technology in Singapore. The A-Go-Gro vertical system was designed by Jack Ng. This system rotates 22 to 26 racks around an "A" shaped structure. The system incorporates a Water Pulley Module that uses flowing water and gravity to rotate the racks. The Sky Greens farm is the first low carbon hydraulic driven vertical farm. (A-Go-Gro Vertical Farming, 2011) "According to Ng the energy needed to power one A-frame is the equivalent of illuminating just one 60-watt light bulb" (Urban farming looking up in Singapore, 2012). The Sky Greens farm states that this system is able to produce 5 to 10 time more per unit floor area compared to other traditional farms. Also the company mentions that the modular A-frame rotatory system is easy to install and maintain (Benefits – Economic, 2011). Figure 16 provides a side view of two A-Go-Gro towers in the Sky Greens farm in Singapore.

Figure 16 A-Go-Gro towers (A distinctive Global City, 2010).

ZipGrow Towers

Finally, *Impact* evaluated a simpler system that would be usable in the growing areas that have a 10 ft. ceiling height, which was defined in the architectural design. The ZipGrow towers are composed of a PVC square shape hollow frame that acts as a housing for a matrix growing media made of recycled polyethylene terephthalate (PET). This growing media holds the seedlings in place within the vertical system when encased in the frame, allowing the towers to be hung and irrigated from the top. This system is suitable for hydroponic and aquaponic systems (Planting a ZipGrow Tower). Figure 17 shows an example of a farming set up with ZipGrow towers. The system is capable of growing 2 to 3 times as much as traditional horizontal production. (ZipGrown Production Estimates)

Figure 17 Commercial greenhouse with ZipGrow vertical growing system (DuQuette).

3.2.4 Mechanical System Design

Mechanical systems within buildings are responsible for creating a comfortable indoor environment that can be easily controlled by its occupants. A good mechanical system will promote strong air quality, and be integrated with the building's envelope to promote energy efficiency.

Upon initial review of the floor plans given, the group noticed there was a range of uses and occupancy loads for the different rooms in the building. It was apparent that the system chosen must be flexible, as the mechanical solution for the market space might not be the same solution employed for the growing areas. This made it necessary to utilize a system that separates the building into different zones with different heating and cooling capacities.

The system selection criteria for the mechanical system can be seen below

- Provide system with low power usage
- Integrate with natural climate conditions
- Consider adaptation to other areas and climates
- Offer innovative ways of heating and cooling
- Accommodates occupant load
- Create different building zones that satisfy the heating and cooling load capacities of the specific rooms

In order to find the heating and cooling loads for the non-growing areas of the building a spreadsheet was created to calculate the individual loads of each room being conditioned. The spreadsheets included average indoor and outdoor design temperatures for Milwaukee during the summer and winter, solar heat gain factors (SHGF) through glass, cooling load factors (CLF) of the exterior glass based on the glass's orientation, and internal heat gain values for people, lights and equipment.

Calculating Heating Loads

The heating load is the amount of heat lost to the surrounding environment and thus the amount of heat needed from the mechanical system to retain a comfortable environment. This process begins with calculating the rate of heat transfer through all exterior surfaces including walls, windows, and the floor slab on grade.

Rate of Heat Transfer

Q=U x A x TD

- Q= heat transfer rate, BTU/hr.
- R= thermal resistance of material hr-ft^2-F/BTU
- A= surface area through which heat flows, ft^2
- TD= temperature difference across which heat flows, from higher to lower temperature

Heat Transfer Loss: Floor Slab on Grade

Q=E x L x TD

- Q= Heat transfer loss through floor slab on grade, BTU/hr.
- E= edge heat loss coefficient, BTU/hr.-F per ft. of edge length
- L= total length of exposed edges of floor slab, ft.
- TD= Design temperature difference between inside and outside

Calculating Cooling Loads

The cooling load is the amount of cooling necessary to counteract external and internal heat gains to create a comfortable indoor environment. To find cooling load one must find the conduction and solar radiation rate through walls and glass and the internal heat gains from artificial lights, and people.

Conduction Heat Gain through Exterior Structure

Q=U x A x CLTD

- Q= cooling load for roof, wall, or glass, BTU/hr.
- U= overall heat transfer coefficient for roof, wall or glass, BTU/hr-ft^2-F
- A= area of roof, wall, or glass, ft^2
- CLTD= cooling load temperature difference, F

Solar Radiation through Glass

Q=SHGF x A x SC x CLF

- Q= solar radiation cooling load for glass, BTU/hr.
- SHGF= maximum solar heat gain factor, BTU/hr-ft^2
- A= area of glass, ft^2
- SC= shading coefficient
- CLF= cooling load factor for glass

All of these equations are based on formulas within the 1997 *American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Handbook-Fundamentals*.

Calculating Internal Heat Gains

Lighting

Interior heat gain from lighting was calculated through finding the total interior lighting power allowance (watts) using the space by space method, which has different factors based on the room type. The formula, from the International Energy Conservation Code (IECC) section C405.5.2 Interior Lighting Power, using values from table C405.5.2 (2) can be seen below.

$Q = LPD \times A$

- Q=heat gain from lighting fixtures, BTU/hr.
- LPD= lighting power density, W/ft^2
- A= area of room, ft^2

People

Interior heat gain from people in each was calculated by finding the expected occupancy of the room and multiplying this value by the sensible heat rate of a person doing moderately active office work.

$Q_s = q_s \times n$

- Q_s= sensible heat gain
- q_s= sensible heat gain per person
- n= number of people (expected occupancy)

The final spreadsheets for the heating and cooling loads can be seen in Appendix D and Appendix E respectively. These spreadsheets separate the building by floor, room, and wall orientation. A small portion of the spreadsheet can be seen in Figure 18, which demonstrates how each room was separated by its exterior wall orientation, which would change the CLTD and GLF. Figure 18 also shows the total load of the room in CFM, which was then transferred to tons to be more easily applicable to the mechanical system chosen.

Room	Wall Lngth	Gross Wall A	Glass Area	Net Wall A	Room Area	Wall U	Glass U	Wall CLTD	Glass CLF	Glass c BTUH	Wall c BTUH	Expected occupancy	Occupancy BTUH	Lights BTUH	Appliances BTUH	Total Load	CFM	CFM Total	tons	tons total
First Floor																				
Workshop N	13.0	169.0	0.0	169.0	810.1	0.06	0.36	8	0	0.0	81.1	8	2000	1134.1	221.8	3437.0	208.3		0.52	
Workshop E	34.0	442.0	100.0	342.0		0.06	0.36	18	78	7800.0	369.4					8169.4	495.1	703.4	1.24	1.76

Figure 18 Cooling Load Spreadsheet Example.

System Selection

With the previous criteria and these calculations complete the group began reviewing and comparing different systems including water source heat pumps (WSHP) and ground source heat pumps (GSHP) because of the reasons stated below.

Advantages of WSHP and GSHP

- Create building zones with individual temperature controls (thermostat)
- Require minimum plenum space allowing the system to fit within the structural framing quite easily
- Self-sufficiently recycles and redistributes waste heat back into the system
- Flexible by having units in different zones capable of heating or cooling or completely shut off simultaneously
- Not all pumps need to be operating at the same time, which saves pumping energy
- Low operating cost

The main difference between the two systems comes from how heat is generated and released. In ground source heat pumps the heat is drawn from and rejected to the earth through the use of 100 ft. deep wells in the ground. Water source heat pumps use a boiler to attain additional heat and a cooling tower as a heat sink. A final decision was made to choose a WSHP system because GSHP systems have a very high initial cost due to the massive wells. Additionally the site included many existing buildings that must remain unharmed, and it did not seem feasible to dig extensive holes when there could just be a boiler and cooling tower installed instead.

3.2.5 Electrical System

Impact also worked on the integration of the electrical system within the design. Therefore, before gathering any data or calculating any consumption, the team established the following criteria for this system:

- Reduce power usage
- Provide alternative sources of energy
- Integrate with daylighting features
- Stimulate plant growth
- Comply with the appropriate demands of each space
- Offer automated features and motion sensors in areas that are not always occupied

After the goals were established, the team estimated the building's power consumption by developing a riser diagram and various spreadsheets. *Impact* also focused on the lighting design of the facility, and comparing its baseline to the proposed design.

Riser Diagram

The first step taken was to develop a riser diagram of the electrical systems. Through this diagram, the main electrical consumption equipment in each floor were identified. Also the equipment was categorized by different zones, depending on the voltage required and its location. For the location, two options were used: the growing areas and the other building spaces. In the Figure 19 below, the riser diagram can be seen.

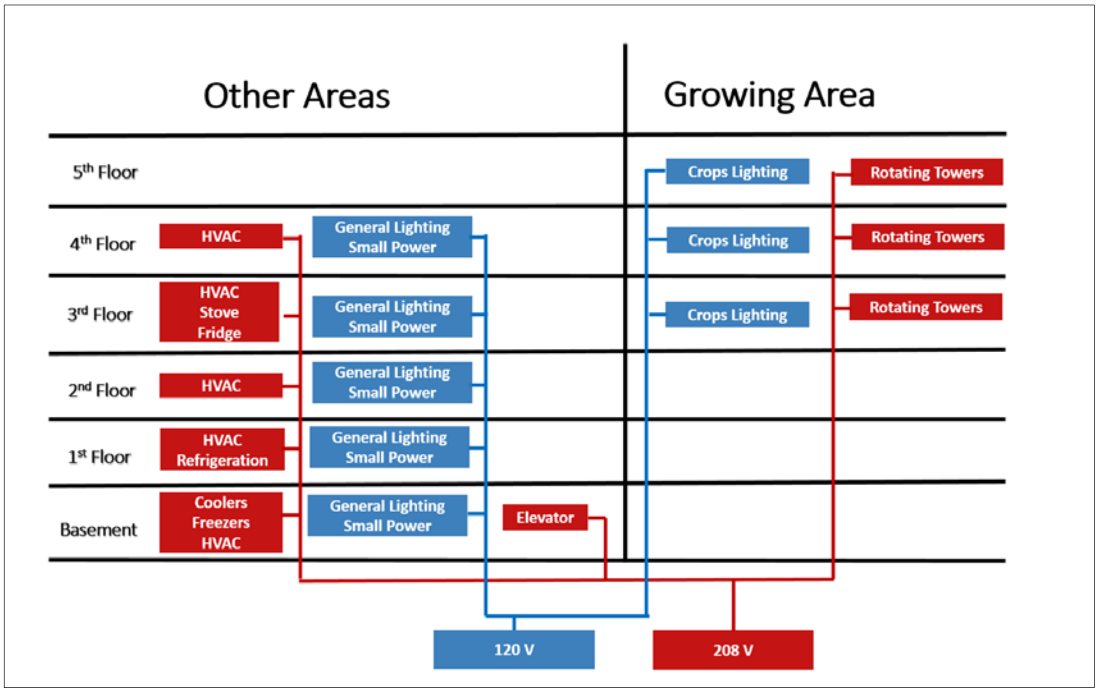


Figure 19 Electrical Riser Diagram.

Electrical Consumption Spreadsheet

Secondly, a spreadsheet was compiled for the electrical system with the main goal of projecting the electrical consumption of the building. Through these calculations, three main aspects were estimated. The first was peak consumption, which consisted of the maximum possible

	Power Consumption (KW)	Number of Units	Total Power Consumption (KW)	Average hourly usage (KWh)	Number of Hours	Total Daily Load (KWh)	Days of the Week Used	Annual Usage	Total Annual Load (KWh)
Basement			149.16			1145.07			348919.83
General Lighting	2.17	-	2.17	2.17	-	9.11	-	-	2367.92
Cooler 1	4.09	1.00	4.09	4.09	16	65.40	7	364	23804.96
Cooler 2	9.77	1.00	9.77	9.77	16	156.39	7	364	56926.61
Cooler 3	11.65	1.00	11.65	11.65	16	186.46	7	364	67870.95
Cooler 4	4.64	1.00	4.64	4.64	16	74.18	7	364	27002.18
Freezer	11.20	1.00	11.20	11.20	18	201.66	7	364	73403.54
Elevator	0.50	1.00	0.50	6.00	8	48.00	7	364	17472.00
Hands Dryer	0.50	2.00	1.00	0.17	8	1.33	5	260	346.67
HVAC Heating	-	-	0.80	0.80	3	2.30	-	-	600.00
Boiler	-	-	105.50	105.50	4	409.34	-	-	79125.00

Figure 20 Electrical Spreadsheet Example.

consumption at a certain period of time. The second was daily consumption. This value was based on the average number of hours each equipment was used per day. Lastly, the total annual consumption was calculated. Similar to the daily consumption, this projection based on average number of days in use per year multiplied by the daily load. An example of this spreadsheet can be seen in seen in Figure 20, where the basement floor is calculated. To reference the full spreadsheet, see Appendix F.

Due to the variety of equipment, there were several tools used to obtain the power consumption of each. Below are the different methods used:

- For most of the office and kitchen appliances, the power consumption values were obtained from Chapter 18 *ASHRAE Fundamentals 2013*, Tables 6 to 9. This value was given in Watts (W).
- For the freezers and coolers equipment, U.S. Coolers & Freezers "Walk-In Refrigeration Sizing Estimate" tool was utilized. This tool provided the team with the BTUH consumption of each cooler and freezer based on its dimensions and temperature required. This value was later converted into kilowatt hours (kWh).
- For the Heating, Ventilating and Air Conditioning (HVAC) system and the lighting power consumption, the values from the manufacturer's specifications were used. The information about the specific units and fixtures used in the building were provided through the design of the mechanical and lighting systems.
- For any remaining equipment, a specific product was selected and its manufacturer's specification data was utilized in the spreadsheet. These equipment were the elevator, hands dryer, electric saw, market refrigeration, projector, blender, and refrigerator.

Lighting Baseline

In addition to projecting the building's energy consumption, *Impact* focused on designing the lighting system of all of its spaces, including the offices, processing areas, classrooms, and growing areas, among all others. Before immersing into the design of each space and its fixtures, the maximum energy consumption was established with the use of *ASHRAE Fundamentals 2013*. Through Table 2 of *ASHRAE Fundamentals 2013* Chapter 18 the power density (W/ft^2) of each of the spaces in the design was determined and recorded in a Microsoft Excel document. Similar to the building's electrical consumption spreadsheet, it focused on three main aspects: the peak consumption (Power Consumption), the daily consumption (Total Daily Load) and the annual consumption (Total Annual Load). An example of this spreadsheet can be seen in seen in Figure 21, and its complete table can be referenced in Appendix G.

	Area	Lighting Power Densities (W/m^2)	Lighting Power Densities (W/ft^2)	Power Consumption (KW)	Average hourly usage(KWh)	Hours Used Daily	Total Daily Load (KWh)	Days of the Week Used	Annual Usage	Total Annual Load (KWh)
Basement				5.06			21.09			5484
Cooler 1	101.98	6.8	0.63	0.06	0.06	3	0.19	5	260	50
Cooler 2	321.58	6.8	0.63	0.20	0.20	3	0.61	5	260	158
Cooler 3	400.1	6.8	0.63	0.25	0.25	3	0.76	5	260	197
Cooler 4	124.14	6.8	0.63	0.08	0.08	3	0.24	5	260	61
Freezer	235.15	6.8	0.63	0.15	0.15	3	0.45	5	260	116
Storage I	1336.61	6.8	0.63	0.84	0.84	4	3.38	5	260	878
Storage II	1247.56	6.8	0.63	0.79	0.79	4	3.15	5	260	819
Storage III	1754.68	6.8	0.63	1.11	1.11	4	4.43	5	260	1152
Women's Locker Room	324.47	8.1	0.75	0.24	0.24	3	0.73	5	260	190
Men's Locker Room	325.23	8.1	0.75	0.24	0.24	3	0.73	5	260	191
Recycling Room	119.79	1.2	0.11	0.01	0.01	1	0.01	5	260	3
Elevator Lobby	164.93	6.88	0.64	0.11	0.11	6	0.63	5	260	164
Stairs I	180	7.4	0.69	0.12	0.12	6	0.74	5	260	193
Stairs II	191	7.4	0.69	0.13	0.13	6	0.79	5	260	205
Corridors	1075.03	7.1	0.66	0.71	0.71	6	4.25	5	260	1106

Figure 21 Electrical Consumption Spreadsheet.

Lighting Design

The first step in the design of the lighting system was to determine the lighting levels required for each room. Therefore, the minimum lighting levels recommended by the Illumination Engineering Society were recorded. Then with the use of *AGI32*, each floor, with its different rooms and separations was modeled. *AGI32* is a simulation software used to calculate the amount of light that will be delivered in a determined area. Later, the light fixtures were selected, including recessed, pendant, surface mounted and wall mounted. In order to allow for different levels of lights, each of the fixtures selected had multiple lumen output options to allow a more flexible design.

After the rooms were modeled, the fixtures selected, and its IES files downloaded, the team proceeded to place the fixtures in the *AGI32* model. Room by room, the team verified that the fixtures being placed complied with the lighting levels required that had previously being recorded. Also, with the help of the software, the lighting densities were calculated to verify the proposed design was under the values required by *ASHRAE Fundamentals* for each space. The *AGI32* calculations for part of the basement floor can be seen in Figure 22. Additionally, Appendix H contains all of the *AGI32* floor plan calculations.

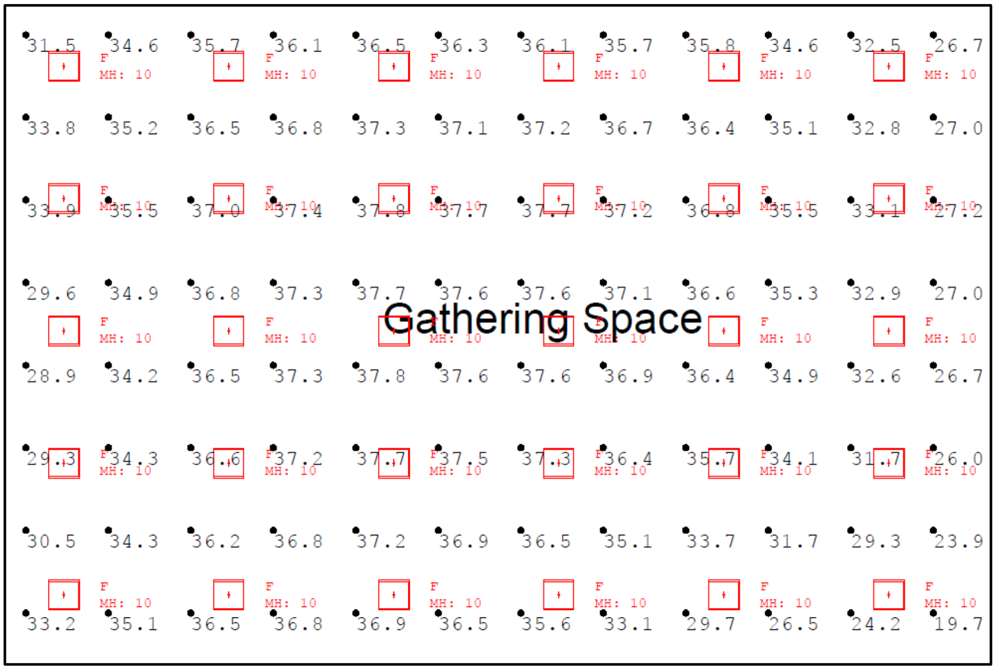


Figure 22 Basement Lighting Calculations.

Once the lighting design of each room had been completed, the fixtures used in each were quantified and their wattage consumption calculated. This served to determine the energy consumption of the design, in a similar to the previous lighting and the electrical spreadsheets. Therefore, once again, the peak, daily and annual consumption of the design was calculated, as can be observed in Figure 23. Also, in Appendix I the complete table can be found.

	Area	Lighting Level	Average Illuminance	Number of Fixtures	Fixture Specified	Power Consumption per Fixture (W)	Room Power Consumption (W)	Lighting Density (W/ft^2)	Average hourly usage(KWh)	Hours Used per Day	Total Daily Load (KWh)	Days per Week Used	Annual Usage	Total Annual Load (KWh)
Basement				**79**			**2168**		**2.17**		**9.11**			**2367.92**
Cooler 1	101.98	10	11.13	2	G	29	58	0.57	0.06	3	0.17	5	260	45.24
Cooler 2	321.58	10	13.3	4	G	29	116	0.36	0.12	3	0.35	5	260	90.48
Cooler 3	400.1	10	13.26	4	G	29	116	0.29	0.12	3	0.35	5	260	90.48
Cooler 4	124.14	10	11.38	2	G	29	58	0.47	0.06	3	0.17	5	260	45.24
Freezer	235.15	10	10.01	2	F	38	76	0.32	0.08	3	0.23	5	260	59.28
Storage 1	1336.6	10	11.97	9	G	29	261	0.20	0.26	4	1.04	5	260	271.44
Storage 2	1247.6	10	12.14	9	G	29	261	0.21	0.26	4	1.04	5	260	271.44
Storage 3	1754.7	10	12.18	13	G	29	377	0.21	0.38	4	1.51	5	260	392.08
Women's Bathroom	324.47	15	19.42	3 3	G H	29 7	108	0.33	0.11	3	0.32	5	260	84.24
Men's Bathroom	325.23	15	14.34	2 2	G H	29 7	72	0.22	0.07	3	0.22	5	260	56.16
Recycling Room	119.79	10	11.33	2	G	29	58	0.48	0.06	1	0.06	5	260	15.08
Elevator Lobby	164.93	10	12.88	1	B	56.9	56.9	0.34	0.06	6	0.34	5	260	88.76
Stairs I	180	15	17.99	4	H	7	28	0.16	0.03	6	0.17	5	260	43.68
Stairs II	191	15	18.68	4	H	7	28	0.15	0.03	6	0.17	5	260	43.68
Corridors	1075	15	16.39	13	F	38	494	0.46	0.49	6	2.96	5	260	770.64

Figure 23 Peak Daily and Annual Consumption Spreadsheet.

3.2.6 Plumbing

Another of the elements of the systems integration category was plumbing. At the beginning, *Impact* established the following criteria to be achieved through the design.

- Provide efficient usage of water
- Reuse water as much as possible
- Integrate as many different components as possible

Similar to the electrical system, once the criteria was established, the team developed a riser diagram of the water distribution in the facility and estimated the building's consumption through the use of spreadsheets. The team also evaluated the incorporation of a rain harvesting system to the building.

Riser Diagram

One of the first steps taken was to develop the riser diagram of the plumbing system. Through this graphic, the team identified the areas of water consumption and its distribution within the building. In order to carry this last step, the team identified three water sources:

- City Water – water from the city's sewage entering the building.
- Grey Water /Rain Harvesting – wastewater or harvested water that could be recycled and used in other applications on site.
- Blackwater – wastewater containing fecal matter, urine, and any other organic component.

Once the sources were identified, the team determined for each incoming element the source entering the equipment and the source leaving it. These were later graphed in the riser diagram, which can be seen in Figure 24.

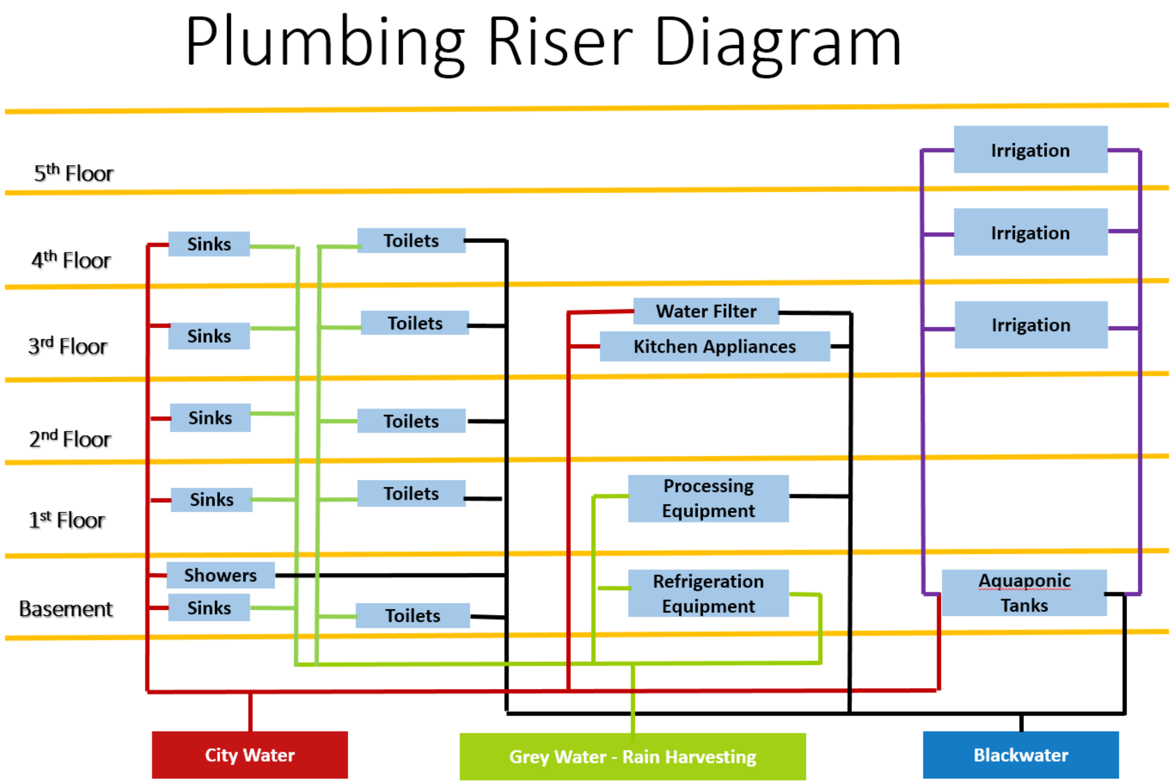


Figure 24 Plumbing Riser Diagram.

Water Consumption Spreadsheet

Impact also estimated the building's water consumption by the use of a Microsoft Excel spreadsheet. First, each of the plumbing fixtures and any additional equipment requiring water per floor were identified. Then, the gallons consumed and the projected average number of uses were calculated to obtain a monthly and annual consumption of water, seen in Figure 25 and Appendix J.

Water Loads Estimation									
	Type In	Type Out	Number of Fixtures	Gallons per ..	Time of Use (Mins)	Average Number of Uses Per Day	Total Daily Load (Gallons)	Days of the Month Used	Monthly Usage (Gallons)
Basement (32 Occupants)									
Showers	City	Grey	2	2 (Minute)	5	4	41.00	22	902
Bathroom Faucets (low flow aerators)	City	Grey	2	1.5 (Minute)	0.5	16	12	22	264
Toilets (HET)	City	Black	2	1.28 (flush)	-	16	19.2	22	422.4
Fire System	City	NA	-	-	-	-	-	-	-

Figure 25 Water Consumption Spreadsheet Example.

In order to obtain estimates for each of the fixtures and equipment water consumption and use, the team relied on three different types of calculations based on the element analyzed. These three areas were the following:

- Plumbing Fixtures – these fixtures included showers, faucets, toilets, urinals, and the dishwater. For each of them, the gallon consumption was based on the Maximum consumption allowed by the Environmental Protection Agency WaterSense® Label. Then, the "Total Daily Uses Calculation" found in Table 1 of the USGBC Water Use Reduction Additional Guidance was used to estimate the times or minutes of use each fixture had. The water consumption of every fixture was given differently: toilets & urinals (gallons per flush), faucets and showers (gallons per minute), and dishwasher (gallons per load). Therefore, when using the values found in Table 1 of the "Total Daily Uses Calculation" the USGBC Water Use Reduction Additional Guidance, each of these parameters were taken into account.
- Fire Protection – the team used the "Fire Flow Water Consumption In Sprinklered and Unsprinklered Buildings" report by The Fire Protection Research Foundation to obtain the annual usage of a typical office building's sprinkler system. Through this research, the team found that every year the consumption of the sprinkler system would consist in its Backflow test, carried once a year, and its Inspectors Test, carried four times a year. The numbers used for our calculations were based on a 23,000 ft^2 building, which was the closest found to the vertical farm building being designed. The numbers can be seen in Table 11

Table 11 Fire Protection Water Consumption

Fire Protection Water Consumption			
Water Usage	**Water Consumption (Gal.)**	**Uses per Year**	**Water Consumption per Year (Gal.)**
Backflow Test	755	1	755
Inspector Test	35	4	140
		Total per Year	895

- Irrigation - to calculate the irrigation, the team used a water usage of plants factor provided by Professor John W. Bartok Jr., an Agricultural Engineer and Emeritus Professor of the University of Connecticut. This water usage factor takes into account multiple variables that affect the plants' consumption including temperature, humidity level, air movement, light level, sunlight crop canopy and hydroponic system used, that Professor Bartrok has developed through his research in Greenhouse Management. Therefore, as recommended, a rate of 0.2 gallons/ft^2 per summer day, 0.02 gallons/ft^2 per summer day, and 0.11 gallons/ft^2 per fall or spring day were used. These factors were multiplied by the growing area of the greenhouse systems designed in order to calculate the monthly consumption during each of the seasons.

3.3 Structural Analysis and Design

To more clearly explain the structural design process, Table 12 identifies a number of architectural features that required independent structural solutions. In the Results section of this document are the solutions engineered for these key features.

Table 12 Structural Design Process

#	Architectural Features	Structural Solution	Notes
1	Open Market Atrium		
2	Stair/Elevator Shaftway		
3	Heavy Water Tank Loads on Level G		
	Assembly Area		
4	Prominent Encased Columns		
5	Greenhouses		
6	Rain Collection Troughs		
7	Exterior Fascade Panels		
8	Ceiling Height: 10' Floor to Floor Height: 13'		

Risk Category was an initial step in the research of code compliance for the facility. Risk Category 2 was selected from Figure 26, which in turn directly impacted the wind, snow, and earthquake loads.

Table 1.5-1 Risk Category of Buildings and Other Structures for Flood, Wind, Snow, Earthquake, and Ice Loads

Use or Occupancy of Buildings and Structures	Risk Category
Buildings and other structures that represent a low risk to human life in the event of failure	I
All buildings and other structures except those listed in Risk Categories I, III, and IV	II
Buildings and other structures, the failure of which could pose a substantial risk to human life.	III
Buildings and other structures, not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure.	
Buildings and other structures not included in Risk Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where their quantity exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.	
Buildings and other structures designated as essential facilities.	IV
Buildings and other structures, the failure of which could pose a substantial hazard to the community.	
Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity exceeds a threshold quantity established by the authority having jurisdiction to be dangerous to the public if released and is sufficient to pose a threat to the public if released.[a]	
Buildings and other structures required to maintain the functionality of other Risk Category IV structures.	

[a]Buildings and other structures containing toxic, highly toxic, or explosive substances shall be eligible for classification to a lower Risk Category if it can be demonstrated to the satisfaction of the authority having jurisdiction by a hazard assessment as described in Section 1.5.2 that a release of the substances is commensurate with the risk associated with that Risk Category.

Figure 26 Risk Category of Buildings and Structures (ASCE 7-05).

When analyzing steel members, the majority were calculated based upon a simply supported loading condition where shear and moment diagrams were drawn to assess major stresses. Appendix K is a sample calculation of a girder with three point loads from adjacent beams. Criteria that limited the sections of beams were the strength, or moment capacity, and serviceability, or deflection. Table 13 highlights deflection limits for members based upon their structural usage.

Table 13 Deflection Limits (ASCE 7-05)

CONSTRUCTION	*L*	*S* or *W* f	*D* + *L* d, g
Roof members:[e]			
Supporting plaster or stucco ceiling	l/360	l/360	l/240
Supporting nonplaster ceiling	l/240	l/240	l/180
Not supporting ceiling	l/180	l/180	l/120
Floor members	l/360	—	l/240
Exterior walls and interior partitions:			
With plaster or stucco finishes	—	l/360	—
With other brittle finishes	—	l/240	—
With flexible finishes	—	l/120	—
Farm buildings	—	—	l/180
Greenhouses	—	—	l/120

Initially, when the team was brainstorming potential layouts for the Growing Power project, the goal was to innovate a footprint unlike the model provided by the competition. Fitting this within the guideline to maintain the floor area designed, as well as within the site boundaries proved to be difficult. The assembly area needed an unimpeded space, this inlet idea seen in Figure 27 reduced floor area while maintaining the limited building footprint. Not too much could be done with the building footprint because of lot size so *Impact* investigated height restrictions and limitations. If the design was classified as a high-rise, 75 feet, a number of regulations would then apply per *IBC 2012*, so it was made a point to keep the design under this height limit. The height of the upper-most floor is the level that needs to be under 75 ft. *Impact* decided upon 5 floors plus an additional floor below

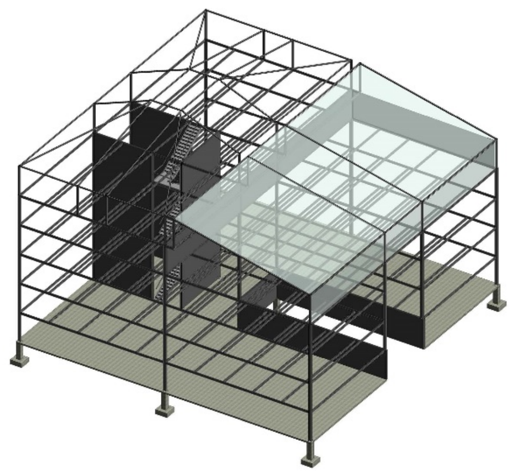


Figure 27 Preliminary Structural Design.

grade.

Modeled above, this was the preliminary design. Despite its inability to encompass architectural space requirements, the final design managed to maintain a number of the original details. The preliminary design was the result of a conscious effort to increase the day lighting of office areas in addition to greenhouse spaces. With a "U-shape" *Impact* believed the market would be integrated with the entrance to welcome facility users. An alteration noticeable in Figure 27 is the levels that have greenhouse space. Reducing it to Floors 3 and above in an effort to maintain the efficient use of space through the stair step pattern, kept the market space open to visitors. The angle of the greenhouse roofing systems are similar to one another and only at one pitch instead of the traditional double pitched roof. Doing this increases sunlight penetration from the South. With one pitch, *Impact* anticipated rain runoff as well as snow sliding becoming a safety hazard. Troughs, or gaps, were designed between greenhouse levels, serving both to mitigate potential hazards and to collect rainwater/ precipitation. Steel grating was chosen to cover these open areas, and this “grey-water” can be utilized in a number of ways within the facility.

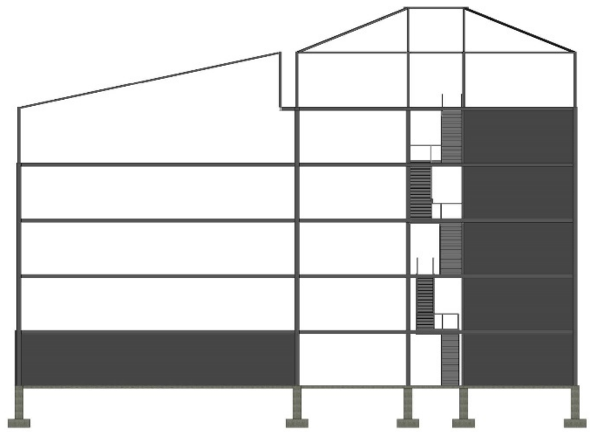


Figure 28 Preliminary Design East Elevation.

Also, seen in Figure 27 and Figure 29, steel is the main structural material. We noticed the prevalence of concrete in the given design but opted for steel as a way to open spaces and better customize the framing for occupancy load variations. We acknowledged that the greenhouses would have heavy equipment and materials housed in them, so this ability to design for non-uniform loads was chosen. When considering future occupancy loading cases we felt it was best to keep freezers and heavy equipment for storage on the slab on sub-grade in the basement. It would not make sense for the aquaponic tanks to also be housed in the basement because traffic is limited at that level to employees only. Our basement area initially was larger than required (Figure 28), so we opted to reduce the basement area so that a section of our market on the first floor would be on grade, Figure 29. By doing this, we saved time and money on materials as well as site-preparation that would have been required to support the tanks.

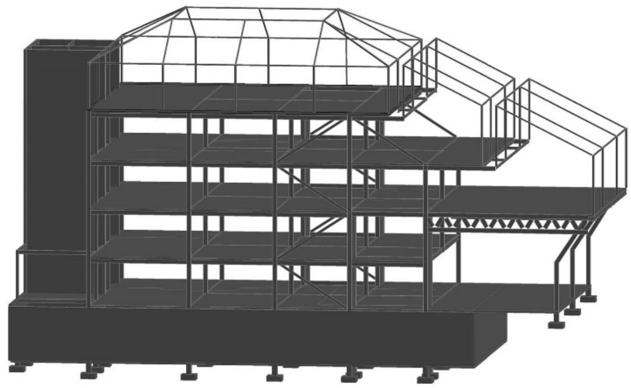
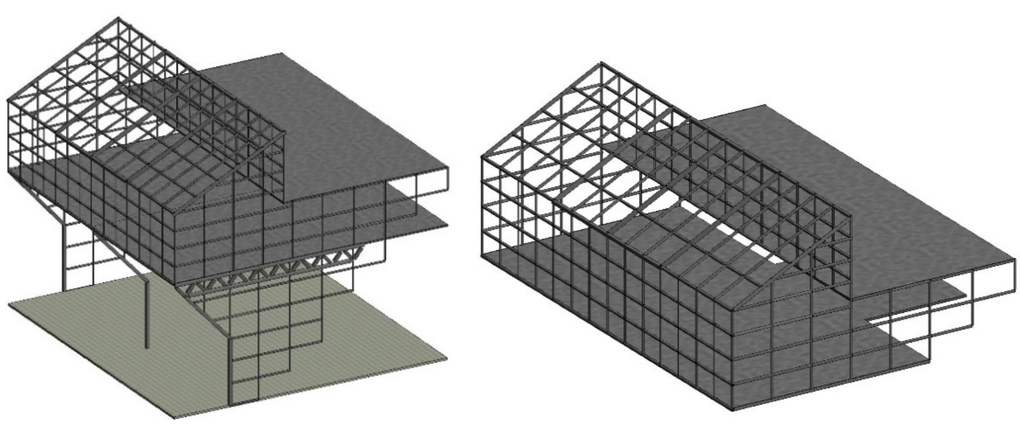


Figure 29 Final Design.

The greenhouses were extracted from the super structure for both design and *Revit* drawing. Designing each individually, stainless steel HSS member sizes were assigned to the proper elements. The HSS structural framing for the greenhouses seemed beneficial to serve to frame the glazing too. Each individual green house was fit to each floor, and this resulted in the structures having different load paths and member sizing due to the loads that the structures were expected to experience. The models were constructed using *Autodesk Revit* but they were first drafted by hand to highlight the details of the greenhouse structure such as length, spacing, number of components, levels, placement of the members in terms of view and level, and member size. This information was logged in an *Excel* spreadsheet in order to make tracking the previously mentioned elements easier.



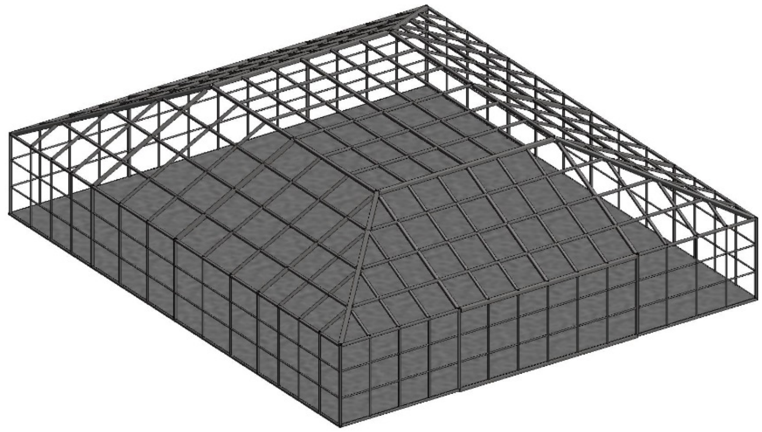


Figure 30 Lower, Middle, and Upper Greenhouse Framing (L-R, T-B).

While working with *Revit* placing HSS members on the sloped roof was problematic. Sketching the greenhouse led to quantifying the members pertaining to that roof. From there the similar triangle method was utilized to determine the horizontal placement of the HSS members in both the x and y direction so that it may properly fit the greenhouse structure. The front of the three greenhouse structures are visually consistent with one another.

When drawing the different greenhouses of their respected floor, the panel system was considered and glazing was designed to look like steps. The facade panels are not part of the greenhouse system and that is illustrated on the third and fourth floor greenhouse structures in Figure 30.

A special feature added during integration of the greenhouses and super structure was a 'sill' system at the bottom of the fifth floor greenhouse. This sill was the solution to the issue when point loads from greenhouse columns were placed on the wide flange member beneath it. The sill is an HSS member that takes the point loads and converts them into a uniform load that is then distributed to the wide flange below. Figure 31 visually depicts this.

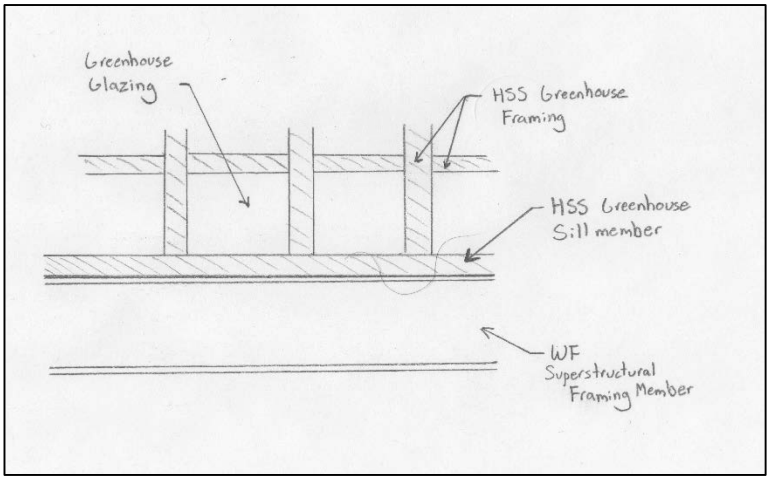


Figure 31 Green House Sill Feature.

The Geotechnical Report was thoroughly evaluated in order to design the type of foundations. Using gathered data and recommendations we opted for shallow foundations. A slab footing, also known as a floating slab was ruled out because of risk of settlement of the top layer of soil. Isolated footings combined with spread footings and shear wall footings were our choice to disperse building loads to the soil. When column footings would have been located within relative proximity to one another we combined footings. Moment resisting footings were also designed as required for resisting lateral loads above grade.

3.4 Construction Project Management

In this project, *Impact* developed a project management plan as part of the integration component of the competition. The team planned the construction of the project by analyzing and choosing the best possible approach in order to finish the building on time and within budget. As part of the project management plan, the group analyzed the project delivery method and developed the site plan layout, cost estimates, and construction schedule. In addition, the team developed a BIM model using *Autodesk Revit* and *Autodesk Navisworks* in order to create an integrative 4D model.

3.4.1 Project Planning and Delivery Method

First, *Impact* performed an analysis of different project delivery methods, more specifically by comparing the Design-Bid-Build and the Design-Build approaches. The team analyzed the advantages and disadvantages of both delivery methods in order to define the best fit for the project. Since the competition proposes a unique project that requires an innovative design, the chosen project delivery method had to be flexible and demonstrate that its approach suits the project requirements.

3.4.2 Site Plan Layout

As part of the project management a site plan layout was developed in order to address safety, security, accessibility, and constructability concerns. Spaces were allocated in the property depending on the activities that would take place in that area. Also, *Impact* designated where the temporary buildings for offices and crew rooms will be placed. The team's goal when developing the site plan layout was to minimize the risk and interference between activities on site. Finally, the presence of trucks, cranes, and heavy equipment were taken into consideration when the team developed the site plan.

3.4.3 Cost Analysis

Once the architectural and structural designs were developed, a Design Development cost estimate was prepared. The cost of work items were calculated using R.S. Means data, which collects cost information from construction firms and contractors. This information may be subjective in some cases due to the amount of data available from different companies as well as the location of the projects in which companies worked. For this analysis, the 2014 edition of R.S. Means Inc. *Building Construction Costs* and *Square Foot Costs* books were used.

Materials Takeoff

When preparing the design development cost estimate, considering the amount and price of labor and materials to be used was crucial. The different design options proposed by the team had an impact on the cost of materials as well as the amount of labor that is needed to build the project. The team took off the various materials included in the design of the building by creating item schedules in Revit and tabulated the quantities using spreadsheets. Revit simplified the process of quantifying every item used in the model.

Cost Estimation

Impact decided to create two different types of cost estimates for the construction project. During early project development, the team created an estimate at the conceptual design stage. Then, when design was complete, the team compiled a design development cost estimate.

Conceptual Design Estimate

For the conceptual design cost estimate that the team prepared, the different areas and rooms of the building were quantified and identified according to their use. Since the proposed building has multiple purposes such as office space, food market, agriculture/industrial production, educational space, and assembly area, the team used RS Means (2011) Square Food Estimate Models that would represent these different facility uses. A detailed list of the Models used can be seen in the Table 14.

Table 14 R.S. Means Models

RS Means Model number	Type	Facility Purposes
M.120	Commercial/Industrial/Institutional	College, Classroom, 2-3 Story
M.150	Commercial/Industrial/Institutional	College, Laboratory
M.210	Commercial/Industrial/Institutional	Factory, 3 Story
M.460	Commercial/Industrial/Institutional	Office, 2-4 Story
M.640	Commercial/Industrial/Institutional	Supermarket

Impact decided to calculate a square foot estimate for the proposed design using a unified model approach in order to obtain an estimate that would better represent the cost of the project, but still consider the different purposes of the building. For example, if the different models were used to calculate the cost for each area category, the model for a supermarket specified foundations that had a low cost because of the characteristics of the facility. The supermarket model corresponded to a one-story building of 44,000 square feet of area, which does not require the same type of foundations as a 3-story factory of 90,000 square feet of area. To overcome these types of discrepancies, *Impact* decided to create a compiled modified model that would represent the different components of the building housed in the same structure. The cost data provided by RS Means is based on a national average and location factors were used to update the total project costs to Milwaukee and Miami.

Design Development Estimate

Once all the work items were quantified in the takeoff process, the team developed the design development cost estimate using *RS Means Building Cost Data 2014*. *Impact* broke the work items into the *2012 CSI MasterFormat* divisions in order to produce a Class-A, detailed and itemized estimate. The project's estimate included detailed cost for material, labor, equipment, and overhead and profit for all the construction work and building components contemplated within the design development documents. For the systems not included in the design, a square foot cost estimate was performed in order to complete the project's overall estimate. Finally, the project cost estimate was summarized into the UniFormat Categories to facilitate its presentation and communication.

Life Cycle Cost

When designing the lighting systems of the building, the team used a life cycle cost analysis approach in order to define a cost beneficial solution. *Impact* decided to consider sustainable or efficient alternatives for the lighting system and then compare their consumption to the lighting baseline determined by *ASHRAE*. The team focused on the use of LED lighting to perform this analysis. In order to estimate the amount of money saved due to energy efficient fixtures used in the project, the team used the Future Equivalent Worth formula.

$$FV = A\,\frac{(1+i)^t - 1}{i}$$

Where:

- FV is the Future Worth
- A is the money saved each year
- i is the interest rate
- t is the number of years

Impact estimated the amount of energy saved on a yearly basis and multiplied this value by the electric energy cost. Then, that yearly saving value was converted into its future equivalent worth, 25 five years in the future.

3.4.4 Project Schedule

Impact created a project construction schedule based on the project's work activities. The steps to carry this process are described below:

1. Broke down the scope of the project into manageable portions and name them as activities.
2. Provided an estimate of each activity's duration using productivity rates data from R.*S. Means Building Construction Costs 2014*.
3. Established logical relations among activities in order to create a sequence.
4. Determined the earliest and latest possible times for execution based on the duration of the activities and the relationship they have with other activities.
5. Identified the project's critical sequence and slack time for non-critical activities as result of the scheduling in the previous step.
6. Reviewed and updated the project schedule as needed.

(Halpin and Senior, 2011).

Impact used Microsoft Project software to create the project schedule. The team used the network diagram and Gantt chart provided by the software to understand and manage the schedule duration. The critical path was identified as the sequence of activities that would have direct impact on the overall completion time of the project if they suffer any type of delay. This critical path was used to determine the activities with the greater importance and to look for alternatives in order to reduce their duration. Finally, *Impact* considered different options that will would increase the amount of work done and would reduce the activity durations.

3.4.5 Building Information Modeling (BIM)

Before the design process started, the team used a BIM approach as a resource for integrative collaboration between disciplines. As a multidisciplinary team, maintaining a good communication is vital throughout a project. Therefore, the team used multiple tools to share information and to keep the group members constantly informed.

- University's server and Microsoft SharePoint to store and share large size files
- Google Drive to share and work on written documents
- Autodesk Revit to integrate the different models
- WhatsApp and University's email to maintain constant communication between team members

Through the use of BIM and collaborative design techniques, the team was able to take advantage of multiple software applications that permitted the integration of the building systems within the design. Figure 32 displays a list of the software applications used by the structural, architectural, mechanical, lighting/electrical, and project management disciplines.

Software	S	A	M	L/E	PM
AGi32				x	
AutoCAD	x	x		x	
COMcheck			x		
MS Excel	x	x	x	x	x
MS Project					x
MS Word	x	x	x	x	x
MS PowerPoint	x	x	x	x	x
Revit Architecture		x	x	x	x
Revit Structure	x				
TEDDS	x				

Figure 32 Software Application Table.

In addition, *Impact* decided to use software applications to obtain a better understanding of the construction phase of the project. There are multiple applications for the digital models that can be obtained through BIM. In this project, the team incorporated the analysis of 3D and 4D models that enabled virtual design and construction of the project, facilitating a visual clarification of the building's construction. After creating the 3D Autodesk Revit model, the team grouped the intelligent objects by construction phases. These phases were broader than the detailed work activities in the schedule in order to facilitate the construction simulation processes. Then, the team used *Autodesk Navisworks* to incorporate the 3D Autodesk Revit model with a summarized project schedule produced in Microsoft Project in order to create the virtual construction simulation. A description of the process for creating the *Autodesk Navisworks* simulation is detailed in the flow in Figure 33.

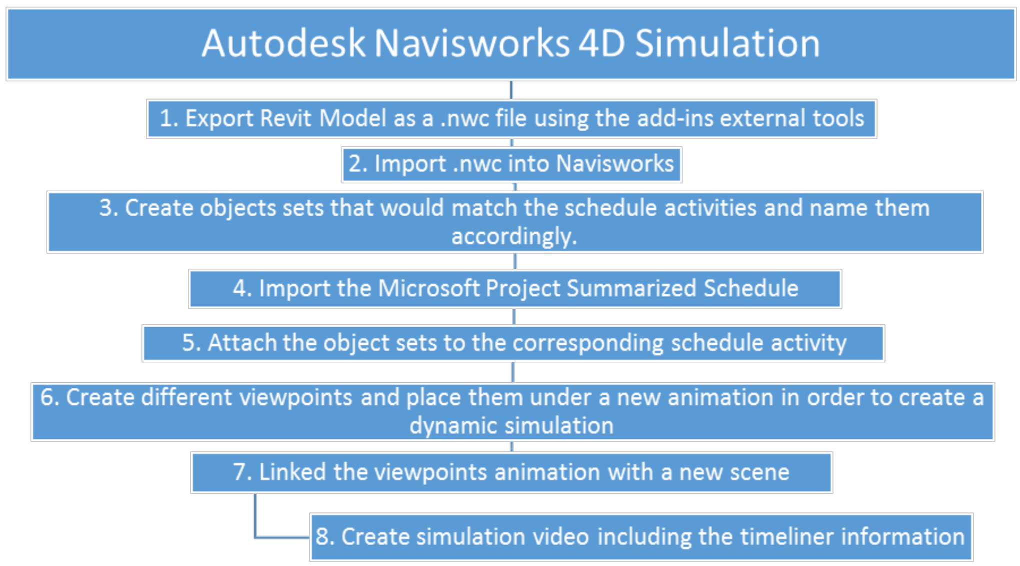


Figure 33 Autodesk Navisworks Flow.

By incorporating the use of the 4D model to simulate the construction of the project, the team was able to get a better understanding of the sequence and relationships between work activities. Therefore, the schedule was reviewed and updated with the information obtained from the modeling.

4. Results & Analysis

After deciding the criteria for the various building system the group chose specific systems and solutions to develop. The following section presents these new designs and the reasoning behind them.

- The architectural layouts are presented with the floor plans of the old layout compared to the newly designed layouts with changes highlighted.
- The integrated system solutions are presented for the following systems; fire protection, building envelope, glazing, greenhouse mechanical, greenhouse lighting, mechanical, electrical, and plumbing.
- The final structural system is also defined including an analysis of the appropriate codes, structural framing design, design focuses of the project, and the foundation system.
- The project management results are explained in a natural progression of project delivery method, site layout, cost estimate, schedule, and building information modeling.
- The sustainable and environmental practices are addressed by a LEED certification evaluation.

4.1 Overall Building Architecture

The new exterior design took inspiration from UC San Diego Giesel Library, shown in Figure 34 below. Key features taken from the libraries design include:

- Exterior slanted columns: add powerful architectural feature to the overall design of the library
- Step Back Profile: Creates aesthetically pleasing side profile

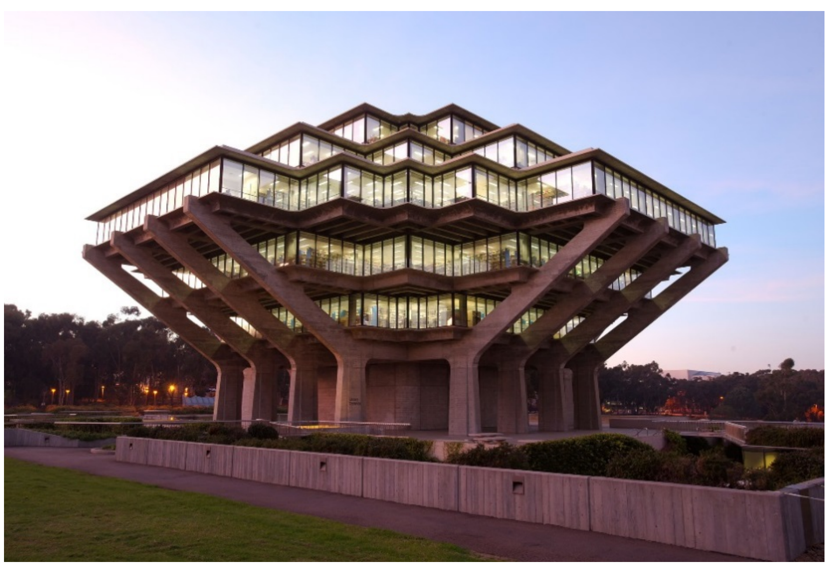


Figure 34 Giesel Library, UC San Diego (UC San Diego 2012).

The overall building architecture was kept mostly the same due to the competency of the original design, among other reasons. The growing areas require direct sunlight and thus cannot be stacked on top of one another, retaining the ascending stepped profile. There were a few smaller changes that enhanced the group's design starting with the growing areas now having single slant roofs instead of pitched roofs to allow a greater amount of sun exposure from the south. The new design also only has three growing areas, eliminating the growing area formally on the second floor. This change consolidated the use of the growing areas to three floors and away from the more public second floor. Additionally thermally controlling three growing areas instead of four was more cost efficient and an easier task in general. Managing the growth and having a greater return on investment is another byproduct of having three larger growing areas as opposed to four smaller ones. There was also now space available to enlarge the growing areas on the third and fourth floors from 1980 ft^2 to 3500 ft^2 and 2011 ft^2 to 2950.4 ft^2, respectively. The total area of the original four growing areas was 11483 ft^2 and total area of the new design is 12,050.4 ft^2. *Impact's* exterior architectural design is illustrated in Figure 35.

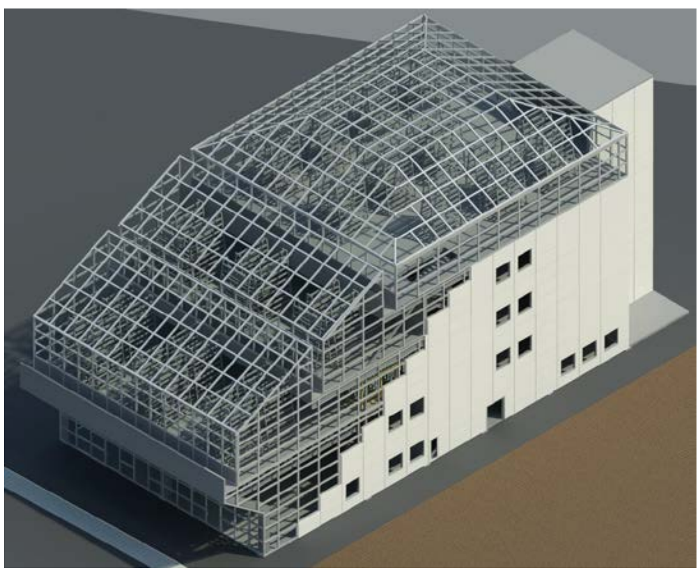


Figure 35 Growing Power Exterior Render.

In addition, *Impact's* design incorporates three Hollow Structural Section (HSS) steel columns that go along with the architectural and structural decision of using exposed columns throughout the building, as seen in Figure 36. These three columns are integrated to a truss joist system supporting the third floor area, that is then connected to the steel framing and the composite slab that composes the building's structure. More detailed information about the structural system will be provided in the following Sections.

Figure 36 Exterior Architectural Design Columns.

One of the special features of the columns in the entry is their encasement. Although the current model does not show the detail, the HSS column will be surrounded by a perforated, custom-made metal cover. In addition to its architectural appeal, this type of encasement will not interfere with the connection between the column and the truss it supports. An example of this type of structure can be seen in Figure 37.

Figure 37 Perforated Metal Encasement (architectural Grille).

4.1.1 Floor Layouts

The complete set of floor plans and elevation views of *Impact's* design can be seen in Appendix L. Below, the advantages and features of the original floor plans and changes made to the final layout are explained in detail for each of the floors.

When examining the existing rooms floor by floor the group noted the following components:

- Room type/use
- Room area

- Adjacencies and flow paths

The process of changing the architectural layouts started with reviewing the project criteria given:

- The use of each space must be retained
- Each space must have the same area or more than the original design
- The architectural layout must be complimentary to the goals and vision of Growing Power Inc.

Basement Advantages/Features

Original basement layout can be seen below in Figure 38.

- All storage areas are within close proximity to the market area
- Regular storage is the most flexible in terms of what items can be stored and has the most area available to it on the basement floor
- Storage rooms don't need to be conditioned, simplifies the heating and cooling system for the entire floor
- Locker rooms are not on a public floor so workers can change and shower in privacy

Figure 38 Original Basement Floor Plan.

Table 15 Area Comparison: Basement

Room	Original Area (ft^2)	New Area (ft^2)
Storage	4312	4338.9
Coolers	930	1148.7
Freezer	234	235.15

New Basement Changes and Reasoning

- Decreased entire floor length from 163 feet to 125 feet
  - This change was made so aquaponic demonstration tank can be supported by a slab on grade
- Increased total area of both the storage and coolers
  - Space was available to expand these spaces without changing the building footprint. Offers more storage space for goods and sellable items

The new basement floorplan can be seen in the Figure 39 below.

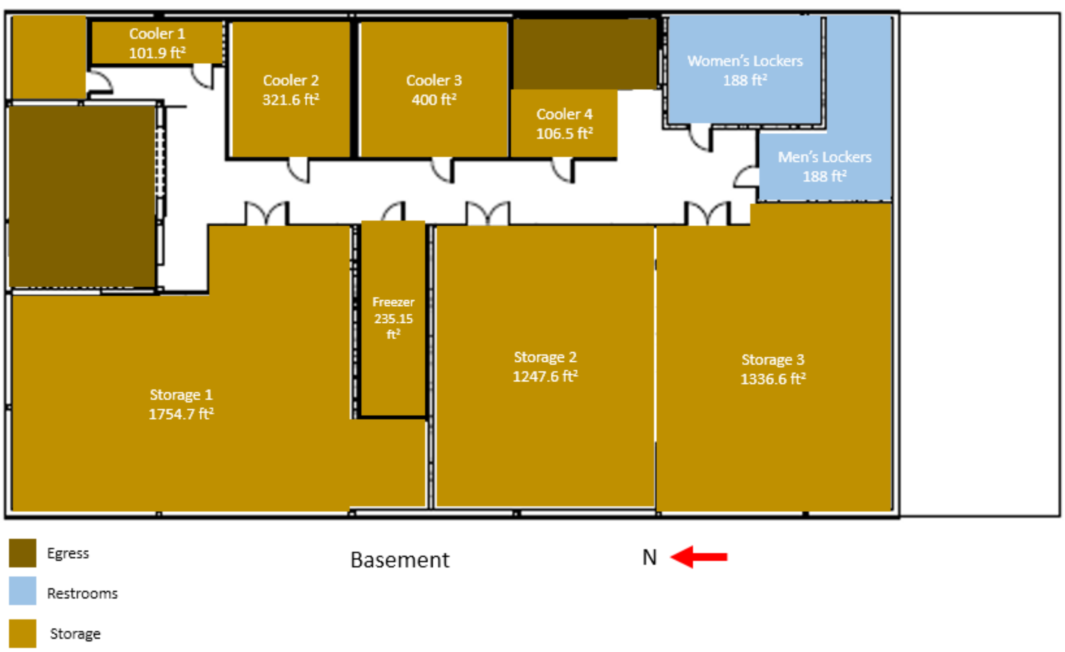


Figure 39 New Basement Floor Plan.

First Floor Advantages/Features

Original first floor layout can be seen below in Figure 40.

- Market is the most publicly used space and is located at the front entrance

- Shipping, Processing and Market areas are located in a row for easy progression of goods to be shipped into the building, go through processing, and placed in the market area
- A side entrance leads directly to staircase, for the people who want to get to other floors without going through the market

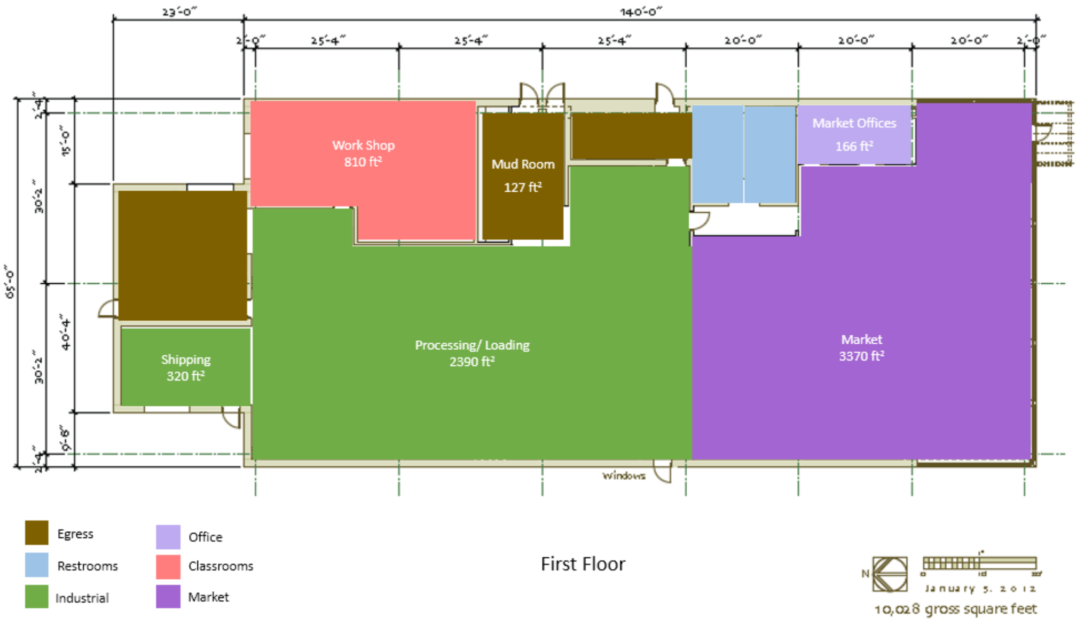


Figure 40 Original First Floor Plan.

Table 16 Area Comparison: First Floor

Room	Original Area (ft^2)	New Area (ft^2)
Market	3370	3647.2
Processing/Loading	2390	3036.4
Shipping	320	330.8
Workshop	810	810.1
Market Offices	166	175.8
Mud Room	127	211

First Floor Changes and Reasoning

The new first floor plan can be seen in the Figure 41.

- Market area increased from 3370 ft^2 to 3647.2 ft^2
  - Increased area to have more selling floor space
- Market offices were moved from the east wall to the north wall of the market
  - Allows more unobstructed daylight to enter the market area from the east wall

- Added third staircase
  - Added to meet the egress requirements of the second floor

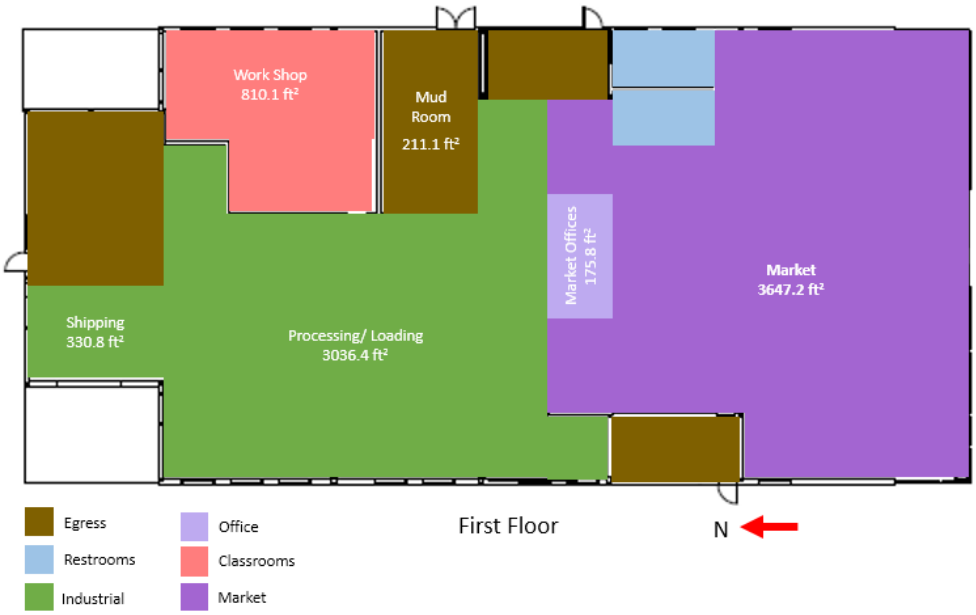


Figure 41 New First Floor Plan.

Market

From this new layout, a two-story atrium was formed as a consequence of the elimination of the second floor growing area. This modification creates a dynamic and memorable entrance, drawing people into the building. The two story curtain walls that now encloses the market allows sunlight to reach further into the building's interior, decreasing the requirement of artificial light during the day. The market itself functions as the community hub and the most visited space within the building. The market exemplifies Growing Power's motto of providing the community with resources to grow high quality and sustainable food. In addition to the market where the products grown on site are sold, *Impact's* design includes two aquaponic demonstration tanks in this space. The aquaponic demonstration tanks are an educational tool to show how fish and plants can be grown concurrently in a self-sufficient system. This feature will serve as an attraction for the community to learn about sustainable food production. The tanks are placed on the slab on grade, integrating the architectural feature with the structural design. In Figure 42, a rendering of the market is observed.

Figure 42 Market Rendering.

Second Floor Advantages/Features

Original second floor layout can be seen below in Figure 43.

- Assembly area of 4059 ft^2 to be used for large scale gathering events
- Assembly space is located on the second floor for easy access to the public from the ground level.

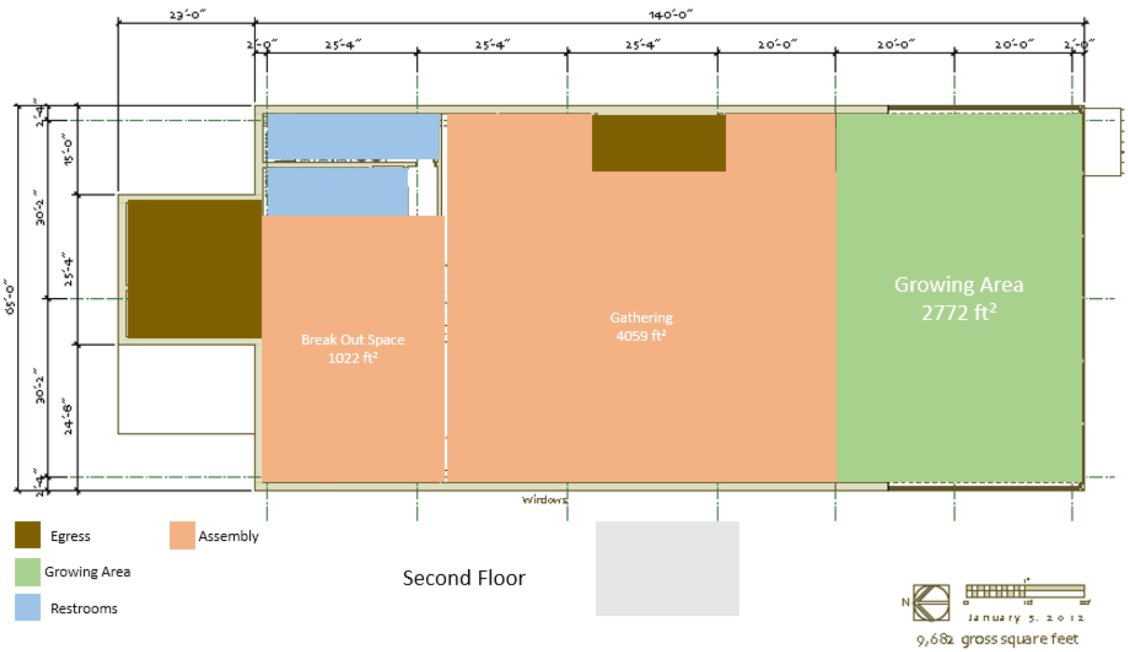


Figure 43 Original Second Floor Plan.

Table 17 Area Comparison: Second Floor

Room	Original Area (ft^2)	New Area (ft^2)
Breakout Space	1022	1374.6
Gathering Space	4059	3967.5
Growing Area	2772	NA

Second Floor Changes and Reasoning

The new second floor plan can be seen in Figure 44.

- Growing Area was removed
  - Growing area was removed from a public floor to decrease the degree the public could tamper with the space.

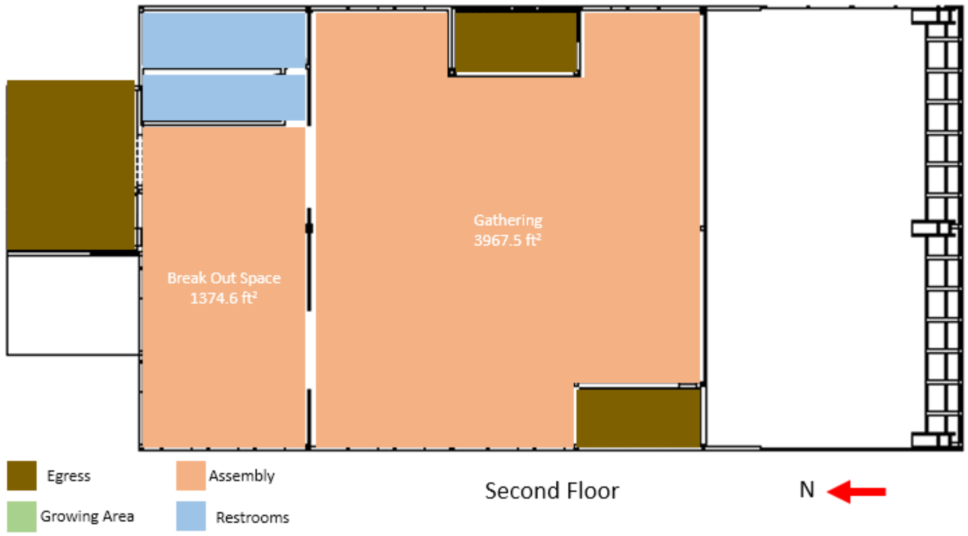


Figure 44 New Second Floor Plan.

Gathering Area

In addition, *Impact* increased the occupant capacity of this floor dedicated to showcase presentations and events from 463 occupants to 600 occupants by adding a third staircase. This change will allow Growing Power to host bigger events for the community. A render view of the assembly space is shown in Figure 45. The details of this floor plan can be seen in page the Drawings section.

Figure 45 Assembly Space Render.

Third Floor Advantages/Features

Original third floor layout can be seen below in Figure 46.

- Contains the building's learning space complete with 3 classrooms, two of which can be combined into one and a demonstration kitchen
- Growing area is directly adjacent to demonstration kitchen for easy access to fresh produce

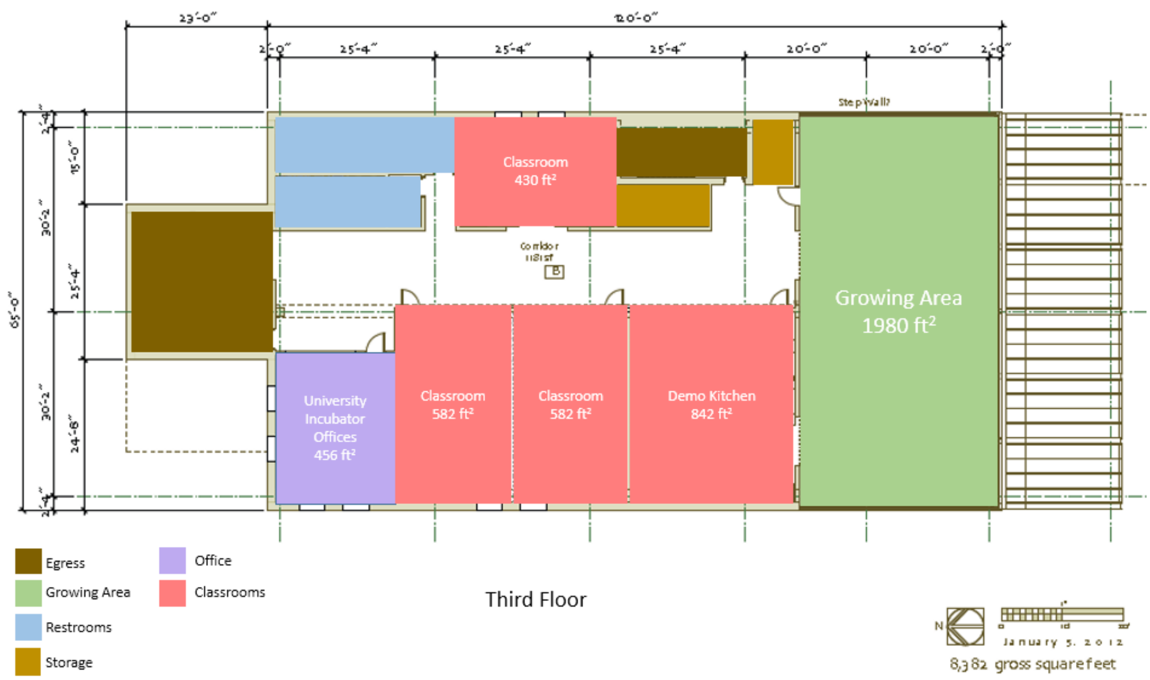


Figure 46 Original Third Floor Plan.

Table 18 Area Comparison: Third Floor

Room	Original Area (ft^2)	New Area (ft^2)
Classroom 1, 2, 3	1594	1808.3
Demo Kitchen	842	984
University Incubator Offices	456	485.8
Growing Area	1980	3500

Third Floor Changes and Reasoning

The new third floor can be seen in Figure 47.

- Classrooms are all directly adjacent to one another on one wall with a movable partition between them.

- Classrooms are flexible to create various sized room based on the needs of the class

- Demonstration Kitchen has direct access to growing area
  - Easy access for fresh produce to be used in the kitchen

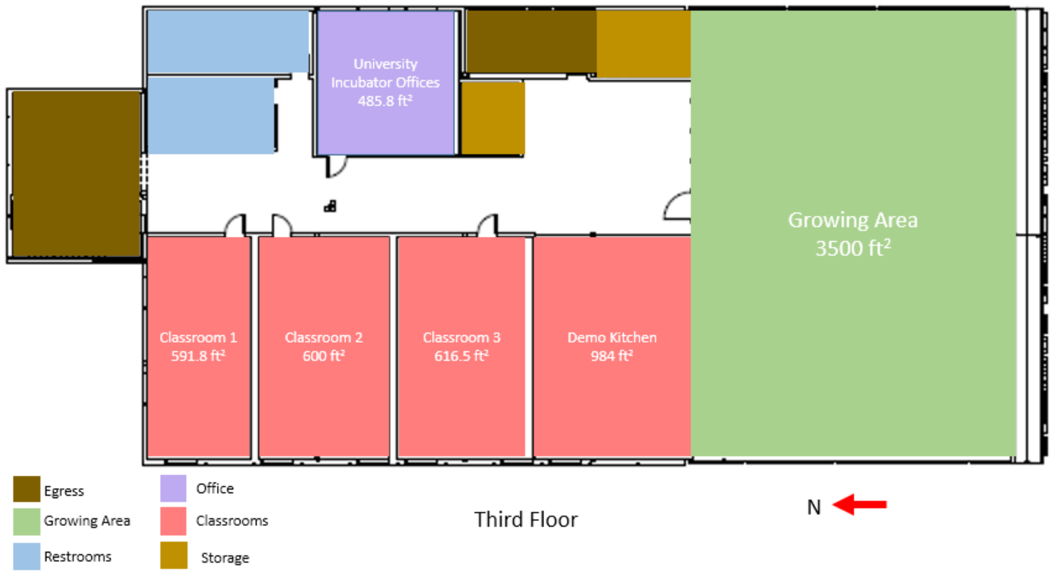


Figure 47 New Third Floor Plan.

Fourth Floor Advantages/Features

The original fourth floor can be seen in the Figure 48.

- Business floor comprised of the Growing Power offices, meeting room, the director's office and a reception area for Growing Power's clients
- Seven workstations in general office area
- Business area is separated from reception and staff area

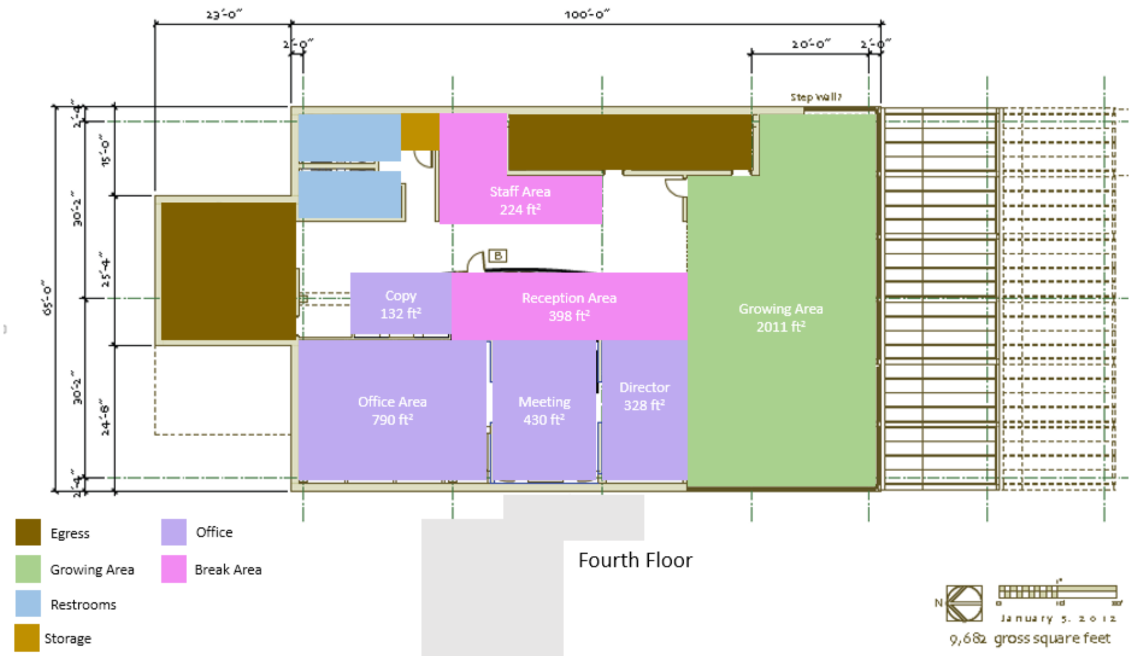


Figure 48 Original Fourth Floor Plan.

Table 19 Area Comparison: Fourth Floor

Room	Original Area (ft^2)	New Area (ft^2)
Office Area	790	880.9
Meeting Room	430	444.4
Director Office	328	394.4
Copy Room	132	133
Reception Area	398	529.2
Staff Area	224	334.5
Growing Area	2011	2950.4

Fourth Floor Changes/Reasoning

The new fourth floor plan can be seen in Figure 49.

- Copy room has exterior wall on the north building face
  - Allows natural light to enter the room
- Reception Area has direct access to the meeting room and director's office
  - Allows clients and customers to easier access to meet with the director or attend a meeting as opposed to going around through the office area

- Office Area expanded by 90 ft²
    - Allows room for approximately 1 more workstations

.

Figure 49 New Fourth Floor Plan.

Fifth Floor Advantages/Features

The original fifth floor plan can be seen in the Figure 50.

- Used exclusively as a growing area
- Floor left unchanged

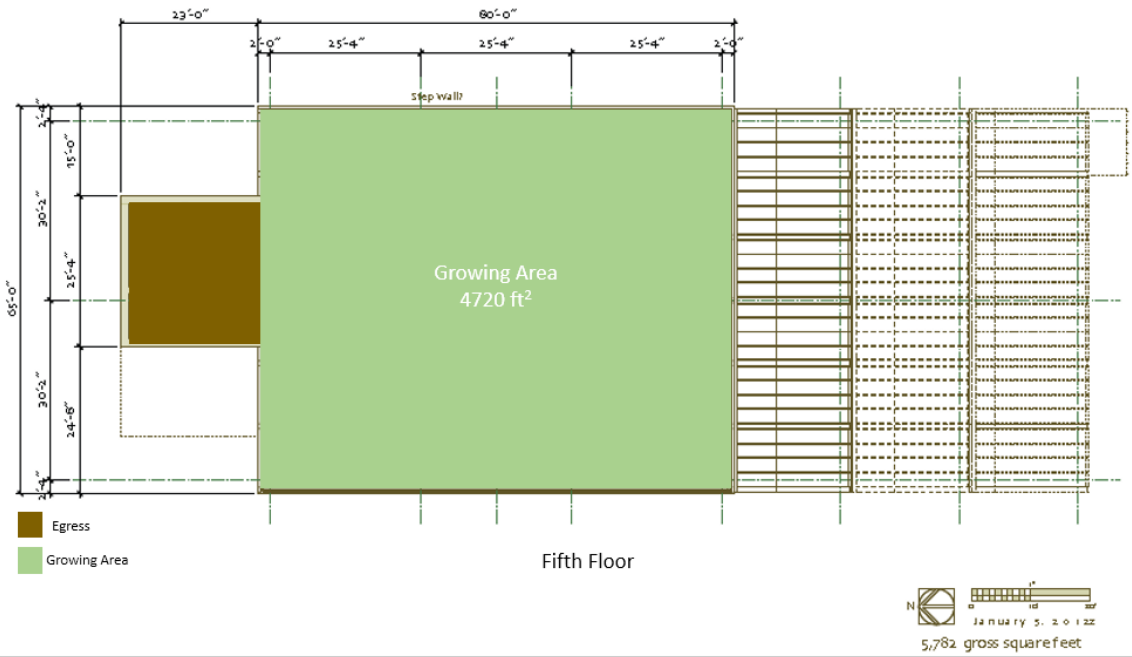


Figure 50 Original Fifth Floor Plan.

Table 20 Area Comparison: Fifth Floor

Room	Original Area (ft^2)	New Area (ft^2)
Growing Area	4720	5600

4.2 Systems Integration

The following sections explain the integration of systems investigated by the team. Fire protection, building envelope, greenhouse systems, mechanical & plumbing systems, and electrical and interior lighting were analyzed to thoroughly understand their effects on one another and the facility system as a whole.

4.2.1 Fire Protection System

The fire safety systems of Growing Power's facility were determined based on the selection of the building's Type IIA construction and Low-Hazard Factory Industrial (F-2) occupancy. Although the building will be located in a suburban residential area, its lot area at 5500 West Silver Spring Drive is considered a Planned Development District (PD/DPD), according to the Milwaukee Code of Ordinances Chapter 295 – Subchapter 9 Special Districts. This type of district is intended to allow flexibility in its land development, and promote creativity, variety and environmental sensitivity. It also encourages development compatible with its surroundings and consistent with the city's comprehensive plan. Therefore, the construction of Growing's Power Vertical Farm and its F-2 consideration will be allowed in the area.

As previously mentioned through the Methodology section, all areas of the building will be equipped with an automatic sprinkler system. The system installed must be designed in accordance to NFPA 13: Standard for the Installation of Sprinkler Systems.

In regards to the means of egress, 2 two-flight stairways were established for exit access. This decision was made based Chapter 10 of the *IBC*® and the fact that most of the floors, except for the basement and the second floor, have an occupancy load higher than 49 but lower than 500 people. Both of the stairways have an enclosure width of 10 feet and they are separated by a distance of 71 feet. This distance also complies with the requirements of the *International Building Code*® chapter 10, where it is required that for fully sprinkled system, the distance between the two exits must be one third of the diagonal measure of the area. Lastly, the 13 feet high floor-to-floor stairs will require 23 risers, as suggested by the Exit Stairway design table found in "The Architect's Studio Companion" book. The location, dimensions and separation distance of these two stairs can be seen in Figure 51.

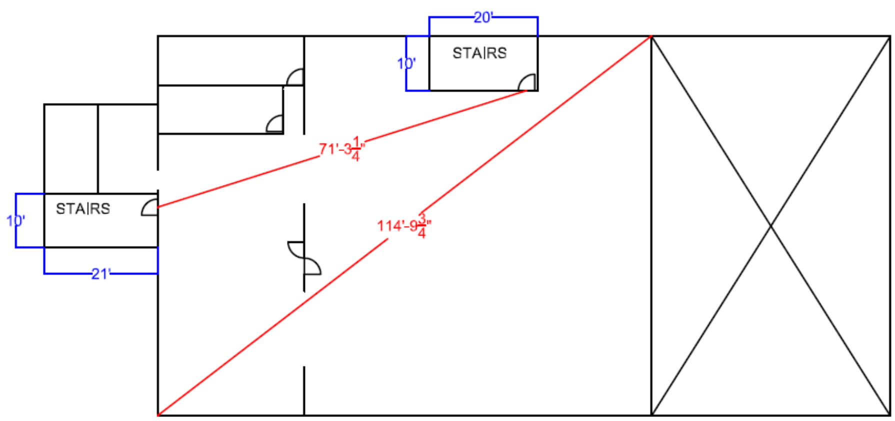


Figure 51 Initial Stairs Location.

Meanwhile for the second floor assembly area, a third stair case was added to accommodate the floor's occupant capacity, which was increased from 463 to 600. This third stairway will serve only the first and second floors of the building, and will also have an enclosure width of 10 feet, similar to the other two stairways. Based on the floor area available, the room has a capacity of 781. However, since the three staircases limit the total occupant capacity to 600 people, signs across the room will be installed to display the maximum permissible occupancy. The floor layout can be seen in Figure 52.

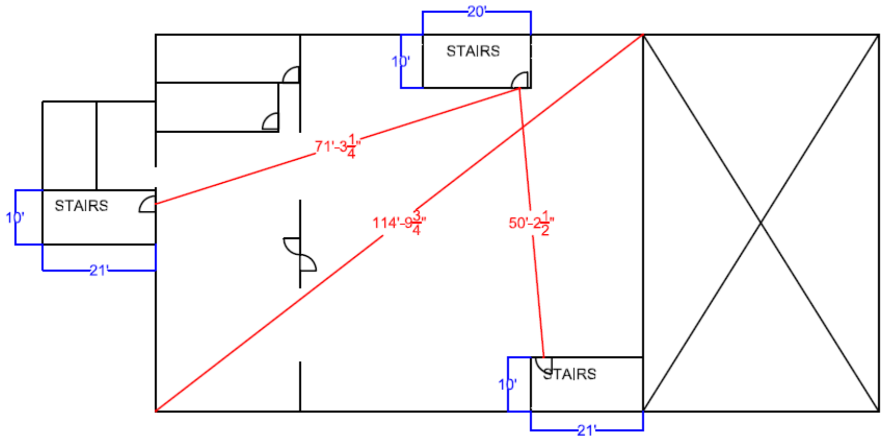


Figure 52 Final Second Floor Stairs Location.

4.2.2 Building Envelope

Precast panels can be flexibly shaped to create the forms required for the design. The range of panel sizes incorporated in the design can be seen below. The majority of the panels are 7' 6" by 13" tall with a 5' by 5' space for a window. Upon further research the group discovered the advantages of fully integrated panels, which are listed below

- Cut down on construction time
- Applicable to locations around the country
- Light weight enough to be supported by building structure
- Flexible in sizes and shapes available

These architecturally precast panels come with continuous insulation (CI) built in. The panels are 30 lb. /ft^2 and also include a secondary draining system to collect and drain incidental moisture, a preinstalled window and joint sealant for panel to window connections. The panel is comprised of lightweight concrete connected to a light gauge steel frame by galvanized steel pins that are gravity, wind and seismic anchors. These rods create a miniscule thermal bridge that does not detract from the overall thermal performance of the panel. The panel layers can be seen in Table 21. A section of the panel can be seen in the Figure 53 below, and a description of the panel layer is provided in Table 21.

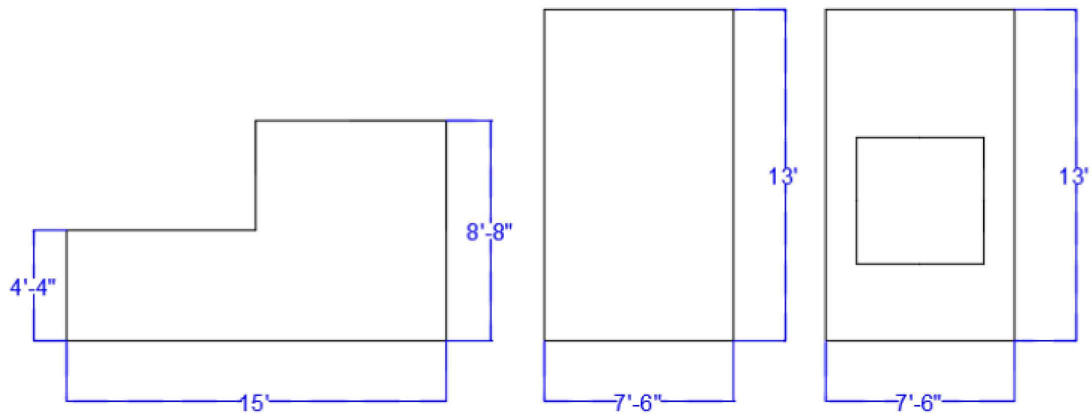


Figure 53 Panel Sizes.

Table 21 Panel Layers

Panel Layer	Description	R Value
2 1/2" light weight reinforced concrete	5500 psi average compressive strength	1.3
3" of NFCI spray foam continuous insulation	Works as both an air and vapor barrier, with high resistance to fungal and bacterial growth	20.4
4" x 1" hollow steel support frame	Light gauge steel with galvanizing pin connectors that work as gravity, wind and seismic anchors for the light weight concrete	0
Gypsum wall board	Added during building construction, on site	.45
Total R Value		22.15

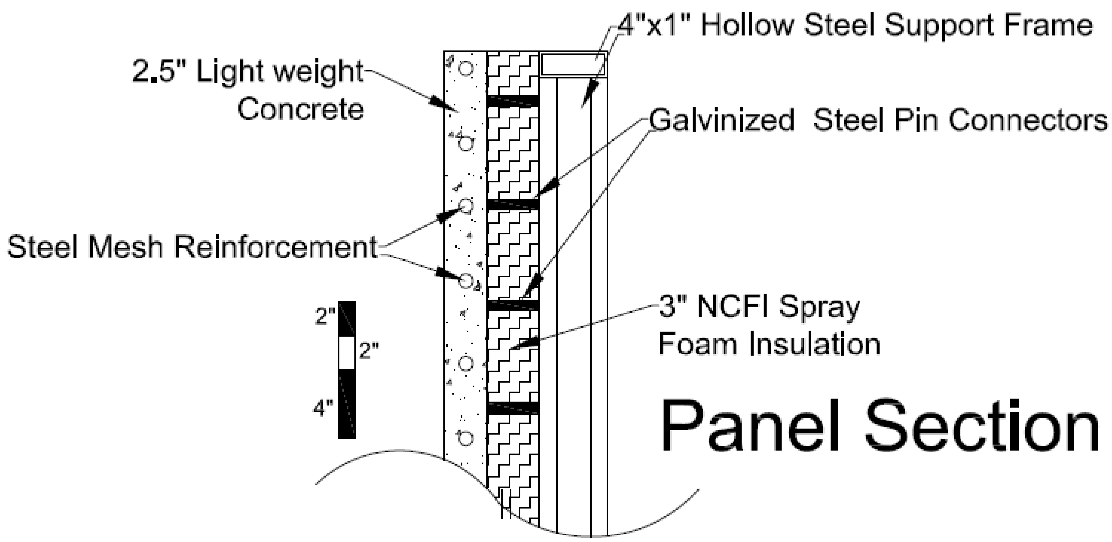


Figure 54 Panel Cross Section.

The precast panels created the desired R value and a low U Value of .045 while also cutting down on cost and construction time because of the fully integrated design. The panels are delivered with windows installed; the only labor required is the placement of the panels themselves and the gypsum wallboard finish on the interior.

Glazing System

In addition to the exterior paneling system, the second major aspect of the building's façade design was glazing. All of the growing area glazing system uses a double-pane low emissivity coating glass with argon filling. This low emissivity coating, known as Low-E, mainly provides a low U-value, which ultimately reduces the heating and cooling load. In addition, it also allows a good amount of visible light in and a low Solar Heat Gain Coefficient (SHGC).

The glazing system designed uses two different types of Cardinal Glass Industries' products. The first one is LoE 272. This product composes all of the glazing, to the exception of the fifth floor roof. Its low U-value of 0.25 and its high visible light transmittance of 70% will provide plants the necessary light to grow. Meanwhile, following the input provided by Solar Innovations[10], *Impact* decide to use a second type of Low-E glass, LoE 240, in the roof of the fifth floor greenhouse. This glass product has the same U-value of 0.25, but has a slight tint layer that provides a lower visible light transmittance of 37% and lower SHGC of 0.24. This will reduce the glare in the fifth floor growing area. Both glass panels have an overall thickness of 25 mm. As mentioned in the methodology, the products researched, were compared to the properties of a double-paned clear glass. Therefore, the final comparison between the products selected and the clear glass alternative is presented in the Table 22.

Table 22 Final Glazing Products Comparison

Final Glazing Products Comparison					
Exterior Glass	Airspace	Inboard Glass	U-Value	Visible Light	Solar Heat Gain Coefficient
Clear (6mm)	Air (13mm)	Clear (6mm)	0.47	80%	0.72
LoE 272 (6mm)	Argon (13mm)	Clear (6mm)	0.25	70%	0.4
LoE 240 (6mm)	Argon (13mm)	Clear (6mm)	0.25	37%	0.24

4.2.3 Greenhouse Systems

Impact analyzed the different systems described in the previous section and decided to use a combination of the A-Go-Gro vertical rotating system and the ZipGrow towers system. *Impact* used a different system than the one specified in the original design because of three reasons.

1. The lack of detailed information available about the VertiCrop system used in the original design.
2. The irrigation and plant seeding processes can be improved by combining features from the different systems described in the Methodology section,
3. Sections of greenhouse areas have limited ceiling height

Impact modified the A-Go-Gro rotating tower design in order to adapt it to the space conditions present our building design. The team limited the tower height dimension based on the vertical clearance available in the inclined glazed roof areas on the south side of the building. The height of the system is 17’6”. The base dimension for the tower remained be similar to the original A-Go-Gro towers, with a depth of 9’11”, and a width of 6’1”.

In addition to the dimension modifications, the team altered the racks design of the growing racks by introducing concepts from the Volksgarden Rotatory Garden system. In order to facilitate the irrigation and placement of the plants, the team decided to use a “C” shape channel to hold the growing media where the plants will be seeded, and adapting plates to connect them to the rotatory chain. Figure 55 show the concepts from the Volksgarden Rotatory Garden system while Figure 56 shows a detail drawing of the “C” shape channel and the adapting plate used for our vertical rotatory system design. The L-shapes on the top part of the plate will serve as a shelf into which the “C” shapes will be inserted.

Figure 55 Omega Garden channel and adapting plate details (Omega Garden).

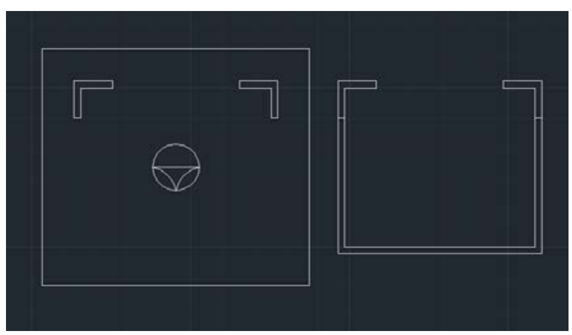


Figure 56 AutoCAD detail drawing of adapting plate and “C” shape channel section.

Impact decided to use Grodan stonewool Gro-Blocks as growing media. *Grodan Microplugs* would be used as plant starters to hold the seedlings. Then, these small *Grodan Microplugs* will be inserted into *Grodan Delta* blocks that would serve as growing media when the plants are placed in the racks. Figure 57 shows an example of these stonewool blocks and microplugs.

Figure 57 Grodan Stonewool products. (GRODAN Stonewool, 2014).

Impact developed drawings in order to provide a complete detail of the vertical rotating systems. The system will incorporate two lighting fixtures placed in the middle of the A-shape frame and will span though the depth of the system in order to provide lighting to the plants while they rotate. The drawings for the vertical rotating towers can be found in Appendix M. *Impact* also developed a simplified 3D model of the system using Autodesk Revit, which is shown in Figure 58 The horizontal members on the model are the racks where the plants are placed. These racks are connected to a chain on the interior part of the “A” shape frames, which make them rotate. The light fixtures will be placed horizontally across from both “A” shape the frames. The frame members where these fixtures will be attached are not shown on the 3D model of the system but can be depicted in the drawings in Appendix M.

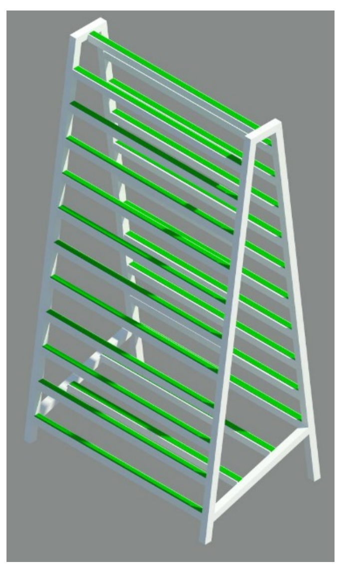


Figure 58 3D model of the vertical rotating towers system frame.

Impact decided to maintain the ZipGrow towers system concepts without major modifications. Each individual tower will be hanging from an overhead frame. Irrigation will be provided by using a dripping system from the top of the towers. Also, the towers will receive exposure to artificial lighting from the lighting fixtures that will hang from the overhead metal frame. The lighting fixtures will be placed horizontally in between the crop rows. The team arranged the ZipGrow towers in a way that two rows of towers will face each other to increase the plants' exposure to artificial lighting. These configuration can be appreciated in a plan view of the growing areas in Appendix N. Figure 59 shows an Autodesk Revit 3D model of this system framing.

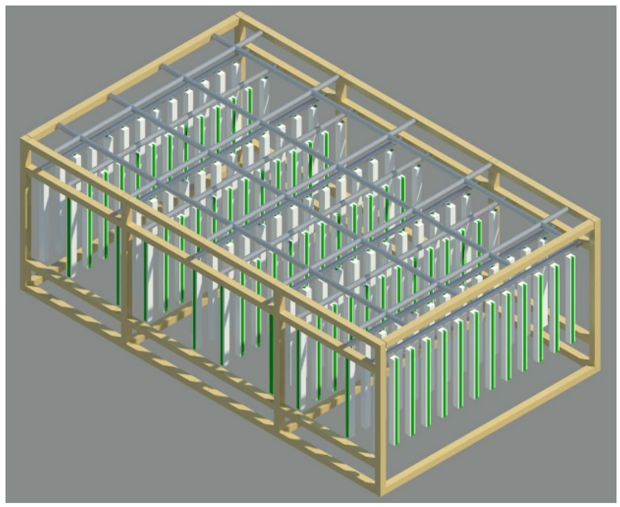


Figure 59 3D model of the ZipGrow towers system frame.

Layout of the Systems

The layout greenhouse systems within the top three floors of the building was determined by taking into consideration two factors that conditioned the use of one system or another in the different growing areas. These two factors were the ceiling height of the different growing zones and the plant capacity per unit of area that each system could hold.

Impact decided to place the A-Go-Gro systems in the areas that have higher roof level on the most southern portion of the third and fourth floors in order to take advantage of the natural light exposure the plants will have. The team placed most of the A-Go-Gro towers in a way that the plants will have exposure to sunlight throughout a full rotation. The team also decided to space them apart with at least a 4ft clear separation in order to give enough clearance for the people working in the greenhouse. Also the layout provides space for maintenance of a specific tower without having to alter the rest of the systems, and the majority of the towers are grouped in pairs so that the water and lighting systems of those might be shared. Six vertical rotatory towers were placed in the third floor, nine vertical rotatory towers on the fourth floor, and twenty-seven vertical rotatory towers on the fifth floor. The vertical rotatory towers will be exposed to natural lighting from the south, east, and west sides of the building as well as from the roof. The placemen to the systems can be appreciated in the layout plan view of the greenhouse areas in Appendix N.

Impact decided to use the areas with a lower ceiling for the ZipGrow towers system, as noted in Figure 60, because the tower's height is 5ft, and the frame's maximum height is 8ft. The team arranged the ZipGrow towers in a way that they can be grouped together by the framing structures and provide enough space for people to work or maintain the system. There are a total of 332 ZipGrow towers locate throughout the four areas assigned to ZipGrow towers systems.

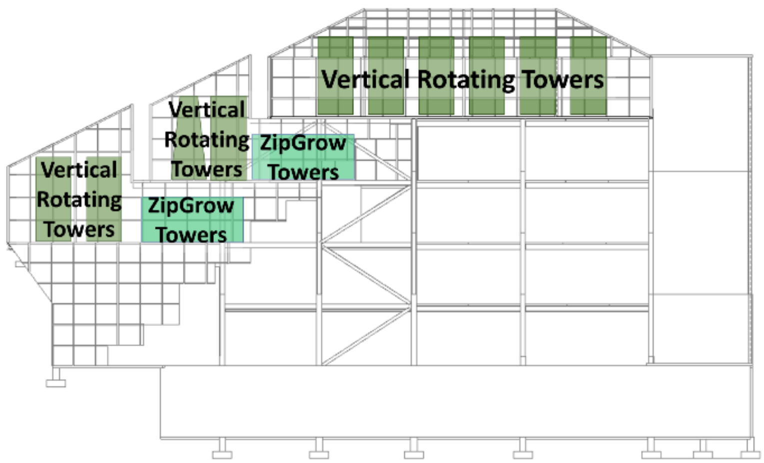


Figure 60 Growing Towers in Growing Areas.

The team performed a growing capacity analysis of both systems in order to choose the system to be used on the fifth floor. Table 23 shows the calculation for the amount of plants grown per unit floor area for each system.

Table 23 System growing capacity per unit area comparison

System	Area (sf)	Number of towers/racks	Plants per tower/rack	Total Plants	Plants per sf
ZipGrow Towers	400	144	6	864	**2.17**
Vertical Rotatory Tower	60	24	30	720	**12**

As shown in the table the vertical rotatory towers system has a greater amount of plants being grown per unit area at a given point in time. In addition, it was also considered that the top level of the building enabled the possibility of having a higher glazed roof. Therefore, the team used only vertical rotatory towers for the fifth floor of the building.

Finally, *Impact* also assigned areas in the 3 greenhouse levels for the processing and seeding of new plants. The team placed movable shelves that will be used to transport newly grown plants from these areas to the different systems. These movable shelves can be found on every level of the greenhouse areas and will serve to transport the new plants for both systems. Also, static shelves were placed with the purpose of housing the newly seeded plants until they have grown enough to be placed in the systems. These static shelves will also have artificial lighting. A layout plan view of the greenhouse areas can be found in Appendix N.

LED Lighting for Growing Areas

In addition to maximizing the sunlight through the towers and the exterior glazing system, *Impact*'s design uses an LED lighting system for the plants to increase the production of crops, especially during the winter season when the daylight hours are reduced. This system will be composed of a 105 W purple light LED fixture placed in between the crops, as can be seen in Figure 61. Two lights will cover the 18 foot high rotating towers, and one light for the 5 foot ZipGrow towers. The specifications for the lighting fixture used can be seen in Table 24.

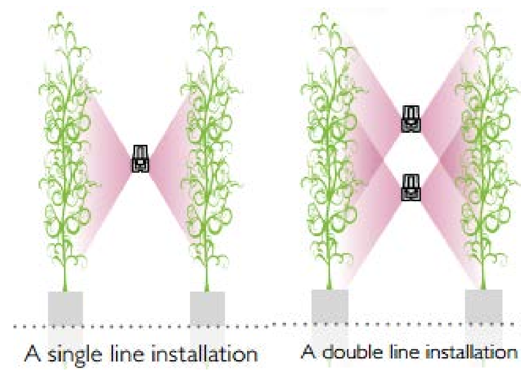


Figure 61 LED Lighting in Growing Towers (Phillips).

Table 24 Crops Lighting Specifications

Crops Lighting Specifications				
Product	Wattage (W)	Length (mm)	Length (ft)	umol/s
GreenPower LED interlighting module deep red/blue	105	2473	8.11	220

To minimize the energy consumption of the LED fixtures, the growing areas have lighting controlled by zones. Each type of fruit, vegetable or herb that can be grown in these spaces may have different requirements for the amount of light and exposure time. Therefore, each zone is controlled by a daylighting sensor that will adjust to the lighting required by each type of crop. Then this will be controlled by the customer, who will have a panel to regulate the zones depending on the type of plant growing in it. An example of the defined zones is illustrated on the floor layout seen in Figure 62 while the layout for the three growing areas can be seen in Appendix N.

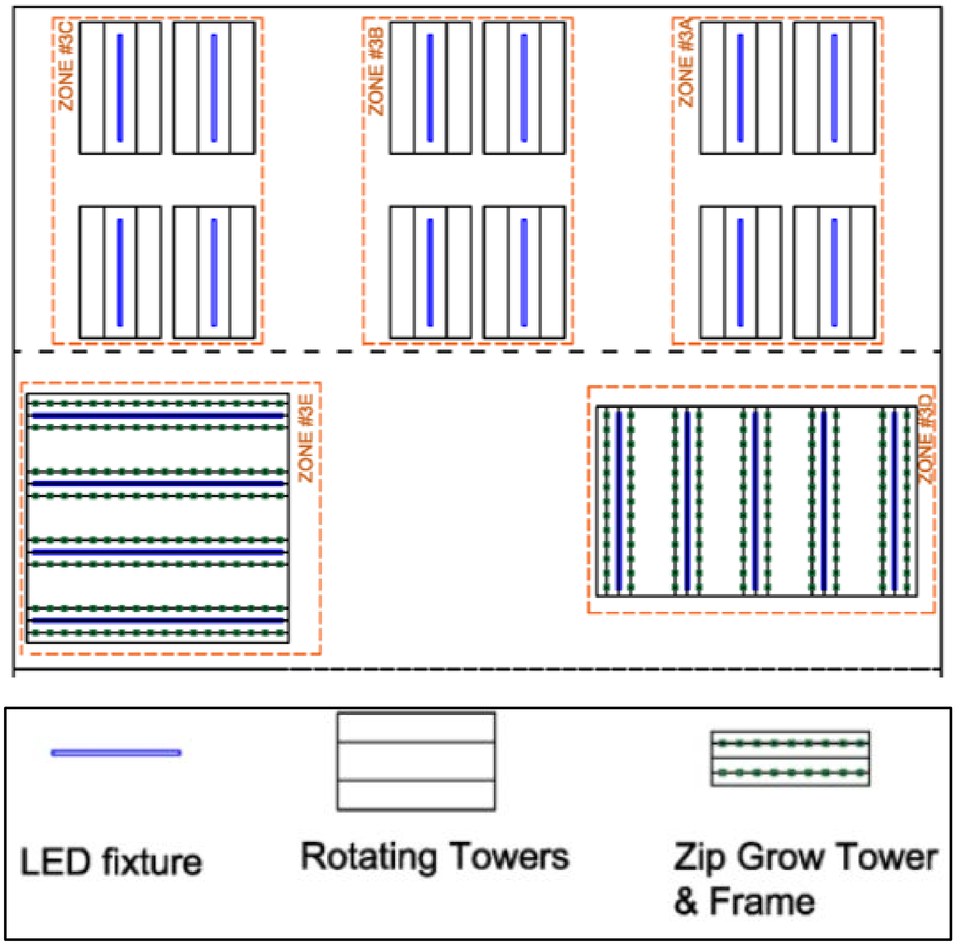


Figure 62 Growing Area Zones.

4.2.4 Mechanical System

As stated earlier the group chose to use a water source heat pump system (WSHP) for the non-growing area spaces of the building. A WSHP system is a highly adaptable and energy efficient system. The system employs units of varying sizes, based on their tonnage, and distributes them throughout the building creating different zones connected through a water distribution loop. A boiler of appropriate capacity is placed in the mechanical room within the basement and cooling tower, of appropriate capacity is placed behind the building on grade. With the heating and cooling loads for each room calculated and the system selected the group proceeded to create zones on each floor.

Zones were separated based on ease of control, so most zones created were single rooms but a few zones were created from adjacent rooms with occupants continuously traveling back and forth between the two rooms. The total heating and cooling load capacities for each zone were converted from BTU/hr. to tons. Specific unit sizes were selected based on their tonnage ranging from 0.5 tons to 10 tons. Heat pumps sorted by size and floor can be seen in Table 25. Zones that required more than 4 tons received additional heat pumps. There were certain exceptions to this size limit with large rooms such as the market and assembly spaces. All units 3.5 tons and below could easily fit within the structural framing within the plenum space. Units of 7.5 tons and 10 tons would have to be placed on the floor. The total tonnage and unit weight present for each floor can be seen in Table 26. Next the group created key plans for each floor highlighting the room name, cooling load capacity, heat pump tonnage and number of units. All key mechanical key plans are located in Appendix O.

Table 25 Heat Pump Unit Sizes by Floor

Size (tons)	0.5	1	1.5	2	3	3.5	7.5	10
Unit Weight (lb)	165	173	264	269	343	431	676	785
Floor								
Basement	1							
1	1			1	1			4
2					2		3	
3		1	3			1		
4	1	1	2	1	1			

Table 26 Total Tons per floor

Floor	Areas of conditioned space	Total tons	Total Unit Weight
Basement	324.5	0.5	165
1	7669.5	45.5	3917
2	5342.1	28.5	2714
3	3278	9	1396
4	2716.4	8.5	1305

Growing Area Mechanical System

The growing areas only require heating so the group decided to utilize a baseboard heating system around the perimeter of the growing area. The colder air close to the exterior glass naturally falls to the floor level and the baseboard counteracts this airflow by creating a draft barrier that warms the air along the walls and the entire space as a whole. This heating method also balances the natural humidity in the growing area and prevents molding and rotting of the plants. The piping within the baseboard uses heated water directly from the same boiler used by the water source heat pumps.

Growing Area Ventilation

The primary goals of any greenhouse ventilation system include:

- Minimizing interior drafts
- Providing accurate humidity control
- Preventing the over-heating of plants
- Sustaining optimum growing conditions

All of these goals can be met by implementing a forced air ventilation system for the growing areas. This system is comprised of an exhaust fan on the west face of the growing area about three feet above the plant level and motorized air inlets directly across from the fan on the east face of the growing area. Whenever the inside temperature surpasses comfortable levels the thermostat will automatically open the shutters and the exhaust fan will turn on. Outside air is then pulled in and across the growing area until it is exhausted through the exhaust fan. When the desired temperature is reached again this system will automatically shut itself off and the air inlets will close. Forced air ventilation was chosen over natural ventilation because there is greater control of the temperature and humidity within the space creating optimal growing conditions for plants.

4.2.5 Electrical & Interior Lighting

In addition to the purple LED lighting used in the greenhouses, the remainder of the building will be illuminated with white lighting LED fixtures. This lighting design is used throughout the building, and incorporates a total of eight different Cooper Lighting fixtures. As can be seen in Table 27, this fixtures only represent four different models, with various light output levels. The light output levels were determined based on the different illuminance requirements for the room. For example, the classrooms used a fixture with an output of 4622 for a 50 foot candles, while the corridors used a 2330 lumens fixture, as it requires a lower illuminance of 15 foot candles. Also the height at which the fixture was located, also influenced the light output. For example, the atrium required a higher lumen output in order to deliver the 30 foot candle requirement at a longer distance from the surface. The layout of these fixtures can be seen in the *AGI32* calculations, provided in Appendix H.

Table 27 Lighting Product Specifications

Table 27: Lighting Product Specifications					
Product	Specification	Power Consumption (W)	Lumens Delivered	Total Number of Fixtures	Total Consumption (kW)
Divide	DSI-WS-4L35-1C-UNV-4	74.4	7167	18	1339.2
	DSI-WS-3L35-1C-UNV-4	56.9	6678	30	1707
	DSI-WS-2L35-1C-UNV-4	45.4	4622	72	3268.8
RZL WB	RZL-WB-3L35-1C-UNV-4	48	5210	40	1920
	RZL-WB-2L35-1C-UNV-4	42	4170	47	1974
HE Luminous	282-R-2L35-ESTG-UDD-SI-95HT	38	3000	132	5016
	282-R-1L35-ESTG-UDD-SI-95HT	29	2330	104	3016
22 DR	S22DR-1-L35-ETG-4-U-DD-S92HT	7	440	80	560

With the use of LED fixtures throughout the building, *Impact* was able to cut the energy consumption of lighting in comparison to the limits required by *2013 ASHRAE Fundamentals*, previously calculated. The baseline provided by *ASHRAE* on based in the conditions for the energy efficiencies of T8 lamps with electronic ballasts. Therefore, the LED design provides 45% savings compared to a fluorescent system. Below in Table 28, can be seen a summary of this comparison. For a more detailed breakdown, please refer to Appendix P.

Table 28 LED Fluorescent Comparison

Annual Lighting Design Comparison	
Total *ASHRAE* Handbook (kWh)	**59690**
Total *Impact* Design (kWh)	**26451**
Energy Saved (kWh)	**33239**
Cost Saved ($)	**4653**

Regenerative Elevator

A regenerative elevator is another energy conscious feature of *Impact's* design. This type of elevator got its name from its regenerative technology. The elevator uses energy as it rises. However when it descend, it releases energy that is captured by the motor and reused when it descends again. The regen elevator saves about one third of the electricity consumed by a Motor Generator elevator servicing 5 floors. This can be seen in Figure 63. An additional advantage to its energy efficiency is that this type of elevator does not require an elevator machine room. This created an additional room that was later replaced with a recycling room, one of the requirements of the 2011 Edition of the Milwaukee Commercial Building Code[15]. Figure 63[14] illustrates the regenerative elevator system.

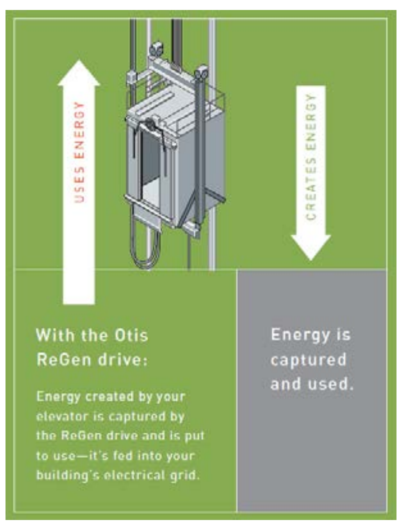


Figure 63 Otis Regen Elevator (Otis).

4.2.6 Plumbing Systems

The water consumption of the building was estimated to be 472,238 gallons annually. The various types and usage quantities can be seen in Table 29. For a more detailed monthly breakdown, Appendix Q provides this information.

Table 29 Water Consumption Chart

Water Consumption Summary	
Usage	Gallons per Year
Irrigation	153,863
Urinals & Toilets	149,101
Fire Protection	895
Aquaponic Tank	4,128
Other	169,320
Total Consumption	**472238**

In addition to the calculation of the consumption, the distribution of the complete plumbing system was elaborated. As it can be seen in Figure 64, the building's water four water sources, two which will serve as supply (City Main & Rain Harvesting) and two which will collect the water (Greywater & Blackwater). The rain harvesting system will only serve the irrigation for the growing areas, meanwhile the City's System will provide water for the rest of the plumbing system, as well as to the growing area in case there is not enough water for irrigation. Meanwhile, the water from the faucets will be collected by a greywater system and the rest of the buildings by blackwater due to the organic material.

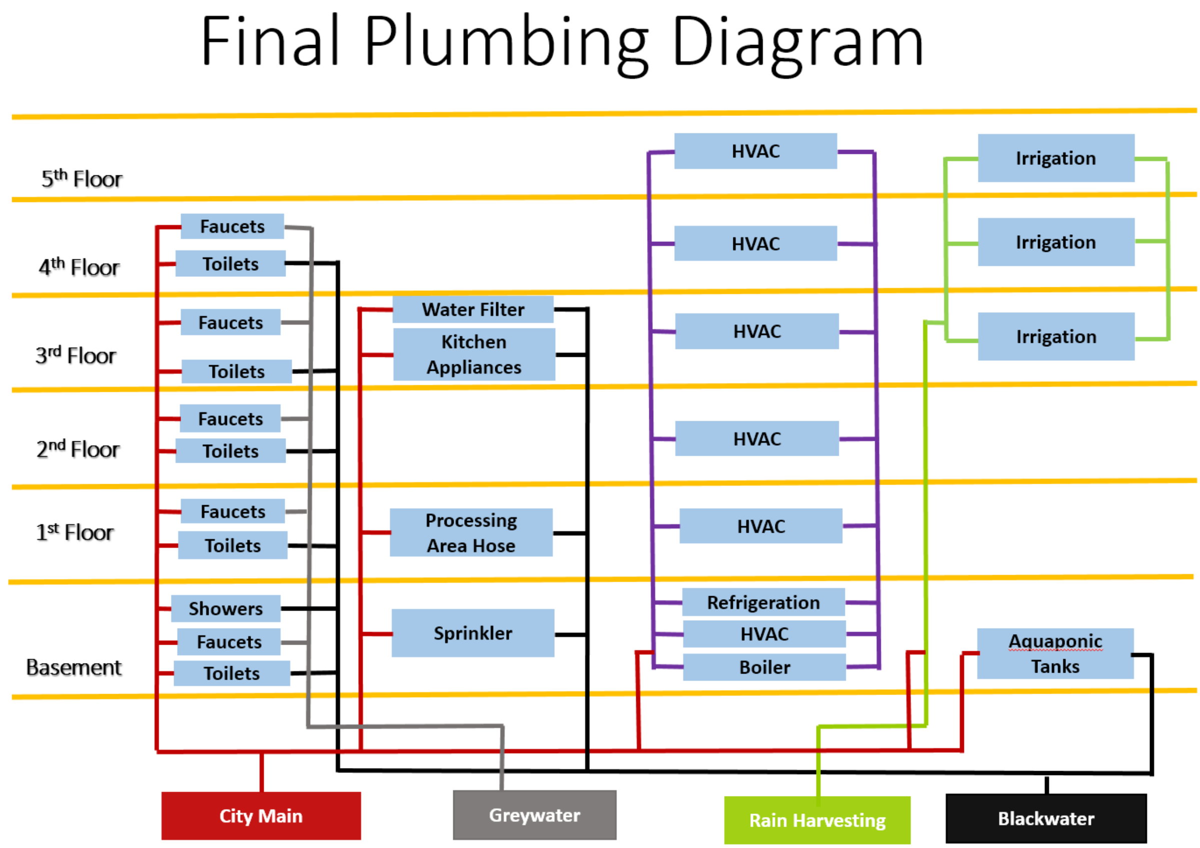


Figure 64 Final Plumbing Design.

Rain Harvesting System

Impact's design incorporated a rain harvesting system into the design. This system supplements the demand for water irrigation, and integrates it with the troughs used for the snow collection, as shown in Figure 65. Depending on the season of the year, this system will harvest from 9,600 to 17,100 gallons of water per month. The initial intent was to use the harvested water for irrigation, in addition to the urinals and toilets. However, after analyzing the monthly rainfall in the area and the collection surface area, the team determined that the water collected will only satisfy the irrigation demand. In addition, this decision reduces the implementation and cost of greywater treatment on site.

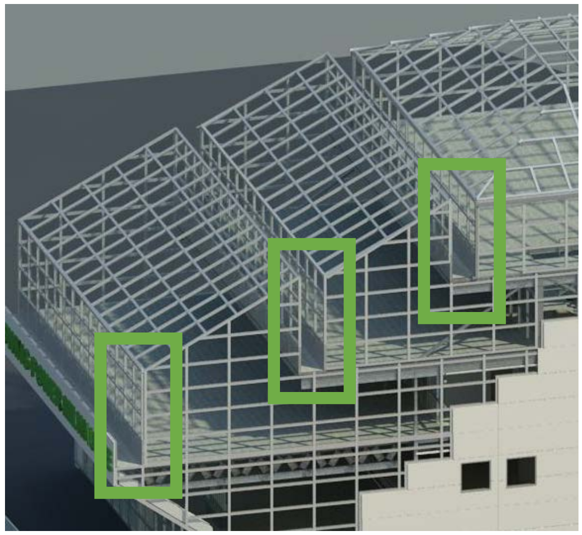


Figure 65 Rain Water Troughs.

In Milwaukee, the warmest months, and consequently the months of highest water demand for irrigation, coincide with those of greatest rainfall, making the system very efficient for this location and diminishing the size of the required underground tank. Meanwhile, during the winter when there is less exposure to the sun, the temperatures are cooler and the rate of evapotranspiration is lower, the demand for irrigation decreases. This relation can be observed in Table 30.

Table 30 Water Consumption per Month per Season

Water Consumption per Month per Season		
	Irrigation Water Demand	Average Gallons Collected per Month
Winter	2331	9646
Spring	12822	13676
Summer	23313	17098
Fall	12822	12653

In addition to the trough design, the proposed system will have 4 inch wide gutters located at the perimeter of the fifth floor roof to maximize the collection of rain. This water will then be piped through 4 inch downspouts which would the empty into the trough, carried through the internal pipes and finally stored in a 10,000 gallon underground tank. To avoid sediments in the system, a metal grate will serve as a first flush system. The first flush keeps large solid debris that accumulate on the roof from entering the system. Growing Power staff will be able to clean this tray through the access window that each greenhouse has. In addition, to the first flush, the system will have a sediment filter, and an activated-carbon filter to remove any organic matter. A drawing of the gutter and downspout system is shown in Figure 65. For a complete layout of the system refer to Appendix R.

Figure 66 Gutter & Downspout Render.

4.3 Structural Systems

Structural Notes are provided in Appendix S. A surface analysis of building code requirements, followed by a couple of sections explaining the design of important structural elements continue this section.

4.3.1 Analysis of Codes

The *2014 Wisconsin Commercial Building Code* along with numerous other design aids were utilized during the analysis of this facility. The *2010 Florida Building Code* was also reviewed for an understanding of the similarities and differences to the *2012 International Building Code*. When approaching a majority of structural design, *ASCE 7-10* was adhered to. Key loads which were calculated or researched from historical models are listed in Table 31.

Table 31 Structural Design Loads

1	DEAD LOADS		
	(A)	WEIGHT OF BUILDING COMPONENTS	AS REQUIRED
	(B)	ROOFING ALLOWANCE	60 PSF
	(C)	GREENHOUSE ROOF AREA - GLAZING & FRAMING	15 PSF
	(D)	GREENHOUSE AREAS	80 PSF
2	LIVE LOADS		
	(A)	OCCUPANCY CATEGORY	II
	(B)	INTERIOR UNLESS NOTED OTHERWISE	100 PSF
	(C)	LIGHT STORAGE	125 PSF
	(D)	LOADING DOCK	250 PSF
	(E)	MECHANICAL EQUIPMENT ROOM	150 PSF OR EQUIP WT
	(F)	CLASSROOMS	40 PSF
	(G)	OFFICES	50 PSF
	(H)	GREENHOUSE AREAS	80 PSF
3	SNOW LOADS		
	(A)	GROUND SNOW LOAD	30 PSF
	(B)	FLAT ROOF SNOW LOAD	20 PSF + DRIFT
	(C)	GREENHOUSE SLOPED ROOF SNOW LOAD	15 PSF + DRIFT
4	WIND LOADS		
	(A)	BASIC WIND SPEED	115 MPH (WI) & 180 MPH (FL)
	(B)	MAXIMUM WIND BASE SHEAR - EAST-WEST	35 KIPS
	(C)	MAXIMUM WIND BASE SHEAR - NORTH-SOUTH	25 KIPS
	(D)	MAIN WIND FORCE RESISTING SYSTEM - SHORT DIRECTION	SPECIAL REINFORCED MASONRY SHEAR WALL
	(E)	MAIN WIND FORCE RESISTING SYSTEM - LONG DIRECTION	STEEL SPECIAL TRUSS MOMENT FRAME
5	SEISMIC LOADS		
	(A)	BASIC LATERAL FORCE RESISTING SYSTEM - SHORT DIRECTION	SPECIAL REINFORCED MASONRY SHEAR WALL
	(B)	BASIC LATERAL FORCE RESISTING SYSTEM - LONG DIRECTION	STEEL SPECIAL TRUSS MOMENT FRAME
	(C)	ANALYSIS PROCEDURE	EQUIVALENT LATERAL FORCE
	(D)	BUILDING SEISMIC WEIGHT	2,200 KIPS
	(E)	BASE SHEAR DUE TO SEISMIC LOADS	60 KIPS

Not including the two small roofs in the rear of the building, the glazed greenhouse roofs account for all roof surface area. A majority of this greenhouse glazing is sloped; in fact all greenhouse roofing is sloped except for a flat section on the top greenhouse. Occupancy live loads were not designed for the roof because access to greenhouse roofing is restricted. Glazing panels were represented as dead loads, and snow loads were calculated. Rain will simply drain with the slope, avoiding ponding effects and similar situations that a flat roof has. The maintained temperature inside of the greenhouse provides a slippery slope for the roof, per code.

Snow Loads were essential to the Milwaukee location design. When navigating *ASCE 7-10*, the determination of ground snow loads, flat-roof, and sloped-roof systems was important. *Impact*'s design does not feature a "low-slope roof" because the monoslope is greater than 15-degrees. The roof is a fully-exposed sloped roof which requires a roof slope factor, Cs. The Cs applicable to *Impact*'s design was 1.0, effectively leveling off the roof during analysis as expressed in Figure 67. In addition to the fully exposed nature which is an adjustment factor, the thermal factor is important for the majority of *Impact*'s roofing which is greenhouse glass. The greenhouse is "maintained at an internal temperature of 50 degrees-F or more which makes it a warm roof and a slippery surface". The definition of a slippery surface to ASCE is if there is "unobstructed and sufficient space available below the eaves to accept all the sliding snow". Our trough system is suitable for this as it will melt any gathered snow.

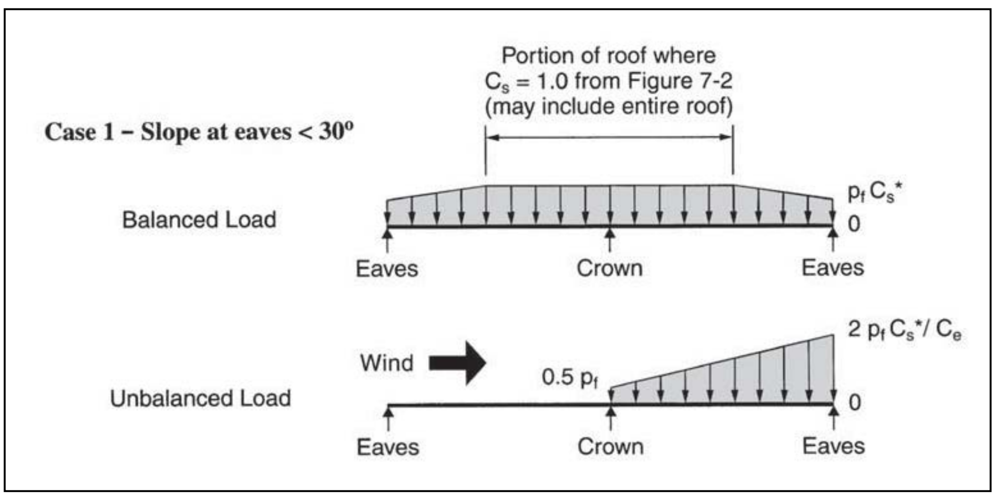


Figure 67 Slope Adjustment Factor (ASCE 7-05).

The shallow slope doesn't enable the team to use a Cs reduction factor, but it does allow the design to be further investigated. The R-vale of our glass is less than 30 ft^2 hr F/Btu so when using Figure 68 the solid line is followed and crossed with the 26-degree slope angle. Drift was examined, but because of the geometry of *Impact's* roofing system, no additional build-up needed to be taken into account. Although slopes are separated, the horizontal distance requires attention towards superimposed snow which is analyzed not in combination with drift, unbalanced, partial, or rain-on-snow loads. Rain-on-snow criteria was inapplicable because Milwaukee's ground snow load is greater than 20 lb/ft^2. There is no ponding instability as well because the slope is sufficient.

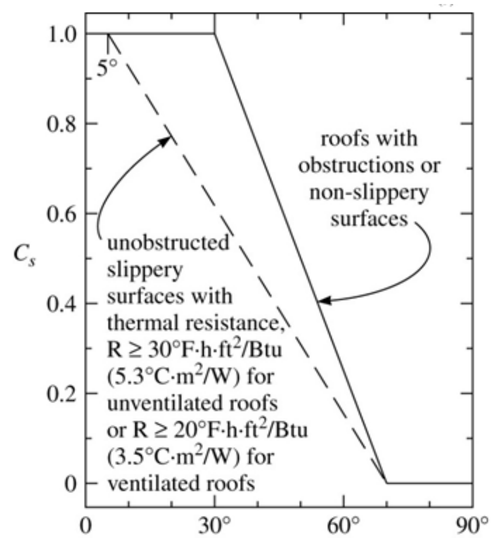


Figure 68 Slippery Surface Plot (ASCE 7-05).

Wind and Seismic loads were analyzed for their lateral effects. Chapters 12 and 19 of *ASCE 7-10* were used for Seismic design. Chapter 26 was used for wind pressure loading. Mentioned earlier in Features, dual systems were designed as our lateral force resisting systems. When gathering factors for load calculations, the specific systems were chosen from tables supplied in Appendix T. Seismic Base Shear was calculated and Seismic Weight summed.

Flood Loads do not apply to this building because it is not located in an area prone to flooding as defined on a flood hazard map.

Figures 70-74 graphically display dead and live occupancy loads used to calculate the steel framing system. Specified by the metal deck and concrete combined slab catalog located in Appendix U, the dead load was rounded to 60 psf. The only different dead loads are for the roofs and subgrade ceilings. The basement has a subgrade roof that supports a layer of soil as well as a mechanical cooling tower (orange). The increased dead load is accounted for with a lower live load for maintenance as this is not a high traffic area. The blue area on this same plan is the loading dock which will experience high live loads from trucks, hence the 250 psf load situation. All greenhouse areas on floors 3, 4, and 5 are coded in black and were designed with 80 psf live and dead load. The 80 psf live load was selected as these areas are largely growing units and paths are hallway-like. There is limited occupancy maximums for the greenhouse areas so this is sufficient. It was *Impact*'s decision to provide a surplus dead load to the composite slab weight to account for all growing equipment. Instead of calculating each point load for legs of growing towers, the distributed load was efficient. Punching shear of the concrete on metal deck was checked and approved. Classrooms, offices, and light storage received live loads as specified by Chapter 4 of *ASCE 7-10*.

Figure 69 Area Load Color Key.

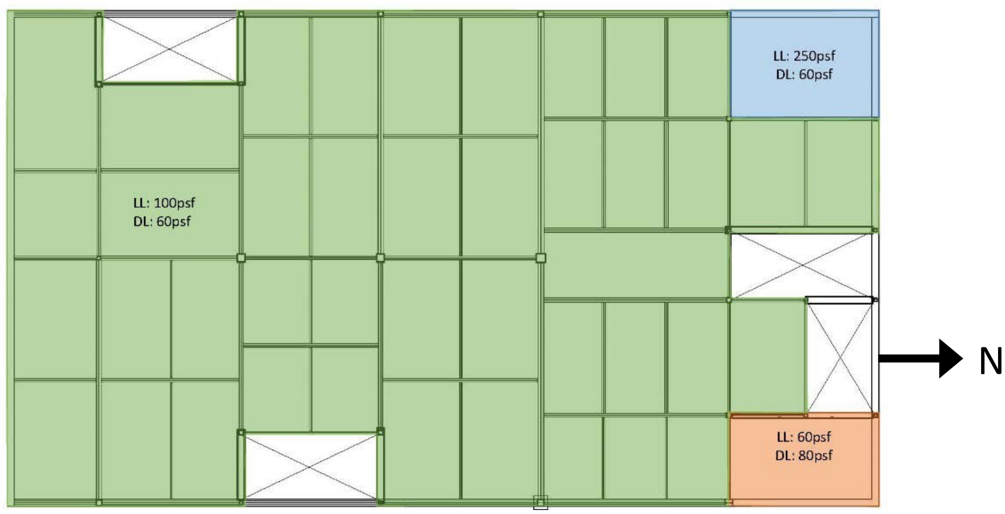


Figure 70 First Floor.

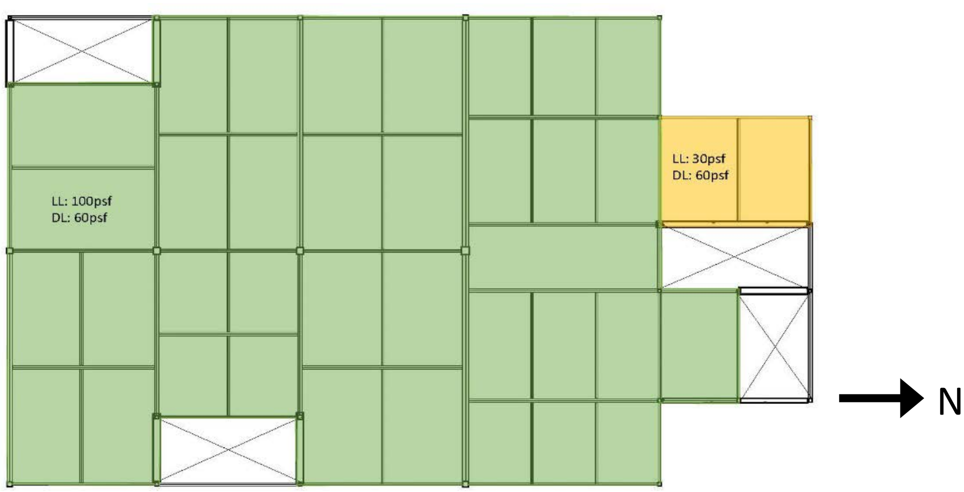


Figure 71 Second Floor.

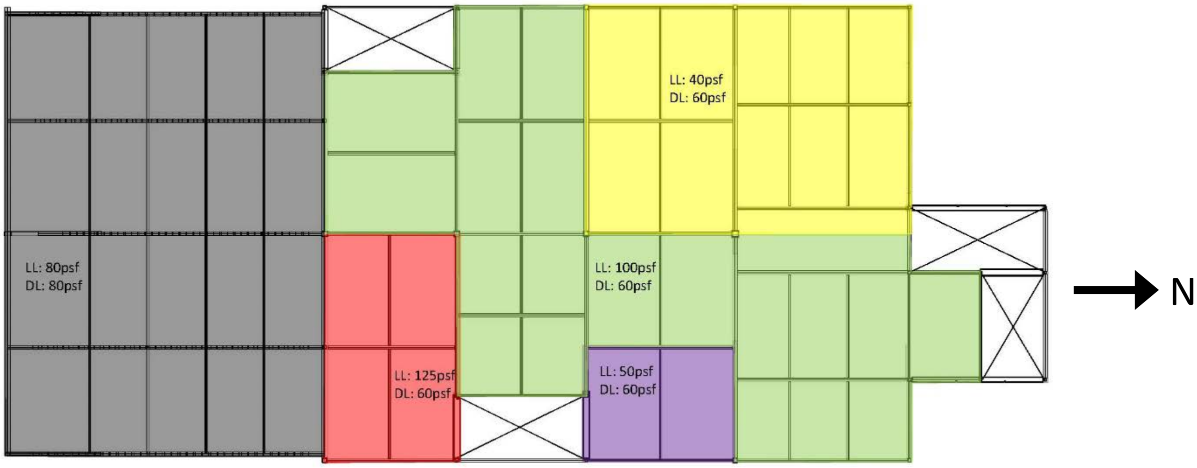


Figure 72 Third Floor.

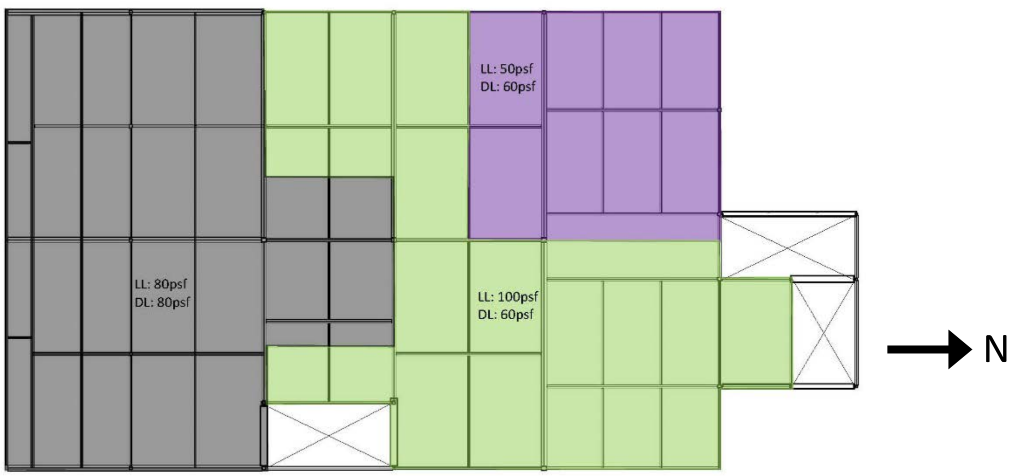


Figure 73 Fourth Floor.

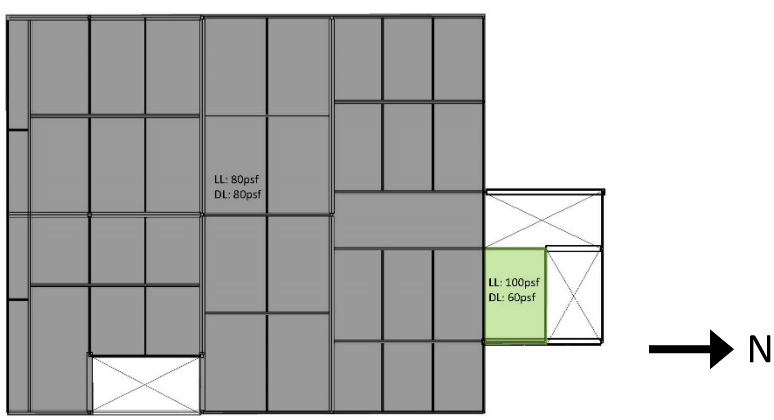


Figure 74 Fifth Floor.

4.3.2 Steel Framing Design

To analyze gravity loads on horizontal members a spreadsheet was created to track each and every member (found in Appendix V). Labels were given to members and their lengths and other situational properties were listed. Using area loads and tributary areas, uniform loads were calculated for framing which ran perpendicular to the metal decking as this is the primary support for it. Once the beams with uniform loads were calculated and their start and end shears found, girders with only point loads from shear connections or a combination of point and uniform loads

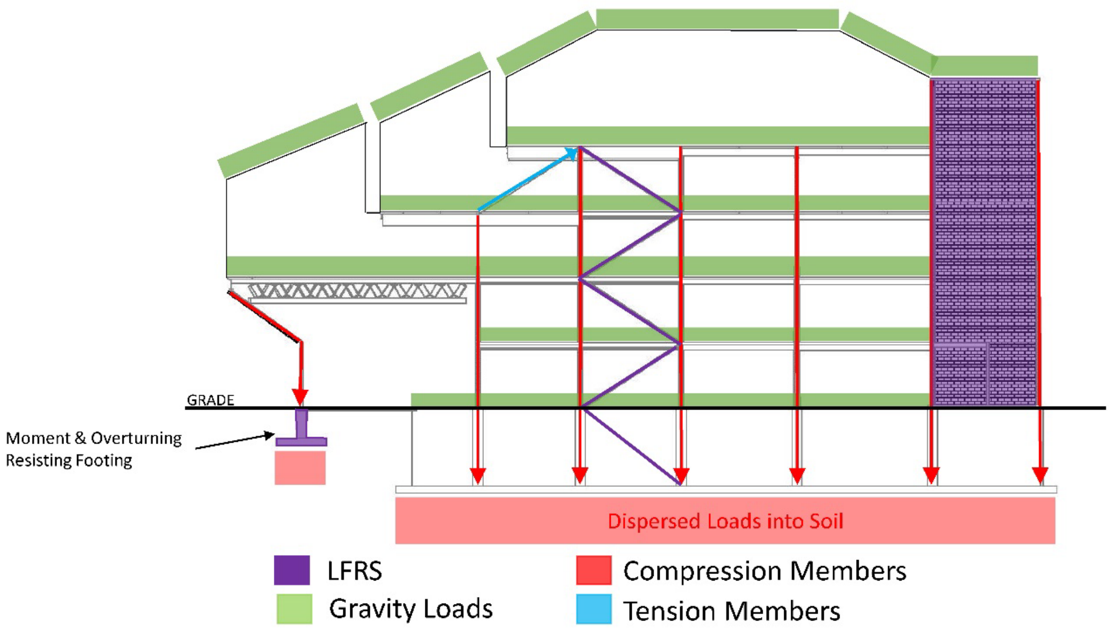


Figure 75 Load Path Analysis.

were analyzed. Figure 75 schematically traces load paths from start (green) to dispersion into the soil (red). The purple elements serve as Lateral Force Resisting Elements (LFRS).

When designing sections for the beams, total deflection was compared to the maximum allowable deflection and sections chosen based upon their factored moments. The sections with the most efficient use of material for their weight were selected using Table 3-2 of the *AISC Steel Construction Manual*, WF organized by Zx. Listed in the aforementioned spreadsheet are start and end reactions for all members so that the steel fabricator will be able to engineer details for shear and moment connections where needed. Once the total loads from each floor were summed, the axial forces on each column were analyzed. The gradual buildup of load in some cases made it a viable option to reduce the size of the HSS column section as elevation grew. A spreadsheet was used to organize which horizontal members connected to columns for each floor, Appendix W. This ensured an accurate calculation of the column load takedown. Loads from this spreadsheet are identified in Appendix X. Seen in Figure 76, the column sizes vary.

Column Schedule

Levels		C-1	D-1	F-1	G-1	F-2	G-2	A-3	C-3	D-3	F-3	G-3	I-3	A-4	E-4	I-4	A-5	E-5
Roof (65'-0")																		
4 (52'-0")	13'		4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4				4x4x1/4							
3 (39'-0")	13'		4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	6x6x3/16	6x6x3/8	6x6x3/8	6x6x3/16	6x6x3/16
2 (26'-0")	13'		4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/16	4x4x1/4	6x6x3/8	9x9x3/8	8x8x5/16	6x6x3/8	8x8x5/16
1 (13'-0")	13'		4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/8	6x6x3/8	6x6x3/16	8x8x5/16	12x12x3/8	8x8x3/8	8x8x5/16	9x9x3/8
G (0'-0")	13'	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/8	6x6x3/8	6x6x3/8	6x6x3/8	6x6x3/16	9x9x3/8	14x14x1/2	10x10x3/8	8x8x3/8	12x12x3/8
Basement (-15'-0")	15'					6x6x3/16	6x6x3/16		8x8x5/16	6x6x3/8	8x8x5/16	8x8x5/16			16x16x1/2			14x14x1/2
Grid Lines		C-1	D-1	F-1	G-1	F-2	G-2	A-3	C-3	D-3	F-3	G-3	I-3	A-4	E-4	I-4	A-5	E-5
Column Number		001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	016	017
Footing Type		A*	A*	D*	D*	D	D	A*	A	A	A	A	A*	B*	C	B*	B*	C
Baseplate Type		A	A	A	A	A	A	A	B	A	B	B	A	B	F	C	B	E

Levels		H-5	I-5	A-6	B-6	E-6	H-6	I-6	A-7	B-7	E-7	I-7	E-7	C.1-7	F.3-7	A.1-9	E-9	H.1-9
Roof (65'-0")																		
4 (52'-0")	13'																	
3 (39'-0")	13'	6x6x3/16	4x4x1/4	6x6x3/8		8x8x5/16	4x4x1/4	6x6x3/8										
2 (26'-0")	13'	6x6x3/8	4x4x1/4	6x6x3/8		8x8x3/8	6x6x3/16	6x6x3/16	6x6x3/8			6x6x3/8	6x6x3/8	6x6x3/16	6x6x3/16			
1 (13'-0")	13'	6x6x3/8	4x4x1/4	8x8x5/16	6x6x3/16	10x10x3/8	6x6x3/8	6x6x3/16	6x6x3/8	6x6x3/8		8x8x3/8	6x6x3/8			8x8x5/16	8x8x5/16	8x8x5/16
G (0'-0")	13'	8x8x5/16	6x6x3/16	8x8x5/16	6x6x3/8	12x12x3/8	6x6x3/8	6x6x3/8	6x6x3/8	6x6x3/8		9x9x3/8				8x8x5/16	8x8x5/16	8x8x5/16
Basement (-15'-0")	15'	8x8x3/8			6x6x3/8	14x14x1/2	8x8x5/16			8x8x5/16	6x6x3/8							
Grid Lines		H-5	I-5	A-6	B-6	E-6	H-6	I-6	A-7	B-7	E-7	I-7	E-7	C.1-7	F.3-7	A.1-9	E-9	H.1-9
Column Number		018	019	020	021	022	023	024	025	026	027	028	029	030	031	032	033	034
Footing Type		D	D*	D*	D	C	D	D*	D*	D	A	B*	/	/	/	/	C	C
Baseplate Type		B	A	B	A	E	B	A	A	B	A	B	/	/	/	/	/	/

*=indicates part of foundation wall

Figure 76 Column Schedule.

This Column Schedule lists numerical labels for columns as they were designed as well as grid references. Also noticeable at the bottom of Figure 76, footing types and baseplate types are specified by their correlating letter, explained in the Foundations Section.

4.3.3 Design Focuses

Impact emphasized the importance to mesh aesthetic and functional ideas with the physical layout of the structure. Beginning with design focuses, main features of the facility are laid out. Highlighted below are main architectural features that were implemented using a variety of structural solutions. *Impact* highly valued integration in the multi-phased planning and design of the Growing Power facility. Intentions were to not only have modern and innovative ideas and details but to provide innovative solutions to combine them with the physical structure. Below in Table 32 are these primary features, visually depicted in Figure 77.

Table 32 Architectural Features with Structural Solutions

#	Architectural Features	Structural Solution	Notes
1	Open Market Atrium	Cantilevers	Eliminates several obstructive columns
		Open-Web Steel Truss Joists	Maximizes exterior light penetration, able to span 45', less steel per foot length, allows mechanical penetrations
2	Stair/Elevator Shaftway	Masonry Shear Wall Shafts	Also acts as a lateral force resistance system
3	Heavy Water Tank Loads on Level G	Reduced Basement Floor area	Slab on grade, saves time and money by reducing excavation volume
	Assembly Area	Mid Span Columns with Steel Framing	Steel is great for customizing areas and bays to maintain column alignment
4	Prominent Encased Columns	Moment Footings	HSS columns, encased with architectural material act as the south wall lateral force resisting system
5	Greenhouses	Stainless Steel HSS members structurally supporting Live and Dead Roof Loads while framing the glazing	Acting as mullions, the HSS members serve dual roles transfering loads to the main frame
		HSS Sill	Sill transfers column point loads which are not aligned with the super-structure columns into uniform loads
6	Rain Collection Troughs	Dual Level Column Bases	Frontward columns are supported by the primary use level of the greenhouse while opposite columns are integrated with the trough system
		Three Individual Greenhouse Systems	Discontinuous roof faces, segmenting potential load surfaces
7	Exterior Fascade Panels	Recognition of Surface Loading and Hanging Loads	Panels, Act as a continuous surface which transfers Wind Loads to their connection points to the project's frame
		Customization of Mullions to match panel dimensions	Maintaining structural requirements
8	Ceiling Height: 10' Floor to Floor Height: 13'	Awareness when designing bays and framing schemes	Metal Decking spans and beam/girder layout

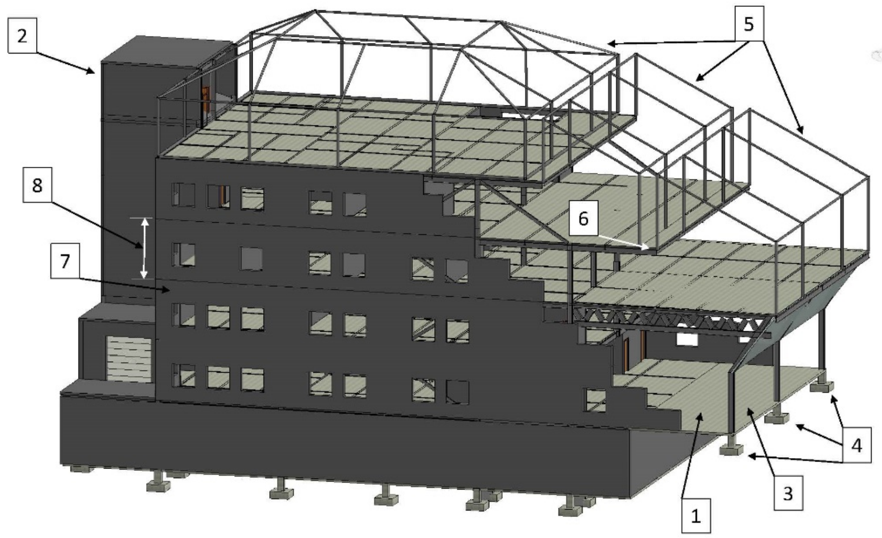


Figure 77 Architectural Features.

Open Market Atrium

Open to the level above, the first floor market space was intended to welcome the visitor and provide significant daylight to visitors. The large opening and absence of a second floor meant that there would be a lack of interior columns in this space. Open web truss joists were chosen to span the 45 foot opening supporting the third floor. The ceiling of the atrium is exposed structural elements. The 36-inch deep open web of the selected truss allows light and mechanical equipment to pass through as needed while weighing significantly less than a comparative wide flange girder; see Appendix Y for specification. By utilizing the truss joists rather than wide flange beams, *Impact* was able to decrease steel weight from 22,000 lbs to roughly 12,500 lbs to support this area.

Trusses are versatile. They are used for the construction of both floors and flat roofs. The selection of trusses was due to the fact that the spans were too large for wide flange members and the load on the above floor is too high. We also did not want to have exposed interior columns on the market floor, as we wanted to achieve a cleaner look. We did however, join the 5 trusses with two large girders distributing the load to three angled columns that serve as exterior columns. These columns help support the trusses and the load that they are being exposed to as well as act as a lateral resisting system for the front part of the building. We researched the additional column loads that this will add and as a result, we determined that it would be necessary that moment footings be added to the base of each of the three angled column.

The overlapping floors located above the market space, but with the second floor below initially seemed proper for column placement for the top half of the structure. When analyzed, the load paths needed to vertically track to the foundation through the market area. As a solution, to reduce aforementioned columns, cantilever girders were designed for the overhanging growing areas. Using a software to aid in analysis, TEDDS was useful for cantilevers and a sample calculation is provided in Appendix Z. In addition to structural inconveniences, the avoided columns would have been obstructive to greenhouse layout. *Impact*'s growing systems are modular and their layout dispersed across the floor area. Excessive columns would have interfered with this plan.

Lateral Force Resisting System

Side-by-side elevator and stair shafts extending from the basement to top level in the north side of the facility breaks the steel framing grid. Initially a second staircase was placed along the eastward facing wall, designed for accordingly. After team review of *International Building Code* 2012, a third stairway connecting the entry level to the second floor was added to satisfy egress requirements. The mirroring stairwells are built up with concrete masonry units (CMU) acting as core systems for each face.

As explained below, our lateral force resisting system (LFRS) was designed to be integrated with our three stairway shafts and one elevator shaft noticeable in Figure 78. Instead of having two separate elements, we decided to use two vertical steel braces from basement to top floor. In the rear of the building (North side), the concentration of shafts extend from basement to top floor, so this was our lateral resisting core structure. Concrete masonry units (CMU) are specified to construct these shear walls.

Braced framing is used to refer to frames that utilize trusses as the primary load-carrying mechanism at each floor level. Trussing is used for the vertical bracing system in combination with horizontal diaphragms. Trussing is formed by insertion of diagonal members. Shear panels, moment resistive joists between members, and trussing are a few basic ways to achieve bracing for lateral loads. For the structural components that surround the stairs and elevator, we decided to utilize a single diagonally braced system. We chose this particular system as opposed to others because it serves a dual function.

For vibrations and/or lateral forces in the north and southward directions the lateral force resisting system (LFRS) is a combination of special steel truss moment frames and special reinforced masonry shear walls as named in Chapter 12 of *ASCE 7-10*. Tables of LFRS's can be found in Appendix T. The north wall dual shafts were engineered for this resistance as well. Remaining was the south facing wall to ensure torqueing of the structure would not occur if solely the north face was held in place. The three large encased columns at the atrium space are integral to the structure, and their strength is capable of counteracting potential lateral forces. Each column has a moment resisting isolated footing that has been designed to resist shear forces and overturning moments. Using the *United States Geological Survey*, *ASCE 7-10* code was utilized for design. This report can be found Appendix AA. Seismic Base Shear was determined using the Seismic Weight of the building which was used in these footing and shear wall calculations. These three footings are the only foundations on a different level than the majority for the structure.

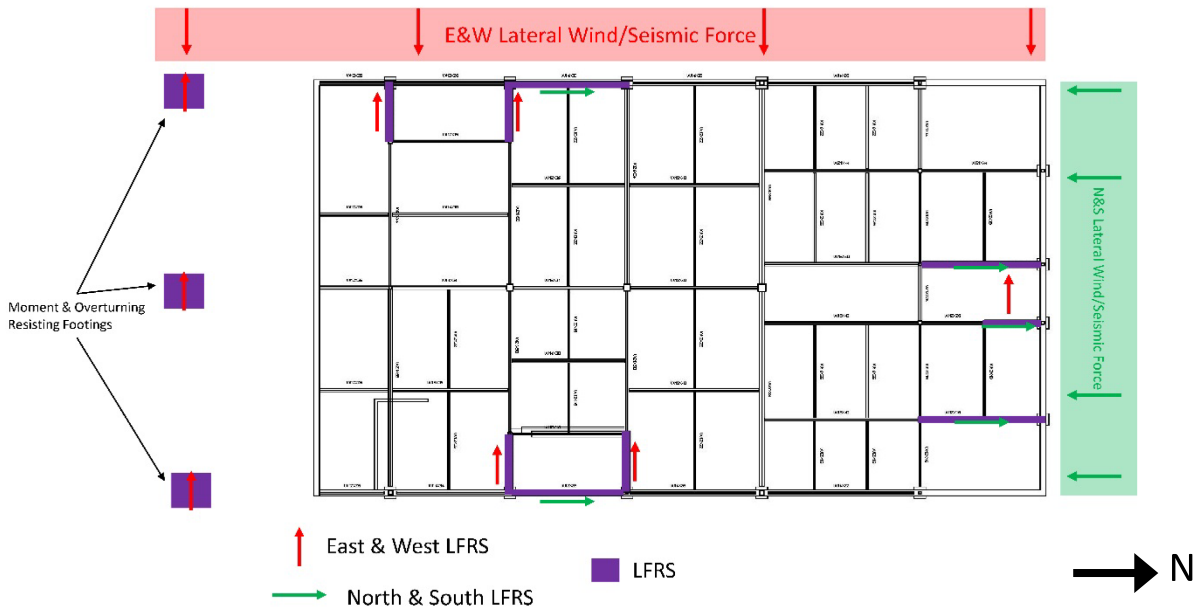


Figure 78 Lateral Force Resisting Systems.

Aquaponic Demonstration Tanks

Part of the educational initiative this project has spawned is addressed by the public market space where interesting and visually appealing systems are displayed. One of these systems is an aquaponic system which has two high capacity water tanks with a ZipGrow system. These high loads were challenging and being elevated was structurally inconvenient. It was *Impact*'s assessment of the advantages of a large basement versus the reduction of it with the aquaponic system bearing on grade. The conclusion was to reduce the basement footprint so that a separate slab on grade would support a section of market space where heavy loads are anticipated. An estimated 900 compacted-cubic yards of soil were saved from being excavated from this decision. Additionally, concrete for added length of foundation wall structure was avoided.

Assembly Area

Prior to the decision to use steel rather than reinforced concrete as the primary structural material, the areas were defined. The irregular layout lent itself to steel framing which can ideally customize spaces. The assembly area requires an open floor layout with few obstructive columns. Column placement was chosen at mid span of steel members spanning from East to West. Once bays were designed, *Impact* tried to replicate the same distances between beams so that maximum distance to be spanned would be regular. By regulating the span lengths to a maximum of 12 feet, a uniform metal decking could be selected. By selecting one metal decking type for the project, the opportunities for construction errors are limited. One detail is required and continuity is emphasized. Decking type 2WH-36 Composite Deck made of 18 gauge steel with a normal weight concrete slab depth of 5.5 inches was selected. Its superimposed load capacity at the project's maximum open span exceeded projected loading scenarios and has a 1 hour fire rating. The specification can be found in Appendix U.

Encased Columns

The three prominent columns at the entrance to the Growing Power facility are encased in an architectural material. In addition to being encased, these columns are called to be galvanized. Galvanization is specified for all material which is exposed to the weather or high amounts of moisture as in the greenhouses. The three encased columns are not exposed to weather, because the glazing protects them from this. Another design alteration was a shift from wide flange members to hollow structural sections (HSS). Not only do HSS members weigh less per linear foot but they are visually more attractive. This is advantageous for *Impact*'s design as there was an intentional effort to have structural steel exposed.

Greenhouses and Rain Collection Troughs

Each of the three greenhouses were custom designed. Research on glazing material, live loads, and visual appearance were involved in this effort.

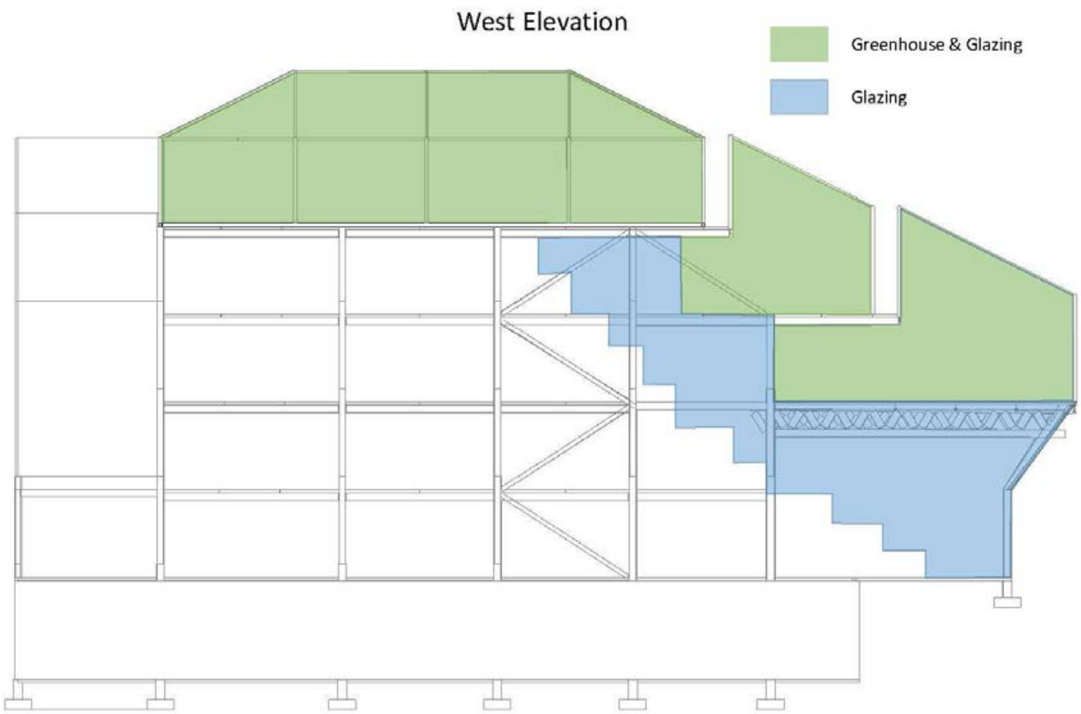


Figure 79 Greenhouse and Glazing Areas.

Table 33 Greenhouse Glazing

Greenhouse Glazing (All walls and roofs except roof on the 5th floor greenhouse)										
Unit Make Up			Physical Properties (Page 19)				Thermal Properties (U-Factor Argon – Page 8)		Light Properties	
Exterior Glass	Airspace	Inboard Glass	Total Thickness	Weight	Max Dimension	Max Area	Summer	Winter	Visible Light	UV Transmission
LoE 272 (6mm)	Argon (13mm)	Clear (6mm)	25mm (0.942 in)	6.5 lbs/ft^2	144 in	50 sq ft	0.22	0.25	70%	14%

5th Floor Greenhouse Roof Glazing										
Unit Make Up			Physical Properties (Page 19)				Thermal Properties (U-Factor Argon – Page 8)		Light Properties	
Exterior Glass	Airspace	Inboard Glass	Total Thickness	Weight	Max Dimension	Max Area	Summer	Winter	Visible Light	UV Transmission
LoE 240 (6mm)	Argon (13mm)	Clear (6mm)	25mm (0.942 in)	6.5 lbs/ft^2	144 in	50 sq ft	0.23	0.25	37%	13%

Placement of growing area was the first decision that began architectural planning. Once the growing areas were split to three greenhouse levels, the team approached the structural roofing design. The one slope roof system was chosen to maximize the potential of natural light penetration.

Three roofs in a row provided an incline for sliding snow that inevitably would accumulate on the roof tops. We broke up the roof with four feet wide troughs as seen in Figure 79. The result of this were three troughs in the empty spaces between the north and south-facing greenhouse walls, as well as one overhanging the south face of the building. To utilize all resources as possible to continue the sustainable design, a collection system was implemented to collect any precipitation gathered by the roof area. There are three precipitation collection trough systems for the greenhouse roofs.

Specifications from Cardinal (selected glazing manufacturer) recommended a maximum glass pane of 50 sqft with a maximum dimension of 144 in. to resist fracture from wind loading, Table 33. The design wind pressure is 35 psf, which can be compared to Figure 80 for adequate strength using the red annotation line. This figure helped in the design of glazing panels as well. Building on the integration of *Impact*'s design, the window panels were designed to similar dimensions as the exterior architectural paneling on the East and West faces of the building. HSS stainless steel members were chosen to both support the greenhouse as well as frame and hold the glazing. The integration of this structurally supporting mullion system can be seen in Figure 81 and 82.

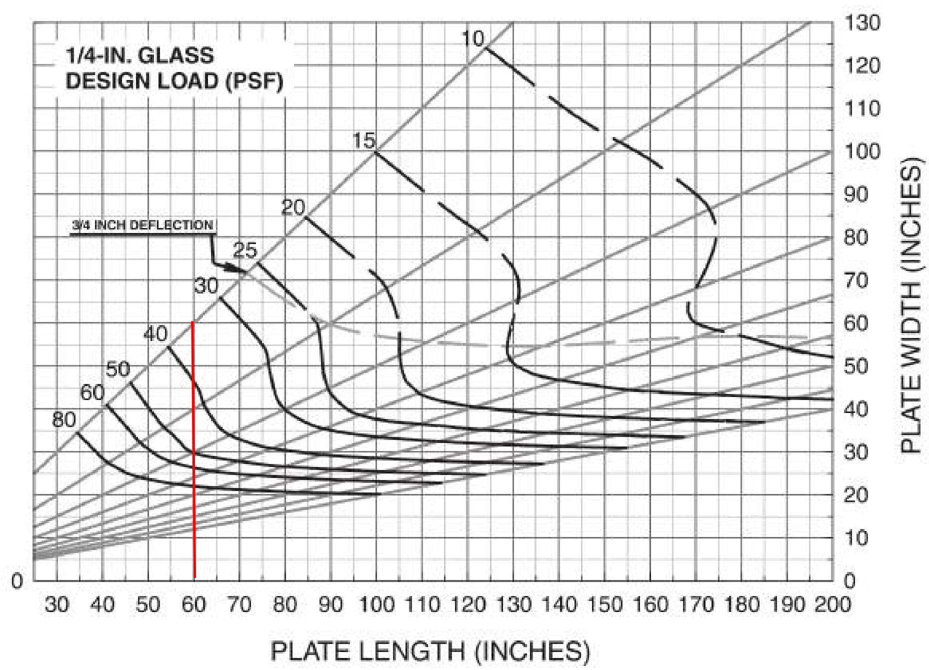


Figure 80 Wind Pressure Loads (Cardinal Glass Industries).

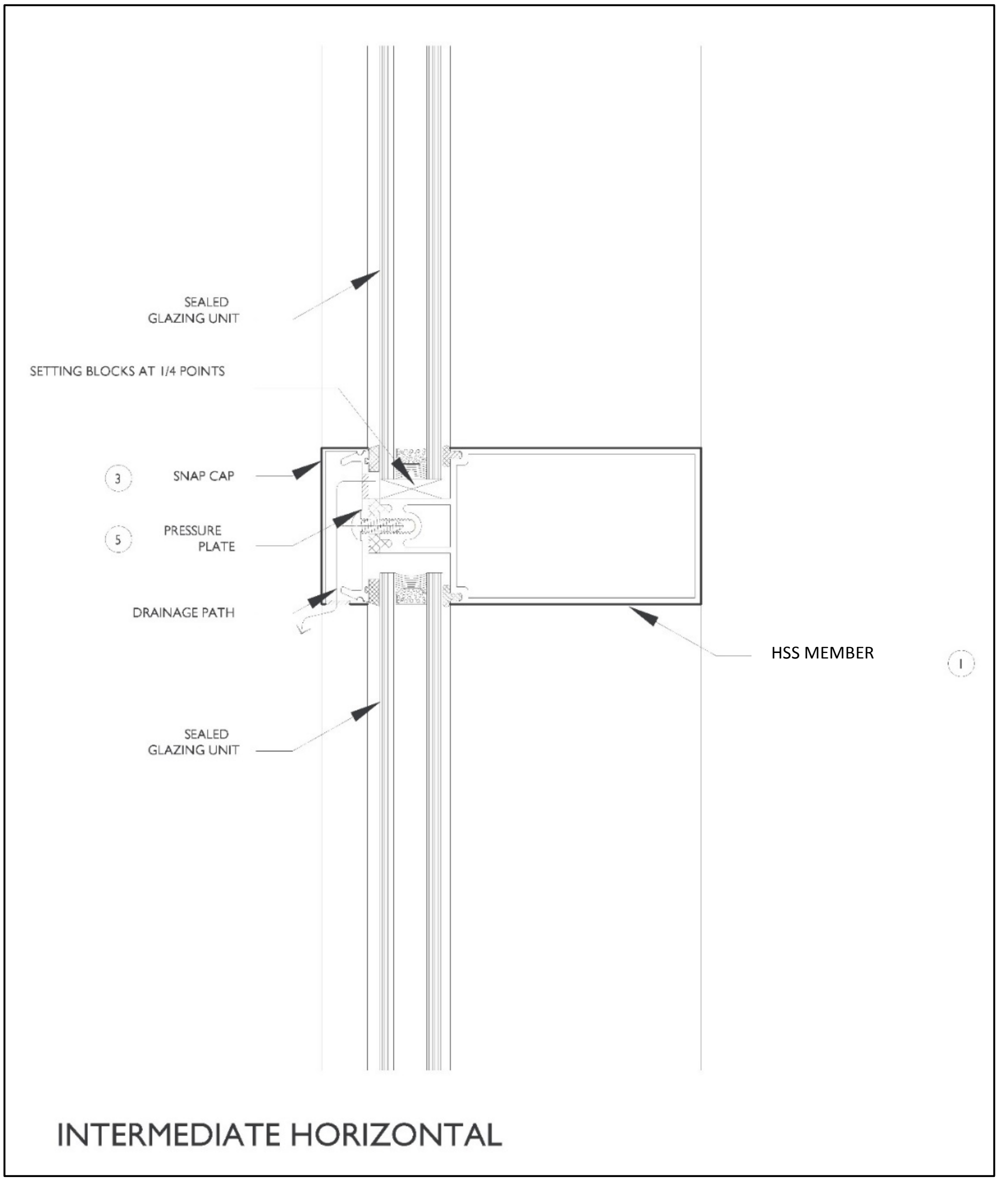


Figure 81 HSS stainless steel framing connection to Glazing (Cardinal Glass Industries).

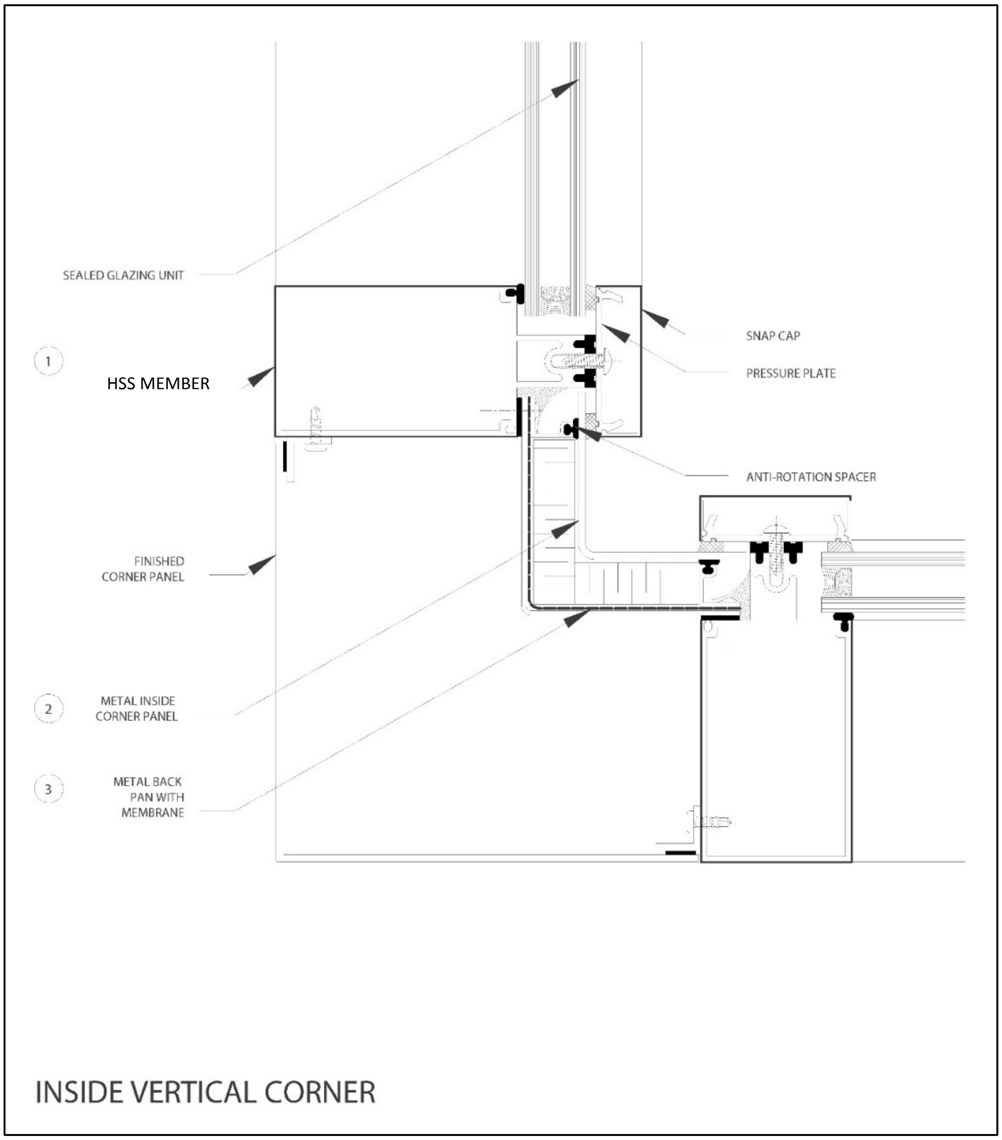


Figure 82 Glazing Connection at Vertical Corner (Cardinal Glass Industries).

Several greenhouse HSS columns line up with the columns of the building's super structure in which direct axial load transfer occurs. In the spans where this does not happen, a horizontal transfer HSS member spans the length and converts point column loads from the greenhouse into a uniform load on the girders of the 4th steel level. A Greenhouse Framing Log is presented as Appendix AB where HSS member sizes for the framing are listed.

Exterior Facade Panels

Façade panels receive wind load just as glazing does on the greenhouses. We recognized the wind pressure and the load distribution that the panels initiated. Each panel acts as a continuous surface which transfers wind loads to the associated steel framing member that it is connected to. This transfer produces lateral loads as well as combined bending and axial effects on the steel columns. Lateral loads from this transfer were minimal as well as the gravity load from panel weight. The connection sketches are included in Appendix AC as details 6-9. Noted in the greenhouse section, these panels were mimicked by the glazing panels to depict a visually uniform façade combination of transparency and solid panels.

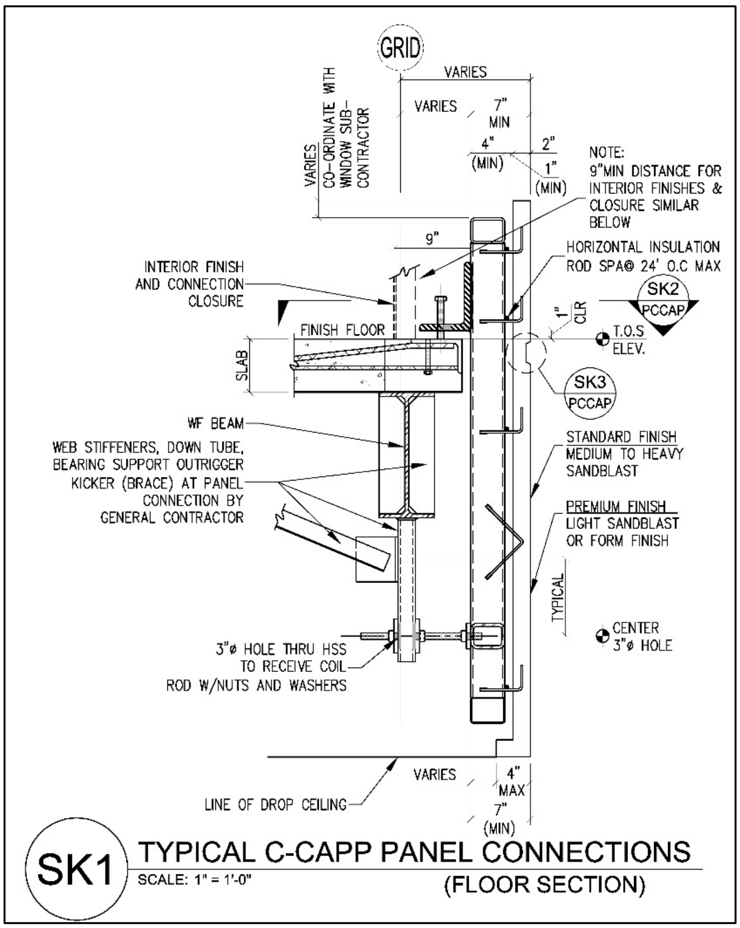


Figure 83 Precast Panel Connection (Clark Pacific).

Floor Heights

The designated floor heights from steel to steel was selected as 13 feet so that ceilings would be a generous 10 feet above the top of finished slab. This provided the structural team with a restriction that all steel members must conform within this 3 foot section between metal decking of the above slab to the drop ceiling of the current level. Understanding that mechanical equipment and ducts need to run in this plenum space, *Impact* aimed to keep maximum member sizes 24 inches deep, leaving an independent level for all mechanical. Some members are larger such as W30x99 girders, which impede upon this gap. Clash detection and integration modeling allows for these instances where early design can run equipment in the unobstructed bays of beams.

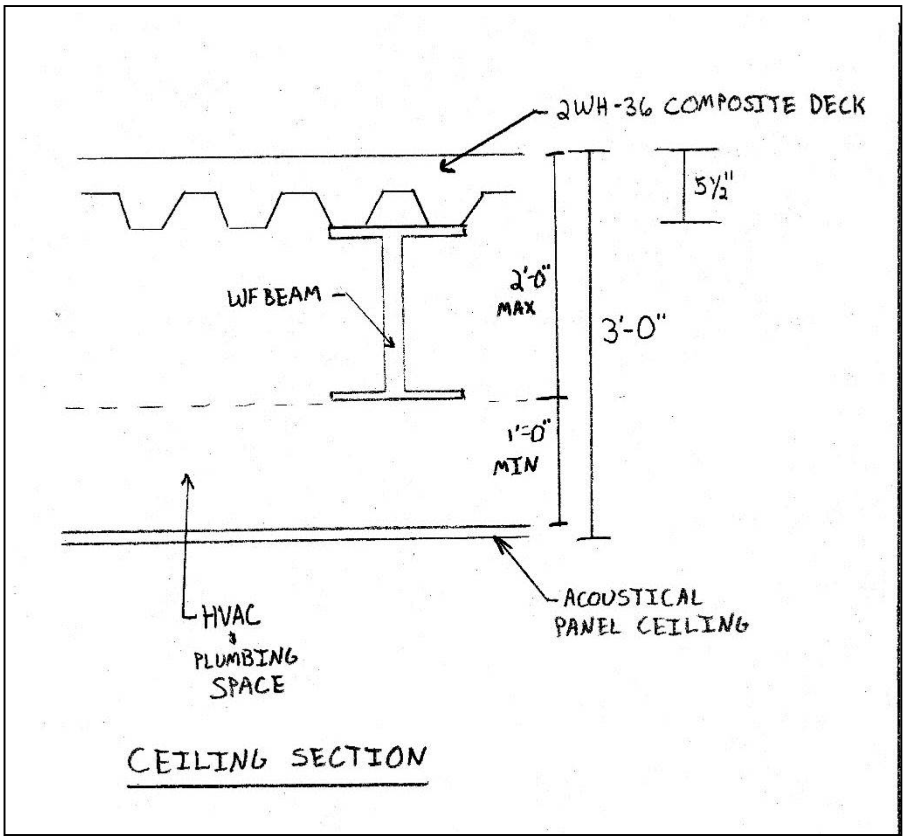


Figure 84 Ceiling Section.

4.3.4 Foundations

When approaching the challenge of foundations the first objective was determining whether a shallow or deep system should be used. The *Geotechnical Report and Analysis* supplied by Growing Power was referenced in each decision relating to foundations. Important facts gathered from this report concerned allowable soil pressure, type of soil, water saturation levels, and recommendations from the geotechnical engineers.

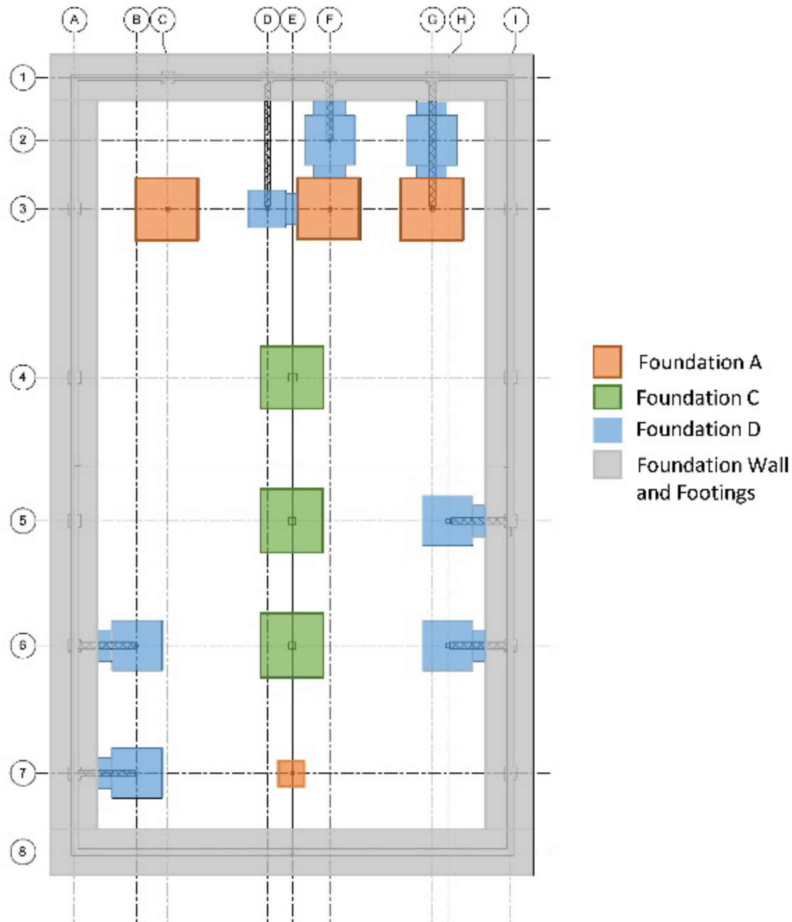


Figure 85 Plan View of Foundations.

Table 34 Footing Log

Footing Log				
Footing Label	A	B	C	D
Type	Isolated	Isolated	Isolated	Strip
Dimensions	8' x 8' x 16"	10' x 10' x 16"	13.5' x 13.5' x 24"	CUSTOM
Load Range (k)	<200	200-400	>400	ALL
Reinforcing	#7 @ 10" o.c.ew.	#7 @ 10" o.c.ew.	#8 @ 10" o.c.ew.	7 @ 10"
Top Elevation	-15'-6"	-15'-6"	-15'-6"	-15'-6"
*=indicates part of foundation wall				

Following recommendations in the geotechnical report, the slab on grade is a separate system from the individual footings for the purposes of settlement and isolating load paths into the surrounding soil. Figure 84 is a plan view where each foundation is displayed as isolated, spread, or part of the foundation wall. Table 34 is the result, where four types of footings were designed to handle all column loads. Appendix AD is a sample calculation of an isolated footing.

The soil on site was determined to be mostly fill material in the upper strata followed by organic silty/sandy clay underlay. This soil will be referred to as the retained soil. A quantity of soil will need to be excavated to provide a depth of at least 15 feet for the basement level of the building. An additional two feet was specified to be trenched for the foundations wall as well as each interior footing. The soil present on site was given a bearing pressure of 1500 psf by the geotechnical engineers. Engineered fill will be the cover material for the 2 additional excavated feet as well as bearing soil for the foundations. This engineered strata with a cast-in-place foundation wall can be seen in Figure 86. Take note that the foundation wall is reinforced.

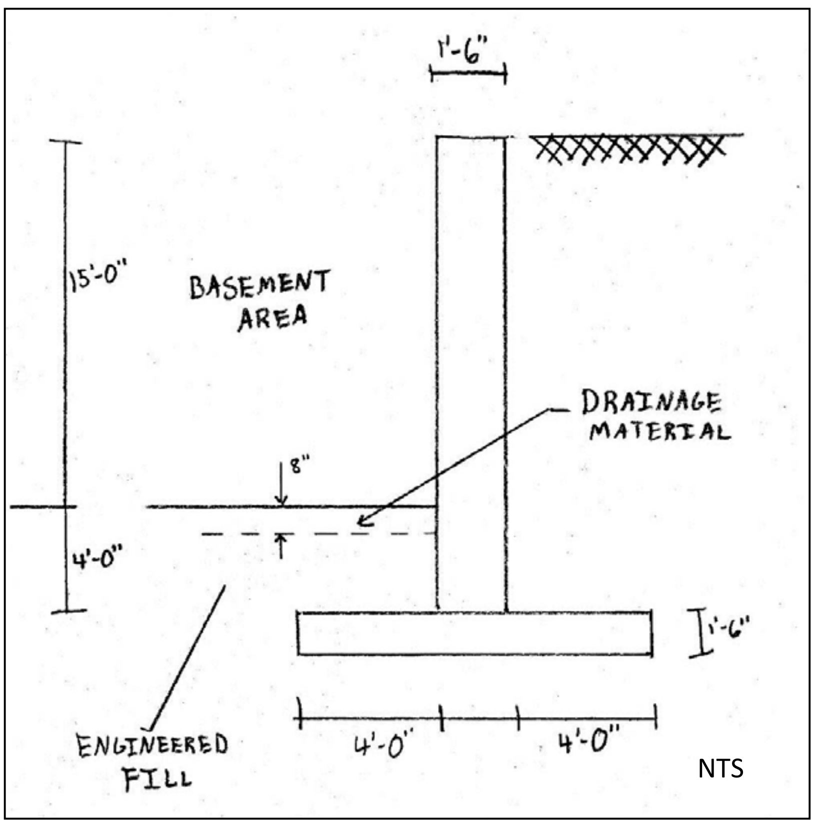


Figure 86 Foundation Wall Detail.

Depending on vehicle size, the additional surcharge from the traffic area would increase the lateral force on the basement wall. This is accounted for by the 200 psf vertical force in Figure 87. This surcharge effect will increase overturning and bending effects in the steel columns.

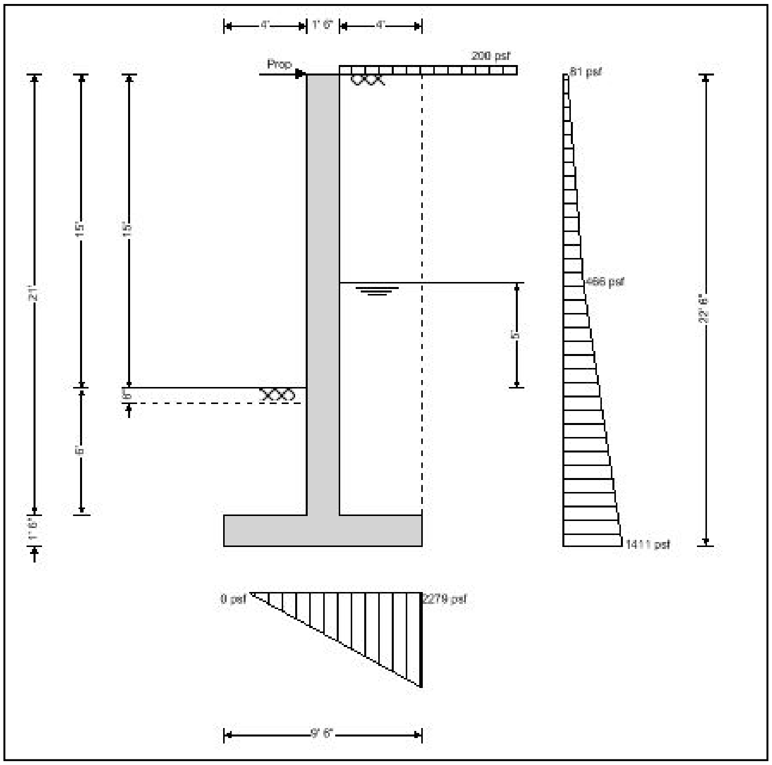


Figure 87 Typical Foundation Wall Analysis.

Successfully transferring axial loads from the HSS columns to the reinforced concrete footings depends on proper baseplate design. The baseplates are welded to the base of columns which when placed are connected to the anchor bolts protruding from a leveling plate as seen in Figure 88. Baseplates were designed with TEDDS. Grout is then injected under the leveling plate to provide a continuous material for load transfer. The number of anchor bolts is determined by potential shear from lateral loads including seismic and wind loading. Details of a typical baseplate are shown in Figure 88.

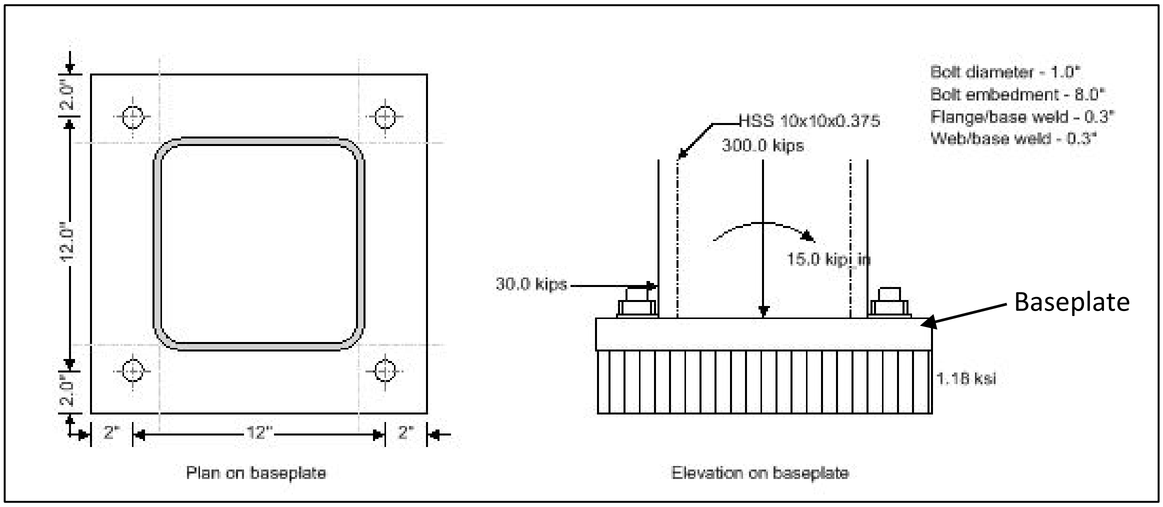


Figure 88 Typical Baseplate Detail.

As for the footing itself, punching shear, beam bending, and one-way shear were analyzed. Reinforcement was placed based upon these factors and spaced at the discretion of the designer. Footings where overturning moments are applied were accounted for as well. Three types of isolated footings were designed to better economize the formwork placement. A fourth, spread footing, is listed for custom applications. Key design information for baseplates is displayed in Table 35. Reinforcement is also specified and exists in both directions. Each footing was assigned to a range of column loads. To maintain uniformity, baseplates were specified as well. For each section of HSS specified in the structural design, there is a corresponding baseplate.

Table 35 Baseplate Log

Baseplate Label		A	B	C	D	E	F
HSS Section	b x h	6 x 6	8 x 8 & 9 x 9	10 x 10	12 x 12	14 x 14	16 x 16
Baseplate Dimensions	b x h	12" x 12"	15" x 15"	16" x 16"	19" x 19"	20" x 20"	23" x 23"
	t	1.5"	1.5"	1.5"	1.5"	1.5"	1.5"

4.4 Construction Project Management

4.4.1 Project Delivery Method

Impact decided to use a Design Build delivery method with a Guaranteed Maximum Price contract. The team believe that the scope of work presented by the project is demanding and specific because of the incorporated greenhouse areas and systems. The use of a Design Build delivery method would allow the owner to provide conceptual plan of the project on the Request for Proposals Then, the Design Built bidders will compete on basis of quality, price, and schedule. The contracted joint venture of architects, engineers, and builders will be in charge of the project from start to end. By using a Guaranteed Maximum Price the owner is assured that the price of the project will remain fixed unless the scope is changed. At the same time, the project's cost estimate will take into account all the work needed to complete the project in contrast to other contract types, like Lump Sum Bid, in which the bids presented would only include only the work detailed in the drawings and documents.

4.4.2 Site Layout

The vertical farm building has a footprint with dimensions of approximately 70 feet by 150 feet and will be placed in the southern frontage of the site. The site is in a suburban residential area; therefore, *Impact* created a site plan layout that will minimize the effects of the construction project on the surroundings. Safety, site accessibility, and security were the main principles that determined the allocation of spaces in the site plan layout. Figure 89 shows area subdivisions designated to specific purposes, allowing traffic accessibility without major interferences to construction activities. The team also addressed security concerns by placing chain link fences around the perimeter of the property during the construction phase. The plan also separates the construction area from the existing buildings and adjacent dwelling. *Impact* placed 4 gates allowing regulated access to all areas in the property. Also, traffic was restricted to a one-way direction on the access road in order to facilitate large vehicle maneuvers and their loading/unloading processes.

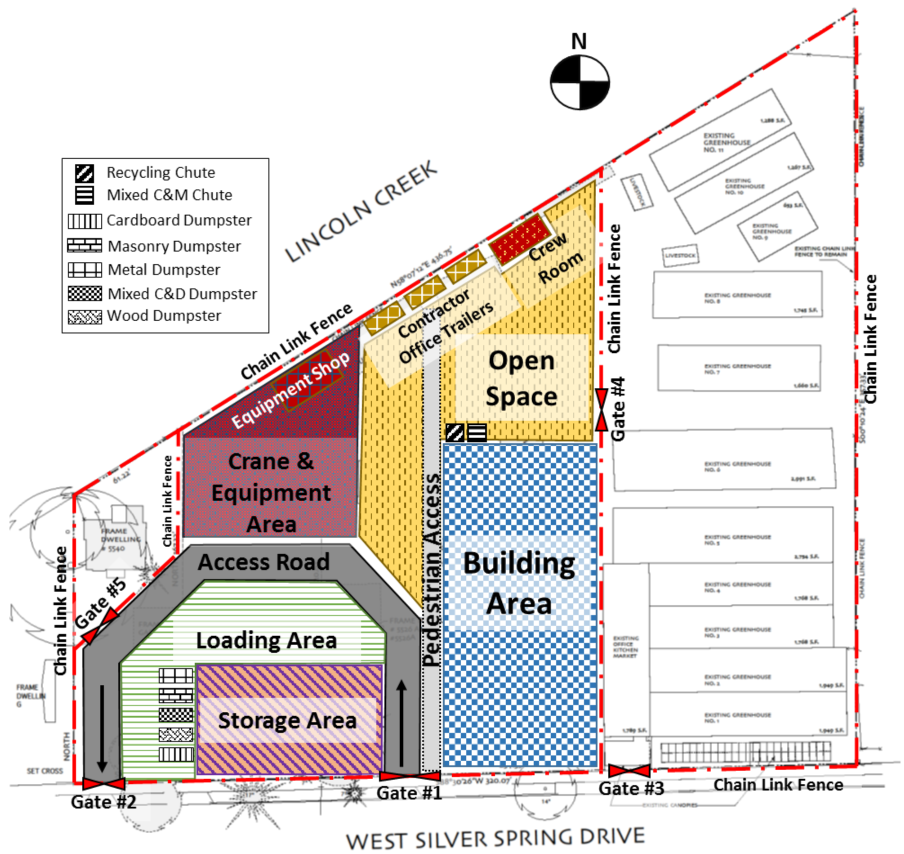


Figure 89 Site Plan Layout.

4.4.3 Cost Estimate

Conceptual Design Estimate

The modified model used in the conceptual design estimate encompassed all the RS Means models detailed in the Cost Estimation Methodology section but it did not completely represent *Impact's* design in an accurate manner because of the limitations that come with the use of the RS Means models. The creation of a modified model approach led to the calculation of a single square foot cost for the whole building. The square foot cost for this modified model was $245.20, which resulted in a project total cost of $12,260,000.

The Conceptual Design estimate in UniFormat categories can be seen in Table 36. In addition, an estimate with more detailed UniFormit subcategories can be seen in Appendix AE. The final project cost was updated to Milwaukee and Miami locations using conversion factors from RS Means. The cost is greater in Milwaukee because its location factor is higher than the national average while Miami has a location factor lower than the national average. This result is about 15.9% greater than the actual project cost specified by the Architect, which was approximately $11 million. Since it was a conceptual design estimate, the accuracy is within an acceptable range of ±15% as detailed in the Estimate Types Background section.

Table 36 Conceptual Design Cost Estimate

Uniformat Category	Total Cost	$ / S.F.	% of Cost
A. Substructure	$ 809,000	$ 16.18	7%
B. Shell	$ 1,673,000	$ 33.46	14%
C. Interiors	$ 2,316,500	$ 46.33	19%
D. Services	$ 4,454,500	$ 89.09	36%
E. Equipment & Furnishings	$ -	$ -	0%
F. Special Construction & Demolition	$ -	$ -	0%
G. Building Sitework	$ -	$ -	0%
Y. Miscellaneous	$ -	$ -	0%
Z. General Conditions	$ 3,007,000	$ 60.14	25%
Project Total Cost Estimate	$ 12,260,000	$ 245.20	50,000 S.F.
Total Cost Estimate: Milwuakee, WI	**$ 12,750,400**	**$ 255.01**	
Total Cost Estimate: Miami, FL	**$ 10,739,760**	**$ 223.39**	

Design Development Estimate

The detailed estimate was a Class-A Design Development estimate which allowed *Impact* to account for all the work items present in the design of the building. Then the team grouped those work items under the UniFormat categories in order to prepare an estimate that was easier to understand. The total cost for the project located in Milwaukee is roughly $12.2 million, resulting in a cost of $245.4 per square foot of construction. *Impact* also analyzed the cost estimate of a future project to be built in Miami, FL, with a cost of $214.97 per square foot as noted in Table 37. Again, the lower cost for the project in Miami is primarily because Miami has a city cost index lower than the national average while Milwaukee's city cost index is higher. The complete detailed estimate in *CSI MasterFormat* and *UniFormat* can be found in Appendixes AF and AG.

Table 37 Design Development Cost Estimate

Uniformat Category	Total Cost	$ / S.F.	% of Cost
A. Substructure	$ 1,212,160	$ 24.24	10%
B. Shell	$ 4,649,667	$ 92.99	39%
C. Interiors	$ 1,093,658	$ 21.87	9%
D. Services	$ 1,950,261	$ 39.01	17%
E. Equipment & Furnishings	$ 104,582	$ 2.09	1%
F. Special Construction & Demolition	$ 331,245	$ 6.62	3%
G. Building Sitework	$ 92,479	$ 1.85	1%
Y. Miscellaneous	$ 600,000	$ 12.00	5%
Z. General Conditions	$ 1,764,000	$ 35.28	15%
Project Total Cost Estimate	$ 11,798,052	$ 235.96	50,000 S.F.
Total Cost Estimate: Milwuakee, WI	**$ 12,269,974**	**$ 245.40**	
Total Cost Estimate: Miami, FL	**$ 10,748,498**	**$ 214.97**	

The project cost estimate for Milwaukee is 11.5% higher than the cost specified by the Architect. Even though this estimate was a design development estimate, the level of detail of the design documents was not sufficient for all the building systems. The team did not design in detail the electrical, mechanical, plumbing and fire protection systems, forcing the use of a square foot cost approach in order to integrate the cost of those systems into the complete estimate. Therefore the design development estimate did not meet the level of accuracy desired for this type of estimate. Normally, a design development estimate, with a high level of detail, would have an accuracy of ±5% as detailed in the Estimate Types Background section.

Finally, *Impact* compared the two estimates. As noted in the Methodology section, the team used the first conceptual estimate as a base line of reference. The first estimate did not accurately accounted for the cost of all the different building components and systems as seen in categories E though Y in Table 37. Even though the categories on the conceptual estimate did not have accurate costs, the overall cost of the building is within the accuracy range. The team compared the conceptual design estimate with the design development estimate and found that the detailed estimate represented the cost of the different building components and system more accurately.

Life Cycle Cost Analysis

The incorporation of interior LED lighting fixtures into the design provided space for a Life Cycle Cost (LLC) analysis. *Impact* found that by using LED fixtures, the annual energy consumption will be reduced by 55.7%. A period of 25 years was defined as the time frame for this analysis because it is the average useful life of the LED fixtures. The team evaluated two possible situations for this analysis.

The first approach involved an interest rate value that would match the historical inflation data in order to project the interest value for the next 25 years. Using R.S. Means historical cost indexes data of the last 25 years, the interest rate of 2.15% was calculated. Therefore, after 25 years, the reduction in energy consumption will save Growing Power $151,926. The second situation considered a fixed interest rate of 5.0%. This approach represented a case in which the inflation rates would increase. After 25 years, Growing Power would save $294,298. As noted, the variation in the interest rate will have a direct effect on the savings Growing Power will have after 25 years.

When considering other components of a LCC analysis. The maintenance costs of the lighting systems were evaluated. With the use of LED fixtures, the replacement cost of incandescent lights will be eliminated. The LED lighting fixtures will not have maintenance costs unless the electric installations for these fixtures require any maintenance work. Therefore, the use of LED lighting is beneficial even though the initial cost of them is higher than the cost for incandescent fixtures. For further details on the energy savings refer to the Electrical & Interior Lighting Results section.

4.4.4 Schedule

Impact developed the project schedule and analyzed different approaches in order to reduce the duration of the project. The team rearranged the relationship of construction activities and overlapped activities that were not interdependent to reduce the construction time. The team divided the project schedule into three main areas:

1. Design Phase: It started in August 28th 2014 at the beginning the WPI Academic Year. Its completion date was on February 6th 2015. In this phase the team developed the architectural, structural and mechanical designs of the project.
2. Preconstruction Phase: It started on January 1st 2015 and will finish in May 5th 2015. In this portion of the project, the team developed the construction schedule and cost estimate based on the design documents from the previous phase.
3. Construction Phase: It will start in April 15th and will be completed by May 13th 2016.

For this project, *Impact* decided to start the construction phase in April 2015 in order to have the building enclosed by the fall season and avoid any construction delays caused by snow. Construction will then be completed by May 2016, in approximately 13 months, as noted in Figure 90. Even though Growing Power did not specify any deadline for the project, the team decreased the

ID	Task Name	Duration	Start	Finish
1	**Constrcution Phase**	**283 days**	**Wed 4/15/15**	**Fri 5/13/16**
2	Construction Starts	0 days	Wed 4/15/15	Wed 4/15/15
3	Start Up - Site Work	8 days	Wed 4/15/15	Fri 4/24/15
4	Excavation & Demolition	29 days	Mon 4/27/15	Thu 6/4/15
5	Substructure	25 days	Mon 5/25/15	Fri 6/26/15
6	Services & Equipment	81 days	Wed 6/17/15	Wed 10/7/15
7	Superstructure	63 days	Mon 6/29/15	Wed 9/23/15
8	Roofing & Exterior Enclosure	49 days	Fri 9/11/15	Wed 11/18/15
9	Building Enclosed	0 days	Wed 11/18/15	Wed 11/18/15
10	MEP Installation	117 days	Thu 11/19/15	Fri 4/29/16
11	Interior Construction & Finis	67 days	Thu 12/17/15	Fri 3/18/16
12	Site Work & Improvements	20 days	Mon 3/21/16	Fri 4/15/16
13	Turn Over & Move In	20 days	Mon 4/18/16	Fri 5/13/16
14	Project Ends	0 days	Fri 5/13/16	Fri 5/13/16

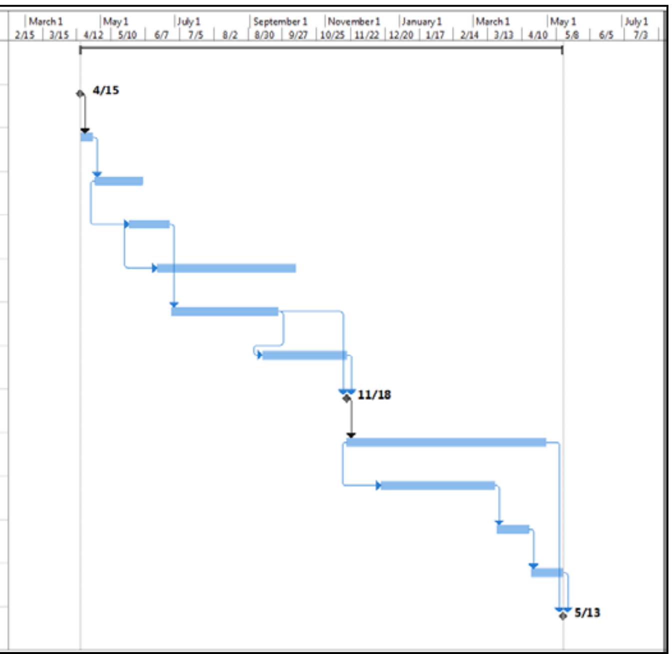


Figure 90 Construction Phase Schedule.

construction time of the project. A complete schedule, including the design and preconstruction phases, can be found Appendix AH.

Impact analyzed the float time available on each schedule activity in order to determine if any delays on the preceding activities will affect the overall project completion date. From this analysis, the team recognized that there is not a considerable amount of float time during the early stages of the construction. The activities related to building enclosure, MEP installation, and building commissioning are the most critical to maintain the project schedule on time. Therefore, it is vital to have the building enclosed as early as possible in order to start the MEP installation. *Impact* would suggest that the structural frames for the glazing walls and roof on the growing areas are prefabricated on ground level and then erected. This will reduce the duration of the roofing work creating float time on preceding activities. Also, the construction management team will have to work with subcontractors to maintain the schedule and reach the building enclosure milestone before the winter months. A complete construction schedule can be found in Appendix AH. The team also decided to take measures to reduce the duration of certain construction activities by increasing the number of crews working on those tasks. The team increased the number of crews instead of having the original crews work overtime because overtime reduces the productivity rate. Reducing the amount of time needed to complete an activity resulted in an increase of the labor cost, which is reflected in Table 38.

Table 38 Additional Labor Cost Summary

Work	R.S. Means Crew	Additional Crews	Additional Labor Cost
Lighting	1 Electrician	4	$ 500,800.00
Painting	1 Painters	6	$ 133,150.61
Flooring	1 Tile Layers	5	$ 70,505.98
Finishes & Interior Construction	2 Carpenters	5	$ 217,062.99
Site Preparation	2 Common Building Laborers	2	$ 8,270.55
Glazing	2 Glaziers	9	$ 1,935,704.40
Compacting Backfill	B-10L	3	$ 20,117.58
Backfill	B-12E	7	$ 923,456.97
Concrete Placing	C-14E	1	$ 10,848.87
Tilling	D-7	2	$ 77,914.61
Exterior Panels Installation	J-1	1	$ 109,376.10
HVAC Installation	Q-5	3	$ 62,186.67

4.4.5 Building Information Modelling (BIM)

As a result of using a BIM approach for the design and planning of this project, *Impact* was able to work as a collaborative and interdisciplinary team. The use of multiple tools to share information facilitated and improved the communication and file management processes. The completion of an integrative digital model of the project was the first result of using software applications such as Autodesk Revit. This 3D model integrated structural, mechanical, and architectural features into the design. The creation of a virtual model provided a better understanding of the project to the different disciplines and enhanced the coordination of work on a collaborative file. Then the virtual representation of the construction phase of the project was completed using *Autodesk Navisworks*, which permitted the integration of the Autodesk Revit model and the Microsoft Project schedule to produce a 5D model. The virtual construction model provided the team with a better understanding of how the construction process would occur. The virtual construction gave a clear representation of how the building would be built; therefore, any work interference between crews or equipment can be prevented. It enhanced the collaborative work of all the disciplines involved in the project to avoid any inconveniences in the construction phase. The simulation provides continuous information about the schedule related to the activities that are taking place in the construction process. Figure 91 shows a summary of the virtual construction phases, these images are taken from the simulation video produced by *Autodesk Navisworks*.

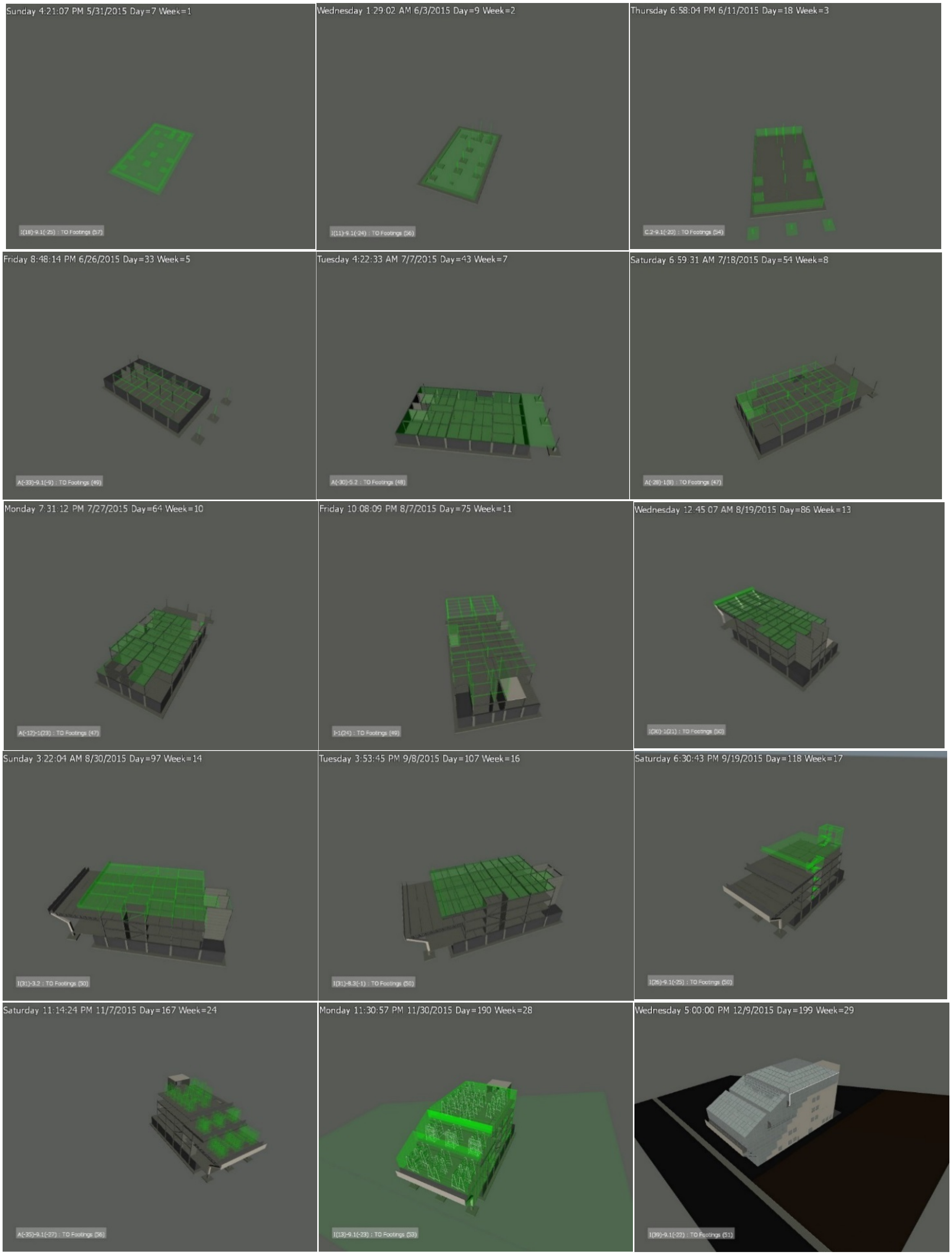


Figure 91 4D Construction Simulation.

4.5 Leadership in Energy & Environmental Design (LEED)

Impact's design for Growing Power's Vertical Farm can qualify for LEED Silver accreditation due to the sustainable practices implemented during the design for its construction and building occupancy phases. Based on LEED v4 for New Construction and Major Renovation (BD+C), the project can obtained 55 points that address sustainable practices in the following categories: Integrative Process, Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation and Regional Priority.

A summary spreadsheet is seen below in Table 39, while the complete spreadsheet is in Appendix AI.

Table 39 Growing Power Vertical Farm LEED v4 for BD+C

Growing Power Vertical Farm LEED v4 for BD+C	
Category	Anticipated Points
Integrative Process	1
Location and Transportation	9
Sustainable Sites	5
Water Efficiency	4
Energy and Atmosphere	11
Materials and Resources	9
Indoor Environmental Quality	10
Innovation	3
Regional Priority	3
Total Possible Points	**55**

Among the best practices of the building are found the water and electric consumption reduction. The incorporation of a rain harvesting system also proved to be one of the main sustainable features. In addition, the design incorporates innovative practices. Through Growing Power's Mission of teaching the community about sustainable food production, the design includes a market area that serves as part of the demonstration for the community.

5. Conclusion

In conclusion, *Impact*'s vertical farm design successfully reaches the initial project goals.

The building design process was a new experience for all members of *Impact*. The project allowed team members to apply their past course work and experience to design the different building systems and constantly learn new material in the process. The integration of these various systems and their design allowed group members to learn from each other's disciplines and how they contributed to the design of sustainable building.

Impact's vertical farm design aligns with Growing Power's vision to "inspire communities to build sustainable food systems that are equitable and ecologically sound". The vertical farm itself is designed as a community center, complete with a public market area that includes an aquaponic demonstration tank. The farm also includes three classrooms, a workshop and a demonstration kitchen. These building components are all meant to teach the general public about sustainable food growing practices and systems.

Integration was achieved by decreasing the basement area to create a slab on grade to easily support the aquaponic demonstration tanks. Precast panels used for the building envelope contain built-in LED lighting connections. Water source heat pump units were designed to easily fit between the beam spacing and are also supported by the building's structural framing. A comprehensive BIM model was created and shared across disciplines to constantly communicate design changes.

Energy Efficiency was achieved by only having three, thermally complex growing areas to heat and ventilate instead of four. Sensors that detect the amount of light required for specific crop types individually control LED lighting fixtures in the growing areas. The building's water source heat pump system is self-sufficient and supplies both heating and cooling to the different building zones. The building's regenerative elevator is also self-sufficient and doesn't require an elevator room.

Cost Efficiency was achieved through a well-planned site that minimizes congestion and construction activities interfering with one another, expediting the construction schedule. Vertical and rotating growing towers allow more plants to be grown in a smaller area, increasing the yield of sellable product. Systems chosen for lighting and mechanical have low yearly operation and maintenance costs.

Safety concerns were addressed with a site plan layout that minimizes risks related to the construction activities that could affect the residential area in the surroundings. The second floor assembly space includes three separate means of egress to meet *International Building Code* requirements based on the space's square foot area.

By project's end the team was able to create a 3D *Revit* model that included architectural floor plans, structural framing, interior finishes, growing apparatuses and preliminary lighting systems. A construction schedule was created with the appropriate phasing noted and a final cost estimate was completed showing the building's overall cost efficiency.

Through the achievement of these goals *Impact*'s vertical farm design exemplifies the beliefs of Growing Power Inc., creating a high performance community center to teach and grow sustainable food systems.

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7. Appendixes

Appendix A: High Performance Facade

System	Advantages	Disadvantages	Explanation
ETFE (ethylene tetrafluoroethylene)	-Low maintenance, recyclable, light weight - Excellent thermal properties with multiple sheet layers (air space between sheets acts as an insulator) - Can be transparent to let light through or slightly opaque to control solar heat gain	-Subject to degradation from UV light -In single sheet it has poor acoustic and thermal performance -Fails at very high temperatures	- Teflon coated polymer that is blown or extruded to form multiple sheets -The sheets are kept at a constant pressure through the use pumps that take varying wind loads -a secondary structural component works to keep the sheets in place
Aerogels	- Has lowest density among all solids -Low thermal conductivity (ideal where high thermal insulation is needed) - Good way to bring diffuse light to the space -Moisture resistant -Strong acoustic properties		-Comprised of synthetic solids made almost entirely of air
Vacuum Insulated Glazing Units	-Better thermal resistance than standard air or gas filled insulated glazing units -No conduction or convection of heat between the two panes of glass -Can achieve U-values less than 0.10 Btu/hr-ft^2 -Can have decreased thickness without harming the thermal performance of the envelope		-A vacuum is formed between two panes of glass (raises thermal resistance) -A grid of spacers is placed between the glass panels -There is usually an insulating core of silica or glass fiber

Electrochromic Glass	-Energy consumption of the building can be reduced	-Change from being opaque to transparent can take several minutes	-A film changes in opacity when electric voltage is applied, and changes again with more voltage - Solar heat gain changes from 0.48 in the clear state to .09 in the transparent state
Suspended Particle Device Glass	-Switch between opaque and translucency is instantaneous	-Energy savings are not significant -Not recommended for exterior building envelopes	-Thin film of liquid crystals is suspended in a transparent conductive material laminated between two layers of glass -Amount of light that passes through the glass is controlled through applying voltage
Self-cleaning Glass	-Reduces maintenance costs for the glass -Helps reduce air pollutants in dense urban areas -The titanium oxide can be applied to concrete surfaces as well	-Not effective in areas with low rainfall	-Uses thin film of titanium dioxide on the exterior works as a photo-catalytic coating -Photo-catalysts: compounds use UV bands of sunlight to facilitate chemical reaction -The dirt on the glass is broken down when exposed to sunlight and then rain washes away the loose particles
Phase-Change Materials	-Absorb high exterior temperatures during the day and can dissipate this	-Not appropriate where views to	-Solid at room temperature then

	heat to the interior at night (trombe walls) -Reflect heat in summer, absorbs low angle heat in the winter	the outside are desired	melts, stores heat in the process -Can be organic or inorganic -Usually placed in triple-insulated glazing unit with integrated PCM (works as a passive heat source) -Visual transmittance is between 0-28% -SHGC as high as 0.48 and low as 0.17
Photovoltaic Glass	-Integrates solar cells that generate energy from light		-Crystalline solar cells that generate energy from light place in between double glazed glass units -Performance and aesthetic depends on their type, size, and position relative to the sun's path - For optimal energy output PV panels should be set at the angle of their latitude (42 degrees for Milwaukee)

Structural Fire Protection

Structural fire protection is an integral component of the fire safety system in a building. It is considered to be a Passive Fire Protection (PFP), which attempts to contain or slow down the spread of fire. In the case of steel, PFP materials insulate steel structures from the effects generated by fire such as high temperatures that will affect the structural stability of a building. These materials can be classified under two types, non-reactive such as board and sprays and reactive, of which thin film intumescent coatings are the most common example (Fire protecting structural steelwork). The following section describes the most common materials and methods used for fire protection of structural steelwork.

Concrete was the most common fire protection material for structural steel systems until the late 1970. This material's use was considerably displaced by the introduction of lightweight protection systems such as boards, sprays and thin film intumescent coating but it is traditional system that is still important to the fire protection market. The main advantage of this system is concrete's durability. It is suitable for cases in which resistance to impact damage, abrasion and weather exposure are important. On the other hand, the main disadvantages are the cost (compared to lightweight systems), space utilization due to its large thickness, and its weight (Fire protecting structural steelwork).

The following images show how concrete encasement system examples.

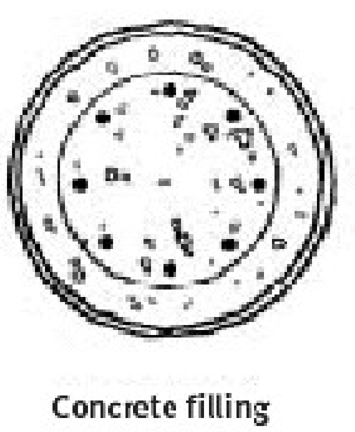


Figure: Fire Protecting Structural Steelwork (Fire Protection, 2014).

Intumescent Coatings

Thin film intumescent coating systems generally have three components: a primer, a basecoat, and a sealer coat. The basecoat usually comprises the following ingredients:

- A catalyst, which decomposes to produce a mineral acid such as phosphoric acid.
- A carbonific such as starch, which combines with the mineral acid to form a carbonaceous char.
- A binder or resin, which softens at a predetermined temperature.
- A spumific agent, which decomposes together with the melting of the binder, to liberate large volumes of non-flammable gases. These gases include carbon dioxide, ammonia and water vapour. The production of these gases causes the carbonaceous char to swell or foam and expand to provide an insulating layer many times the original coating thickness.

(Fire protecting structural steelwork).

This type of coating may be brushed or sprayed onto steel members. It is applied similarly to paint and can be done either on-site or off-site. A concern of off-site fire-proofing is that the materials used and quality control is extremely hard to manage. The project managers of responsibility can better ensure proper materials if performed on site. Fire coating is mostly used on exposed steelwork. The presence of fire will make the intumescent coating react (more specifically the basecoat), expanding the material and creating foam around the steel members that acts as an insulator (Fire Protection, 2014). In recent years, this material has been designed to achieve up to 120 minutes of fire resistance but it is commonly used in buildings that require 30, 60, and 90 minutes of fire resistance (Fire protecting structural steelwork). The following images show examples of intumescent coatings. The right image is from a reacted coating post-fire.

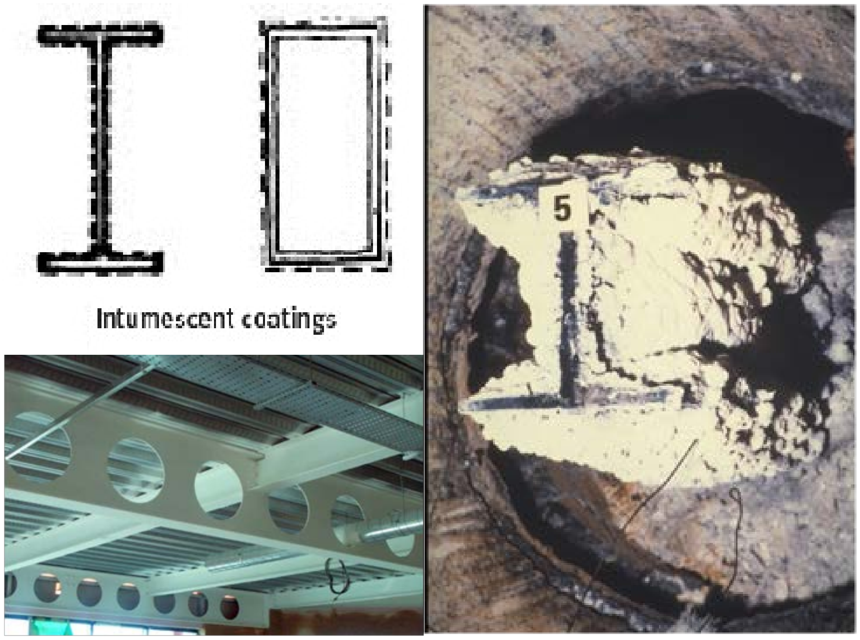


Figure: Fire protecting structural steelwork (Fire Protection, 2014)

Board-Based Systems

The board-based systems are used to form rectangular encasements around exposed and hidden steel members, such as internal beams and columns. The level of fire resistance achieved depends upon the type and thickness of the boards used and the method of attachment. Normally, board thickness may be guaranteed in they are factory manufactured. Generally there are two classifications of board protection, lightweight and heavyweight. Lightweight boards are typically 150-250 kg/m^3 while heavyweight boards usually range from 700-900 kg/m^3. Heavyweight boards are typically used where aesthetics are important in contrast to lightweight boards that are not suitable for decorative finishes and usually lower cost than heavyweight equivalents (Fire protecting structural steelwork).

The following images show examples of board-based systems.

Figure:1 Fire protecting structural steelwork (Fire Protection, 2014).

Sprayed Fire Protection Systems

Sprayed fire protection systems are commonly used in the United States. They are usually based upon cementitious materials and are applied directly onto the structural member's surface. Due to their method of application, they can be used to protect complex shapes and details but they may present inconveniences to site operations due to the wet trade its represents. Also, coated members may not be suitable for aesthetic purposes because of the coarse uneven texture obtained. The fire resistance level is comparable to that of board-based materials. The greater advantage of sprayed fire protection systems is the low cost comparable to other similar systems. The cost does not increase significantly with increases in protection thickness because most of the cost of application is affected by labor and equipment while the minority of the cost is in the actual materials used (Fire protecting structural steelwork).

The following image shows an example of a sprayed system.

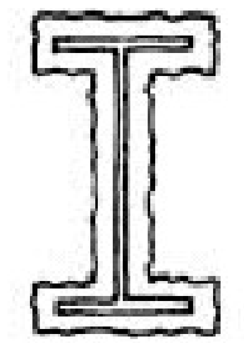


Figure: Spray Fireproofing (Fire Proofing, 2014)

The following graph presents the distribution of market share that of the different fire protection materials and methods for structural steelwork. As it can be appreciated, the use of Intumescent coatings has considerably increased over the past decade.

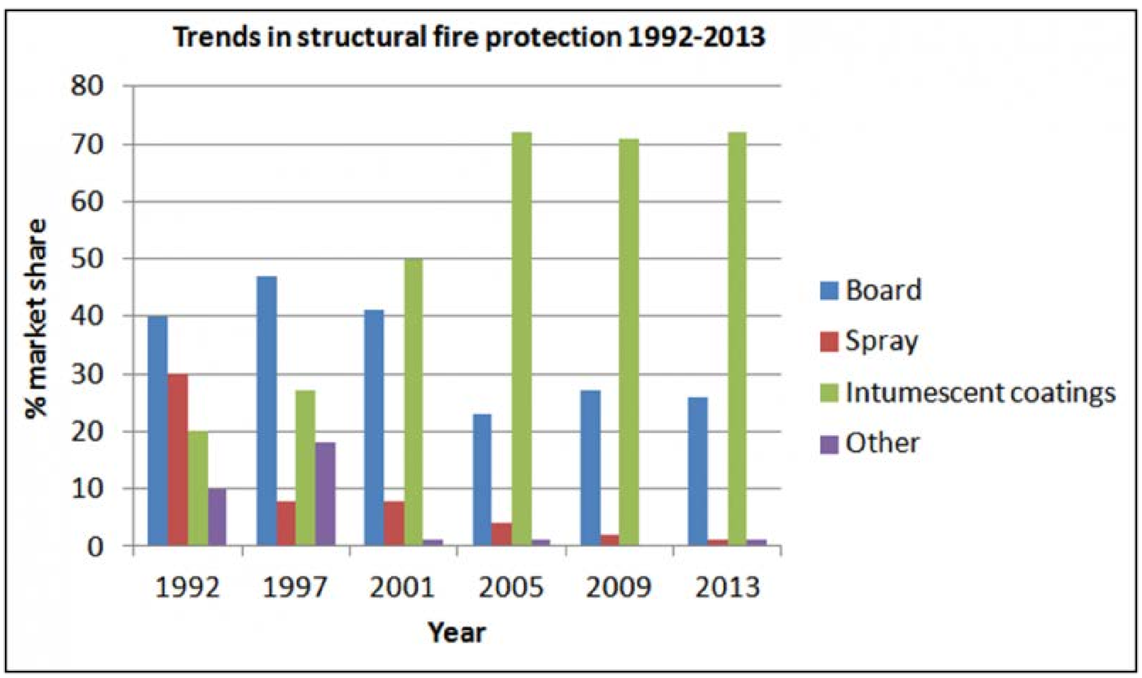


Figure: Trends in structural fire protection (Fireproofing, 2014)

Protection thickness

In order to determine the protection thickness required for a specific steel member the section factor (A/V) needs to be defined. This factor is calculated to each particular by dividing the surface area per unit length by its volume per unit length. This parameter expresses how quickly a steel member will heat up when exposed to fire. "The section factor for a member with box protection is lower than that for a member with profile protection, and hence box protected steelwork heats up more slowly and requires less protection" (Fire Protection, 2014).

Typical spray or board thicknesses for a column in a multi-story building are as set out in the following table.

Table: Board Thickness Requirements (Fire Protection, 2014).

Fire resistance (minutes)	Profile Protection (mm)	Box Protection (mm)
30	10	12
60	18	15
90	24	20
120	30	25

Hydropower

The water wheel is an example of hydro energy which is the technology that is used to convert moving water into any sort of mechanical or electrical energy. The water wheel is an extremely ecofriendly approach, meaning that it does not pollute. The electricity that is generated comes from a coil generator that is connected to the wheel shaft and in order to produce more energy, the flow of the water needs to be greater. There are five kinds of water wheels: the undershot and overshot wheel, pitchback wheel, breastshot wheel, and the horizontal wheel.

Undershot Water Wheel

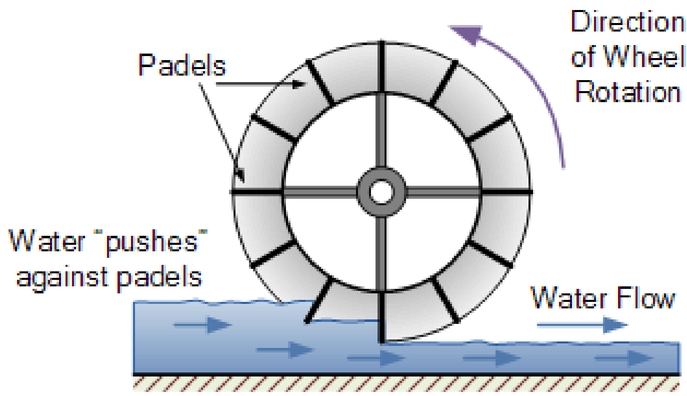


Figure: Undershot Water Wheel Design

The undershot wheel is perhaps the simplest, cheapest and easiest type of wheel to construct. The water flowing below pushing against the submerged paddles on the lower part of the wheel allowing it to rotate in one direction which is the same direction that the water is flowing in. The undershot water wheel is that it requires large amounts of water moving at a quick speed in order to rotate the wheel.

Overshot Water Wheel

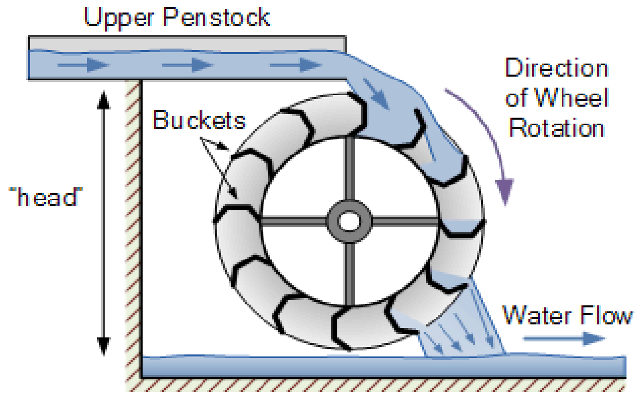


Figure: Overshot Water Wheel Design

The *overshot waterwheel* is more complicated in terms of construction and design than the undershot waterwheel as well as more expensive. With the assistance of gravity, the water-filled buckets are able to move the wheel in order to fill up the empty buckets on the other side to keep the cycle going. The overshot design uses nearly all of the waters energy to produce power.

Pitchback Water Wheel

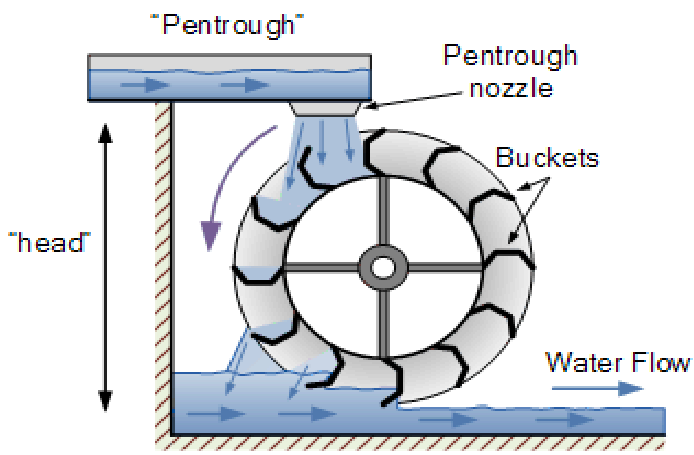


Figure: Pitchback Water Wheel Design

The pitchback waterwheel design is a combination of the overshot and undershot wheel designs. It uses the gravitational weight of the water just like the overshot wheel design and uses the flow of the water below just like the undershot wheel design. *P*itchback waterwheel design uses a funnel to distribute the water vertically down to the wheel. This action causes the wheel to rotate in the opposite direction to the flow of the water above because of the way the buckets are oriented. The pitchback design uses the waters energy twice, once from above the wheel and once from below to help push and rotate the wheel.

Breastshot Water Wheel

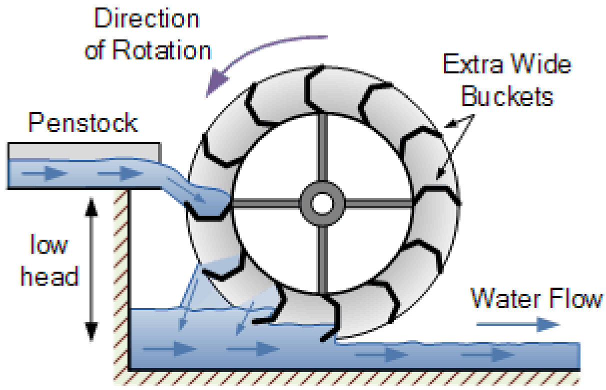


Figure: Breastshot Water Wheel Design

The breastshot water wheel design is where the water enters the buckets about half way up the height of the wheel and then flows out at the bottom in the same direction that the wheel is rotating. The breastshot waterwheel design is used when the head of water is low and is not enough for the overshot or pitchback design. A disadvantage with this design is that the gravitational weight of the water is only used for about one quarter of the rotation whereas the previous designs it applied for half the rotation. In response to the low head, the buckets are wider to extract amount of potential energy from the water. However, this can play as a disadvantage because of the weight that is being chauffeured by each bucket.

Horizontal Waterwheel

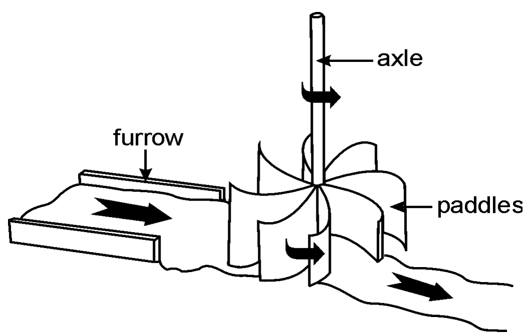


Figure: Horizontal Water Wheel Design

This type of wheel is usually located underneath the building. This design is the only one of the designs that lays on its side and the paddles are pelted with a jet of water in order for it to move and generate power. The water hits the paddles at the center and then flows underneath and away from the system. It is easy and simple to construct but it is not favored as much as the previous designs mentioned. This design can be converted into a loop system where the water used to move the paddles is reused to keep the wheel rotating. The other designs may be converted in to loop systems but it is not as effective.

Generated by COM*check-Web* Software

Envelope Compliance Certificate

2012 IECC

Section 1: Project Information

Project Type: **New Construction**
Project Title : Urban Farm

Construction Site:
5500 West Silver Spring Drive
Milwaukee, Wisconsin 53202

Owner/Agent:

Designer/Contractor:

Additional Efficiency Package: **High efficiency HVAC. Systems that do not meet the performance requirement will be identified in the mechanical requirements checklist report.**

Section 2: General Information

Building Location (for weather data):	**Milwaukee, Wisconsin**
Climate Zone:	**6a**
Building Space Conditioning Type(s):	**Nonresidential**
Vertical Glazing / Wall Area Pct.:	**6%**

Activity Type(s)	**Floor Area**
Convention Center:Exhibit space	23892

Section 3: Envelope Assemblies

Envelope PASSES: Design 0.1% better than code.

Climate-Specific Requirements:

Component Name/Description	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	Proposed U-Factor	Budget U-Factor(a)
Ext. Wall: Other Exterior Wall, Heat capacity 0.0 (b)	11742	---	---	0.050	0.051
Window: Metal Frame, Thermal Break, Perf. Type: Other testing/cert. Product ID: panels, SHGC 0.45 (c)	1207	---	---	0.360	0.360
Door: Insulated Metal, Swinging	140	---	---	0.430	0.370
Floor: Unheated Slab-On-Grade, Horizontal without vertical 3 ft.	186	---	10.0	---	---
Basement: Solid Concrete, 10in. Thickness, Normal Density, Furring: Wood, Wall Ht 12.0, Depth B.G. 0.0	8750	0.0	10.0	0.080	0.108

(a) Budget U-factors are used for software baseline calculations ONLY, and are not code requirements.

(b) 'Other' components require supporting documentation for proposed U-factors.

(c) Fenestrations product performance must be certfied in accordance with NFRC and requires supporting documentation.

Section 4: Compliance Statement

Compliance Statement: The proposed envelope design represented in this document is consistent with the building plans, specifications and other calculations submitted with this permit application. The proposed envelope system has been designed to meet the 2012 IECC requirements in COM*check-Web* and to comply with the mandatory requirements in the Requirements Checklist.

Name - Title

Signature

Date

Appendix D: Heating Load Spreadsheet

Heating			LOAD CALCULATION TEMPLATE																
			Summer	Winter															
		Outdoors	90.00	-7.0		Supply Air	120 F												
		Indoors	75.00	68.0															
		Daily Range	16.00																
																		Trane Heat Pumps	
Room	Wall Lngth	Gross Wall A	Glass Area	Net Wall A	Room Area	Room Volume	Wall U	Glass U	Wall h BTUH	Glass h BTUH	Floor BTUH	Heating Load	Total BTUH	CFM		Tons		Nominal Size	Tons
First Floor																			
Workshop N	12.5	162.5	0	162.5	810.1	10531.30	0.06	0.36	731.3	0		731.3		14.8		0.04			
Workshop E	34.3	445.3	100.00	345.3			0.06	0.36	1553.6	2700		4253.6	4984.9	85.9	100.70	0.21	0.25		
Women's Restroom	16.5	214.5	50.00	164.5	129.9	1689.22	0.06	0.36	740.3	1350		2090.3		42.2		0.11		0.006	0.5
Market S			2100.00	0.0	3647.2	94827.98	0.06	0.25	0.0	39375		39375.0		795.5		1.99			
Market E			832.48	0.0			0.06	0.25	0.0	15609		15609.0		315.3		0.79			
Market W			832.48	0.0			0.06	0.25	0.0	15609		15609.0		315.3		0.79			
Slab on Grade				0.0			0.06				7400.26	7400.3	77993.3	149.5	1575.62	0.37	3.94		
Processing N	14.3	185.3	25.00	160.3	3036.4	39473.72	0.06	0.36	721.1	675		1396.1		28.2		0.07			
Processing W	70.0	910.0	175.00	735.0			0.06	0.36	3307.5	4725		8032.5	9428.6	162.3	190.48	0.41	0.48		
Shipping N	16.8	217.8	25.00	192.8	330.8	4299.75	0.06	0.36	867.4	675		1542.4		31.2		0.08			
Shipping W	21.0	273.0	0.00	273.0			0.06	0.36	1228.5	0		1228.5		24.8	55.98	0.06	0.14		
Stairs 1	20.0	260.0	0.00	260.0	171.0	2223.00	0.06	0.36	1170.0	0		1170.0		23.6		0.06		0.006	0.5
Stairs 2	10.0	130.0	0.00	105.0	180.0	2340.00	0.06	0.36	472.5	0		472.5		9.5		0.02		0.006	0.5
Stair 3	20.3	264.3	0.00	264.3	173.0		0.06	0.36	1189.3	0		1189.3		24.0		0.06		0.006	0.5
Second Floor																			
Men's Restroom	3.5	45.5	0.00	45.5	191.4	2488.07	0.06	0.36	204.8	0		204.8		4.1		0.01			
Women's Restroom I	9.0	117.0	0.00	117.0	216.6	2815.28	0.06	0.36	526.5	0		526.5		10.6		0.03			
Women's Restroom E	27.0	351.0	0.00	351.0			0.06	0.36	1579.5	0		1579.5	2106.0	31.9	42.55	0.08	0.12	0.006	0.5
Breakout Space N	31.0	403.0	50.00	353.0	1374.6	17869.15	0.06	0.36	1588.5	1350		2938.5		59.4		0.15			
Breakout Space W	27.0	351.0	75.00	276.0			0.06	0.36	1242.0	2025		3267.0		66.0	125.36	0.17	0.31		
Gathering Area	84.0	1092.0	200.00	892.0	3967.5	51577.50	0.06	0.36	4014.0	5400		9414.0		190.2		0.48	0.48		
Third Floor																			
Class 1 N	31.0	403.0	50.00	353.0	591.8	7692.75	0.06	0.36	1588.5	1350		2938.5		59.4		0.15			
Class 1 W	18.5	240.5	25.00	215.5			0.06	0.36	969.8	675		1644.8	4583.3	33.2	92.59	0.08	0.23		
Class 2	19.0	247.0	50.00	197.0	600.0	7800.00	0.06	0.36	886.5	1350		2236.5		45.2		0.11	0.11		
Class 3	19.0	247.0	50.00	197.0	616.5	8014.50	0.06	0.36	886.5	1350		2236.5		45.2		0.11	0.11		
Demo Kitchen	28.0	364.0	32.50	331.5	991.9	12894.44	0.06	0.36	1491.8	878		2369.3		47.9		0.12	0.12		
Encubator Ofices	23.5	305.5	50.00	255.5	485.8	6315.27	0.06	0.36	1149.8	1350		2499.8		50.5		0.13	0.13		
Women's Restroom I	13.0	169.0	0.00	169.0	244.0	3172.00	0.06	0.36	760.5	0		760.5		15.4		0.04			
Women's Restroom E	27.0	351.0	0.00	351.0			0.06	0.36	1579.5	0		1579.5	2340.0	31.9	47.27	0.08			
Men's Restroom	1.8	23.0	0.00	23.0	211.0	2743.00	0.06	0.36	103.5	0		103.5		2.1		0.01	0.12	0.006	0.5
Growing Area S		0.0	1120.00	0.0	3500.0		0.06	0.25		21000		21000.0		545.5		1.36			
Growing Area N		0.0	1109.00	0.0			0.06	0.25		20794		20793.8		540.1		1.35			
Growing Area E,W		0.0	2014.00	0.0			0.06	0.25		37763		37762.5		980.8		2.45			
Growing Area Roof		0.0	2030.00	0.0			0.06	0.25		38063		38062.5	117618.8	988.6	3055.03	2.47	7.64		
Fourth Floor																			
Copy	16.1	209.3	25.00	184.3	133.0	1729.00	0.06	0.36	829.4	675		1504.4		30.4		0.08	0.08		
Office Area N	14.4	187.5	25.00	162.5	880.9	11451.18	0.06	0.36	731.1	675		1406.1		28.4		0.07			
Office Area W	38.4	499.5	100.00	399.5			0.06	0.36	1797.6	2700		4497.6	5903.6	90.9	119.27	0.23	0.30		
Director's Office	12.7	164.7	0.00	164.7	394.4	5127.07	0.06	0.36	741.2	0		741.2		15.0		0.04	0.04		
Staff Area	26.6	345.6	75.00	270.6	334.0	4342.00	0.06	0.36	1217.7	2025		3242.7		65.5		0.16	0.16		
Meeting Room	19.6	254.5	25.00		444.4	5776.55	0.06	0.36	0.0	675		675.0		13.6		0.03	0.03		
Women's Restroom I	9.5	123.5	0.00	123.5	140.0	1820.00	0.06	0.36	555.8	0		555.8		11.2		0.03			
Women's Restroom E	16.8	218.8	0.00	218.8			0.06	0.36	984.6	0		984.6	1540.3	19.9		0.05			
Men's Restroom	3.0	39.0	0.00	39.0	136.0	1768.00	0.06	0.36	175.5	0		175.5		3.5	34.66	0.01	0.09	0.006	0.5
Growing Area S		0.0	1120.00	0.0	2950.4		0.06	0.25	0.0	21000		21000.0		545.5		1.36			
Growing Area N		0.0	927.50	0.0			0.06	0.25	0.0	17391		17390.6		451.7		1.13			
Growing Area E,W		0.0	1468.84	0.0			0.06	0.25	0.0	27541		27540.8		715.3		1.79			
Growing Area Roof		0.0	1610.00	0.0			0.06	0.25	0.0	30188		30187.5	96118.9	784.1	2496.59	1.96	6.24		
Fifth Floor																			
Growing Area S			910.00	0.0	5600.0		0.06	0.25		17063		17062.5		443.2		1.11			
Growing Area N			552.50	0.0			0.06	0.25		10359		10359.4		269.1		0.67			
Growing Area E,W			2080.00	0.0			0.06	0.25		39000		39000.0		1013.0		2.53			
Growing Area Roof			6138.14	0.0			0.06	0.25		115090		115090.1	181512.0	2989.4	4714.60	7.47	11.79		
Basement	0.0	0.0												0.0		0.00			
Locker Rooms	58.3	699.0	0.00	757.3	324.5		0.08		2847.3	0		2847.3		57.5		0.14		0.006	0.5
Totals												546278.3		13317.3		33.29			

Appendix E: Cooling Loads Spreadsheets

Cooling

LOAD CALCULATION TEMPLATE

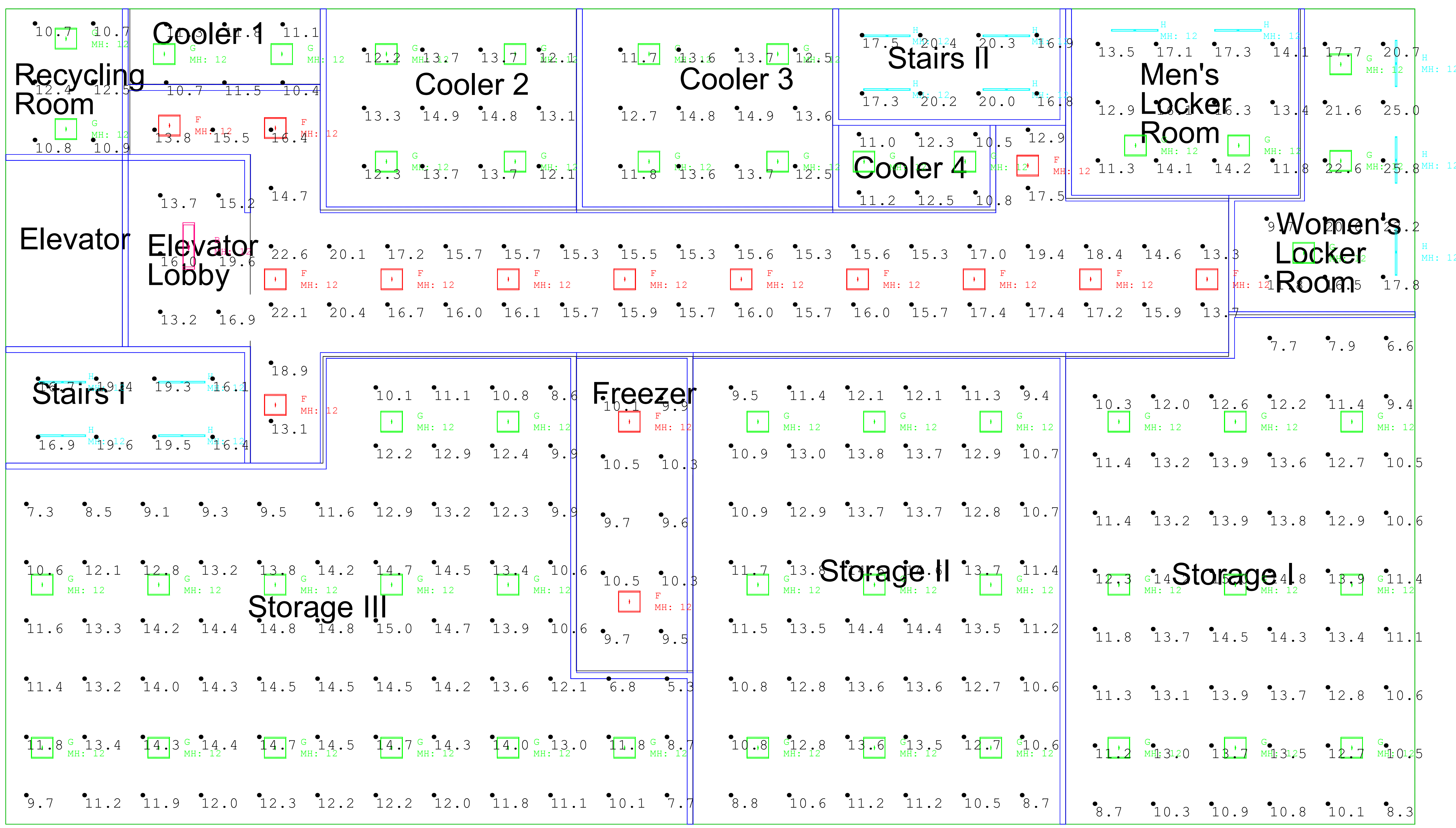
	Summer	Winter	
			Supply Air 58 F
Outdoors	90.0	-7.0	
Indoors	75.0	68.0	
Daily Range	16.0		

Room	Wall Lngth	Gross Wall A	Glass Area	Net Wall A	Ceiling Area	Room Area	Room Volume	Wall U	Glass U	Wall CLTD	Glass CLF	Glass c BTUH	Wall c BTUH	Expected occupancy	Occupancy BTUH	Lights BTUH	Appliances BTUH	Total Load	CFM	CFM Total	tons	tons total	Trane WSHP Unit Selection: Nominal Size	tons	# of units	Dimensions LxHtxW(Inches)	Net Weight lbs
First Floor																											
Workshop N	13.0	169.0	0.0	169.0		810.1	10531.3	0.06	0.36	8	0	0.0	81.1	8	2000	1134.1	221.8	3437.0	208.3		0.52						
Workshop E	34.0	442.0	100.0	342.0				0.06	0.36	18	78	7800.0	369.4					8169.4	495.1	703.4	1.24	1.76	0.024	2	1	46 x 18 x 23	269
Market S		0.0	2100.0	0.0		3647.2	94828.0	0.06	0.22	11	47	98700.0	0.0	100	25000	5835.6		129535.6	7850.6		19.63						
Market E		0.0	832.5	0.0				0.06	0.22	18	78	64933.4	0.0					64933.4	3935.4		9.84						
Market W		0.0	832.5	0.0				0.06	0.22	18	78	64933.4	0.0					64933.4	3935.4		9.84						
Ceiling		0.0	0.0		2485.0			0.06	0.36	9	0	0.0	1341.9					1341.9	81.3	15802.7	0.20	39.51	120	10	4		
Processing N	14.3	185.3	25.0	160.3		3036.4	39473.7	0.06	0.36	8	30	750.0	76.9	5	1250	2429.2		4506.1	273.1		0.68						
Processing W	70.5	916.5	175.0	741.5				0.06	0.36	18	78	13650.0	800.8		0			14450.8	875.8	1148.9	2.19	2.87	0.036	3	1	50 x 19 x 25	343
Market Office		0.0				87.9		1.53	0.36	9	0	0.0	0.0	1	250	87.9	453.8	791.7	48.0		0.12		0.006	0.5			
Market Office		0.0				87.9		1.53	0.36	9	0	0.0	0.0	1	250	87.9	453.8	791.7	48.0	96.0	0.12	0.24	0.006	0.5	1	40 x 15 x 20	165
Second Floor																											
Breakout Space N	31.0	403.0	50.0	353.0		1374.6	17869.2	0.06	0.36	8	30	1500.0	169.4	100	25000	1649.5		28318.9	1716.3		4.29						
Breakout Space W	27.0	351.0	75.0	276.0			0.0	0.06	0.36	18	78	5850.0	298.1					6148.1	372.6	2088.9	0.93	5.22	0.036	3	2	50 x 19 x 25	343
Gathering Area	84.0	1092.0	200.0	892.0		3967.5	51577.5	0.06	0.36	18	78	15600.0	963.4	490	122500	4761.0	221.8	144046.1	8730.1		21.83						
Ceiling		0.0	0.0		285.2			0.06	0.36	9	0	0.0	154.0					154.0	14.0	8744.1	0.03	21.86	0.09	7.5	3	40 x 15 x 20	165
Third Floor																											
Class 1 N	31.0	403.0	50.0	353.0		591.8	7692.8	0.06	0.36	8	30	1500.0	169.4	15	3750	710.1	221.8	6351.3	384.9		0.96						
Class 1 W	18.5	240.5	25.0	215.5				0.06	0.36	18	78	1950.0	232.7					2182.7	132.3	517.2	0.33	1.29	0.018	1.5	1	46 x 18 x 23	264
Class 2	19.0	247.0	50.0	197.0		600.0	7800.0	0.06	0.36	18	78	3900.0	212.8	15	3750	720.0	221.8	8804.5	533.6		1.33	1.33	0.018	1.5	1	46 x 18 x 23	264
Class 3	19.0	247.0	50.0	197.0		616.5	8014.5	0.06	0.36	18	78	3900.0	212.8	15	3750	739.8	221.8	8824.3	534.8		1.34						
Ceiling					52.5			0.06	0.36	9		0.0	28.4					28.4	1.7	536.5	0.00	1.34	0.018	1.5	1	46 x 18 x 23	264
Demo Kitchen W	28.0	364.0	32.5	331.5		984.0	12792.0	0.06	0.36	18	78	2535.0	358.0	15	3750	1377.6	9980.0	18000.6	1090.9		2.73						
Demo Kitchen S	35.0	455.0	0.0	455.0				0.35	0.36	9		0.0	1592.5					1592.5	144.8		0.36						
Ceiling					619.3			0.06	0.36	9		0.0	334.4					334.4	20.3	1256.0	0.05	3.14	0.042	3.5	1	58 x 21 x 33	431
Incubator Ofices	23.5	305.5	50.0	255.5		485.8	6315.3	0.06	0.36	18	78	3900.0	275.9	4	1000	485.8	443.6	6105.3	370.0		0.93	0.93	0.012	1	1		
Fourth Floor																											
Copy	16.1	209.3	25.0	184.3		133.0	1729.0	0.06	0.36	8	30	750.0	88.5	1	250	146.3	8000.0	9234.8	559.7		1.40						
Ceiling					133.0			0.06		9			71.8					71.8	4.4	564.0	0.01	1.41	0.018	1.5	1	46 x 18 x 23	264
Office Area N	14.4	187.5	25.0	162.5		880.9	11451.2	0.06	0.36	8	30	750.0	78.0	8	2000	968.9	4350.3	8147.2	493.8		1.23						
Office Area W	38.5	500.5	100.0	400.5				0.06	0.36	18	78	7800.0	432.5					8232.5	498.9		1.25						
Ceiling					880.9			0.06		9			475.7					475.7	28.8	1021.5	0.07	2.55	0.036	3	1	50 x 19 x 25	343
Director's Office W	12.7	164.7	25.0	139.7		394.4	5127.2	0.06	0.36	18	78	1950.0	150.9	2	500	394.4	221.8	3217.1	195.0		0.49						
Directors Office E	21.5	279.5	0.0	279.5				0.35	0.36	9		0.0	880.4					880.4	80.0		0.20						
Director's Office S	27.1	352.0	0.0	352.0				0.35	0.36	9	0	0.0	1232.1					1232.1	112.0		0.28						
Ceiling					394.4			0.06		9			213.0					213.0	12.9	399.9	0.03	1.00	0.018	1.5	1	46 x 18 x 23	264
Staff Area	26.6	345.6	75.0	270.6		334.5	4348.5	0.06	0.36	18	78	5850.0	292.2	4	1000	368.0	5000.0	12510.2	758.2		1.90						
Ceiling					334.5			0.06		9			180.6					180.6	10.9	769.1	0.03	1.92	0.024	2	1	46 x 18 x 23	269
Meeting Room W	19.6	254.5	25.0	229.5		444.4	5776.6	0.06	0.36	18	0	0.0	137.7	6	1500	444.4	221.8	2303.9	139.6		0.35						
Ceiling					444.4			0.06		9			239.9					239.9	14.5	154.2	0.04	0.39	0.006	0.5		40 x 15 x 20	165
Reception Area S	20.0	260.0	0.0	260.0		529.2	6880.1	0.35	0.36	9	0	0.0	819.0	3	750	582.2		2151.2	195.6		0.49						
Ceiling					529.2			0.06		9			285.8					285.8	17.3	212.9	0.04	0.53	0.01	1	1		
Basement																											
Locker Rooms	58.3	757.3	0.0	757.3		324.5		0.08																			
																	Totals	573158.5	34919.0		87.30				22		

Electric Power Loads Estimation									
	Power Consumption (KW)	Number of Units	Total Power Consumption (KW)	Average hourly usage (KWh)	Number of Hours	Total Daily Load (KWh)	Days of the Week Used	Annual Usage	Total Annual Load (KWh)
Basement			**149.16**			**1145.07**			**348919.83**
General Lighting	2.17	-	2.17	2.17	-	9.11	-	-	2367.92
Cooler 1	4.09	1.00	4.09	4.09	16	65.40	7	364	23804.96
Cooler 2	9.77	1.00	9.77	9.77	16	156.39	7	364	56926.61
Cooler 3	11.65	1.00	11.65	11.65	16	186.46	7	364	67870.95
Cooler 4	4.64	1.00	4.64	4.64	16	74.18	7	364	27002.18
Freezer	11.20	1.00	11.20	11.20	18	201.66	7	364	73403.54
Elevator	0.50	1.00	0.50	6.00	8	48.00	7	364	17472.00
Hands Dryer	0.50	2.00	1.00	0.17	8	1.33	5	260	346.67
HVAC Heating	-	-	0.80	0.80	3	2.30	-	-	600.00
Boiler	-	-	105.50	105.50	4	409.34	-	-	79125.00
First Floor			**29.83**			**173.27**			**56245.21**
General Lighting	4.42	-	4.42	4.42	-	30.29	-	-	7874.78
Computer	0.10	1.00	0.10	0.10	10	0.97	4	208	201.76
Monitor	0.03	1.00	0.03	0.03	10	0.28	4	208	58.24
Rechargable Power Tools	0.01	2.00	0.03	0.03	3	0.08	4	208	16.22
Electric Saw	1.20	2.00	2.40	1.20	4	4.80	4	208	998.40
Drill	0.72	1.00	0.72	0.36	4	1.44	4	208	299.52
Rechargable Power Tools	0.01	2.00	0.03	0.03	3	0.08	5	260	20.28
Refrigerated Island	0.86	1.00	0.86	0.86	16	13.73	7	364	4996.99
Refrigeration	2.29	2.00	4.57	4.57	16	73.12	7	364	26615.68
Computer (2.3 GHz, 3GB RAM)	0.10	2.00	0.19	0.19	10	1.94	5	260	504.40
Monitor (480mm)	0.03	2.00	0.06	0.06	10	0.56	5	260	145.60
Multifunction Printer	0.03	1.00	0.03	0.03	10	0.30	5	260	78.00
Hands Dryer	0.50	2.00	1.00	0.17	8	1.33	7	364	485.33
HVAC Heating	-	-	3.20	3.20	3	9.22	-	-	2400.00
HVAC Cooling	-	-	15.40	15.40	3	44.35	-	-	11550.00
Second Floor			**18.69**			**64.81**			**12834.94**
General Lighting	2.90	-	2.90	2.90	-	21.99	-	-	1855.26
Hands Dryer	0.50	4.00	2.00	0.33	8	2.67	2	78	208.00
Projector	0.35	1.00	0.35	0.35	4	1.42	2	78	110.45
Laptop (2.0 GHz, 2GB RAM, 430mm)	0.04	1.00	0.04	0.04	4	0.14	2	78	11.23
HVAC Heating	-	-	0.80	0.80	3	2.30	-	-	600.00
HVAC Cooling	-	-	13.40	13.40	3	38.59	-	-	10050.00
Third Floor			**100.47**			**478.76**			**142551.13**
General Lighting	4.02	-	4.02	4.02	-	21.10	-	-	5509.68
Growing Area Lighting	8.72	-	8.72	8.72	-	81.69	7	364	29735.16
Rotating Tower System	1.00	12.00	12.00	12.00	12	144.00	7	364	52416.00
Hands Dryer	0.50	2.00	1.00	0.17	8	1.33	4	208	277.33
Projector	0.35	3.00	1.06	1.06	4	4.25	4	208	883.58
Computer	0.10	3.00	0.29	0.29	4	1.16	4	208	242.11
Monitor	0.03	3.00	0.08	0.08	4	0.34	4	208	69.89
Stove (Induction Cooktop)	21.01	2.00	42.03	42.03	2	84.05	4	208	17482.82
Oven Convection Half-Size (Rated)	5.51	2.00	11.02	11.02	2	22.04	4	208	4584.32
Oven Convection Half-Size (Standby)	1.08	2.00	2.17	2.17	22	47.70	4	208	9920.77
Fridge	0.13	1.00	0.13	0.13	10	1.32	7	364	480.00
Blenders	0.30	4.00	1.20	0.60	2	1.20	4	208	249.60
Incubator	0.45	2.00	0.90	0.90	24	21.65	7	364	7879.87
Computer	0.10	2.00	0.19	0.19	8	1.55	5	260	403.52
Monitor	0.03	2.00	0.06	0.06	8	0.45	5	260	116.48
HVAC Heating	-	-	0.80	0.80	3	2.30	-	-	600.00
HVAC Cooling	-	-	15.60	15.60	3	44.93	-	-	11700.00
Fourth Floor			**44.08**			**372.00**			**127969.13**
General Lighting	2.90	-	2.90	2.90	-	13.91	-	-	5850.05
Growing Area Lighting	6.14	-	6.14	6.14	-	55.76	7	364	20294.82
Rotating Tower System	1.00	9.00	9.00	9.00	24	216.00	7	364	78624.00
Hands Dryer	0.50	2.00	1.00	0.17	8	1.33	5	260	346.67
Computer	0.10	20.00	1.94	1.94	10	19.40	5	260	5044.00
Monitor	0.03	20.00	0.56	0.56	10	5.60	5	260	1456.00
Projector	0.35	1.00	0.35	0.35	8	2.83	5	260	736.32
Printer	0.80	1.00	0.80	0.80	2	1.60	5	260	416.00
Coffe Brewing Urn (Rated)	3.81	1.00	3.81	0.64	5	3.18	5	260	825.50
Coffe Brewing Urn (Standby)	0.35	1.00	0.35	0.29	5	1.47	5	260	381.33
Microwave	3.19	1.00	3.19	1.60	2	3.19	5	260	830.44
Fridge	0.13	1.00	0.13	0.13	10	1.32	7	364	480.00
Water Cooler	0.70	1.00	0.70	0.70	12	8.40	5	260	2184.00
HVAC Heating	-	-	0.80	0.80	3	2.30	-	-	600.00
HVAC Cooling	-	-	13.20	13.20	3	38.02	-	-	9900.00
Fith Floor			**34.50**			**334.41**			**124554.25**
General Lighting	1.84	-	1.84	1.84	-	0.45	-	-	2992.81
Growing Area Lighting	9.66	-	9.66	9.66	-	57.96	7	364	21097.44
Rotating Tower System	1.00	23.00	23.00	23.00	12	276.00	7	364	100464.00

Total Energy Consumption	**Peak Consumption**	**377**	**Maximum Daily Consumption**	**2568**	**Annual Consumption**	**813074**

ASHRAE Fundamentals Baseline- Lighting Calculation										
	Area	Lighting Power Densities (W/m^2)	Lighting Power Densities (W/ft^2)	Power Consumption (KW)	Average hourly usage(KWh)	Hours Used Daily	Total Daily Load (KWh)	Days of the Week Used	Annual Usage	Total Annual Load (KWh)
Basement				5.12			21.15			5500
Cooler 1	101.98	6.8	0.63	0.06	0.06	3	0.19	5	260	50
Cooler 2	321.58	6.8	0.63	0.20	0.20	3	0.61	5	260	158
Cooler 3	400.1	6.8	0.63	0.25	0.25	3	0.76	5	260	197
Cooler 4	124.14	6.8	0.63	0.08	0.08	3	0.24	5	260	61
Freezer	235.15	6.8	0.63	0.15	0.15	3	0.45	5	260	116
Storage I	1336.61	6.8	0.63	0.84	0.84	4	3.38	5	260	878
Storage II	1247.56	6.8	0.63	0.79	0.79	4	3.15	5	260	819
Storage III	1754.68	6.8	0.63	1.11	1.11	4	4.43	5	260	1152
Women's Locker Room	324.47	8.1	0.75	0.24	0.24	3	0.73	5	260	190
Men's Locker Room	325.23	8.1	0.75	0.24	0.24	3	0.73	5	260	191
Recycling Room	119.79	6.8	0.63	0.08	0.08	1	0.08	5	260	20
Elevator Lobby	164.93	6.88	0.64	0.11	0.11	6	0.63	5	260	164
Stairs I	180	7.4	0.69	0.12	0.12	6	0.74	5	260	193
Stairs II	191	7.4	0.69	0.13	0.13	6	0.79	5	260	205
Corridors	1075.03	7.1	0.66	0.71	0.71	6	4.25	5	260	1106
First Floor				10.79			75.60			19657
Market	3647.23	11.8	1.10	4.00	4.00	8	31.97	5	260	8312
Women's Bathroom	129.94	10.5	0.97	0.13	0.13	4	0.51	5	260	132
Men's Bathroom	135.65	10.5	0.97	0.13	0.13	4	0.53	5	260	138
Shipping & Receiving	330.75	13.9	1.29	0.43	0.43	6	2.56	5	260	666
Processing	3036.44	13.9	1.29	3.92	3.92	8	31.35	5	260	8151
Office I	87.88	8.1	0.75	0.07	0.07	8	0.53	5	260	137
Office II	87.08	8.1	0.75	0.07	0.07	8	0.52	5	260	136
Mud Room	211.1	7.1	0.66	0.14	0.14	2	0.28	5	260	72
Workshop	810.1	17.1	1.59	1.29	1.29	2	2.57	5	260	669
Elevator Lobby	164.93	6.88	0.64	0.11	0.11	8	0.84	5	260	219
Stair I	180	7.4	0.69	0.12	0.12	8	0.99	5	260	257
Stair II	191	7.4	0.69	0.13	0.13	8	1.05	5	260	273
Stair III	172.9	7.4	0.69	0.12	0.12	6	0.71	5	260	185
Corridors	225.13	7.1	0.66	0.15	0.15	8	1.19	5	260	309
Second Floor				7.42			45.05			4015
Gathering Space	3967.5	13.2	1.23	4.86	4.86	6	29.18	1.5	78	2276
Breakout Space	1374.55	13.2	1.23	1.68	1.68	6	10.11	1.5	78	788
Women's Bathroom	216.56	10.5	0.97	0.21	0.21	6	1.27	1.5	78	99
Men's Bathroom	191.39	10.5	0.97	0.19	0.19	6	1.12	1.5	78	87
Elevator Lobby	164.93	6.88	0.64	0.11	0.11	6	0.63	1.5	78	49
Stair I	180	7.4	0.69	0.12	0.12	8	0.99	5	260	257
Stair II	191	7.4	0.69	0.13	0.13	8	1.05	5	260	273
Stair III	172.9	7.4	0.69	0.12	0.12	6	0.71	5	260	185
Third Floor				8.08			45.94			11726
Classroom I	548.94	13.3	1.23	0.68	0.68	4	2.71	4	208	564
Classroom II	685	13.3	1.23	0.85	0.85	4	3.38	4	208	704
Classroom III	722.1	13.3	1.23	0.89	0.89	4	3.57	4	208	742
Kitchen	842.88	10.7	0.99	0.84	0.84	2	1.67	4	208	348
Storage I	100.5	6.8	0.63	0.06	0.06	1	0.06	4	208	13
Storage II	140.54	6.8	0.63	0.09	0.09	1	0.09	4	208	18
University Incubator	485.79	13.8	1.28	0.62	0.62	8	4.98	7	364	1813
Women's Bathroom	244.09	10.5	0.97	0.24	0.24	6	1.43	4	208	297
Men's Bathroom	211.19	10.5	0.97	0.21	0.21	6	1.24	4	208	257
Elevator Lobby	164.93	6.88	0.64	0.11	0.11	6	0.63	5	260	164
Stairs I	180	7.4	0.69	0.12	0.12	8	0.99	5	260	257
Stairs II	191	7.4	0.69	0.13	0.13	8	1.05	5	260	273
Growing Area Corridors	3500	7.1	0.66	2.31	2.31	8	18.46	5	260	4799
Corridors	1434.75	7.1	0.66	0.95	0.95	6	5.68	5	260	1476
Fourth Floor				5.49			42.31			11001
Copy Room	94.6	8.1	0.75	0.07	0.07	2	0.14	5	260	37
Office Area	886.18	8.1	0.75	0.67	0.67	8	5.33	5	260	1386
Meeting Room	444.35	13.2	1.23	0.54	0.54	6	3.27	5	260	850
Director Office	394.39	8.1	0.75	0.30	0.30	8	2.37	5	260	617
Reception & Corridor	1561.95	7.1	0.66	1.03	1.03	8	8.24	5	260	2142
Staff Area	334.49	9.4	0.87	0.29	0.29	8	2.34	5	260	607
Storage	25.94	6.8	0.63	0.02	0.02	1	0.02	5	260	4
Women's Bathroom	140.9	10.5	0.97	0.14	0.14	8	1.10	5	260	286
Men's Bathroom	136.54	10.5	0.97	0.13	0.13	8	1.06	5	260	277
Elevator Lobby	164.93	6.88	0.64	0.11	0.11	8	0.84	5	260	219
Stairs I	180	7.4	0.69	0.12	0.12	8	0.99	5	260	257
Stairs II	191	7.4	0.69	0.13	0.13	8	1.05	5	260	273
Growing Area Corridors	2950.38	7.1	0.66	1.95	1.95	8	15.56	5	260	4046
Fifth Floor				3.93			29.97			7792
Stairs I	180	7.4	0.69	0.12	0.12	4	0.49	5	260	129
Stairs II	191	7.4	0.69	0.13	0.13	4	0.52	5	260	136
Elevator Lobby	164.93	6.88	0.64	0.11	0.11	4	0.42	5	260	110
Growing Area Corridors	5409	7.1	0.66	3.57	3.57	8	28.53	5	260	7417
			Peak Consumption	40.83	Maximum Daily Consumption		260.03	Annual Consumption		59690



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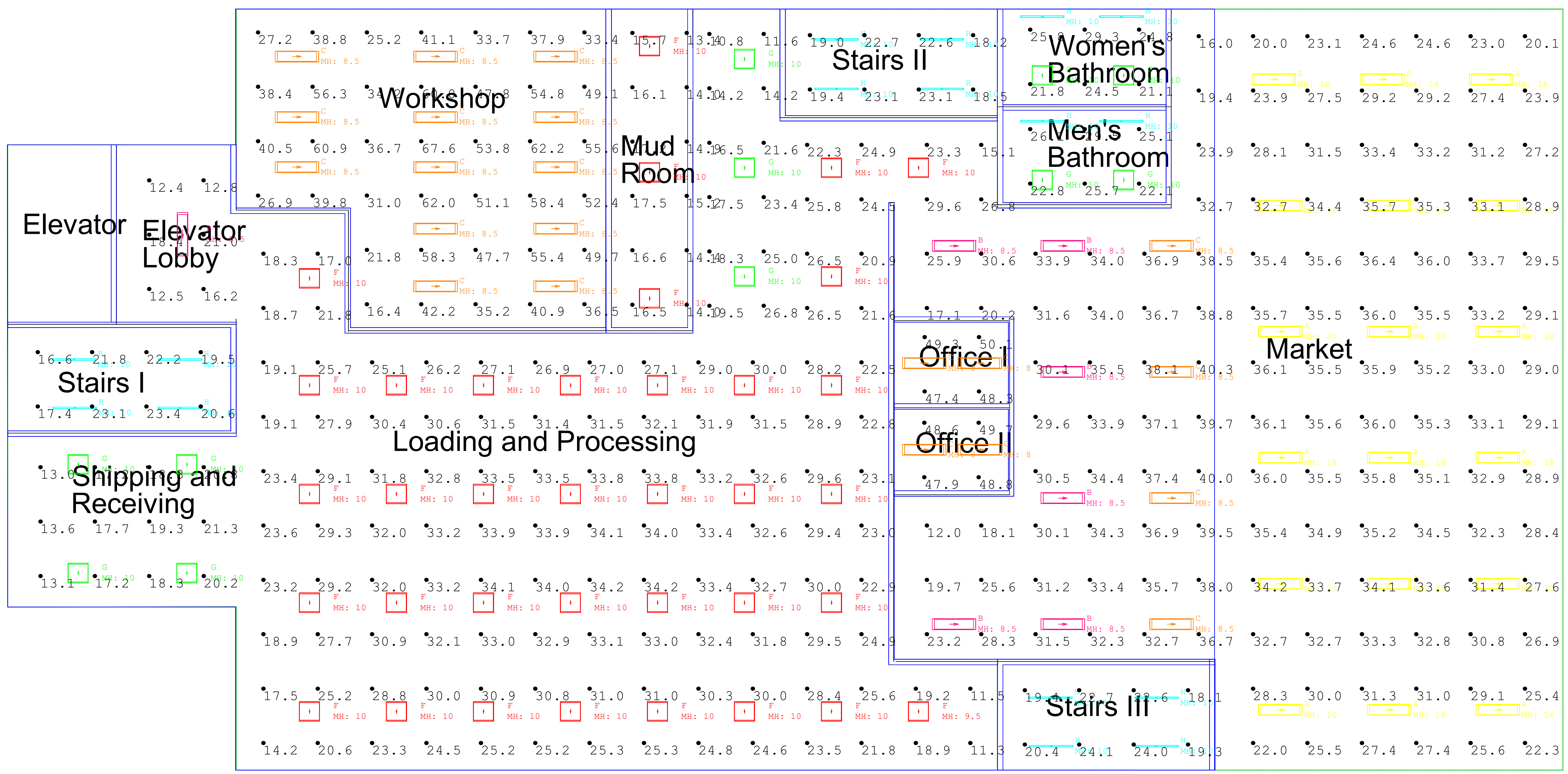
#	Date	Comments

Revisions

Drawn By: Veronica Rivero Gorrin
Date:2/25/2015

Lighting Design
Basement



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Revisions

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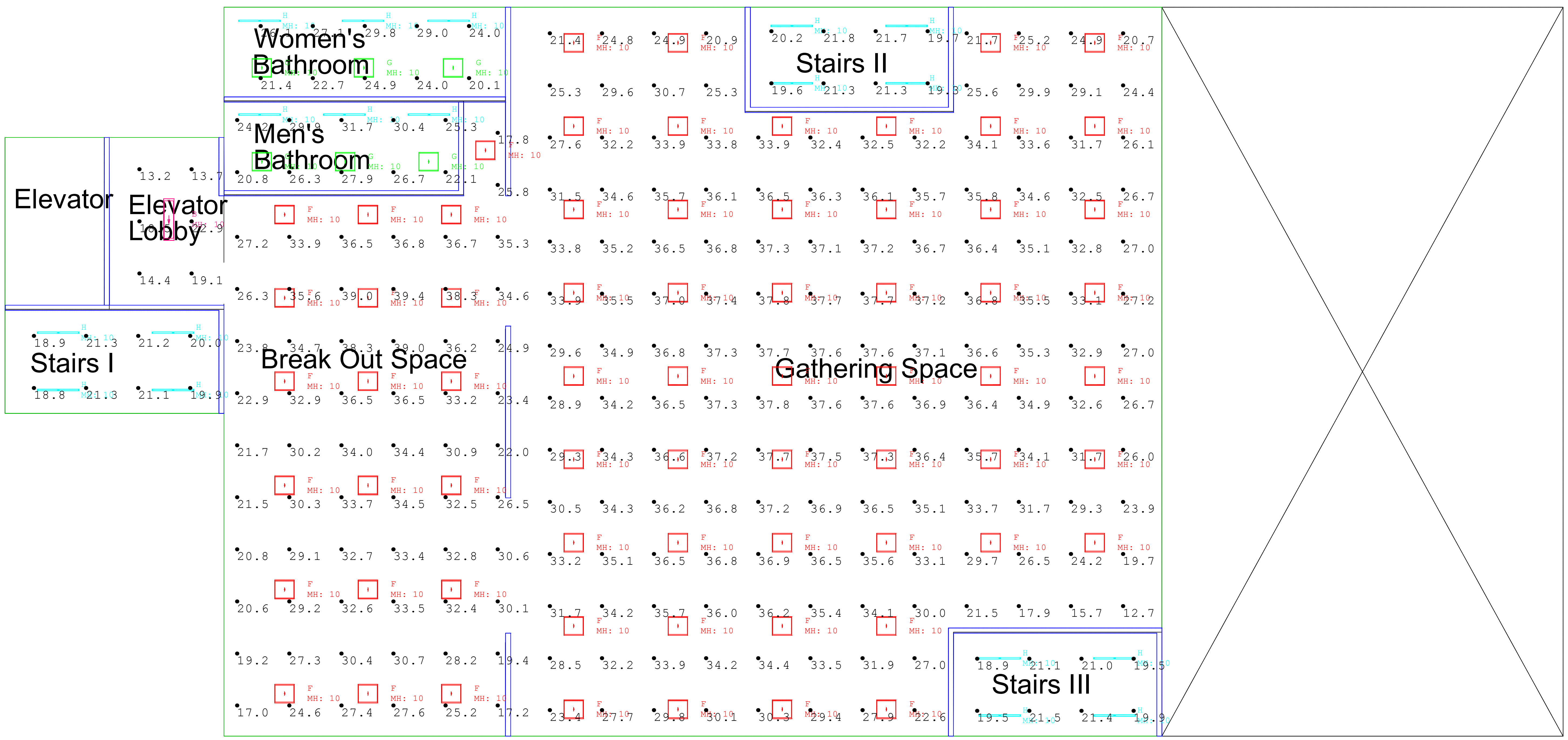
Date:2/25/2015

Lighting Design
First Floor



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Revisions

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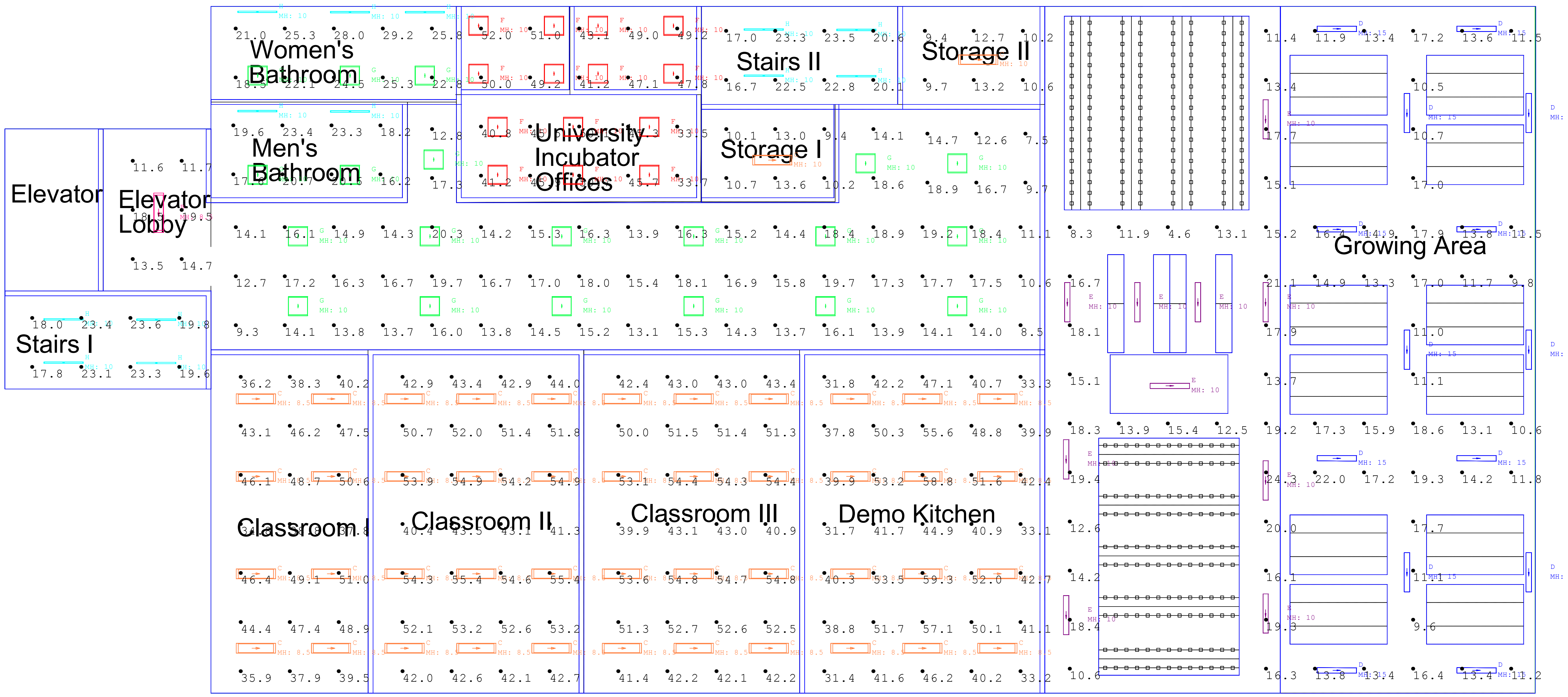
Lighting Design

Second Floor



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Revisions

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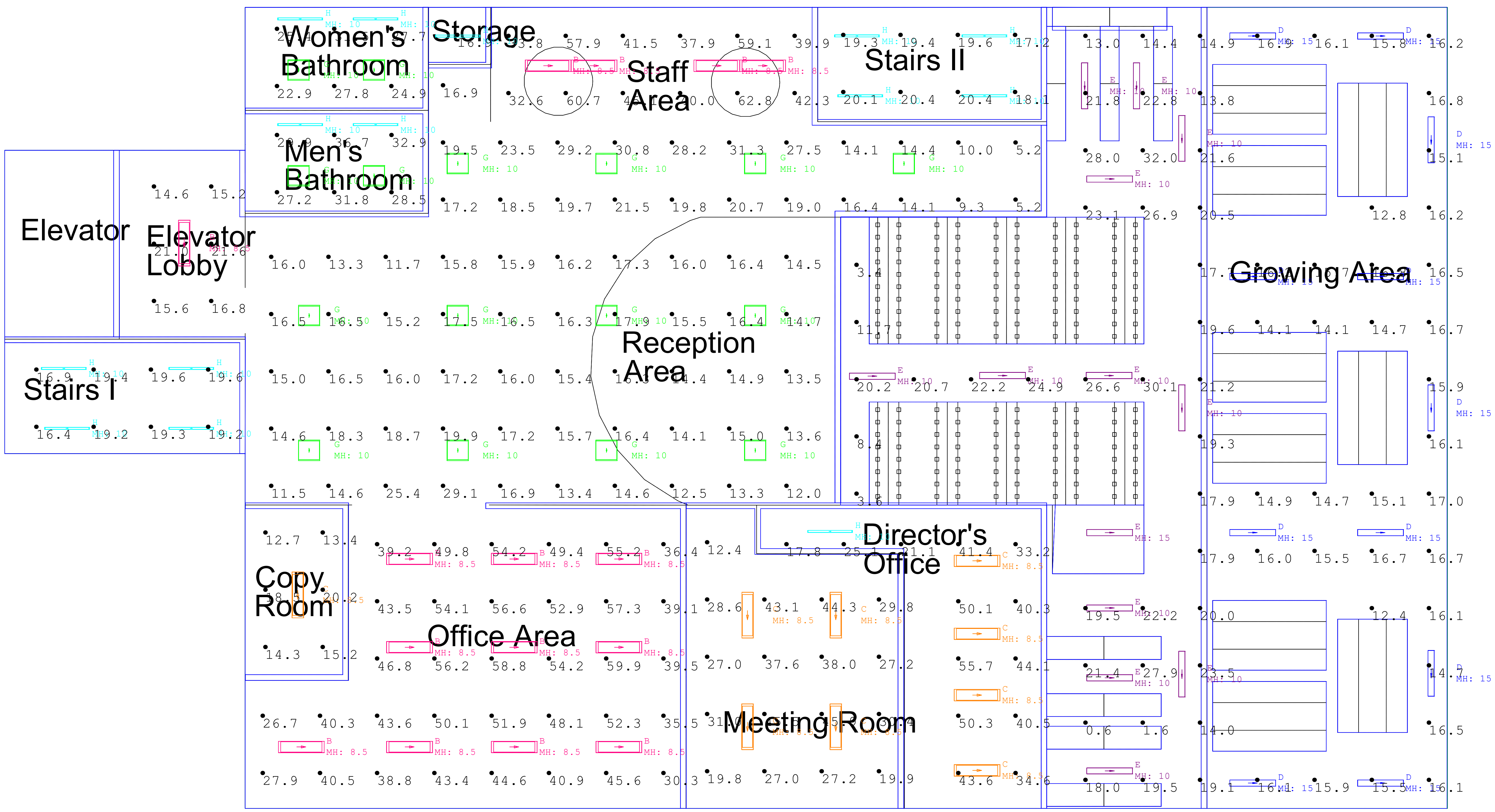
Date:2/25/2015

Lighting Design

Third Floor



Revisions

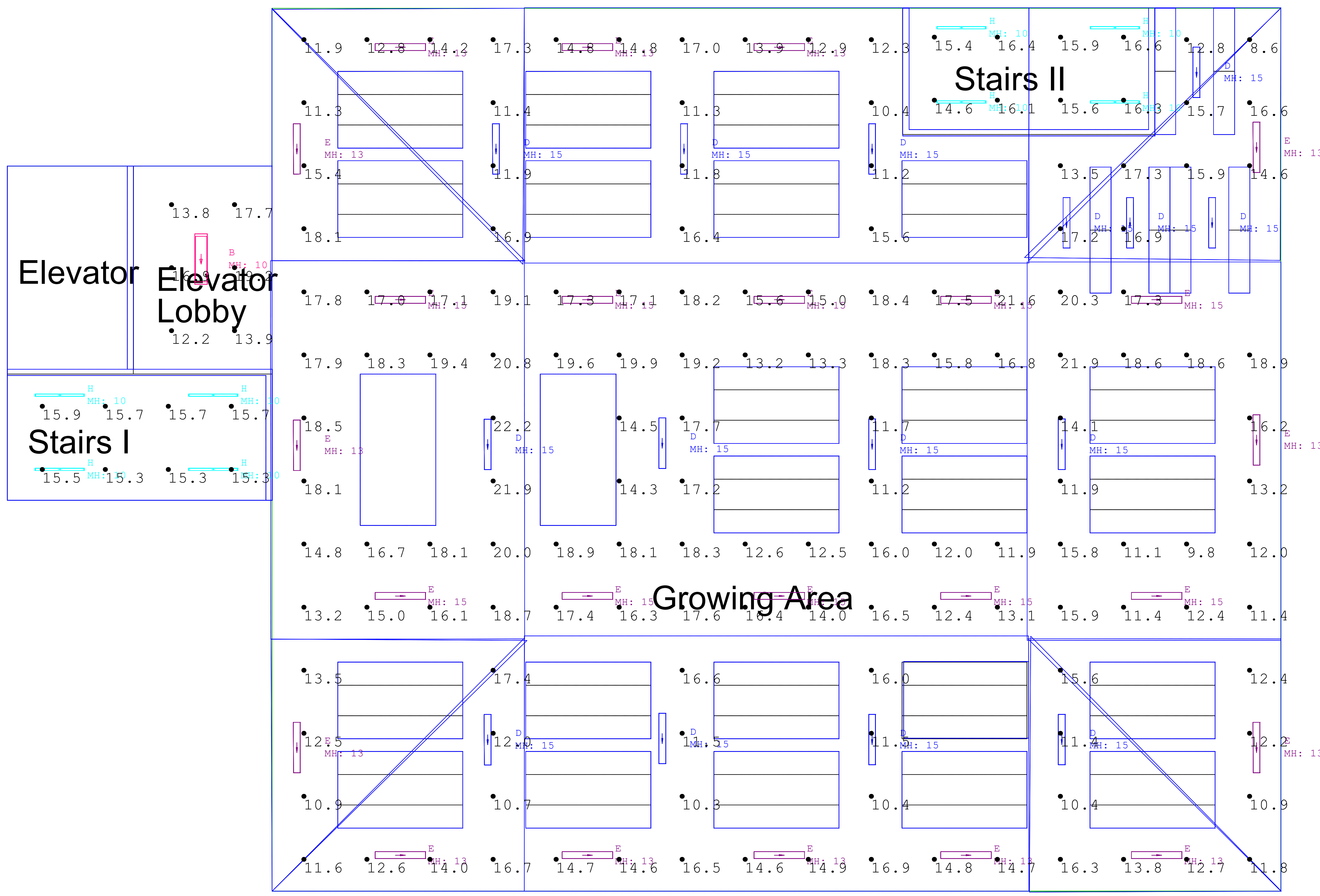
#	Date	Comments

Drawn By: Veronica Rivero Gorrin

Date:2/25/2015

Lighting Design

Fourth Floor



#	Date	Comments

Revisions

Drawn By: Veronica Rivero Gorrin

Date:2/25/2015

Lighting Design

Fifth Floor

Lighting Levels Estimation

	Area	Lighting Level Required	Average Illuminance	Number of Fixtures	Fixture Specified	Power Consumption per Fixture (W)	Room Power Consumption (W)	Lighting Density (W/ft^2)	Average hourly usage(KWh)	Hours Used per Day	Total Daily Load (KWh)	Days per Week Used	Annual Usage	Total Annual Load (KWh)
Basement				**79**			**2168**		**2.17**		**9.11**			**2367.92**
Cooler 1	101.98	10	11.13	2	G	29	58	0.57	0.06	3	0.17	5	260	45.24
Cooler 2	321.58	10	13.3	4	G	29	116	0.36	0.12	3	0.35	5	260	90.48
Cooler 3	400.1	10	13.26	4	G	29	116	0.29	0.12	3	0.35	5	260	90.48
Cooler 4	124.14	10	11.38	2	G	29	58	0.47	0.06	3	0.17	5	260	45.24
Freezer	235.15	10	10.01	2	F	38	76	0.32	0.08	3	0.23	5	260	59.28
Storage 1	1336.61	10	11.97	9	G	29	261	0.20	0.26	4	1.04	5	260	271.44
Storage 2	1247.56	10	12.14	9	G	29	261	0.21	0.26	4	1.04	5	260	271.44
Storage 3	1754.68	10	12.18	13	G	29	377	0.21	0.38	4	1.51	5	260	392.08
Women's Bathroom	324.47	15	19.42	3 3	G H	29 7	108	0.33	0.11	3	0.32	5	260	84.24
Men's Bathroom	325.23	15	14.34	2 2	G H	29 7	72	0.22	0.07	3	0.22	5	260	56.16
Recycling Room	119.79	10	11.33	2	G	29	58	0.48	0.06	1	0.06	5	260	15.08
Elevator Lobby	164.93	10	12.88	1	B	56.9	56.9	0.34	0.06	6	0.34	5	260	88.76
Stairs I	180	15	17.99	4	H	7	28	0.16	0.03	6	0.17	5	260	43.68
Stairs II	191	15	18.68	4	H	7	28	0.15	0.03	6	0.17	5	260	43.68
Corridors	1075.03	15	16.39	13	F	38	494	0.46	0.49	6	2.96	5	260	770.64
First Floor				**107**			**4422**		**4.31**		**30.29**			**7874.78**
Market	3647.23	30	30.95	18 6 4 1	A B C **F**	74.4 56.9 45.4 **38**	**1900.2**	**0.52**	1.90	**8**	15.20	5	260	3952.42
Women's Bathroom	129.94	15	24.55	2 2	**G** H	**29** 7	**72**	**0.55**	0.07	**4**	0.29	5	260	74.88
Men's Bathroom	135.65	15	26.53	2 2	**G** H	**29** 7	**72**	**0.53**	0.07	**4**	0.29	5	260	74.88
Shipping & Receiving	330.75	15	17.5	4	**G**	**29**	**116**	**0.35**	0.12	**6**	0.70	5	260	180.96
Processing	3036.44	30	27.56	32	**F**	**38**	**1216**	**0.40**	1.22	**8**	9.73	5	260	2529.28
Office I	87.88	50	48.78	1	B	56.9	**56.9**	**0.65**	0.06	**8**	0.46	5	260	118.35
Office II	87.08	50	48.75	1	B	56.9	**56.9**	**0.65**	0.06	**8**	0.46	5	260	118.35
Mud Room	211.1	15	15.46	3	**F**	**38**	**114**	**0.54**	0.11	**2**	0.23	5	260	59.28
Workshop	810.1	50	44.23	13	C	45.4	**590.2**	**0.73**	0.59	**2**	1.18	5	260	306.90
Elevator Lobby	164.93	10	15.55	1	B	56.9	**56.9**	**0.34**	0.06	**8**	0.46	5	260	118.35
Stairs I	180	15	20.58	**4**	H	7	**28**	**0.16**	0.03	**8**	0.22	5	260	58.24
Stairs II	191	15	20.83	**4**	H	7	**28**	**0.15**	0.03	**8**	0.22	5	260	58.24
Stairs III	172.9	15	21.33	**4**	H	7	**28**	**0.16**	0.03	**6**	0.17	5	260	43.68
Corridors	225.13	15	18.28	**3**	**G**	**29**	**87**	**0.39**	0.09	**8**	0.70	5	260	180.96
Second Floor				**91**			**2896**		**2.90**		**21.99**			**1855.26**
Gathering Space	3967.5	30	32.26	48	**F**	**38**	**1824**	**0.46**	1.82	**8**	14.59	1.5	78	1138.18
Breakout Space	1374.55	30	29.7	19	**F**	**38**	**722**	**0.53**	0.72	**8**	5.78	1.5	78	450.53
Women's Bathroom	216.56	15	24.9	3 3	**G** H	**29** 7	**108**	**0.50**	0.11	**4**	0.43	1.5	78	33.70
Men's Bathroom	191.39	15	22.59	3 2	**G** H	**29** 7	**101**	**0.53**	0.10	**4**	0.40	1.5	78	31.51
Elevator Lobby	164.93	10	16.97	1	B	56.9	**56.9**	**0.34**	0.06	**6**	0.34	1.5	78	26.63
Stairs I	180	15	20.34	**4**	H	7	**28**	**0.16**	0.03	**8**	0.22	5	260	58.24
Stairs II	191	15	20.63	**4**	H	7	**28**	**0.15**	0.03	**8**	0.22	5	260	58.24
Stairs III	172.9	15	20.35	**4**	H	7	**28**	**0.16**	0.03	**8**	0.22	5	260	58.24
Third Floor				**118**			**4440**		**4.02**		**21.10**			**5509.68**
Classroom I	548.94	50	43.28	8	C	45.4	**363.2**	**0.66**	0.36	**4**	1.45	4	208	302.18
Classroom II	685	50	48.77	12	C	45.4	**544.8**	**0.80**	0.54	**4**	2.18	4	208	453.27
Classroom III	722.1	50	48.35	12	C	45.4	**544.8**	**0.75**	0.54	**4**	2.18	4	208	453.27
Kitchen	842.88	50	44.14	12	C	45.4	**544.8**	**0.65**	0.54	**2**	1.09	4	208	226.64
Storage I	100.5	10	10.95	1	C	45.4	**45.4**	**0.45**	0.05	**1**	0.05	4	208	9.44
Storage II	140.54	10	10.95	1	C	45.4	**45.4**	**0.32**	0.05	**1**	0.05	4	208	9.44
University Incubator	485.79	50	45.62	14	**F**	**38**	**532**	**1.10**	0.53	**8**	4.26	7	364	1549.18
Women's Bathroom	244.09	15	24.25	**3** **3**	**G** H	**29** 7	**108**	**0.44**	0.11	**6**	0.65	4	208	134.78
Men's Bathroom	211.19	15	19.93	**2** **2**	**G** H	**29** 7	**72**	**0.34**	0.07	**6**	0.43	4	208	89.86
Elevator Lobby	164.93	10	14.92	1	B	56.9	**56.9**	**0.34**	0.06	**6**	0.34	5	260	88.76
Stairs I	180	15	21.09	**4**	H	7	**28**	**0.16**	0.03	**8**	0.22	5	260	58.24
Stairs II	191	15	20.89	**4**	H	7	**28**	**0.15**	0.03	**8**	0.22	5	260	58.24
Growing Area Corridor	3500	15	14.7	14 10	D E	48 42	**672** **420**	**0.19**	0.67	**8**	5.38	5	260	1397.76
Corridors	1434.75	15	15.38	15	**G**	**29**	**435**	**0.30**	0.44	**6**	2.61	5	260	678.60
Fourth Floor				**78**			**2898**		**2.90**		**13.91**			**5850.05**
Copy Room	94.6	10	15.72	1	C	45.4	45.4	0.48	0.05	2	0.09	5	260	23.61
Office Area	886.18	50	46.99	10	B	56.9	569	0.64	0.57	8	4.55	5	260	1183.52
Meeting Room	444.35	30	31.45	4	C	45.4	181.6	0.41	0.18	6	1.09	5	260	283.30
Director Office	394.39	50	38.29	4 1	C H	45.4 7	188.6	0.48	0.19	8	1.51	5	260	392.29
Reception & Corridor	1561.95	15	16.86	12	**G**	**29**	348	0.22	0.35	8	2.78	5	260	723.84
Staff Area	334.49	**50**	**46.15**	**4**	B	56.9	227.6	0.68	0.23	8	1.82	5	260	473.41
Storage	25.94	10	16.9	1	H	7	7	0.27	0.01	1	0.01	5	260	1.82
Women's Bathroom	140.9	15	26.7	2 2	**G** H	**29** 7	72	0.51	0.07	8	0.58	5	260	149.76
Men's Bathroom	136.54	15	31.17	2 2	**G** H	**29** 7	72	0.53	0.07	8	0.58	5	260	149.76
Elevator Lobby	164.93	10	17.47	1	B	56.9	56.9	0.34	0.06	8	0.46	5	260	118.35
Stairs I	180	15	18.7	**4**	H	7	28	0.16	0.03	8	0.22	5	260	58.24
Stairs II	191	15	19.33	**4**	H	7	28	0.15	0.03	8	0.22	5	260	58.24
Growing Area Corridor	2950.38	15	17.27	11 13	D E	48 42	1074	0.36	1.07	8	8.59	5	260	2233.92
Fifth Floor				**48**			**1841**		**1.84**		**0.45**			**2992.81**
Stairs I	180	15	15.55	**4**	H	7	28	0.16	0.03	4	0.11	5	260	29.12
Stairs II	191	15	15.86	**4**	H	7	28	0.15	0.03	4	0.11	5	260	29.12
Elevator Lobby	164.93	10	15.62	1	B	56.9	56.9	0.34	0.06	4	0.23	5	260	59.18
Growing Area Corridor	5409	15	15.13	15 24	D E	48 42	1728	0.32	1.73	8	13.82	4	208	2875.39

Peak Consumption	18.13	Maximum Daily Consumption	96.85	Annual Consumption	26451

Appendix J: Monthly Water Consumption Spreadsheet

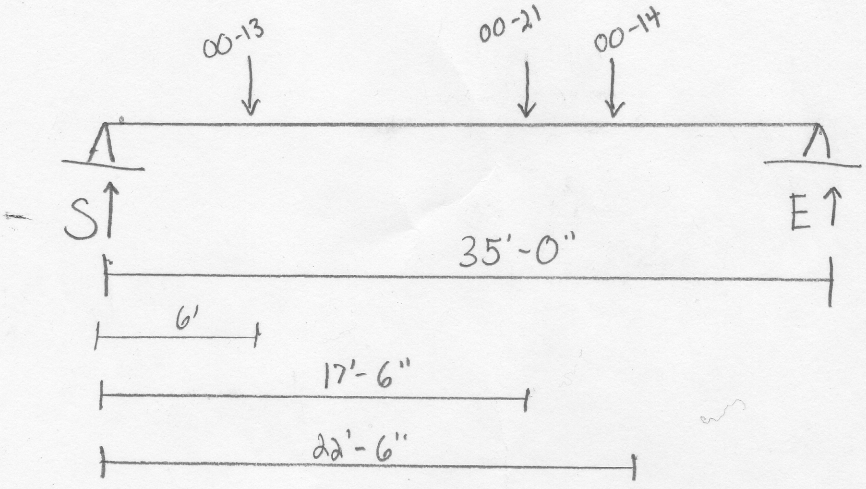
Water Loads Estimation									
	Type In	Type Out	Number of Fixtures	Gallons per ..	Time of Use (Mins)	Average Number of Uses Per Day	Total Daily Load (Gallons)	Days of the Month Used	Monthly Usage (Gallons)
Basement (32 Occupants)									
Showers	City	Grey	2	2 (Minute)	5	4	41.00	22	902
Bathroom Faucets (low flow aerators)	City	Grey	2	1.5 (Minute)	0.5	16	12	22	264
Toilets (HET)	City	Black	2	1.28 (flush)	-	16	19.2	22	422.4
Fire System	City	NA	-	-	-	-	-	-	-
First Floor (182 Occupants)									
Bathroom Faucets (low flow aerators)	City	Black	4	1.5 (Minute)	0.5	91	68.25	22	1502
Urinals	Grey	Black	1	0.5 (flush)	-	73	36.4	22	800.8
Toilets	Grey	Black	3	1.28 (flush)	-	91	116.48	22	2562.56
Fish Tank	City	Black	2	-	-	-	-	-	344
Processing (hose)	City	Black	4	1.5 (Minute)	5	50	300	22	6600
Second Floor (600 Occupants)									
Bathroom Faucets (low flow aerators)	Potable	Black	4	1.5 (Minute)	0.5	300	225	7	1575
Urinals	Grey	Black	1	0.5 (flush)	-	240	120	7	840
Toilets	Grey	Black	8	1.28 (flush)	-	300	384	7	2688
Third Floor (117 Occupants)									
Bathroom Faucets (low flow aerators)	City	Black	4	1.5 (Minute)	0.5	58.5	43.875	16	702
Urinals	Grey	Black	2	0.5 (flush)	-	46.8	23.4	16	374.4
Toilets	Grey	Black	6	1.28 (flush)	-	58.5	74.88	16	1198
Irrigation & Greenhouse Tank	City/Rain	Black/Evaporate	-	-	-	-	-	-	-
Kitchen Sink	City	Black	2	1.5 (Minute)	5	20	30	16	480
Dishwasher	City	Black	1	3.5 (load)	-	1	3.5	16	56
Fourth Floor (41 Occupants)									
Bathroom Faucets (low flow aerators)	City	Black	2	1.5 (Minute)	0.5	123	92.25	22	2029.5
Urinals	Grey		1	0.5 (flush)	-	82	41	22	902
Toilets	Grey	Black	3	1.28 (flush)	-	123	157.44	22	3464
Irrigation & Greenhouse Tank	City/Rain	Black/Evaporate	-	-	-	-	-	-	-
Fifth Floor (48 Occupants)									
Irrigation & Greenhouse Tank	City/Rain	Black/Evaporate	-	-	-	-	-	-	-

Total (Gallons)	**Daily Consumption**	**1788.68**	Annual Consumption	**27706**

Typical Simply Supported Beam Calc.

Member 00-17

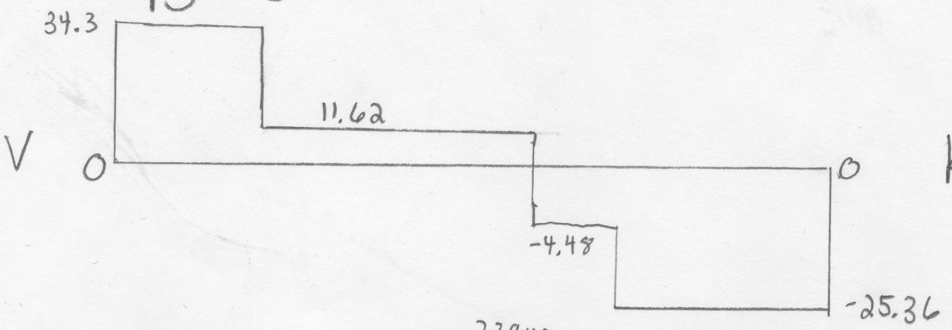
00-13 = 22.68 k
00-21 = 16.1 k
00-14 = 20.88 k

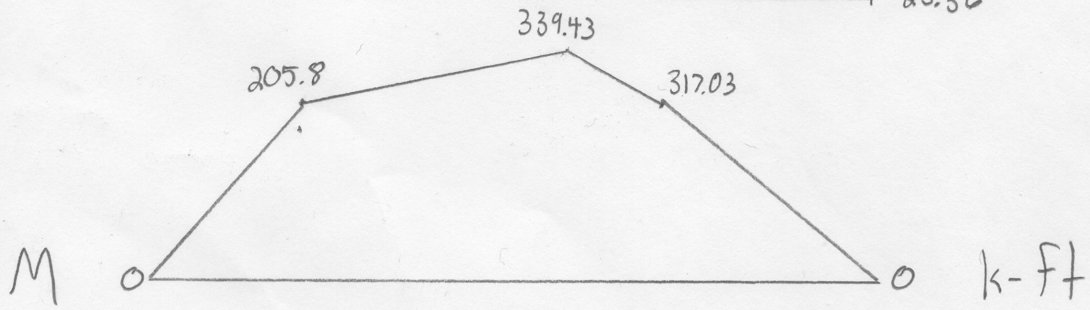


$$\Sigma M_S = 0 = (22.68^k \cdot 6') + (16.1^k \cdot 17.5') + (20.88^k \cdot 22.5') - (E^k \cdot 35')$$

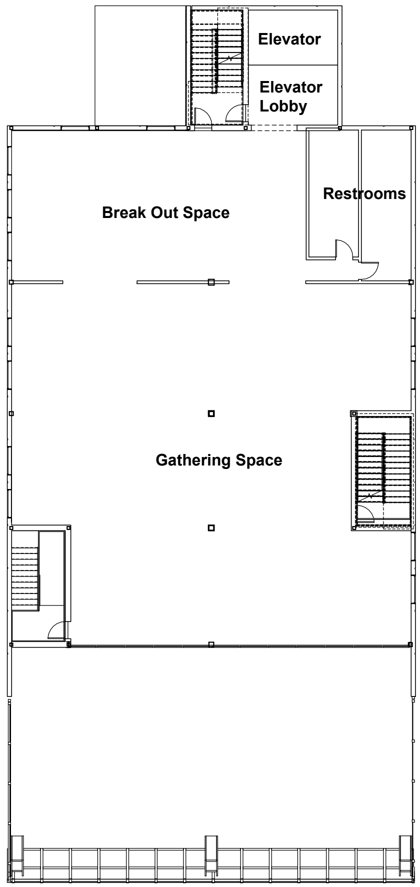
↑ E = 25.361 k

↑ S = 34.3 k

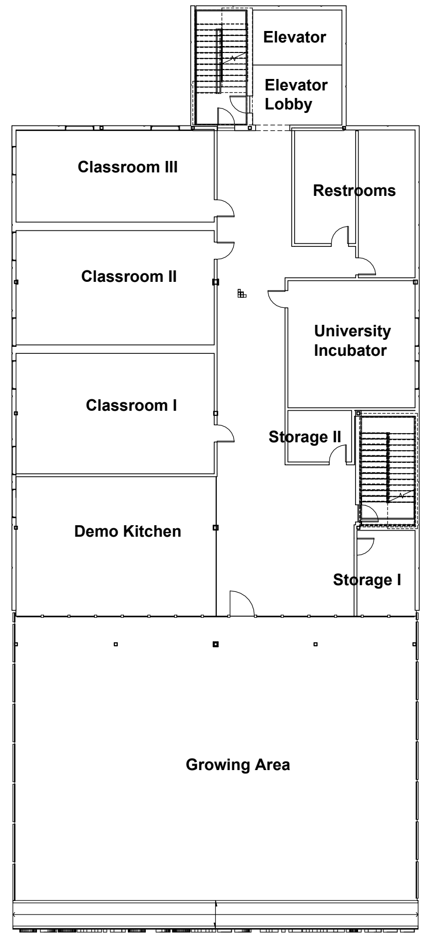




Appendix L: Architectural Drawings



1 Level 2 - Architectural
1/8" = 1'-0"



2 Level 3 - Architectural
1/8" = 1'-0"

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

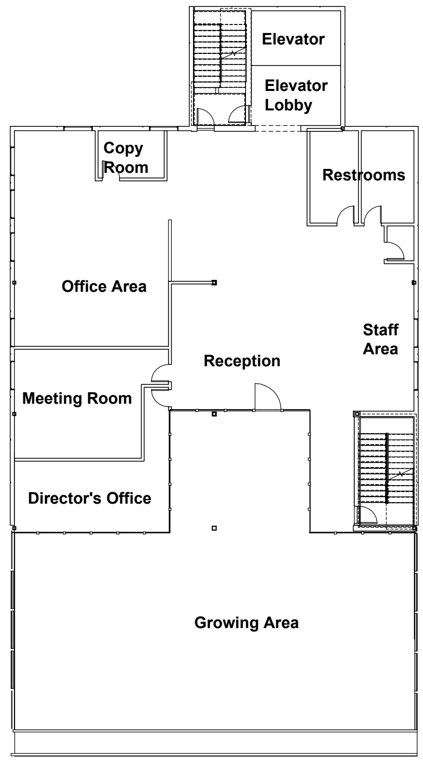
Floor Plans - Second & Third Floor

Project Number	
Date	03/05/15
Drawn By	JJWVA
Checked By	

A2

Scale 1/8" = 1'-0"

3/17/2015 5:49:37 PM



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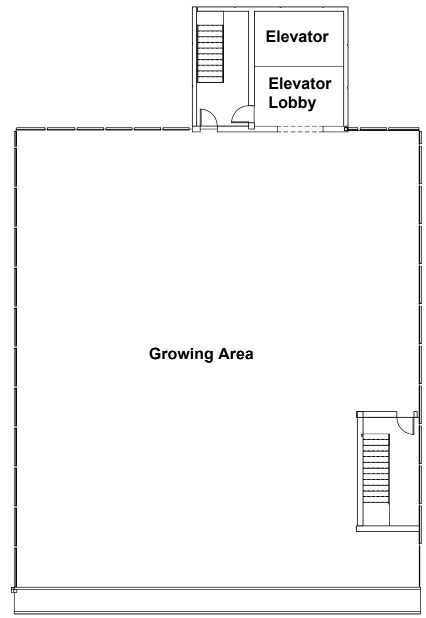

2 Level 5 - Architectural
1/8" = 1'-0"

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

Floor Plans - Fourth & Fifth Floor

Project Number	
Date	03/05/15
Drawn By	JJWVA
Checked By	

A3

Scale	1/8" = 1'-0"

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

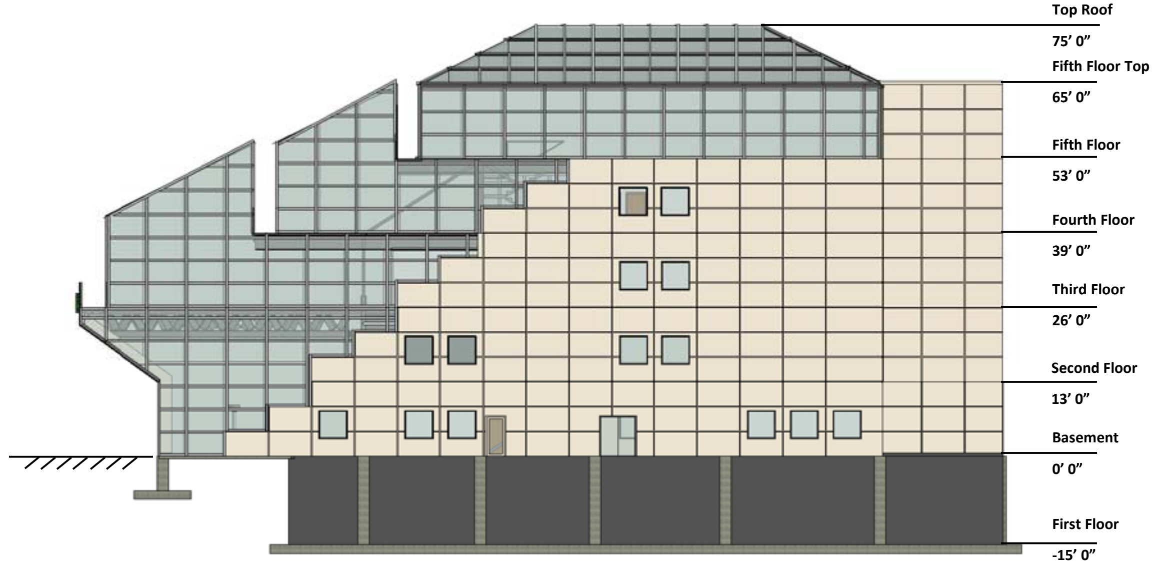
Elevations - North & South

Date	02/10/15
Drawn By	JJWVA
Checked By	Checker

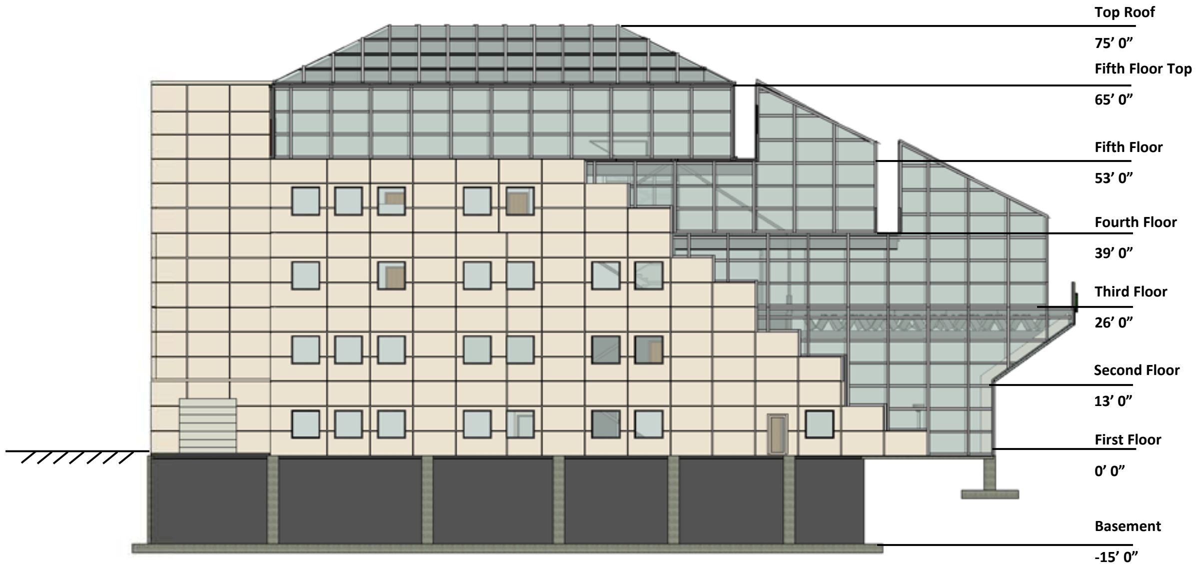
A4

Scale

2/11/2015 2:41:34 PM



1 Elevation East



2 Elevation West

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

Elevations - East & West

Date 02/10/15

Drawn By JJWVA

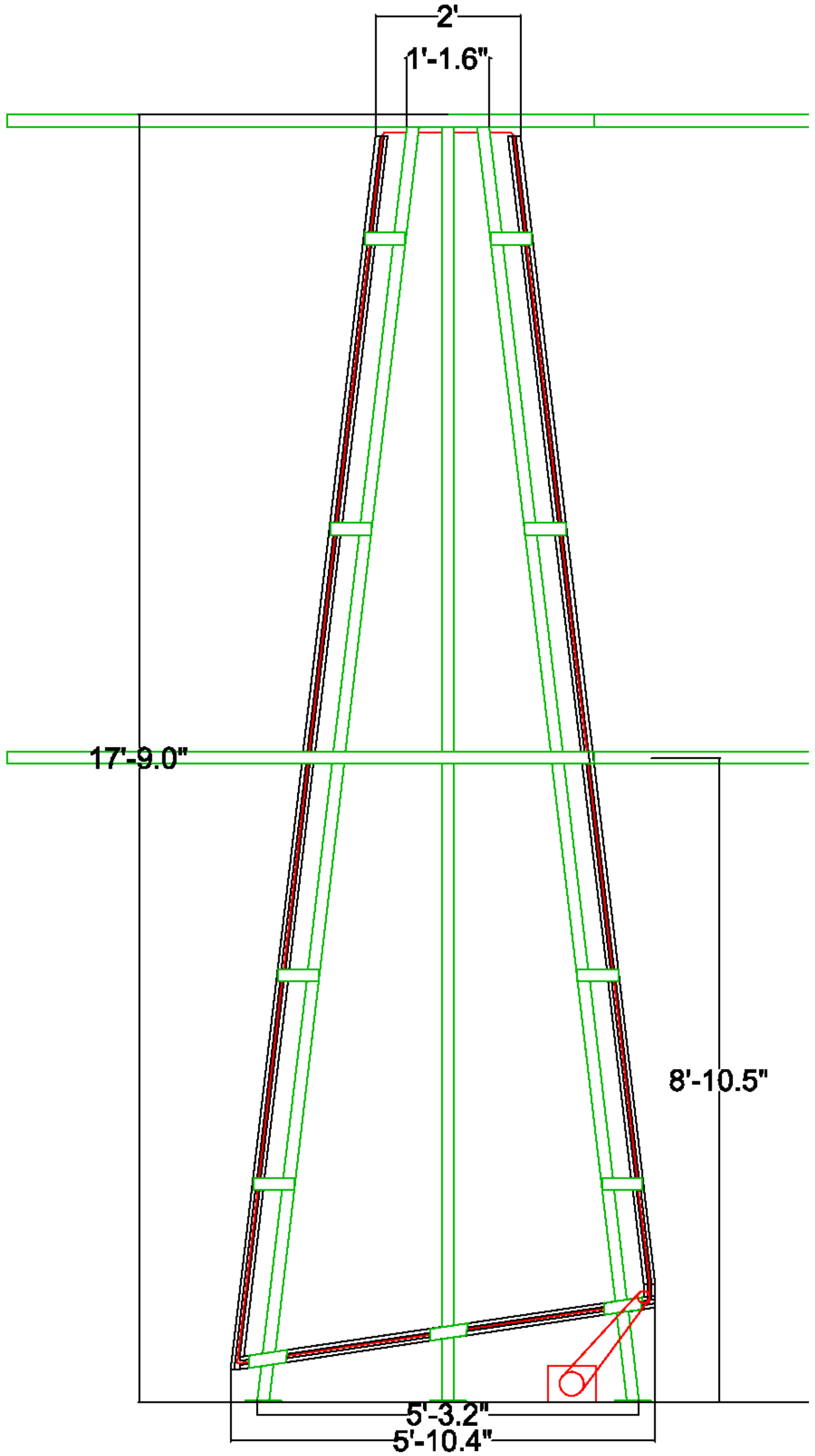
Checked By Checker

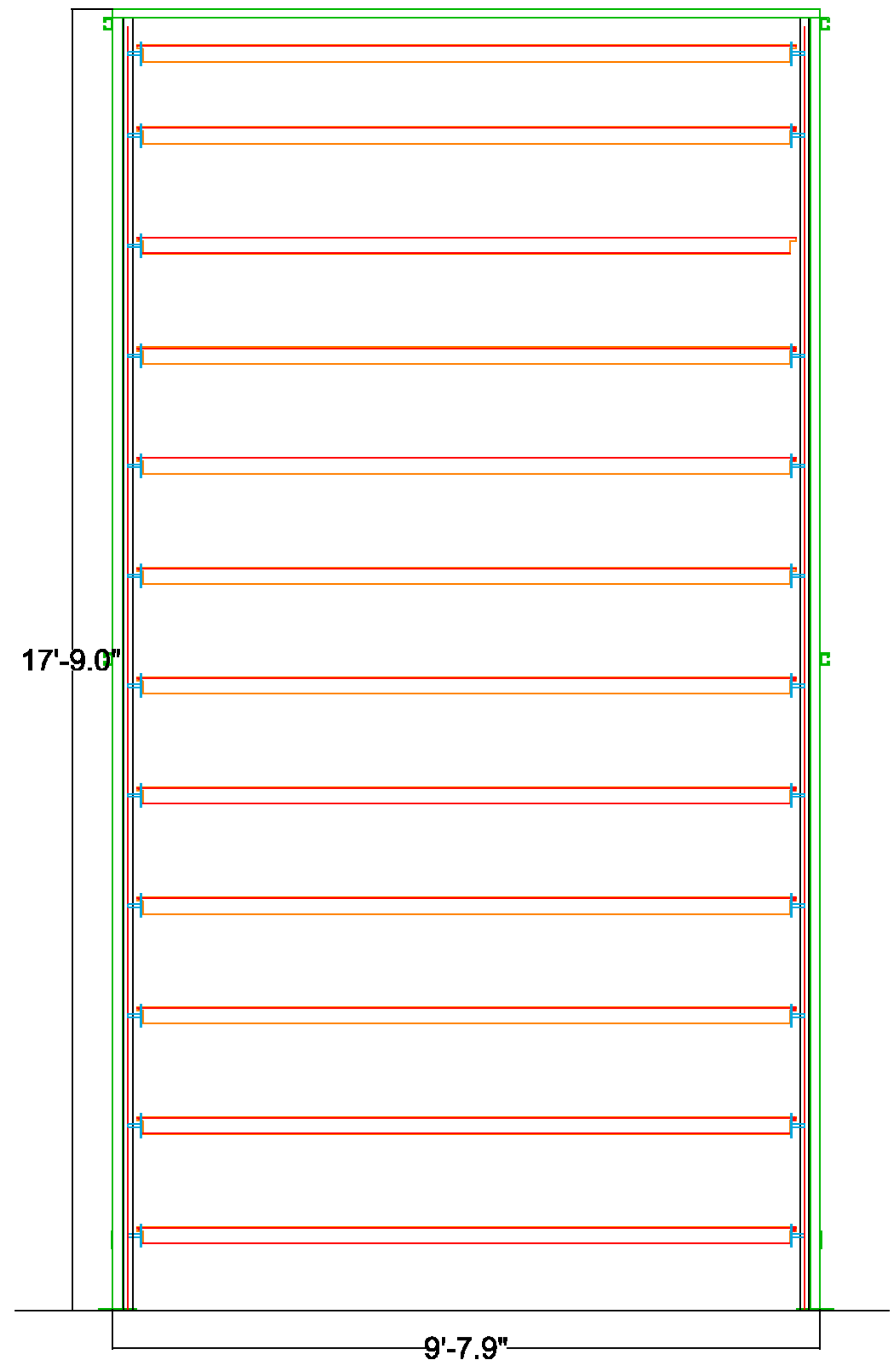
A5

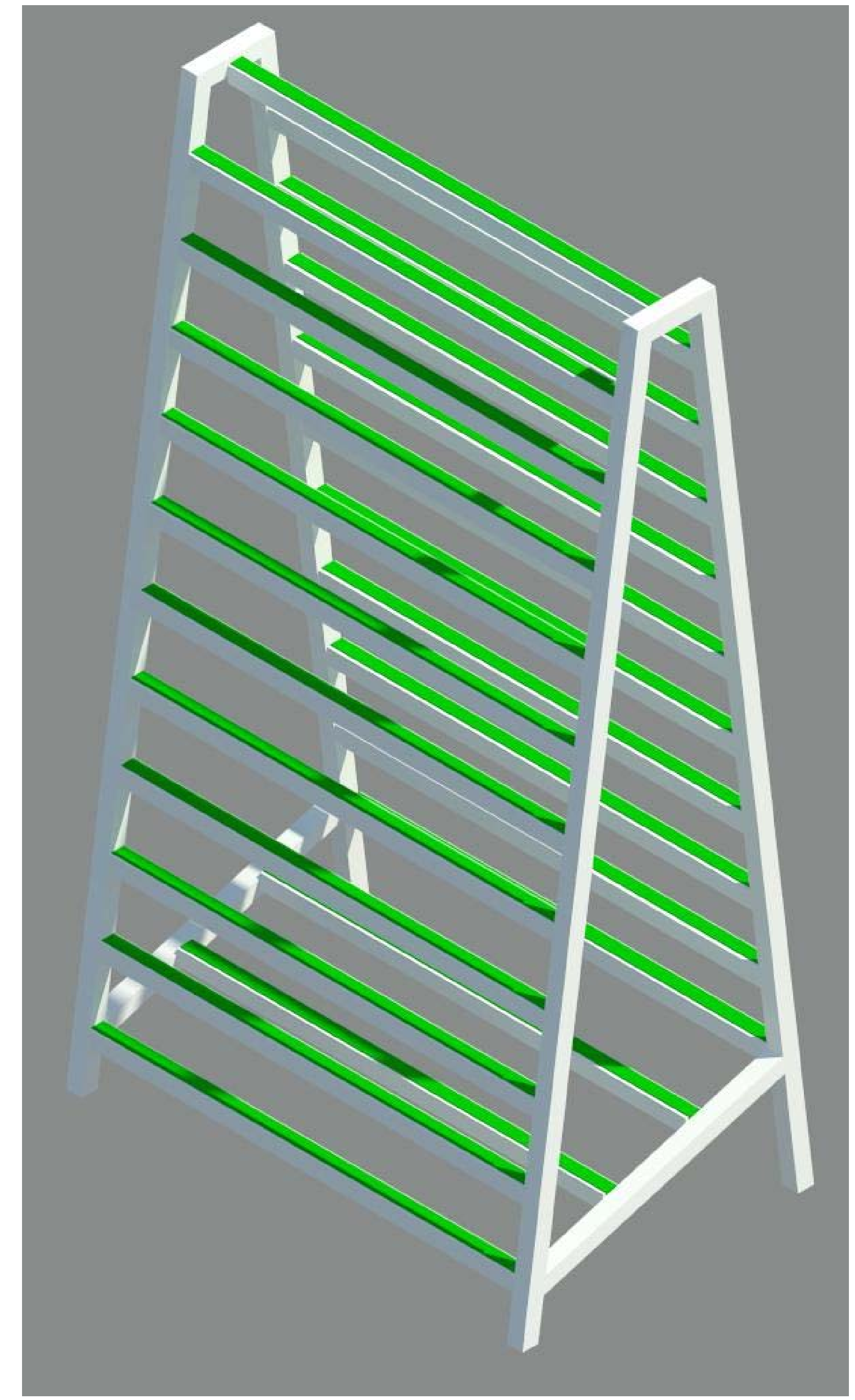
Scale

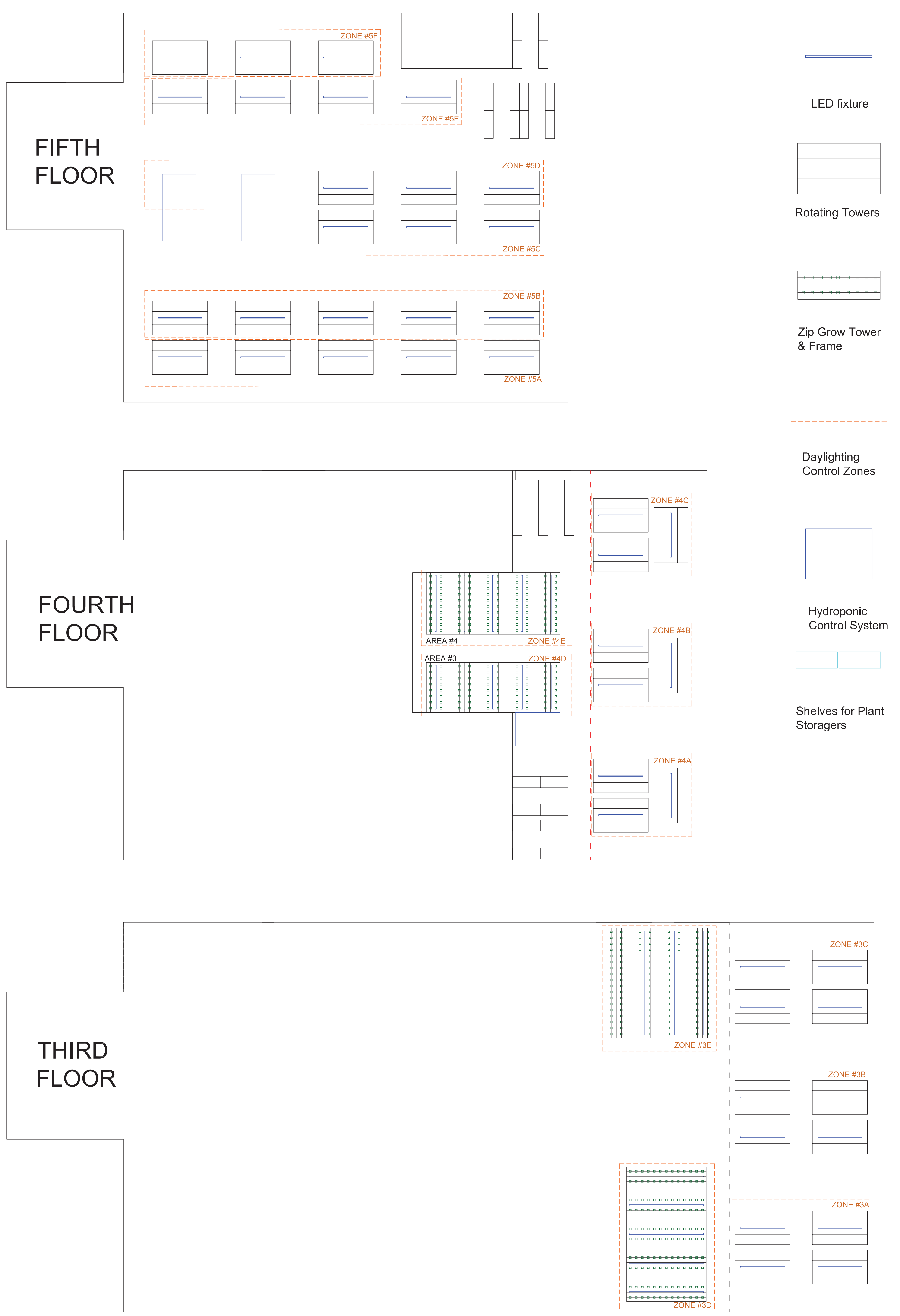
2/11/2015 2:41:42 PM

Appendix M: Vertical Rotating Tower Drawings

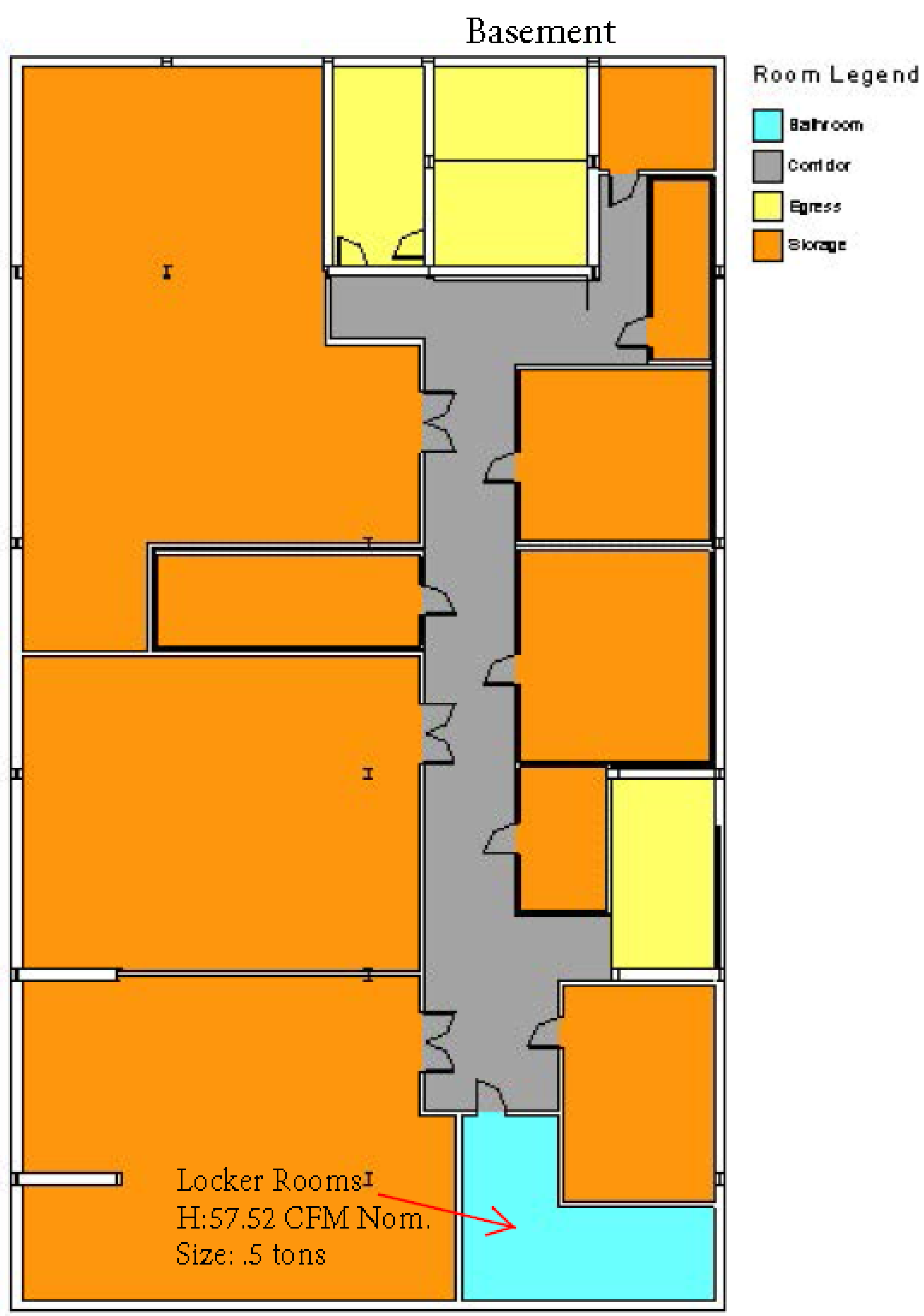


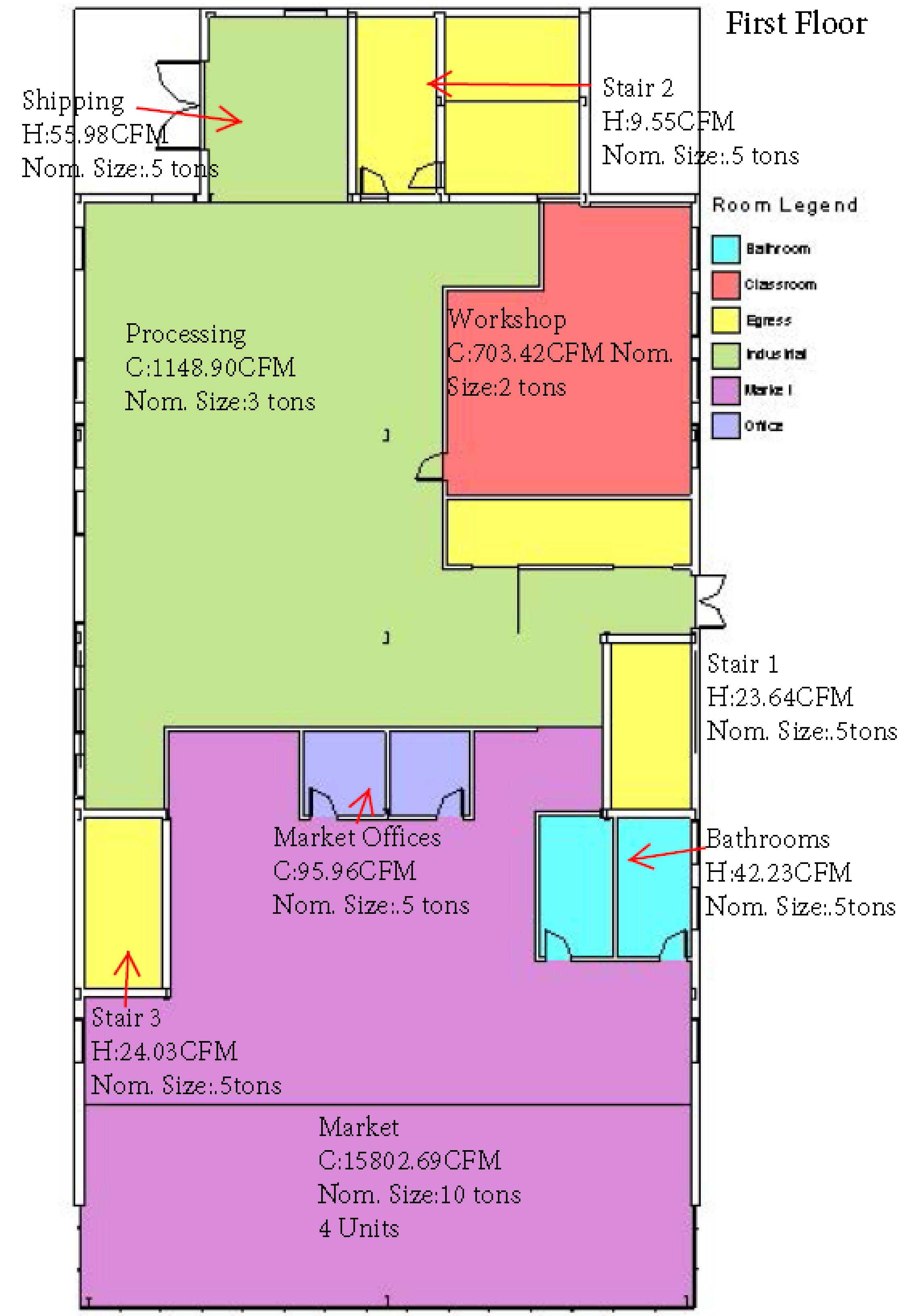


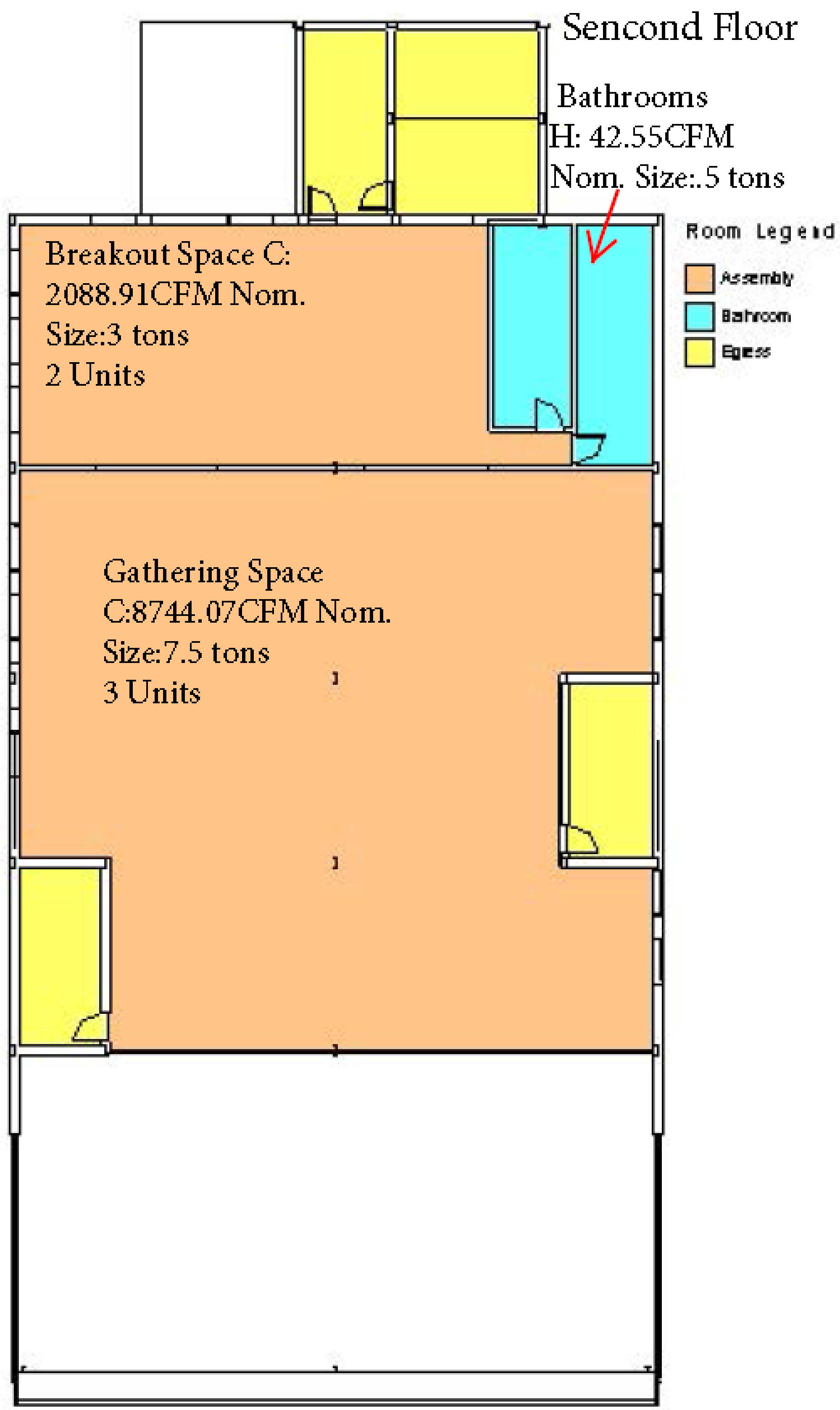


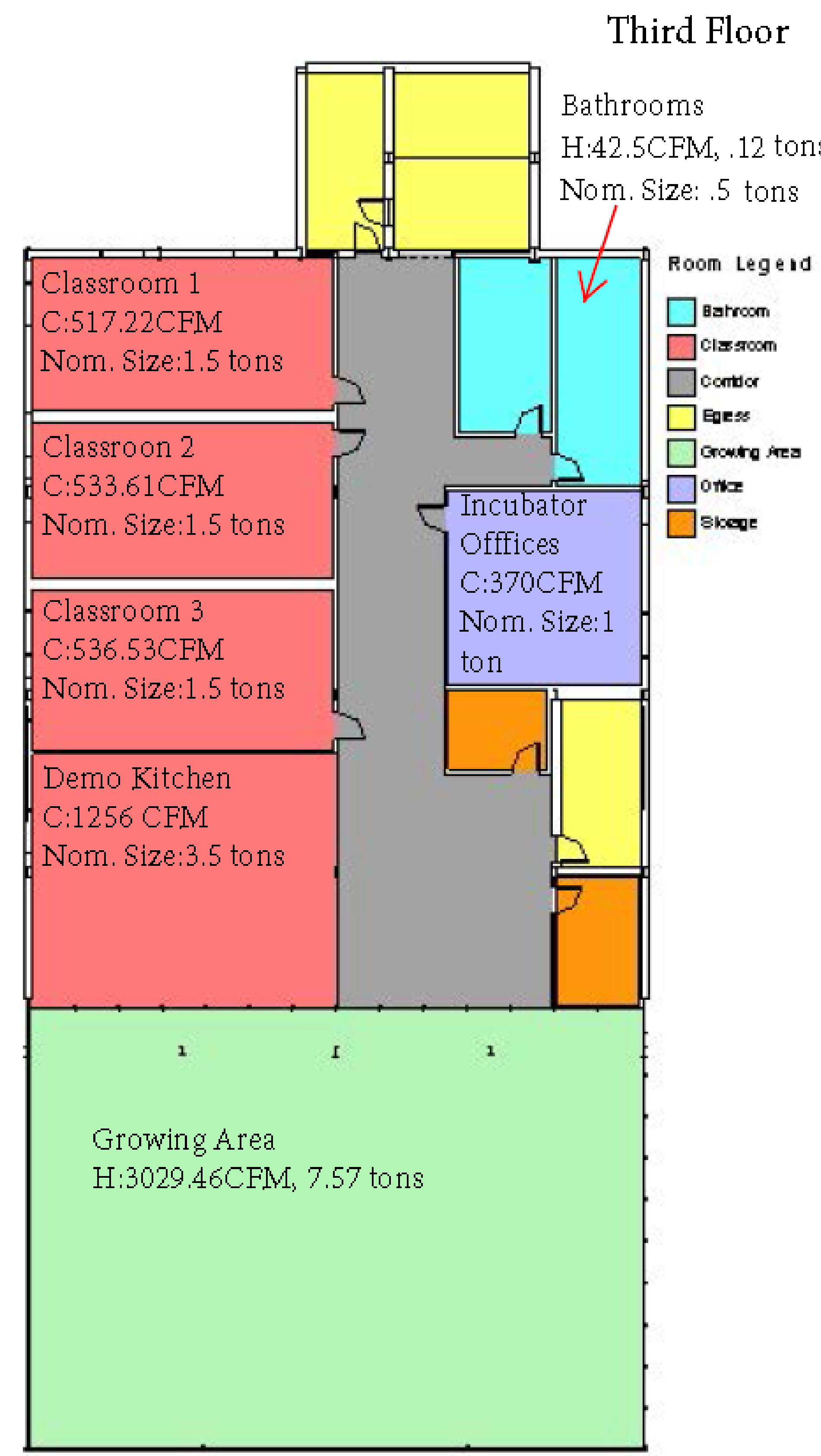


FIFTH FLOOR
ZONE #5F
ZONE #5E
ZONE #5D
ZONE #5C
ZONE #5B
ZONE #5A
FOURTH FLOOR
ZONE #4C
ZONE #4B
ZONE #4A
AREA #4
ZONE #4E
AREA #3
ZONE #4D
THIRD FLOOR
ZONE #3E
ZONE #3D
ZONE #3C
ZONE #3B
ZONE #3A
LED fixture
Rotating Towers
Zip Grow Tower & Frame
Daylighting Control Zones
Hydroponic Control System
Shelves for Plant Storagers

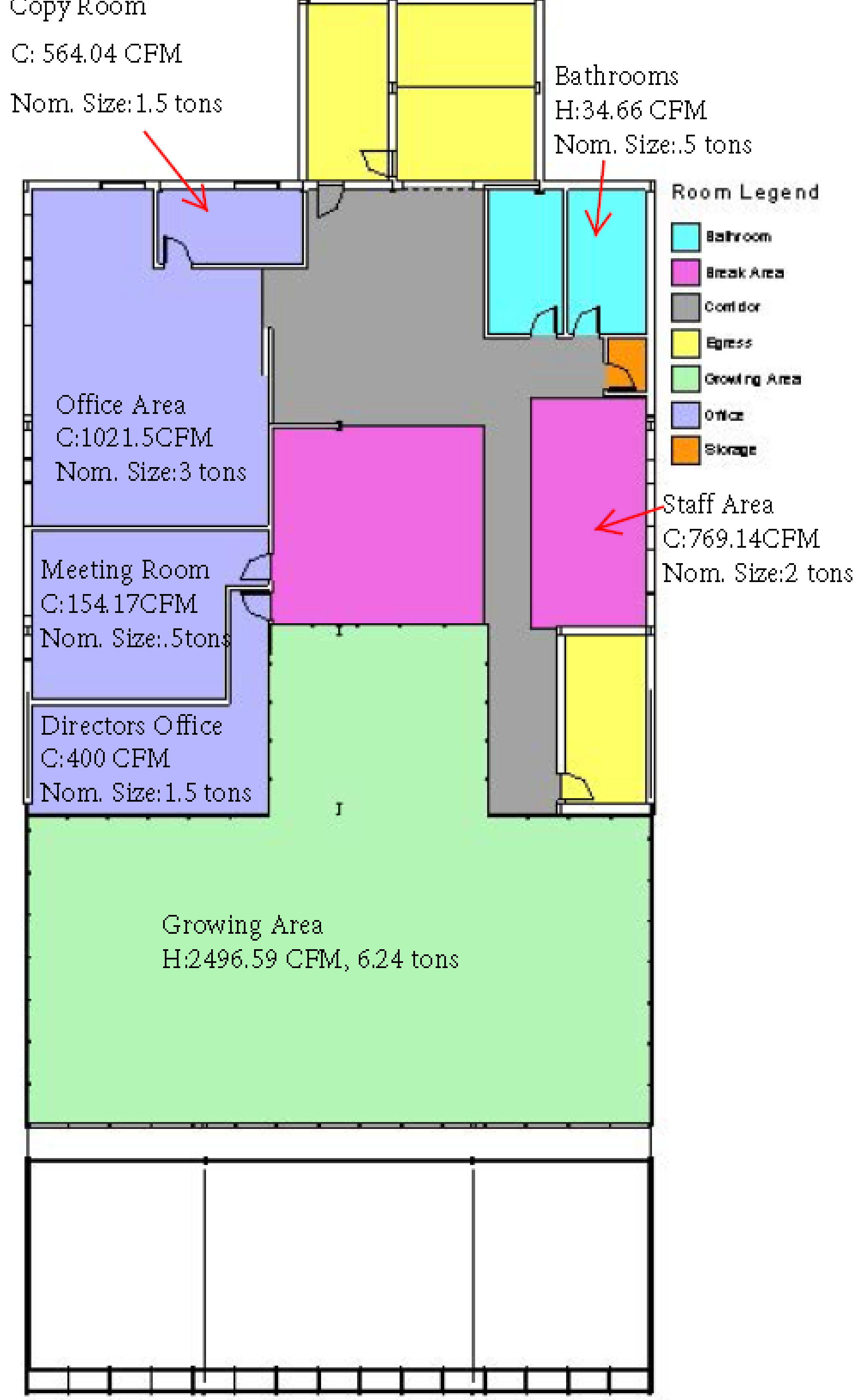

Basement
Room Legend
Bathroom
Corridor
Egress
Storage
Locker Rooms
H:57.52 CFM Nom.
Size: .5 tons


First Floor
Shipping
H:55.98CFM
Nom. Size:.5 tons
Stair 2
H:9.55CFM
Nom. Size:.5 tons
Room Legend
Bathroom
Classroom
Egress
Industrial
Market
Office
Processing
C:1148.90CFM
Nom. Size:3 tons
Workshop
C:703.42CFM Nom.
Size:2 tons
Stair 1
H:23.64CFM
Nom. Size:.5tons
Market Offices
C:95.96CFM
Nom. Size:.5 tons
Bathrooms
H:42.23CFM
Nom. Size:.5tons
Stair 3
H:24.03CFM
Nom. Size:.5tons
Market
C:15802.69CFM
Nom. Size:10 tons
4 Units

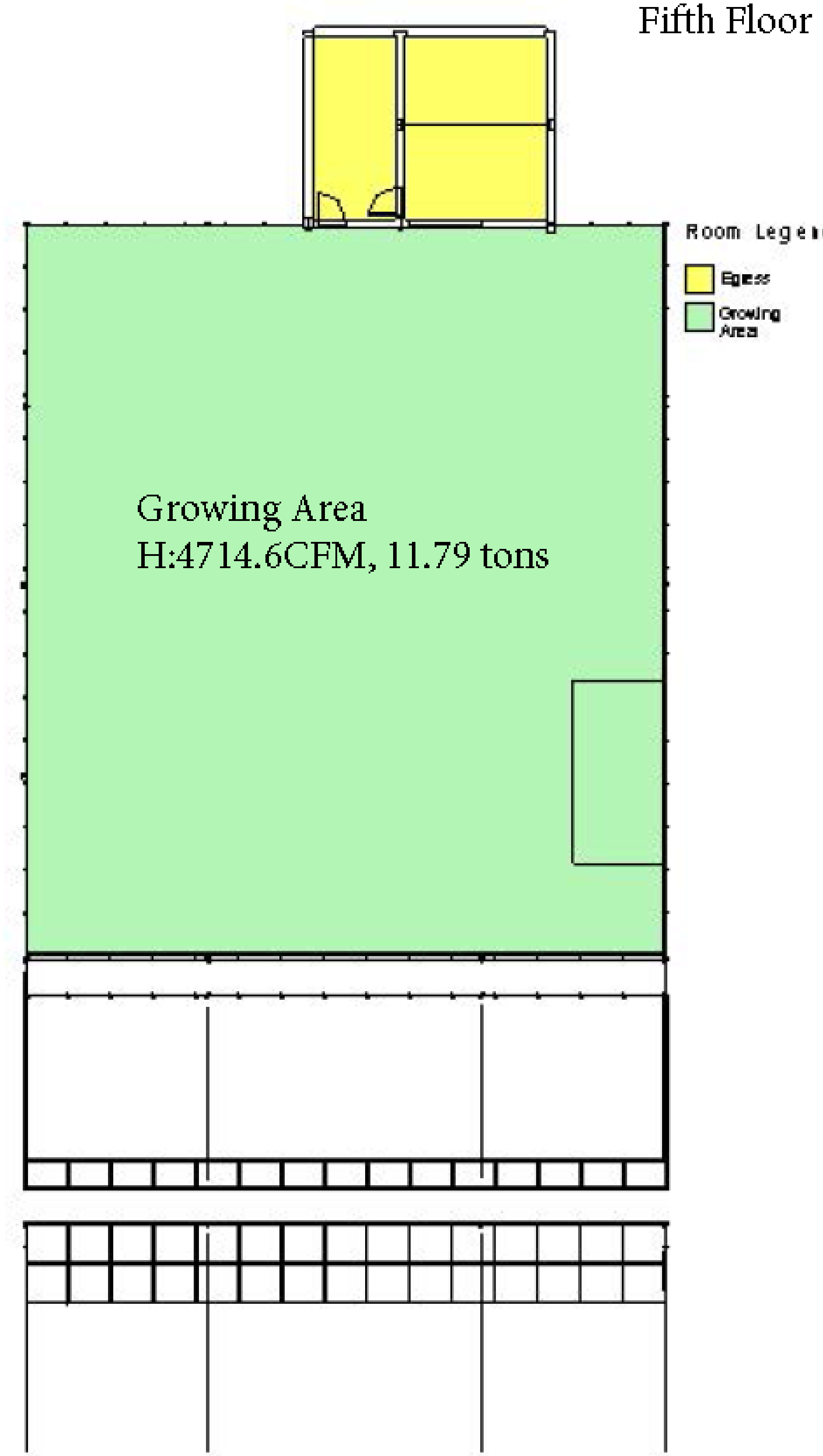

Sencond Floor
Bathrooms
H: 42.55CFM
Nom. Size:.5 tons
Room Legend
Assembly
Bathroom
Egress
Breakout Space C:
2088.91CFM Nom.
Size:3 tons
2 Units
Gathering Space
C:8744.07CFM Nom.
Size:7.5 tons
3 Units


Third Floor
Bathrooms
H:42.5CFM, .12 tons
Nom. Size: .5 tons
Room Legend
Bathroom
Classroom
Corridor
Egress
Growing Area
Office
Storage
Classroom 1
C:517.22CFM
Nom. Size:1.5 tons
Classroon 2
C:533.61CFM
Nom. Size:1.5 tons
Classroom 3
C:536.53CFM
Nom. Size:1.5 tons
Demo Kitchen
C:1256 CFM
Nom. Size:3.5 tons
Incubator
Offfices
C:370CFM
Nom. Size:1
ton
Growing Area
H:3029.46CFM, 7.57 tons

Fourth Floor



Fifth Floor



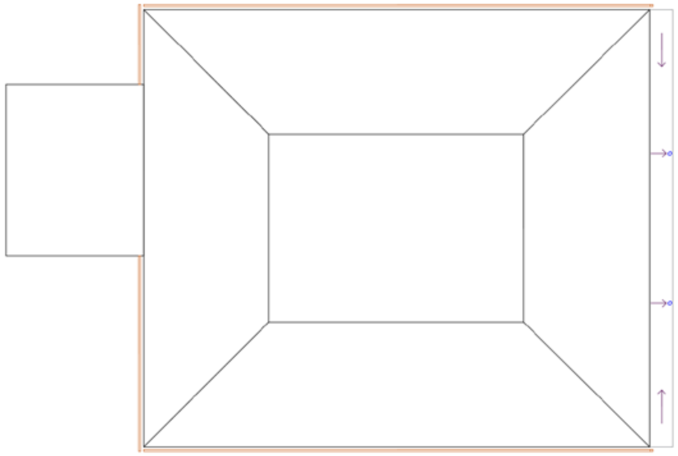
	Area	ASHRAE 90 Lighting Density (W/ft^2)	New Design Lighting Density (W/ft^2)
Basement			
Cooler 1	101.98	0.63	0.57
Cooler 2	321.58	0.63	0.36
Cooler 3	400.1	0.63	0.29
Cooler 4	124.14	0.63	0.47
Freezer	235.15	0.63	0.32
Storage I	1336.61	0.63	0.20
Storage II	1247.56	0.63	0.21
Storage III	1754.68	0.63	0.21
Women's Locker Room	324.47	0.75	0.33
Men's Locker Room	325.23	0.75	0.22
Recycling Room	119.79	0.63	0.48
Elevator Lobby	164.93	0.64	0.34
Stairs I	180	0.69	0.16
Stairs II	191	0.69	0.15
Corridors	1075.03	0.66	0.46
First Floor			
Market	3647.23	1.10	0.52
Women's Bathroom	129.94	0.97	0.55
Men's Bathroom	135.65	0.97	0.53
Shipping & Receiving	330.75	1.29	0.35
Processing	3036.44	1.29	0.40
Office I	87.88	0.75	0.65
Office II	87.08	0.75	0.65
Mud Room	211.1	0.66	0.54
Workshop	810.1	1.59	0.73
Elevator Lobby	164.93	0.64	0.34
Stair I	180	0.69	0.16
Stair II	191	0.69	0.15
Stair III	172.9	0.69	0.16
Corridors	225.13	0.66	0.39
Second Floor			
Gathering Space	3967.5	1.23	0.46
Breakout Space	1374.55	1.23	0.53
Women's Bathroom	216.56	0.97	0.50
Men's Bathroom	191.39	0.97	0.53
Elevator Lobby	164.93	0.64	0.34
Stair I	180	0.69	0.16
Stair II	191	0.69	0.15
Stair III	172.9	0.69	0.16
Third Floor			
Classroom I	548.94	1.23	0.66
Classroom II	685	1.23	0.80
Classroom III	722.1	1.23	0.75
Kitchen	842.88	0.99	0.65
Storage I	100.5	0.63	0.45
Storage II	140.54	0.63	0.32
University Incubator	485.79	1.28	1.10
Women's Bathroom	244.09	0.97	0.44
Men's Bathroom	211.19	0.97	0.34
Elevator Lobby	164.93	0.64	0.34
Stairs I	180	0.69	0.16
Stairs II	191	0.69	0.15
Growing Area Corridors	3500	0.66	0.19
Corridors	1434.75	0.66	0.30
Fourth Floor			
Copy Room	94.6	0.75	0.48
Office Area	886.18	0.75	0.64
Meeting Room	444.35	1.23	0.41
Director Office	394.39	0.75	0.48
Reception & Corridor	1561.95	0.66	0.22
Staff Area	334.49	0.87	0.68
Storage	25.94	0.63	0.27
Women's Bathroom	140.9	0.97	0.51
Men's Bathroom	136.54	0.97	0.53
Elevator Lobby	164.93	0.64	0.34
Stairs I	180	0.69	0.16
Stairs II	191	0.69	0.15
Growing Area Corridors	2950.38	0.66	0.36
Fith Floor			
Stairs I	180	0.69	0.16
Stairs II	191	0.69	0.15
Elevator Lobby	164.93	0.64	0.34
Growing Area Corridors	5409	0.66	0.32

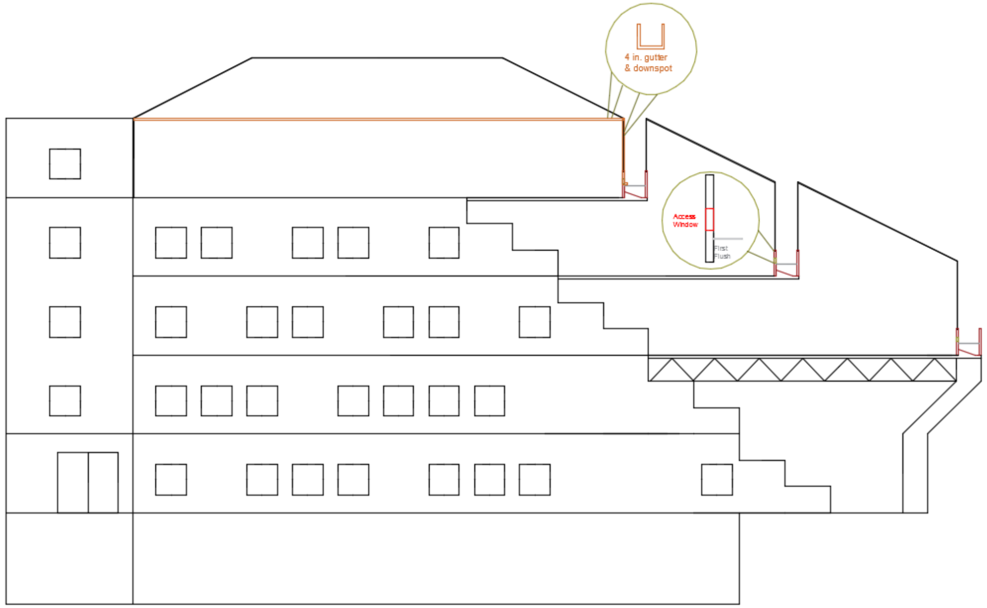
Appendix Q: Annual Water Consumption Spreadsheet

Water Loads Estimation

	Monthly Usage (Gallons)												Annual Usage (Gallons)
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	
Basement (32 Occupants)													
Showers	902	902	902	902	902	902	902	902	902	902	902	902	10824
Bathroom Faucets (low flow aerators)	264	264	264	264	264	264	264	264	264	264	264	264	3168
Toilets (HET)	422	422	422	422	422	422	422	422	422	422	422	422	5068.8
Fire System	790	-	-	35	-	-	35	-	-	35	-	-	895
First Floor (182 Occupants)													
Bathroom Faucets (low flow aerators)	1502	1502	1502	1502	1502	1502	1502	1502	1502	1502	1502	1502	18018
Urinals	801	801	801	801	801	801	801	801	801	801	801	801	9609.6
Toilets	2563	2563	2563	2563	2563	2563	2563	2563	2563	2563	2563	2563	30750.72
Fish Tank	344	344	344	344	344	344	344	344	344	344	344	344	4128
Processing (hose)	6600	6600	6600	6600	6600	6600	6600	6600	6600	6600	6600	6600	79200
Second Floor (600 Occupants)													
Bathroom Faucets (low flow aerators)	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	1575	18900
Urinals	840	840	840	840	840	840	840	840	840	840	840	840	10080
Toilets	2688	2688	2688	2688	2688	2688	2688	2688	2688	2688	2688	2688	32256
Third Floor (117 Occupants)													
Bathroom Faucets (low flow aerators)	702	702	702	702	702	702	702	702	702	702	702	702	8424
Urinals	374	374	374	374	374	374	374	374	374	374	374	374	4492.8
Toilets	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	1198	14376.96
Irrigation & Greenhouse Tank	784	784	4315	4315	4315	7845	7845	7845	4315	4315	4315	784	51775
Kitchen Sink	480	480	480	480	480	480	480	480	480	480	480	480	5760
Dishwasher	56	56	56	56	56	56	56	56	56	56	56	56	672
Fourth Floor (41 Occupants)													
Bathroom Faucets (low flow aerators)	2030	2030	2030	2030	2030	2030	2030	2030	2030	2030	2030	2030	24354
Urinals	902	0	0	0	0	0	0	0	0	0	0	0	902
Toilets	3464	3464	3464	3464	3464	3464	3464	3464	3464	3464	3464	3464	41564.16
Irrigation & Greenhouse Tank	563	563	3097	3097	5631	5631	5631	5631	3097	3097	563	563	37165
Fifth Floor (48 Occupants)													
Irrigation & Greenhouse Tank	984	984	5410	5410	5410	9837	9837	9837	5410	5410	5410	984	64922
Total	**30827**	**29135**	**39626**	**39661**	**42160**	**50116**	**50151**	**50116**	**39626**	**39661**	**37092**	**29135**	**477307**

Appendix R: Rain Catchment Layout





STRUCTURAL STEEL

1 STRUCTURAL STEEL SHALL BE NEW STEEL CONFORMING TO THE FOLLOWING:

(A)	UNLESS OTHERWISE NOTED	ASTM 992 OR A588 GRADE 50 (Fy=50 KSI)
(B)	ANGLES, CHANNELS, PLATES, BASE PLATES, AND BARS	ASTM A36 (Fy=36 KSI)
(C)	SQUARE AND RECTANGLE HOLLOW STRUCTURAL SECTIONS (HSS)	ASTM (A500, GRADE B (Fy=46 KSI)
(D)	ANCHOR RODS	ASTM F1554
(E)	HIGH STRENGTH BOLTS	ASTM A325

2 BOLTED CONNECTIONS SHALL BE AS FOLLOWS

(A) MINIMUM BOLT DIAMETER - 3/4"; TWO BOLTS MINIMUM

(B) STANDARD, OVERSIZED, OR HORIZONTAL SHORT-SLOTTED HOLES IN WEBS OF BEAMS

(C) SHEAR CONNECTIONS FOR MOMENT-CONNECTED MEMBERS - FRICTION TYPE HIGH STRENGTH BOLTS IN SINGLE SHEAR

(D) SHEAR CONNECTIONS FOR OTHER MEMBERS - SIMPLE SHEAR CONNECTIONS WITH EITHER FRICTION-TYPE HIGH STRENGTH BOLTS IN SINGLE SHEAR OR BEARING-TYPE HIGH STRENGTH BOLTS (THREADS INCLUDED IN SHEAR PLANE) IN SINGLE OR DOUBLE SHEAR

(E) SIMPLE SHEAR CONNECTIONS SHALL BE CAPABLE OF END ROTATION PER AISC REQUIREMENTS FOR "UNRESTRAINED MEMBERS"

3 BEAM AND GIRDER SHEAR CONNECTIONS TO COLUMNS SHALL CONSIST OF ONLY SIMPLE SHEAR CONNECTIONS CAPABLE OF END ROTATION PER AISC REQUIRMENTS. UNLESS NOTED OTHERWISE ON THE DRAWINGS, ANY CONNECTION TO COLUMNS THAT ARE NOT CAPABLE OF END ROTATION SHALL BE DESIGNED SO THAT NO MOMENT RESULTS ABOUT THE COLUMN CENTERLINE. ANY MOMENT DEVELOPED DUE TO ECCENTRICITY OF THE CENTER OF GRAVITY OF THE CONNECTION GROUP ABOUT THE COLUMN CENTERLINE SHALL BE RESOLVED BY THE INCLUSION OF SUPPLEMENTAL BOLTS OR WELDS

4 ANCHOR RODS, EMBED PLATES, LEVELING PLATES, OR BEARING PLATES SHALL BE LOCATED AND BUILT INTO CONNECTING WORK, PRESET BY TEMPLATES OR SIMILAR METHODS. PLATES SHALL BE SET IN FULL BEDS OF NON-SHRINK GROUT

5 ENDS OF COLUMNS AT SPLICES AND AT OTHER BEARING CONNECTIONS SHALL BE "FINISHED TO BEAR" TO COMPLETE TRUE BEARING

6 STRUCTURAL STEEL MEMBERS AND CONNECTIONS EXPOSED TO THE WEATHER SHALL BE GALVANIZED. REGIONS OF FIELD WELDS TO BE GALVANIZED SHALL BE TOUCHED UP WITH A ZINC RICH COATING AFTER COMPLETION AND INSPECTION OF THE WELD

7 CANTILEVERS SHALL BE TEMPORARILY SHORED UNTIL MOMENT CONNECTION IS INSTALLED TO FULL STRENGTH

STRUCTURAL DESIGN LOADS

1	DEAD LOADS		
	(A)	WEIGHT OF BUILDING COMPONENTS	AS REQUIRED
	(B)	ROOFING ALLOWANCE	60 PSF
	(C)	GREENHOUSE ROOF AREA - GLAZING & FRAMING	15 PSF
	(D)	GREENHOUSE AREAS	80 PSF
2	LIVE LOADS		
	(A)	OCCUPANCY CATEGORY	II
	(B)	INTERIOR UNLESS NOTED OTHERWISE	100 PSF
	(C)	LIGHT STORAGE	125 PSF
	(D)	LOADING DOCK	250 PSF
	(E)	MECHANICAL EQUIPMENT ROOM	150 PSF OR EQUIP WT
	(F)	CLASSROOMS	40 PSF
	(G)	OFFICES	50 PSF
	(H)	GREENHOUSE AREAS	80 PSF
3	SNOW LOADS		
	(A)	GROUND SNOW LOAD	30 PSF
	(B)	IMPORTANCE FACTOR (Is)	1.0
	(C)	EXPOSURE FACTOR (Ce)	0.9
	(D)	THERMAL FACTOR (Ct)	0.85
	(E)	FLAT ROOF SNOW LOAD	20 PSF + DRIFT
	(F)	GREENHOUSE SLOPED ROOF SNOW LOAD	15 PSF + DRIFT
4	WIND LOADS		
	(A)	BASIC WIND SPEED	115 MPH (WI) & 180 MPH (FL)
	(B)	IMPORTANCE FACTOR (Iw)	1.0
	(C)	EXPOSURE CATEGORY	C
	(D)	DIRECTIONALITY FACTOR (Kd)	0.85
	(E)	TOPOGRAPHIC FACTOR (Kzt)	1.0
	(F)	GUST FACTOR (G)	0.85
	(G)	EXTERNAL PRESSURE COEFFICIENT (Cp) (WINDWARD)	0.8
	(H)	EXTERNAL PRESSURE COEFFICIENT (Cp) (LEEWARD)	-0.5
	(I)	MAXIMUM WIND BASE SHEAR - EAST-WEST	35 KIPS
	(J)	MAXIMUM WIND BASE SHEAR - NORTH-SOUTH	25 KIPS
	(K)	MAIN WIND FORCE RESISTING SYSTEM - SHORT DIRECTION	SPECIAL REINFORCED MASONRY SHEAR WALL
	(L)	MAIN WIND FORCE RESISTING SYSTEM - LONG DIRECTION	STEEL SPECIAL TRUSS MOMENT FRAME
5	SEISMIC LOADS		
	(A)	Ss	0.087
	(B)	S1	0.046
	(C)	SITE CLASS - SITE SPECIFIC ANALYSIS	E
	(D)	Sds	0.144
	(E)	Sd1	0.108
	(F)	IMPORTANCE FACTOR (Ie)	1
	(G)	SEISMIC DESIGN CATEGORY	B
	(H)	BASIC LATERAL FORCE RESISTING SYSTEM - SHORT DIRECTION	SPECIAL REINFORCED MASONRY SHEAR WALL
	(I)	BASIC LATERAL FORCE RESISTING SYSTEM - LONG DIRECTION	STEEL SPECIAL TRUSS MOMENT FRAME
	(J)	RESPONSE MODIFICATION FACTOR	S= 5.5 L= 7.0
	(K)	OVERSTRENGTH FACTOR (Ωo)	S= 2.5 L= 3.0
	(L)	DEFLECTION AMPLIFICATION FACTOR (Cd)	S= 4.0 L= 5.5
	(M)	ANALYSIS PROCEDURE	EQUIVALENT LATERAL FORCE
	(N)	BUILDING FUNDAMENTAL PERIOD (T)	0.5
	(O)	BUILDING SEISMIC WEIGHT	2,200 KIPS
	(P)	BASE SHEAR DUE TO SEISMIC LOADS	60 KIPS

Table 12.2-1 (*Continued*)

Seismic Force-Resisting System	ASCE 7 Section Where Detailing Requirements Are Specified	Response Modification Coefficient, R^a	Overstrength Factor, Ω_0^g	Deflection Amplification Factor, C_d^b	Structural System Limitations Including Structural Height, h_n (ft) Limits[c] — Seismic Design Category: B	C	D^d	E^d	F^e
4. Special reinforced concrete shear walls[l,m]	14.2	6	2½	5	NL	NL	160	160	100
5. Ordinary reinforced concrete shear walls[l]	14.2	5	2½	4½	NL	NL	NP	NP	NP
6. Detailed plain concrete shear walls[l]	14.2 and 14.2.2.8	2	2½	2	NL	NP	NP	NP	NP
7. Ordinary plain concrete shear walls[l]	14.2	1½	2½	1½	NL	NP	NP	NP	NP
8. Intermediate precast shear walls[l]	14.2	5	2½	4½	NL	NL	40[k]	40[k]	40[k]
9. Ordinary precast shear walls[l]	14.2	4	2½	4	NL	NP	NP	NP	NP
10. Steel and concrete composite eccentrically braced frames	14.3	8	2 ½	4	NL	NL	160	160	100
11. Steel and concrete composite special concentrically braced frames	14.3	5	2	4½	NL	NL	160	160	100
12. Steel and concrete composite ordinary braced frames	14.3	3	2	3	NL	NL	NP	NP	NP
13. Steel and concrete composite plate shear walls	14.3	6½	2½	5½	NL	NL	160	160	100
14. Steel and concrete composite special shear walls	14.3	6	2½	5	NL	NL	160	160	100
15. Steel and concrete composite ordinary shear walls	14.3	5	2½	4½	NL	NL	NP	NP	NP
16. Special reinforced masonry shear walls	14.4	5½	2½	4	NL	NL	160	160	100
17. Intermediate reinforced masonry shear walls	14.4	4	2½	4	NL	NL	NP	NP	NP
18. Ordinary reinforced masonry shear walls	14.4	2	2½	2	NL	160	NP	NP	NP
19. Detailed plain masonry shear walls	14.4	2	2½	2	NL	NP	NP	NP	NP
20. Ordinary plain masonry shear walls	14.4	1½	2½	1¼	NL	NP	NP	NP	NP
21. Prestressed masonry shear walls	14.4	1½	2½	1¾	NL	NP	NP	NP	NP
22. Light-frame (wood) walls sheathed with wood structural panels rated for shear resistance	14.5	7	2½	4½	NL	NL	65	65	65
23. Light-frame (cold-formed steel) walls sheathed with wood structural panels rated for shear resistance or steel sheets	14.1	7	2½	4½	NL	NL	65	65	65
24. Light-frame walls with shear panels of all other materials	14.1and 14.5	2½	2½	2½	NL	NL	35	NP	NP
25. Steel buckling-restrained braced frames	14.1	8	2½	5	NL	NL	160	160	100
26. Steel special plate shear walls	14.1	7	2	6	NL	NL	160	160	100

Table 12.2-1 (*Continued*)

Seismic Force-Resisting System	ASCE 7 Section Where Detailing Requirements Are Specified	Response Modification Coefficient, R[a]	Overstrength Factor, Ω_0[g]	Deflection Amplification Factor, C_d[b]	Structural System Limitations Including Structural Height, h_n (ft) Limits[c] — Seismic Design Category B	C	D[d]	E[d]	F[e]
C. MOMENT-RESISTING FRAME SYSTEMS									
1. Steel special moment frames	14.1 and 12.2.5.5	8	3	5½	NL	NL	NL	NL	NL
2. Steel special truss moment frames	14.1	7	3	5½	NL	NL	160	100	NP
3. Steel intermediate moment frames	12.2.5.7 and 14.1	4½	3	4	NL	NL	35[h]	NP[h]	NP[h]
4. Steel ordinary moment frames	12.2.5.6 and 14.1	3½	3	3	NL	NL	NP[i]	NP[i]	NP[i]
5. Special reinforced concrete moment frames[n]	12.2.5.5 and 14.2	8	3	5½	NL	NL	NL	NL	NL
6. Intermediate reinforced concrete moment frames	14.2	5	3	4½	NL	NL	NP	NP	NP
7. Ordinary reinforced concrete moment frames	14.2	3	3	2½	NL	NP	NP	NP	NP
8. Steel and concrete composite special moment frames	12.2.5.5 and 14.3	8	3	5½	NL	NL	NL	NL	NL
9. Steel and concrete composite intermediate moment frames	14.3	5	3	4½	NL	NL	NP	NP	NP
10. Steel and concrete composite partially restrained moment frames	14.3	6	3	5½	160	160	100	NP	NP
11. Steel and concrete composite ordinary moment frames	14.3	3	3	2½	NL	NP	NP	NP	NP
12. Cold-formed steel—special bolted moment frame[p]	14.1	3½	3[o]	3½	35	35	35	35	35
D. DUAL SYSTEMS WITH SPECIAL MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES	12.2.5.1								
1. Steel eccentrically braced frames	14.1	8	2½	4	NL	NL	NL	NL	NL
2. Steel special concentrically braced frames	14.1	7	2½	5½	NL	NL	NL	NL	NL
3. Special reinforced concrete shear walls[l]	14.2	7	2½	5½	NL	NL	NL	NL	NL
4. Ordinary reinforced concrete shear walls[l]	14.2	6	2½	5	NL	NL	NP	NP	NP
5. Steel and concrete composite eccentrically braced frames	14.3	8	2½	4	NL	NL	NL	NL	NL
6. Steel and concrete composite special concentrically braced frames	14.3	6	2½	5	NL	NL	NL	NL	NL

Continued

ASC STEEL DECK

2WH-36 Composite Deck 3.3

5 ½" Total Slab Depth

Normal Weight Concrete (145 pcf)

Concrete Volume 1.370yd³/100ft²

1 Hour Fire Rating

GA	Vertical Load Span (in)	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	10'-6"	11'-0"	11'-6"	12'-0"	12'-6"	13'-0"
19	**ASD & LRFD - Superimposed Load, W (psf)**															
	ASD, W/Ω	913	772	660	569	495	434	382	339	301	269	242	218	196	178	161
	LRFD, φW	1461	1235	1055	911	792	694	611	542	482	431	387	348	314	284	257
	L/360	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	LRFD - Diaphragm Shear, ϕS_n (plf / ft) 36/4 Attachment Pattern															
	Arc Spot Weld 1/2" Effective Dia	4097	4065	4009	3959	3916	3878	3844	3836	3808	3782	3759	3738	3718	3717	3700
	PAF Base Steel ≥ .25"	3726	3723	3691	3663	3638	3616	3597	3602	3586	3570	3557	3544	3533	3539	3529
	PAF Base Steel ≥ 0.109"	3698	3698	3667	3641	3617	3597	3579	3585	3569	3555	3542	3530	3519	3526	3516
	#12 Screw Base Steel ≥ .034"	3677	3678	3649	3624	3602	3582	3565	3571	3556	3543	3530	3519	3508	3516	3506
	Concrete + Deck = 56.9 psf	I_{cr} = 69.8 in⁴/ft					M_{no}/Ω = 54.0 kip-in/ft					V_n/Ω = 4.57 kip/ft				
	$(I_{cr}+I_u)/2$ = 113.2 in⁴/ft	I_u = 156.6 in⁴/ft					ϕM_{no} = 82.6 kip-in/ft					ϕV_n = 6.86 kip/ft				

GA	Vertical Load Span (in)	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	10'-6"	11'-0"	11'-6"	12'-0"	12'-6"	13'-0"
18	**ASD & LRFD - Superimposed Load, W (psf)**															
	ASD, W/Ω	1004	849	726	627	546	479	423	375	334	299	269	242	219	198	180
	LRFD, φW	1607	1359	1162	1004	874	766	676	600	535	478	430	387	350	317	288
	L/360	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	LRFD - Diaphragm Shear, ϕS_n (plf / ft) 36/4 Attachment Pattern															
	Arc Spot Weld 1/2" Effective Dia	4202	4171	4106	4050	4001	3958	3919	3913	3880	3851	3824	3800	3778	3778	3758
	PAF Base Steel ≥ .25"	3782	3783	3746	3714	3686	3661	3639	3647	3628	3611	3595	3581	3568	3577	3565
	PAF Base Steel ≥ 0.109"	3752	3755	3720	3690	3663	3640	3619	3628	3610	3593	3578	3565	3552	3562	3550
	#12 Screw Base Steel ≥ .034"	3730	3735	3702	3672	3647	3624	3604	3614	3597	3581	3567	3553	3541	3552	3541
	Concrete + Deck = 57.2 psf	I_{cr} = 75.2 in⁴/ft					M_{no}/Ω = 59.1 kip-in/ft					V_n/Ω = 4.57 kip/ft				
	$(I_{cr}+I_u)/2$ = 117.2 in⁴/ft	I_u = 159.1 in⁴/ft					ϕM_{no} = 90.5 kip-in/ft					ϕV_n = 6.86 kip/ft				

GA	Vertical Load Span (in)	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	10'-6"	11'-0"	11'-6"	12'-0"	12'-6"	13'-0"
16	**ASD & LRFD - Superimposed Load, W (psf)**															
	ASD, W/Ω	1238	1049	898	777	678	595	526	468	418	375	338	306	277	252	230
	LRFD, φW	1982	1678	1437	1243	1084	953	842	749	669	600	541	489	443	403	367
	L/360	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	LRFD - Diaphragm Shear, ϕS_n (plf / ft) 36/4 Attachment Pattern															
	Arc Spot Weld 1/2" Effective Dia	4467	4438	4353	4280	4216	4159	4109	4108	4065	4026	3991	3959	3929	3936	3910
	PAF Base Steel ≥ .25"	3925	3937	3888	3846	3809	3776	3747	3765	3739	3716	3695	3676	3658	3675	3659
	PAF Base Steel ≥ 0.109"	3867	3884	3839	3800	3766	3736	3709	3729	3705	3683	3664	3646	3629	3648	3633
	#12 Screw Base Steel ≥ .034"	3866	3883	3838	3799	3765	3735	3708	3728	3704	3682	3663	3645	3629	3647	3632
	Concrete + Deck = 57.8 psf	I_{cr} = 88.5 in⁴/ft					M_{no}/Ω = 72.4 kip-in/ft					V_n/Ω = 4.57 kip/ft				
	$(I_{cr}+I_u)/2$ = 127.1 in⁴/ft	I_u = 165.7 in⁴/ft					ϕM_{no} = 110.7 kip-in/ft					ϕV_n = 6.86 kip/ft				

All Gages	LRFD - Diaphragm Shear, ϕS_n (plf / ft) for all vertical load spans, WWF Designation or Area of Steel per foot width					
	3/4" Welded Shear Studs	6x6 W1.4xW1.4 A_s = 0.028 in²/ft	6x6 W2.9xW2.9 A_s = 0.058 in²/ft	6x6 W4.0xW4.0 A_s = 0.080 in²/ft	4x4 W4xW4 A_s = 0.120 in²/ft	4x4 W6xW6 A_s = 0.180 in²/ft
	12 in o.c.	n/a	5890	6880	8680	11380
	24 in o.c.	n/a	5890	6880	7750	7750
	36 in o.c.	n/a	5170	5170	5170	5170

2W PANELS

Appendix V: Gravity Load Framing

HORIZONTAL

- plant point loads
- special condition
- beam and plant point loads
- beam point loads
- don't fill

													Current Conditions				Chosen										CONNECTIONS		
													Strength			Stiffness	Section Properties												
FLOOR	BEAM #	Nominal LENGTH	TYPE	area LL	area DL	Tributary Width	IFF 3, Dist. Load	Dist total load	Point load 1	Point load 2	Point Load 3	Total Load	Loaded Max M due to uniform	M due to point loads	TOTAL M	Deflection limit (l/360)	SIZE W	SIZE W (weight)	M	E	Ix	Deflection due to uniform	Deflection due to point	TOTAL DEFLECTION	TOTAL WEIGHT	SHEAR (Start)	SHEAR (End)	Total Connection Loads	Difference (error)
	(Floor-#)	(ft)	(1,2, or 3)	(psf)	(psf)	(ft)	(lb/ft)	(k)	(k)	(k)	(k)	(k)	(k-ft)	(k-ft)	(k-ft)	(in)	Depth (in)	(lb/ft)	(k-ft)	(psi)	(in^4)	(in)	(in)	(in)	(lb)	(k)	(k)	(k)	(k)
G-1	000-01	21.00	1	250	60	7.5	2325	48.83	13.200			62.025	128.2	69.3	197.5	0.70	21	44	238	29,000,000	843	0.4162	0.1800	0.5962	924.00	31.000	31.000	62.000	0.025
	000-02	11.00	1					0.00				0.000			0.0	0.37	12	16	50.1	29,000,000	103			0.0000	176.00	0.000	0.000	0.000	0.000
	000-03	11	1	60	80	6.5	910	10.01				10.010	13.8		13.76375	0.3666667	12	16	50.1	29000000	103	0.1004		0.10035972	176	5.005	5.005	10.010	0.000
	000-04	16.50	1	100	60	5.5	880	14.52				14.520	29.9		29.9	0.55	12	19	61.6	29,000,000	130	0.3893		0.3893	313.50	7.260	7.260	14.520	0.000
	000-05	15.00	1	100	60	4.5	720	10.80				10.800	20.3		20.3	0.50	21	44	238	29000000	843	0.0335		0.0335	660.00	5.400	5.400	10.800	0.000
	000-06	16.00	1	100	60	10.0	1600	25.60				25.600	51.2		51.2	0.53	12	19	61.6	29,000,000	130	0.6258		0.6258	304.00	12.800	12.800	25.600	0.000
	000-07	10.00	1									0.000			0.0	0.33	12	16	50.1	29,000,000	103			0.0000	160.00	0.000	0.000	0.000	0.000
	000-08	16.50	1	100	60	10.0	1600	26.40				26.400	54.5		54.5	0.55	12	19	61.6	29,000,000	130	0.7078		0.7078	313.50	13.200	13.200	26.400	0.000
	000-09	12.50	1	100	60	4.5	720	9.00				9.000	14.1		14.1	0.42	12	16	50.1	29000000	103	0.1324		0.1324	200.00	4.500	4.500	9.000	0.000
	000-10	27.00	1						10.800	10.800		21.600		97.2	97.2	0.90	14	26	100	29,000,000	245		1.8350	1.8350	702.00	10.800	10.800	21.600	0.000
	000-11	27.00	2						22.320	22.320		44.640		200.88	200.88	0.90	21	44	238	29,000,000	843		1.1022	1.1022	1188.00	22.320	22.320	44.640	0.000
	000-12	27.00	2	100	60	5.0	800	21.60	11.520	11.520		44.640	72.9	103.68	176.58	0.90	16	40	182	29,000,000	518	0.6368	0.9258	1.5626	1080.00	22.320	22.320	44.640	0.000
	000-13	27.00	2	100	60	5.0	800	21.60	11.880	11.880		45.360	72.9	106.92	179.82	0.90	16	40	182	29,000,000	518	0.6368	0.9547	1.5915	1080.00	22.680	22.680	45.360	0.000
	000-14	27.00	2						20.880	20.880		41.760		187.92	187.92	0.90	18	40	196	29,000,000	612		1.4203	1.4203	1080.00	20.880	20.880	41.760	0.000
	000-15	27.00	1						9.000	9.000		18.000		81	81	0.90	14	22	82.8	29,000,000	199		1.8827	1.8827	594.00	9.000	9.000	18.000	0.000
	000-16	35.00	1	100	60	10.5	1680	58.80	22.320	22.320	16.100	119.540	257.3	352.855	610.1	1.17	30	99	778	29,000,000	3990	0.4902		0.4902	3465.00	53.355	67.385	120.740	-1.200
	000-17	35.00	1	100	60	10.5	1680	58.80	22.680	20.880	16.100	118.460	257.3	339.43	596.7	1.17	27	84	609	29,000,000	2850	0.6863		0.6863	2940.00	64.300	55.361	119.661	-1.201
	000-18	23.00	1						16.100			16.100		96.6	96.6	0.77	14	26	100	29,000,000	245		0.9925	0.9925	598.00	8.050	8.050	16.100	0.000
	000-19	23.00	2						16.100	16.100		32.200		193.2	193.2	0.77	18	40	196	29,000,000	612		0.7947	0.7947	920.00	16.100	16.100	32.200	0.000
	000-20	23.00	1						16.100	16.100		32.200		193.2	193.2	0.77	18	40	196	29,000,000	612		0.7947	0.7947	920.00	16.100	16.100	32.200	0.000
	000-21	23.00	2						16.100	16.100		32.200		193.2	193.2	0.77	18	40	196	29,000,000	612		0.7947	0.7947	920.00	16.100	16.100	32.200	0.000
	000-22	23.00	1						16.100			16.100		96.6	96.6	0.77	14	26	100	29,000,000	245		0.9925	0.9925	598.00	8.050	8.050	16.100	0.000
	000-23	35.00	1	100	60	11.0	1760	61.60	16.100	14.000		91.70	269.5	263.375	532.9	1.17	24	84	559	29,000,000	2370	0.8646	0.3616	1.2262	2940.00	45.860	45.850	91.710	-0.010
	000-24	25.00	1	100	60	11.0	1760	44.00	10.000	16.100		70.100	137.5	122.875	260.4	0.83	21	50	274	29,000,000	984	0.5421		0.5421	1250.00	31.830	38.270	70.100	0.000
	000-25	20.00	1						14.000			14.000		70	70.0	0.67	14	22	82.8	29,000,000	199		0.6987	0.6987	440.00	7.000	7.000	14.000	0.000
	000-26	20.00	2						14.000	14.000		28.000		140	140.0	0.67	18	35	166	29,000,000	510		0.5452	0.5452	700.00	14.000	14.000	28.000	0.000
	000-27	20.00	1						14.000	10.000		24.000		120	120.0	0.67	16	31	135	29,000,000	375		0.6356	0.6356	620.00	12.000	12.000	24.000	0.000
	000-28	20.00	2						10.000	10.000		20.000		100	100.0	0.67	14	30	118	29,000,000	291		0.6825	0.6825	600.00	10.000	10.000	20.000	0.000
	000-29	20.00	1						10.000			10.000		50	50.0	0.67	12	16	50.1	29,000,000	103		0.9642	0.9642	320.00	5.000	5.000	10.000	0.000
	000-30	20.00	1									0.000			0.0	0.67	12	16	50.1	29,000,000	103			0.0000	320.00	0.000	0.000	0.000	0.000
	000-31	25.00	1	100	60	5.0	800	20.00	14.000	20.417		54.417	62.5	180.125	242.6	0.83	21	50	274	29,000,000	984	0.2464		0.2464	1250.00	30.010	24.410	54.420	-0.003
	000-32	25.00	1	100	60	10.0	1600	40.00	10.000	15.400		65.400	125.0	120.25	245.3	0.83	21	50	274	29,000,000	984	0.4928		0.4928	1250.00	29.620	35.780	65.400	0.000
	000-33	20.42	1									0.000			0.0	0.68	12	16	50.1	29,000,000	103			0.0000	326.67	0.000	0.000	0.000	0.000
	000-34	20.42	1	100	60	6.5	1040	21.23				21.233	54.2		54.2	0.68	12	19	61.6	29,000,000	130			0.0000	387.92	10.617	10.617	21.233	0.000
	000-35	20.42	2	100	60	12.5	2000	40.83				40.833	104.2		104.2	0.68	14	30	118	29,000,000	291	0.9265		0.9265	612.50	20.417	20.417	40.833	0.000
	000-36	20.42	1	100	60	6.5	1040	21.23	15.400			36.633	54.2	80.85	135.0	0.68	14	34	136	29,000,000	340	0.4124	0.4785	0.8909	694.17	18.320	18.320	36.640	-0.007
	000-37	20.42	2						15.400	15.400		30.800		161.7	161.7	0.68	18	35	166	29,000,000	510		0.6380	0.6380	714.58	15.400	15.400	30.800	0.000
	000-38	20.42	1						15.400			15.400		80.85	80.9	0.68	14	34	136	29,000,000	340		0.4785	0.4785	694.17	7.700	7.700	15.400	0.000
	000-39	25.00	1	100	60	6.5	1040	26.00	20.417	0.000		46.417	81.3	127.625	208.9	0.83	21	44	238	29,000,000	843	0.3739	0.4698	0.8437	1100.00	23.209	23.210	46.419	-0.002
	000-40	35.00	1	100	60	12.0	1920	67.20	15.400	0.000		82.600	294.0	134.75	428.8	1.17	21	55	314	29,000,000	1140	1.9609	0.7190	2.6799	1925.00	41.300	41.300	82.600	0.000
	000-41	12.67	1									0.000			0.0	0.42	12	16	50.1	29,000,000	103			0.0000	202.67	0.000	0.000	0.000	0.000
	000-42	12.67	1									0.000			0.0	0.42	12	16	50.1	29,000,000	103			0.0000	202.67	0.000	0.000	0.000	0.000
	000-43	12.67	1									0.000			0.0	0.42	12	16	50.1	29,000,000	103			0.0000	202.67	0.000	0.000	0.000	0.000
	000-44	12.67	1									0.000			0.0	0.42	12	16	50.1	29,000,000	103			0.0000	202.67	0.000	0.000	0.000	0.000
	000-45	12.67	1									0.000			0.0	0.42	12	16	50.1	29,000,000	103			0.0000	202.67	0.000	0.000	0.000	0.000
	000-46	15.00	3	100	60	9.0	1440	21.60				21.600	40.5		40.5	0.50	14	22	82.8	29,000,000	199	0.2842		0.2842	330.00	10.800	10.800	21.600	0.000
	000-47	15.00	3	100	60	9.0	1440	21.60				21.600	40.5		40.5	0.50	14	22	82.8	29,000,000	199	0.2842		0.2842	330.00	10.800	10.800	21.600	0.000
	000-48	16.00	3	100	60	9.0	1440	23.04				23.040	46.1		46.1	0.53	12	26	92.8	29,000,000	204	0.3589		0.3589	416.00	11.520	11.520	23.040	0.000
	000-49	16.00	3	100	60	9.0	1440	23.04				23.040	46.1		46.1	0.53	12	26	92.8	29,000,000	204	0.3589		0.3589	416.00	11.520	11.520	23.040	0.000
	000-50	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	14	26	100	29,000,000	245	0.3380		0.3380	429.00	11.880	11.880	23.760	0.000
	000-51	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	14	26	100	29,000,000	245	0.3380		0.3380	429.00	11.880	11.880	23.760	0.000
	000-52	12.50	3	100	60	9.0	1440	18.00				18.000	28.1		28.1	0.42	12	19	61.6	29,000,000	130	0.2098		0.2098	237.50	9.000	9.000	18.000	0.000
	000-53	12.50	3	100	60	9.0	1440	18.00				18.000	28.1		28.1	0.42	12	19	61.6	29,000,000	130	0.2098		0.2098	237.50	9.000	9.000	18.000	0.000
	000-54	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	000-55	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	000-56	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	000-57	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	000-58	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	10	22	64.9	29,000,000	118	0.9867		0.9867	385.00	14.000	14.000	28.000	0.000
	000-59	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	10	22	64.9	29,000,000	118	0.9867		0.9867	385.00	14.000	14.000	28.000	0.000
	000-60	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	000-61	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	000-62	17.50	3	100	60	11.0	1760	30.80				30.800	67.4		67.4	0.58	12	22	73.1	29,000,000	156	0.8210		0.8210	385.00	15.400	15.400	30.800	0.000
	000-63	17.50	3	100	60	11.0	1760	30.80				30.800	67.4		67.4	0.58	12	22	73.1	29,000,000	156	0.8210		0.8210	385.00	15.400	15.400	30.800	0.000
	000-64	16.50	2	100	60	10.0	1600	26.40				26.400	54.5		54.5	0.55	12	19	61.6	29,000,000	130	0.7078		0.7078	313.50	13.200	13.200	26.400	0.000
		1253.83																							43088.83				
		^TOTAL L (ft)																							^TOTAL W(lb)				
																										934.302	946.384		
																									Sum of Reactions-->	1880.686			

Sum of Loads--> 1878.288

FLOOR	BEAM #	Nominal LENGTH	TYPE	area LL	area DL	Tributary Width	IFF 3, Dist. Load	Dist total load	Point load 1	Point load 2	Point Load 3	Total Load	Loaded Max M due to uniform	M due to point loads	TOTAL M	Deflection limit (l/360)	SIZE W	SIZE W (weight)	M	E	Ix	Deflection due to uniform	Deflection due to point	TOTAL DEFLECTION	TOTAL WEIGHT	SHEAR (Start)	SHEAR (End)	Total Connection Loads	Difference (error)
	(Floor-#)	(ft)	(1,2, or 3)	(psf)	(psf)	(ft)	(lb/ft)	(k)	(k)	(k)	(k)	(k)	(k-ft)	(k-ft)	(k-ft)	(in)	Depth (in)	(lb/ft)	(k-ft)	(psi)	(in^4)	(in)	(in)	(in)	(lb)	(k)	(k)	(k)	(k)
1-1	001-01	21.00	1						7.425			7.425		38.98	39.0	0.70	12	16	50.1	29000000	103		1.6092	1.6092	336.00	3.713	3.713	7.425	0.000
	001-02	11.00	1									0.000			0.0	0.37	12	16	50.1	29,000,000	103			0.0000	176.00	0.000	0.000	0.000	0.000
	001-03	11.00	1									0.000			0.0	0.37	12	16	50.1	29,000,000	103			0.0000	176.00	0.000	0.000	0.000	0.000
	001-04	16.00	1	30	60	5.3	473	7.56				7.560	15.1		15.1	0.53	12	16	50.1	29000000	103	0.2333		0.2333	256.00	3.780	3.780	7.560	0.000
	001-05	10.00	1									0.000			0.0	0.33	12	16	50.1	29,000,000	103			0.0000	160.00	0.000	0.000	0.000	0.000
	001-06	16.50	1									0.000			0.0	0.55	12	16	50.1	29,000,000	103			0.0000	264.00	0.000	0.000	0.000	0.000
	001-07	16.50	1	100	60	5.5	880	14.52				14.520	29.9		29.9	0.55	12	16	50.1	29,000,000	103	0.4913		0.4913	264.00	7.260	7.260	14.520	0.000
	001-08	15.00	1	100	60	4.5	720	10.80				10.800	20.3		20.3	0.50	12	16	50.1	29,000,000	103	0.2746		0.2746	240.00	5.400	5.400	10.800	0.000
	001-09	16.00	1	100	60	9.5	1520	24.32				24.320	48.6		48.6	0.53	12	16	50.1	29,000,000	103	0.7504		0.7504	256.00	12.160	12.160	24.320	0.000
	001-10	10.00	1									0.000			0.0	0.33	12	16	50.1	29,000,000	103			0.0000	160.00	0.000	0.000	0.000	0.000
	001-11	16.50	1	100	60	9.5	1520	25.08				25.080	51.7		51.7	0.55	12	19	61.6	29,000,000	130	0.6724		0.6724	313.50	12.540	12.540	25.080	0.000
	001-12	12.50	1	100	60	4.6	736	9.20				9.200	14.4		14.4	0.42	12	16	50.1	29,000,000	103	0.1354		0.1354	200.00	4.600	4.600	9.200	0.000
	001-13	27.00	1						10.800	10.800		21.600		97.2	97.2	0.90	14	26	100	29,000,000	245		1.8350	1.8350	702.00	10.800	10.800	21.600	0.000
	001-14	27.00	2						22.320	22.320		44.640		200.88	200.9	0.90	21	44	238	29,000,000	843		1.1022	1.1022	1188.00	22.320	22.320	44.640	0.000
	001-15	27.00	2	100	60	5.0	800	21.60	11.520	11.520		44.640	72.9	103.68	176.6	0.90	18	40	196	29,000,000	612	0.5390	0.7836	1.3226	1080.00	22.320	22.320	44.640	0.000
	001-16	27.00	2	100	60	5.0	800	21.60	11.880	11.880		45.360	72.9	106.92	179.8	0.90	18	40	196	29,000,000	612	0.5390	0.8081	1.3471	1080.00	22.680	22.680	45.360	0.000
	001-17	27.00	2						20.880	20.880		41.760		187.92	187.9	0.90	18	40	196	29,000,000	612		1.4203	1.4203	1080.00	20.880	20.880	41.760	0.000
	001-18	27.00	1						9.000	9.000		18.000		81	81.0	0.90	14	22	82.8	29,000,000	199		1.8827	1.8827	594.00	9.000	9.000	18.000	0.000
	001-19	35.00	1	100	60	10.5	1680	58.80	22.320	16.100	22.320	119.540	257.3	353.315	610.6	1.17	30	99	778	29,000,000	3990	0.4902		0.4902	3465.00	52.878	67.062	119.940	-0.400
	001-20	35.00	1	100	60	10.5	1680	58.80	22.680	16.100	20.880	118.460	257.3	340.075	597.3	1.17	30	99	778	29,000,000	3990	0.4902		0.4902	3465.00	63.970	54.895	118.865	-0.405
	001-21	23.00	1						16.100			16.100		92.575	92.6	0.77	14	26	100	29,000,000	245		0.9925	0.9925	598.00	8.050	8.050	16.100	0.000
	001-22	23.00	2						16.100	16.100		32.200		185.15	185.2	0.77	18	40	196	29,000,000	612		0.7947	0.7947	920.00	16.100	16.100	32.200	0.000
	001-23	23.00	1						16.100	16.100		32.200		92.575	92.6	0.77	14	26	100	29,000,000	245		1.9851	1.9851	598.00	16.100	16.100	32.200	0.000
	001-24	23.00	2						16.100	16.100		32.200		185.15	185.2	0.77	18	40	196	29,000,000	612		0.7947	0.7947	920.00	16.100	16.100	32.200	0.000
	001-25	23.00	1						16.100			16.100		92.58	92.6	0.77	14	26	100	29,000,000	245		0.9925	0.9925	598.00	8.050	8.050	16.100	0.000
	001-26	35.00	1	100	60	11.0	1760	61.60	16.100	14.000		91.700	269.5	263.375	532.9	1.17	24	84	559	29,000,000	2370	0.8646	0.6760	1.5406	2940.00	45.850	45.850	91.700	0.000
	001-27	25.00	1	100	60	11.0	1760	44.00	10.000	16.100		70.100	137.5	122.875	260.4	0.83	21	50	274	29,000,000	984	0.5421		0.5421	1250.00	31.830	38.270	70.100	0.000
	001-28	20.00	1						14.000			14.000		70	70.0	0.67	14	22	82.8	29,000,000	199		0.6987	0.6987	440.00	7.000	7.000	14.000	0.000
	001-29	20.00	2						14.000	14.000		28.000		140	140.0	0.67	18	35	166	29,000,000	510		0.2726	0.2726	700.00	14.000	14.000	28.000	0.000
	001-30	20.00	1						14.000	10.000		24.000		120	120.0	0.67	16	31	135	29,000,000	375		0.3708	0.3708	620.00	12.000	12.000	24.000	0.000
	001-31	20.00	2						10.000	10.000		20.000		100	100.0	0.67	14	30	118	29,000,000	291		0.3413	0.3413	600.00	10.000	10.000	20.000	0.000
	001-32	20.00	1						10.000			10.000		50	50.0	0.67	12	16	50.1	29,000,000	103		0.9642	0.9642	320.00	5.000	5.000	10.000	0.000
	001-33	20.00	1									0.000			0.0	0.67	12	16	50.1	29,000,000	103			0.0000	320.00	0.000	0.000	0.000	0.000
	001-34	25.00	1	100	60	5.0	800	20.00	14.000	20.500		54.500	62.5	180.625	243.1	0.83	21	50	274	29,000,000	984	0.2464		0.2464	1250.00	30.050	24.450	54.500	0.000
	001-35	25.00	1	100	60	10.0	1600	40.00	10.000	14.700		64.700	125.0	117.625	242.6	0.83	21	50	274	29,000,000	984	0.4928		0.4928	1250.00	29.410	35.290	64.700	0.000
	001-36	20.42	1									0.000			0.0	0.68	12	16	50.1	29,000,000	103			0.0000	326.67	0.000	0.000	0.000	0.000
	001-37	20.42	1	100	60	6.5	1040	21.23				21.233	54.2		54.2	0.68	12	19	61.6	29,000,000	130	1.0785		1.0785	387.92	10.617	10.617	21.233	0.000
	001-38	20.42	2	100	60	12.5	2000	40.83				40.833	104.2		104.2	0.68	14	30	118	29,000,000	291	0.9265		0.9265	612.50	20.417	20.417	40.833	0.000
	001-39	20.42	1	100	60	6.5	1040	21.23	14.700			35.933	54.2	75.34	129.5	0.68	16	31	135	29,000,000	375	0.3739	0.4141	0.7880	632.92	17.970	17.970	35.940	-0.007
	001-40	20.42	2						14.700	14.700		29.400		150.675	150.7	0.68	18	35	166	29,000,000	510		0.6090	0.6090	714.58	14.700	14.700	29.400	0.000
	001-41	20.42	1						14.700			14.700		75.34	75.3	0.68	14	22	82.8	29,000,000	199		0.7804	0.7804	449.17	7.350	7.350	14.700	0.000
	001-42	25.00	1						20.417			20.417		256.25	256.3	0.83	21	50	274	29,000,000	984		0.4025	0.4025	1250.00	10.250	10.250	20.500	-0.083
	001-43	35.00	1	100	60	6.5	1040	36.40	14.700			51.100	159.3	128.625	287.9	1.17	21	55	31	29,000,000	1140	1.0621	0.6863	1.7485	1925.00	25.350	25.350	50.700	0.400
	001-44	16.50	2	30	60	10.0	900	14.85				14.850	30.6		30.6	0.55	12	16	50.1	29,000,000	103	0.5025		0.5025	264.00	7.425	7.425	14.850	0.000
	001-45	15.00	3	100	60	9.0	1440	21.60				21.600	40.5		40.5	0.50	12	16	50.1	29,000,000	103	0.5491		0.5491	240.00	10.800	10.800	21.600	0.000
	001-46	15.00	3	100	60	9.0	1440	21.60				21.600	40.5		40.5	0.50	12	16	50.1	29,000,000	103	0.5491		0.5491	240.00	10.800	10.800	21.600	0.000
	001-47	16.00	3	100	60	9.0	1440	23.04				23.040	46.1		46.1	0.53	12	16	50.1	29,000,000	103	0.7109		0.7109	256.00	11.520	11.520	23.040	0.000
	001-48	16.00	3	100	60	9.0	1440	23.04				23.040	46.1		46.1	0.53	12	16	50.1	29,000,000	103	0.7109		0.7109	256.00	11.520	11.520	23.040	0.000
	001-49	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	16	50.1	29,000,000	103	0.8040		0.8040	264.00	11.880	11.880	23.760	0.000
	001-50	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	16	50.1	29,000,000	103	0.8040		0.8040	264.00	11.880	11.880	23.760	0.000
	001-51	12.50	3	100	60	9.0	1440	18.00				18.000	28.1		28.1	0.42	12	16	50.1	29,000,000	103	0.2648		0.2648	200.00	9.000	9.000	18.000	0.000
	001-52	12.50	3	100	60	9.0	1440	18.00				18.000	28.1		28.1	0.42	12	16	50.1	29,000,000	103	0.2648		0.2648	200.00	9.000	9.000	18.000	0.000
	001-53	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	001-54	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	001-55	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	001-56	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	001-57	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	12	19	61.6	29,000,000	130	0.8956		0.8956	332.50	14.000	14.000	28.000	0.000
	001-58	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	12	19	61.6	29,000,000	130	0.8956		0.8956	332.50	14.000	14.000	28.000	0.000
	001-59	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	001-60	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	001-61	17.50	3	100	60	10.5	1680	29.40				29.400	64.3		64.3	0.58	10	22	64.9	29,000,000	118	1.0360		1.0360	385.00	14.700	14.700	29.400	0.000
	001-62	17.50	3	100	60	10.5	1680	29.40				29.400	64.3		64.3	0.58	10	22	64.9	29,000,000	118	1.0360		1.0360	385.00	14.700	14.700	29.400	0.000
		1233.00																							40637.25				
		^TOTAL L (ft)																							^TOTAL W(lb)				

Sum of Loads--> 1743.572

866.119 877.948

Sum of Reactions--> 1744.067

FLOOR	BEAM # (Floor-#)	Nominal LENGTH (ft)	TYPE (1,2, or 3)	area LL (psf)	area DL (psf)	Tributary Width (ft)	IFF 3, Dist. Load (lb/ft)	Dist total load (k)	Point load 1 (k)	Point load 2 (k)	Point Load 3 (k)	Total Load (k)	Loaded Max M due to uniform (k-ft)	M due to point loads (k-ft)	TOTAL M (k-ft)	Deflection limit (l/360) (in)	SIZE W Depth (in)	SIZE W (weight) (lb/ft)	M (k-ft)	E (psi)	Ix (in^4)	Deflection due to uniform (in)	Deflection due to point (in)	TOTAL DEFLECTION (in)	TOTAL WEIGHT (lb)	SHEAR (Start) (k)	SHEAR (End) (k)	Total Connection Loads (k)	Difference (error) (k)
2-1	002-01	11.00	1									0.000			0.0	0.37	12	16	50.1	29,000,000	103			0.0000	176.00	0.000	0.000	0.000	0.000
	002-02	11.00	1									0.000			0.0	0.37	12	16	50.1	29,000,000	103			0.0000	176.00	0.000	0.000	0.000	0.000
	002-03	10.00	1									0.000			0.0	0.33	12	16	50.1	29,000,000	103			0.0000	160.00	0.000	0.000	0.000	0.000
	002-04	16.50	1									0.000			0.0	0.55	12	16	50.1	29,000,000	103			0.0000	264.00	0.000	0.000	0.000	0.000
	002-05	16.50	1	100	60	5.5	880	14.52				14.520	29.9		29.9	0.55	12	16	50.1	29,000,000	103	0.4913		0.4913	264.00	7.260	7.260	14.520	0.000
	002-06	15.00	1	100	60	4.5	720	10.80				10.800	20.3		20.3	0.50	12	16	50.1	29,000,000	103	0.2746		0.2746	240.00	5.400	5.400	10.800	0.000
	002-07	16.00	1	100	60	4.5	720	11.52				11.520	23.0		23.0	0.53	12	16	50.1	29,000,000	103	0.3554		0.3554	256.00	5.760	5.760	11.520	0.000
	002-08	10.00	1									0.000			0.0	0.33	12	16	50.1	29,000,000	103			0.0000	160.00	0.000	0.000	0.000	0.000
	002-09	16.50	1	100	60	9.5	1520	25.08				25.080	51.7		51.7	0.55	10	19	53.9	29,000,000	96.3	0.9077		0.9077	313.50	12.540	12.540	25.080	0.000
	002-10	12.50	1	100	60	4.5	720	9.00				9.000	14.1		14.1	0.42	12	16	50.1	29,000,000	103	0.1324		0.1324	200.00	4.500	4.500	9.000	0.000
	002-11	27.00	1						6.750	6.750		13.500		60.75	60.8	0.90	12	19	61.6	29,000,000	130		2.1615	2.1615	513.00	6.750	6.750	13.500	0.000
	002-12	27.00	2						13.950	13.950		27.900		125.55	125.6	0.90	16	31	135	29,000,000	375		1.5486	1.5486	837.00	13.950	13.950	27.900	0.000
	002-13	27.00	2	100	60	5.0	800	21.60	7.200	7.200		36.000	72.9	64.8	137.7	0.90	18	35	166	29,000,000	510	0.6468	0.5877	1.2345	945.00	18.000	18.000	36.000	0.000
	002-14	27.00	2	100	60	5.0	800	21.60	11.880	11.880		45.360	72.9	106.92	179.8	0.90	16	40	182	29,000,000	518	0.6368	0.9547	1.5915	1080.00	22.680	22.680	45.360	0.000
	002-15	27.00	2						20.880	20.880		41.760		187.92	187.9	0.90	18	40	196	29,000,000	612		1.4203	1.4203	1080.00	20.880	20.880	41.760	0.000
	002-16	27.00	1						9.000	9.000		18.000		81	81.0	0.90	14	22	82.8	29,000,000	199		1.8827	1.8827	594.00	9.000	9.000	18.000	0.000
	002-17	35.00	1	40	60	10.5	1050	36.75	13.950	10.063	18.000	78.763	160.8	228.7275	389.5	1.17	21	68	399	29,000,000	1480	0.8260		0.8260	2380.00	33.563	45.450	79.013	-0.250
	002-18	35.00	1	65	60	10.5	1313	45.94	22.680	13.080	20.880	102.578	201.0	312.99	514.0	1.17	24	84	559	29,000,000	2370	0.6448		0.6448	2940.00	55.789	46.851	102.640	-0.063
	002-19	23.00	1						10.063			10.063		57.86	57.9	0.77	12	19	61.6	29,000,000	130		1.1691	1.1691	437.00	5.032	5.032	10.064	-0.002
	002-20	23.00	2						10.063	10.063		20.125		115.71875	115.7	0.77	14	30	118	29,000,000	291		1.0446	1.0446	690.00	10.063	10.063	20.126	-0.001
	002-21	23.00	1						10.063	16.100		26.163		150.437	150.4	0.77	18	35	166	29,000,000	510		0.7748	0.7748	805.00	13.080	13.080	26.160	0.003
	002-22	23.00	2						16.100	10.063		26.163		150.44	150.4	0.77	18	35	166	29,000,000	510		0.7748	0.7748	805.00	13.080	13.080	26.160	0.003
	002-23	23.00	1						10.063			10.063		57.86	57.9	0.77	12	19	61.6	29,000,000	130		1.1691	1.1691	437.00	5.032	5.032	10.064	-0.002
	002-24	35.00	1	65	60	11.0	1375	48.13	10.063	14.000		72.188	210.5	210.55125	421.1	1.17	24	68	442	29,000,000	1830	0.8748	0.6999	1.5747	2380.00	36.094	36.094	72.188	0.000
	002-25	25.00	1	65	60	11.0	1375	34.38	10.000	13.080		57.455	107.4	111.55	219.0	0.83	21	44	238	29,000,000	843	0.4943		0.4943	1100.00	25.924	31.156	57.080	0.375
	002-26	20.00	1						14.000			14.000		70	70.0	0.67	12	22	73.1	29,000,000	156		0.8912	0.8912	440.00	7.000	7.000	14.000	0.000
	002-27	20.00	2						14.000	14.000		28.000		140	140.0	0.67	18	35	166	29,000,000	510		0.5452	0.5452	700.00	14.000	14.000	28.000	0.000
	002-28	20.00	1						14.000	10.000		24.000		120	120.0	0.67	16	31	135	29,000,000	375		0.6356	0.6356	620.00	12.000	12.000	24.000	0.000
	002-29	20.00	2						10.000	10.000		20.000		100	100.0	0.67	14	30	118	29,000,000	291		0.6825	0.6825	600.00	10.000	10.000	20.000	0.000
	002-30	20.00	1						10.000			10.000		50	50.0	0.67	12	16	50.1	29,000,000	103		0.9642	0.9642	320.00	5.000	5.000	10.000	0.000
	002-31	20.00	1									0.000			0.0	0.67	12	16	50.1	29,000,000	103			0.0000	320.00	0.000	0.000	0.000	0.000
	002-32	25.00	1	100	60	5.0	800	20.00	14.000	20.420		54.420	62.5	181.63	244.1	0.83	21	50	274	29,000,000	984	0.2464		0.2464	1250.00	30.010	24.410	54.420	0.000
	002-33	25.00	1	100	60	10.0	1600	40.00	10.000	18.375		68.375	125.0	133.97	259.0	0.83	21	50	274	29,000,000	984	0.4928		0.4928	1250.00	30.513	37.863	68.375	0.000
	002-34	20.42	1	100	60	5.0	800	16.33				16.333	41.7		41.7	0.68	12	16	50.1	29,000,000	103	1.0471		1.0471	326.67	8.167	8.167	16.334	-0.001
	002-35	20.42	1	100	60	11.5	1840	37.57				37.567	95.9		95.9	0.68	14	26	100	29,000,000	245	1.0125		1.0125	530.83	18.780	18.780	37.560	0.007
	002-36	20.42	2	100	60	12.5	2000	40.83				40.833	104.2		104.2	0.68	14	30	118	29,000,000	291	0.9265		0.9265	612.50	20.420	20.420	40.840	-0.007
	002-37	20.42	1	100	60	6.5	1040	21.23	18.375			39.608	54.2	93.80	148.0	0.68	18	35	166	29,000,000	510	0.2749	0.3806	0.6555	714.58	19.804	19.804	39.608	0.000
	002-38	20.42	2						18.375	18.375		36.750		187.61	187.6	0.68	18	40	196	29,000,000	612		0.6344	0.6344	816.67	18.375	18.375	36.750	0.000
	002-39	20.42	1						18.375			18.375		93.80	93.8	0.68	14	26	100	29,000,000	245		0.7924	0.7924	530.83	9.188	9.188	18.375	0.000
	002-40	25.00	1	100	60	5.0	800	20.00	50.400	63.000	20.420	153.820	62.5	671.93	734.4	0.83	30	99	778	29,000,000	3990	0.0608		0.0608	2475.00	99.590	54.230	153.820	0.000
	002-41	35.00	1	100	60	10.5	1680	58.80	18.375	50.400	63.000	190.575	257.3	601.00	858.3	1.17	30	108	863	29,000,000	4470	0.4376	1.5690	2.0066	3780.00	95.288	95.288	190.575	0.000
	002-42	45.00	1	100	60	8.75	1400	63.00				63.000	354.4		354.375	1.5	JOIST	38						0.0000	1710	31.5	31.5	63.000	0.000
	002-43	45.00	1	100	60	17.50	2800	126.00				126.000	708.8		708.75	1.5	JOIST	69						0.0000	3105	63	63	126.000	0.000
	002-44	45.00	1	100	60	8.75	1400	63.00				63.000	354.4		354.375	1.5	JOIST	38		SEE JOIST SPEC				0.0000	1710	31.5	31.5	63.000	0.000
	002-45	45.00	2	100	60	17.5	2800	126.00				126.000	708.8		708.8	1.50	JOIST	69						0.0000	3105	63.000	63.000	126.000	0.000
	002-46	45.00	2	100	60	17.5	2800	126.00				126.000	708.8		708.8	1.50	JOIST	69						0.0000	3105	63.000	63.000	126.000	0.000
	002-47	35.00	1	100	60	4.0	1019.3	35.68	63.000			98.675	156.1	551.25	707.32878	1.1667	30	99	778	29000000	3990	0.2974	0.8404	1.13780893	3465	49.3375	49.3375	98.675	0.000
	002-48	35.00	1	100	60	4.0	1019.3	35.68	63.000			98.675	156.1	551.25	707.32878	1.1667	30	99	778	29000000	3990	0.2974	0.8404	1.13780893	3465	49.3375	49.3375	98.675	0.000
	002-49	15.00	3	40	60	9.0	900	13.50				13.500	25.3		25.3	0.50	12	16	50.1	29,000,000	103	0.3432		0.3432	240.00	6.750	6.750	13.500	0.000
	002-50	15.00	3	40	60	9.0	900	13.50				13.500	25.3		25.3	0.50	12	16	50.1	29,000,000	103	0.3432		0.3432	240.00	6.750	6.750	13.500	0.000
	002-51	16.00	3	40	60	9.0	900	14.40				14.400	28.8		28.8	0.53	12	16	50.1	29,000,000	103	0.4443		0.4443	256.00	7.200	7.200	14.400	0.000
	002-52	16.00	3	40	60	9.0	900	14.40				14.400	28.8		28.8	0.53	12	16	50.1	29,000,000	103	0.4443		0.4443	256.00	7.200	7.200	14.400	0.000
	002-53	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	16	50.1	29,000,000	103	0.8040		0.8040	264.00	11.880	11.880	23.760	0.000
	002-54	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	16	50.1	29,000,000	103	0.8040		0.8040	264.00	11.880	11.880	23.760	0.000
	002-55	12.50	3	100	60	9.0	1440	18.00				18.000	28.1		28.1	0.42	12	16	50.1	29,000,000	103	0.2648		0.2648	200.00	9.000	9.000	18.000	0.000
	002-56	12.50	3	100	60	9.0	1440	18.00				18.000	28.1		28.1	0.42	12	16	50.1	29,000,000	103	0.2648		0.2648	200.00	9.000	9.000	18.000	0.000
	002-57	17.50	3	40	60	11.5	1150	20.13				20.125	44.0		44.0	0.58	12	16	50.1	29,000,000	103	0.8125		0.8125	280.00	10.063	10.063	20.125	0.000
	002-58	17.50	3	40	60	11.5	1150	20.13				20.125	44.0		44.0	0.58	12	16	50.1	29,000,000	103	0.8125		0.8125	280.00	10.063	10.063	20.125	0.000
	002-59	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	002-60	17.50	3	40	60	11.5	1150	20.13				20.125	44.0		44.0	0.58	12	16	50.1	29,000,000	103	0.8125		0.8125	280.00	10.063	10.063	20.125	0.000
	002-61	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	12	19	61.6	29,000,000	130	0.8956		0.8956	332.50	14.000	14.000	28.000	0.000
	002-62	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	12	19	61.6	29,000,000	130	0.8956		0.8956	332.50	14.000	14.000	28.000	0.000
	002-63	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	002-64	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	002-65	17.50	3	140	60	10.5	2100	36.75				36.750	80.4		80.4	0.58	14	22	82.8	29,000,000	199	0.7679		0.7679	385.00	18.375	18.375	36.750	0.000
	002-66	17.50	3	140	60	10.5	2100	36.75				36.750	80.4		80.4	0.58	14	22	82.8	29,000,000	199	0.7679		0.7679	385.00	18.375	18.375	36.750	0.000
	002-67	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	19	61.6	29,000,000	130	0.6370		0.6370	313.50	11.880	11.880	23.760	0.000
	002-68	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	19	61.6	29,000,000	130	0.6370		0.6370	313.50	11.880	11.880	23.760	0.000
	002-69	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	19	61.6	29,000,000	130	0.6370		0.6370	313.50	11.880	11.880	23.760	0.000
	002-70	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	19	61.6	29,000,000	130	0.6370		0.6370	313.50	11.880	11.880	23.760	0.000
	002-71	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	002-72	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	002-73	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	002-74	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	002-75	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	002-76	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	002-77	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	002-78	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	002-79	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	19	61.6	29,000,000	130	0.6370		0.6370	313.50	11.880	11.880	23.760	0.000
	002-80	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	19	61.6	29,000,000	130	0.6370		0.6370	313.50	11.880	11.880	23.760	0.000
	002-81	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	19	61.6	29,000,000	130	0.6370		0.6370	313.50	11.880	11.880	23.760	0.000
	002-82	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	19	61.6	29,000,000	130	0.6370		0.6370	313.50	11.880	11.880	23.760	0.000
		1746.50																							64332.58				
		^TOTAL L (ft)																							^TOTAL W(lb)				
																										1469.723	1434.294		

Sum of Loads--> 2904.080

Sum of Reactions--> 2904.017

FLOOR	BEAM #	Nominal LENGTH	TYPE	area LL	area DL	Tributary Width	IFF 3, Dist. Load	Dist total load	Point load 1	Point load 2	Point Load 3	Total Load	Loaded Max M due to uniform	M due to point loads	TOTAL M	Deflection limit (l/360)	SIZE W	SIZE W (weight)	M	E	Ix	Deflection due to uniform	Deflection due to point	TOTAL DEFLECTION	TOTAL WEIGHT	SHEAR (Start)	SHEAR (End)	Total Connection Loads	Difference (error)
	(Floor-#)	(ft)	(1,2, or 3)	(psf)	(psf)	(ft)	(lb/ft)	(k)	(k)	(k)	(k)	(k)	(k-ft)	(k-ft)	(k-ft)	(in)	Depth (in)	(lb/ft)	(k-ft)	(psi)	(in^4)	(in)	(in)	(in)	(lb)	(k)	(k)	(k)	(k)
3-1	003-01	11.00	1									0.000			0.0	0.37	12	16	50.1	29,000,000	103			0.0000	176.00	0.000	0.000	0.000	0.000
	003-02	11.00	1									0.000			0.0	0.37	12	16	50.1	29,000,000	103			0.0000	176.00	0.000	0.000	0.000	0.000
	003-03	10.00	1									0.000			0.0	0.33	12	16	50.1	29,000,000	103			0.0000	160.00	0.000	0.000	0.000	0.000
	003-04	16.50	1									0.000			0.0	0.55	12	16	50.1	29,000,000	103			0.0000	264.00	0.000	0.000	0.000	0.000
	003-05	16.50	1	100	60	5.0	800	13.20				13.200	27.2		27.2	0.55	12	16	50.1	29,000,000	103	0.4467		0.4467	264.00	6.600	6.600	13.200	0.000
	003-06	15.00	1	40	60	4.5	450	6.75				6.750	12.7		12.7	0.50	12	16	50.1	29,000,000	103	0.1716		0.1716	240.00	3.375	3.375	6.750	0.000
	003-07	16.00	1	40	60	4.5	450	7.20				7.200	14.4		14.4	0.53	12	16	50.1	29,000,000	103	0.2221		0.2221	256.00	3.600	3.600	7.200	0.000
	003-08	10.00	1									0.000			0.0	0.33	12	16	50.1	29,000,000	103			0.0000	160.00	0.000	0.000	0.000	0.000
	003-09	16.50	1	100	60	9.5	1520	25.08				25.080	51.7		51.7	0.55	10	19	53.9	29,000,000	96.3	0.9077		0.9077	313.50	12.540	12.540	25.080	0.000
	003-10	12.50	1	100	60	4.5	720	9.00				9.000	14.1		14.1	0.42	12	16	50.1	29,000,000	103	0.1324		0.1324	200.00	4.500	4.500	9.000	0.000
	003-11	27.00	1						6.750	6.750		13.500		60.75	60.8	0.90	12	19	61.6	29,000,000	130		2.1615	2.1615	513.00	6.750	6.750	13.500	0.000
	003-12	27.00	2						13.950	13.950		27.900		125.55	125.6	0.90	16	31	135	29,000,000	375		1.5486	1.5486	837.00	13.950	13.950	27.900	0.000
	003-13	27.00	2	100	60	5.0	800	21.60	7.200	7.200		36.000	72.9	64.8	137.7	0.90	12	22	73.1	29,000,000	156	2.1145	1.9213	4.0358	594.00	18.000	18.000	36.000	0.000
	003-14	27.00	2	100	60	5.0	800	21.60	11.880	11.880		45.360	72.9	106.92	179.8	0.90	14	30	118	29,000,000	291	1.1335	1.6995	2.8330	810.00	22.680	22.680	45.360	0.000
	003-15	27.00	2						20.880	20.880		41.760		187.92	187.9	0.90	18	40	196	29,000,000	612		1.4203	1.4203	1080.00	20.880	20.880	41.760	0.000
	003-16	27.00	1						9.000	9.000		18.000		81	81.0	0.90	14	22	82.8	29,000,000	199		1.8827	1.8827	594.00	9.000	9.000	18.000	0.000
	003-17	35.00	1	40	60	10.5	1050	36.75	13.950	13.082	18.000	81.782	160.8	255.100	415.9	1.17	24	68	442	29,000,000	1830	0.6680		0.6680	2380.00	34.945	46.837	81.782	-0.001
	003-18	35.00	1	100	60	10.5	1680	58.80	22.680	16.100	20.880	118.460	257.3	339.413	596.7	1.17	27	84	609	29,000,000	2850	0.6863		0.6863	2940.00	63.699	54.761	118.460	0.000
	003-19	23.00	1						10.063			10.063		57.86	57.9	0.77	12	19	61.6	29,000,000	130		1.1691	1.1691	437.00	5.032	5.032	10.063	-0.001
	003-20	23.00	2						10.063	16.100		26.163		150.44	150.4	0.77	18	35	166	29,000,000	510		0.7748	0.7748	805.00	13.082	13.082	26.163	0.000
	003-21	23.00	1						16.100	16.100		32.200		185.15	185.2	0.77	18	40	196	29,000,000	612		0.7947	0.7947	920.00	16.100	16.100	32.200	0.000
	003-22	23.00	2						16.100	16.100		32.200		185.15	185.2	0.77	18	40	196	29,000,000	612		0.7947	0.7947	920.00	16.100	16.100	32.200	0.000
	003-23	23.00	1						16.100			16.100		92.575	92.6	0.77	14	26	100	29,000,000	245		0.9925	0.9925	598.00	8.050	8.050	16.100	0.000
	003-24	35.00	1	100	60	11.0	1760	61.60	14.000	13.082		88.682	269.5	236.9675	506.5	1.17	24	84	559	29,000,000	2370	0.8646	0.6082	1.4728	2940.00	44.341	44.341	88.682	-0.001
	003-25	25.00	1	100	60	11.0	1760	44.00	10.000	16.100		70.100	137.5	122.88	260.4	0.83	21	50	274	29,000,000	984	0.5421		0.5421	1250.00	31.830	38.270	70.100	0.000
	003-26	20.00	1						14.000			14.000		70	70.0	0.67	12	22	73.1	29,000,000	156		0.8912	0.8912	440.00	7.000	7.000	14.000	0.000
	003-27	20.00	2						14.000	14.000		28.000		140	140.0	0.67	18	35	166	29,000,000	510		0.5452	0.5452	700.00	14.000	14.000	28.000	0.000
	003-28	20.00	1						14.000	10.000		24.000		120	120.0	0.67	16	31	135	29,000,000	375		0.6356	0.6356	620.00	12.000	12.000	24.000	0.000
	003-29	20.00	2						10.000	10.000		20.000		100	100.0	0.67	14	30	118	29,000,000	291		0.6825	0.6825	600.00	10.000	10.000	20.000	0.000
	003-30	20.00	1						10.000			10.000		50	50.0	0.67	12	16	50.1	29,000,000	103		0.9642	0.9642	320.00	5.000	5.000	10.000	0.000
	003-31	20.00	1									0.000			0.0	0.67	12	16	50.1	29,000,000	103			0.0000	320.00	0.000	0.000	0.000	0.000
	003-32	35.00	1	100	60	10.0	1600	56.00	14.000	12.600		82.600	245.0	232.75	477.8	1.17	24	76	499	29,000,000	2100	0.8871	0.6742	1.5612	2660.00	41.300	41.300	82.600	0.000
	003-33	25.00	1	100	60	10.0	1600	40.00	10.000	12.600		62.600	125.0	109.75	234.8	0.83	21	44	238	29,000,000	843	0.5752		0.5752	1100.00	28.780	33.820	62.600	0.000
	003-34	40.00	1		CANTILEVER							64.300			650.9	1.33	30	99	778	29,000,000	3990				3960.00	88.400	-24.100	64.300	0.000
	003-35	39.50	1						25.200	25.200	25.200	25.200		132.30	132.3	1.32	16	31	135	29000000	375		0.7187	0.7187	1224.50	12.600	12.600	25.200	0.000
	003-36	40.00	1		CANTILEVER							91.800			816.4	1.33	30	108	863	29,000,000	4470				4320.00	118.300	-26.500	91.800	0.000
	003-37	39.50	1						25.200	25.200	25.200	25.200		132.30	132.3	1.32	16	31	135	29000000	375		0.7187	0.7187	1224.50	12.600	12.600	25.200	0.000
	003-38	40.00	1		CANTILEVER							65.600			652.7	1.33	30	99	778	29,000,000	3990				3960.00	88.700	-23.100	65.600	0.000
	003-39	35.00					320.36	11.2126	12.600			23.813	49.1	110.25	159.3	1.17	18	35	166	29,000,000	510	0.7313	0.2642	0.9956	1225.00	11.91	11.91	23.820	-0.007
	003-40	DOES NOT EXIST																										0.000	0.000
	003-41	35.00					320.36	11.2126	12.600			23.813	49.1	110.25	159.3	1.17	18	35	166	29,000,000	510	0.7313	0.2642	0.9956	1225.00	11.91	11.91	23.820	-0.007
	003-42	15.00	3	40	60	9.0	900	13.50				13.500	25.3		25.3	0.50	12	16	50.1	29,000,000	103	0.3432		0.3432	240.00	6.750	6.750	13.500	0.000
	003-43	15.00	3	40	60	9.0	900	13.50				13.500	25.3		25.3	0.50	12	16	50.1	29,000,000	103	0.3432		0.3432	240.00	6.750	6.750	13.500	0.000
	003-44	16.00	3	40	60	9.0	900	14.40				14.400	28.8		28.8	0.53	12	16	50.1	29,000,000	103	0.4443		0.4443	256.00	7.200	7.200	14.400	0.000
	003-45	16.00	3	40	60	9.0	900	14.40				14.400	28.8		28.8	0.53	12	16	50.1	29,000,000	103	0.4443		0.4443	256.00	7.200	7.200	14.400	0.000
	003-46	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	16	50.1	29,000,000	103	0.8040		0.8040	264.00	11.880	11.880	23.760	0.000
	003-47	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	16	50.1	29,000,000	103	0.8040		0.8040	264.00	11.880	11.880	23.760	0.000
	003-48	12.50	3	100	60	9.0	1440	18.00				18.000	28.1		28.1	0.42	12	16	50.1	29,000,000	103	0.2648		0.2648	200.00	9.000	9.000	18.000	0.000
	003-49	12.50	3	100	60	9.0	1440	18.00				18.000	28.1		28.1	0.42	12	16	50.1	29,000,000	103	0.2648		0.2648	200.00	9.000	9.000	18.000	0.000
	003-50	17.50	3	40	60	11.5	1150	20.13				20.125	44.0		44.0	0.58	12	16	50.1	29,000,000	103	0.8125		0.8125	280.00	10.063	10.063	20.125	0.000
	003-51	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	003-52	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	003-53	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	003-54	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	12	19	61.6	29,000,000	130	0.8956		0.8956	332.50	14.000	14.000	28.000	0.000
	003-55	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	12	19	61.6	29,000,000	130	0.8956		0.8956	332.50	14.000	14.000	28.000	0.000
	003-56	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	003-57	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	003-58	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-59	17.50	1	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-60	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-61	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-62	17.50	1	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-63	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-64	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-65	17.50	1	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-66	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-67	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-68	17.50	1	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-69	17.50	3	100	60	9.0	1440	25.20				25.200	55.1		55.1	0.58	12	19	61.6	29,000,000	130	0.8060		0.8060	332.50	12.600	12.600	25.200	0.000
	003-70	DOES NOT EXIST																										0.000	0.000
	003-71	35.00					379.29	13.2752				13.275	58.1		58.1	1.17	12	19	61.6	29,000,000	130	3.3969		3.3969	665.00	6.638	6.638	13.275	0.000
	003-72	35.00					379.29	13.2752				13.275	58.1		58.1	1.17	12	19	61.6	29,000,000	130	3.3969		3.3969	665.00	6.638	6.638	13.275	0.000
	003-73	DOES NOT EXIST																										0.000	0.000
	003-74	4.50														0.15	12	16	50.1	29,000,000	103				72.00	0.000	0.000	0.000	0.000
	003-75	4.50														0.15	12	16	50.1	29,000,000	103				72.00	0.000	0.000	0.000	0.000
		1521.00																							53466.50				
		^TOTAL L (ft)																							^TOTAL W(lb)				
																										1158.051	803.385		
											Sum of Loads-->	1961.419													Sum of Reactions-->	1961.435			

FLOOR	BEAM #	Nominal LENGTH	TYPE	area LL	area DL	Tributary Width	IFF 3, Dist. Load	Dist total load	Point load 1	Point load 2	Point Load 3	Total Load	Loaded Max M due to uniform	M due to point loads	TOTAL M	Deflection limit (l/360)	SIZE W	SIZE W (weight)	M	E	Ix	Deflection due to uniform	Deflection due to point	TOTAL DEFLECTION	TOTAL WEIGHT	SHEAR (Start)	SHEAR (End)	Total Connection Loads	Difference (error)
	(Floor-#)	(ft)	(1,2, or 3)	(psf)	(psf)	(ft)	(lb/ft)	(k)	(k)	(k)	(k)	(k)	(k-ft)	(k-ft)	(k-ft)	(in)	Depth (in)	(lb/ft)	(k-ft)	(psi)	(in^4)	(in)	(in)	(in)	(lb)	(k)	(k)	(k)	(k)
4-1	004-01	11.00	1									0.000			0.0	0.37	12	16	50.1	29,000,000	103				176.00	0.000	0.000	0.000	0.000
	004-02	11.00	1									0.000			0.0	0.37	12	16	50.1	29,000,000	103				176.00	0.000	0.000	0.000	0.000
	004-03	10.00	1									0.000			0.0	0.33	12	16	50.1	29,000,000	103				160.00	0.000	0.000	0.000	0.000
	004-04	16.50	1									0.000			0.0	0.55	12	16	50.1	29,000,000	103				264.00	0.000	0.000	0.000	0.000
	004-05	16.50	1	100	60	5.0	800	13.20				13.200	27.2		27.2	0.55	12	16	50.1	29,000,000	103	0.4467		0.4467	264.00	6.600	6.600	13.200	0.000
	004-06	15.00	1	100	60	4.5	720	10.80				10.800	20.3		20.3	0.50	12	16	50.1	29,000,000	103	0.2746		0.2746	240.00	5.400	5.400	10.800	0.000
	004-07	16.00	1	100	60	4.5	720	11.52				11.520	23.0		23.0	0.53	12	16	50.1	29,000,000	103	0.3554		0.3554	256.00	5.760	5.760	11.520	0.000
	004-08	10.00	1									0.000			0.0	0.33	12	16	50.1	29,000,000	103			0.0000	160.00	0.000	0.000	0.000	0.000
	004-09	16.50	1	100	60	4.5	720	11.88				11.880	24.5		24.5	0.55	12	16	50.1	29,000,000	103	0.4020		0.4020	264.00	5.940	5.940	11.880	0.000
	004-10	12.50	1	100	60	4.5	720	9.00				9.000	14.1		14.1	0.42	12	16	50.1	29,000,000	103	0.1324		0.1324	200.00	4.500	4.500	9.000	0.000
	004-11	27	1	ROOF			456	12.312	10.800	10.800		33.912	41.6	97.2	138.753	0.9	18	35	166	29000000	510	0.36866698	0.88154288	1.250209862	945	16.960	16.960	33.920	-0.008
	004-12	27.00	2						22.320	22.320		44.640		200.88	200.9	0.90	21	44	238	29,000,000	843		1.10219003	1.1022	1188.00	22.320	22.320	44.640	0.000
	004-13	27.00	2	100	60	5.0	800	21.60	11.520	11.520		44.640	72.9	103.68	176.6	0.90	18	40	196	29,000,000	612	0.5390	0.78359367	1.3226	1080.00	22.320	22.320	44.640	0.000
	004-14	27.00	2	100	60	5.0	800	21.60	11.880	11.880		45.360	72.9	106.92	179.8	0.90	18	40	196	29,000,000	612	0.5390	0.80808097	1.3471	1080.00	22.680	22.680	45.360	0.000
	004-15	27.00	2						20.880	20.880		41.760		187.92	187.9	0.90	18	40	196	29,000,000	612		1.42026353	1.4203	1080.00	20.880	20.880	41.760	0.000
	004-16	27	1	ROOF			456	12.312	9.000	9.000		30.312	41.6	81	122.553	0.9	16	31	135	29000000	375	0.5013871	0.99908193	1.5005	837	15.156	15.156	30.312	0.000
	004-17	35	1	100	60	10.5	1680	58.80	22.320	16.100	22.320	119.540	257.3	352.9125	610.2	1.17	30	99	778	29000000	3990	0.49022232		0.4902	3465.00	52.755	66.785	119.540	0.000
	004-18	35	1	100	60	10.5	1680	58.80	22.680	16.100	20.880	118.460	257.3	339.4125	596.7	1.17	27	84	609	29000000	2850	0.68631125		0.6863	2940.00	63.699	54.761	118.460	0.000
	004-19	23	1	ROOF			1097	25.23	16.100			41.331	72.5	92.575	165.11413	0.7666667	18	35	166	29000000	510	0.4670166	0.47680819	0.9438	805	20.666	20.666	41.331	0.000
	004-20	23.00	2						16.100	16.100		32.200		185.15	185.2	0.77	18	40	196	29,000,000	612		0.79468032	0.7947	920.00	16.100	16.100	32.200	0.000
	004-21	23.00	1						16.100	16.100		32.200		185.15	185.2	0.77	18	40	196	29,000,000	612		0.79468032	0.7947	920.00	16.100	16.100	32.200	0.000
	004-22	23.00	2						16.100	16.100		32.200		185.15	185.2	0.77	18	40	196	29,000,000	612		0.79468032	0.7947	920.00	16.100	16.100	32.200	0.000
	004-23	23	1	ROOF			1097	25.23	16.100			41.331	72.5	92.575	165.075	0.7666667	18	35	166	29000000	510	0.4670166	0.47680819	0.9438	805	20.666	20.666	41.331	0.000
	004-24	35.00	1	100	60	11.0	1760	61.60	28.000	16.100		105.700	269.5	385.88	655.4	1.17	30	99	778	29000000	3990	0.51356624	0.58826679	1.1018	3465.00	52.850	52.850	105.700	0.000
	004-25	25.00	1	100	60	11.0	1760	44.00	20.000	16.100		80.100	137.5	185.38	322.9	0.83	30	108	863	29,000,000	4470	0.11933002		0.1193	2700.00	36.830	43.270	80.100	0.000
	004-26	34.5	1		CANTILEVER							89.800			645.8	1.15	30	99	778	29,000,000	3990				3415.50	106.500	-16.700	89.800	0.000
	004-27	30.5	1						28.000	28.000		56.000		294.00	294.0	1.02	21	55	314	29,000,000	1140		3.0090	3.0090	1677.50	28.000	28.000	56.000	0.000
	004-28	34.5	1		CANTILEVER							111.900			934.0	1.15	30	116	943	29,000,000	4930				4002.00	145.500	-33.600	111.900	0.000
	004-29	30.5	1						20.000	20.000		40.000		210	210.0	1.02	21	44	238	29,000,000	843		2.9066	2.9066	1342.00	20.000	20.000	40.000	0.000
	004-30	34.5	1		CANTILEVER							72.800			615.1	1.15	30	99	778	29,000,000	3990				3415.50	94.800	-22.000	72.800	0.000
	004-31	35	2	100	60	5.0	1400	49.00	28.000			77.000	214.375	245.00	459.375	1.1666667	24	76	499	29000000	2100	0.77618534		0.776185345	2660	38.500	38.500	77.000	0.000
	004-32	DOES NOT EXIST																										0.000	0.000
	004-33	35	2	100	60	5	1400	49.00	20.000			69.000	214.375	175.00	389.375	1.1666667	24	68	442	29000000	1830	0.89070449		0.890704494	2380	34.500	34.500	69.000	0.000
	004-34	DOES NOT EXIST																										0.000	0.000
	004-35	20.00	1						10.000			10.000		50	50.0	0.67	12	16	50.1	29000000	103		0.9642	0.964178105	320.00	5.000	5.000	10.000	0.000
	004-36	15.00	3	100	60	9.0	1440	21.60				21.600	40.5		40.5	0.50	12	16	50.1	29,000,000	103	0.5491		0.5491	240.00	10.800	10.800	21.600	0.000
	004-37	15.00	3	100	60	9.0	1440	21.60				21.600	40.5		40.5	0.50	12	16	50.1	29,000,000	103	0.5491		0.5491	240.00	10.800	10.800	21.600	0.000
	004-38	16.00	3	100	60	9.0	1440	23.04				23.040	46.1		46.1	0.53	12	16	50.1	29,000,000	103	0.7109		0.7109	256.00	11.520	11.520	23.040	0.000
	004-39	16.00	3	100	60	9.0	1440	23.04				23.040	46.1		46.1	0.53	12	16	50.1	29,000,000	103	0.7109		0.7109	256.00	11.520	11.520	23.040	0.000
	004-40	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	16	50.1	29,000,000	103	0.8040		0.8040	264.00	11.880	11.880	23.760	0.000
	004-41	16.50	3	100	60	9.0	1440	23.76				23.760	49.0		49.0	0.55	12	16	50.1	29,000,000	103	0.8040		0.8040	264.00	11.880	11.880	23.760	0.000
	004-42	12.50	3	100	60	9.0	1440	18.00				18.000	28.1		28.1	0.42	12	16	50.1	29,000,000	103	0.2648		0.2648	200.00	9.000	9.000	18.000	0.000
	004-43	12.50	3	100	60	9.0	1440	18.00				18.000	28.1		28.1	0.42	12	16	50.1	29,000,000	103	0.2648		0.2648	200.00	9.000	9.000	18.000	0.000
	004-44	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	004-45	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	004-46	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	004-47	17.50	3	100	60	11.5	1840	32.20				32.200	70.4		70.4	0.58	12	22	73.1	29,000,000	156	0.8583		0.8583	385.00	16.100	16.100	32.200	0.000
	004-48	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	12	19	61.6	29,000,000	130	0.8956		0.8956	332.50	14.000	14.000	28.000	0.000
	004-49	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	12	19	61.6	29,000,000	130	0.8956		0.8956	332.50	14.000	14.000	28.000	0.000
	004-50	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	12	19	61.6	29,000,000	130	0.8956		0.8956	332.50	14.000	14.000	28.000	0.000
	004-51	17.50	3	100	60	10.0	1600	28.00				28.000	61.3		61.3	0.58	12	19	61.6	29,000,000	130	0.8956		0.8956	332.50	14.000	14.000	28.000	0.000
	004-52	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	004-53	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	004-54	12.50	3	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	004-55	12.50	2	100	60	10.0	1600	20.00				20.000	31.3		31.3	0.42	12	16	50.1	29,000,000	103	0.2942		0.2942	200.00	10.000	10.000	20.000	0.000
	004-56	35.00					310	10.84				10.840	47.4		47.4	1.17	12	16	50.1	29,000,000	103	3.5007		3.5007	560.00	5.419	5.419	10.838	0.002
	004-57	35.00					310	10.85				10.850	47.5		47.5	1.17	12	16	50.1	29,000,000	103	3.5041		3.5041	560.00	5.419	5.419	10.838	0.012
	004-58	4.50														0.15	12	16	50.1	29,000,000	103				72.00	0.000	0.000	0.000	0.000
	004-59	4.50														0.15	12	16	50.1	29,000,000	103				72.00	0.000	0.000	0.000	0.000
		1185.50																							50112.50				
		^TOTAL L (ft)																							^TOTAL W(lb)				

Sum of Loads--> 1941.876

1174.719 767.151

Sum of Reactions--> 1941.869

Level 1 TOS - Steel 6 000-01 → 000-64

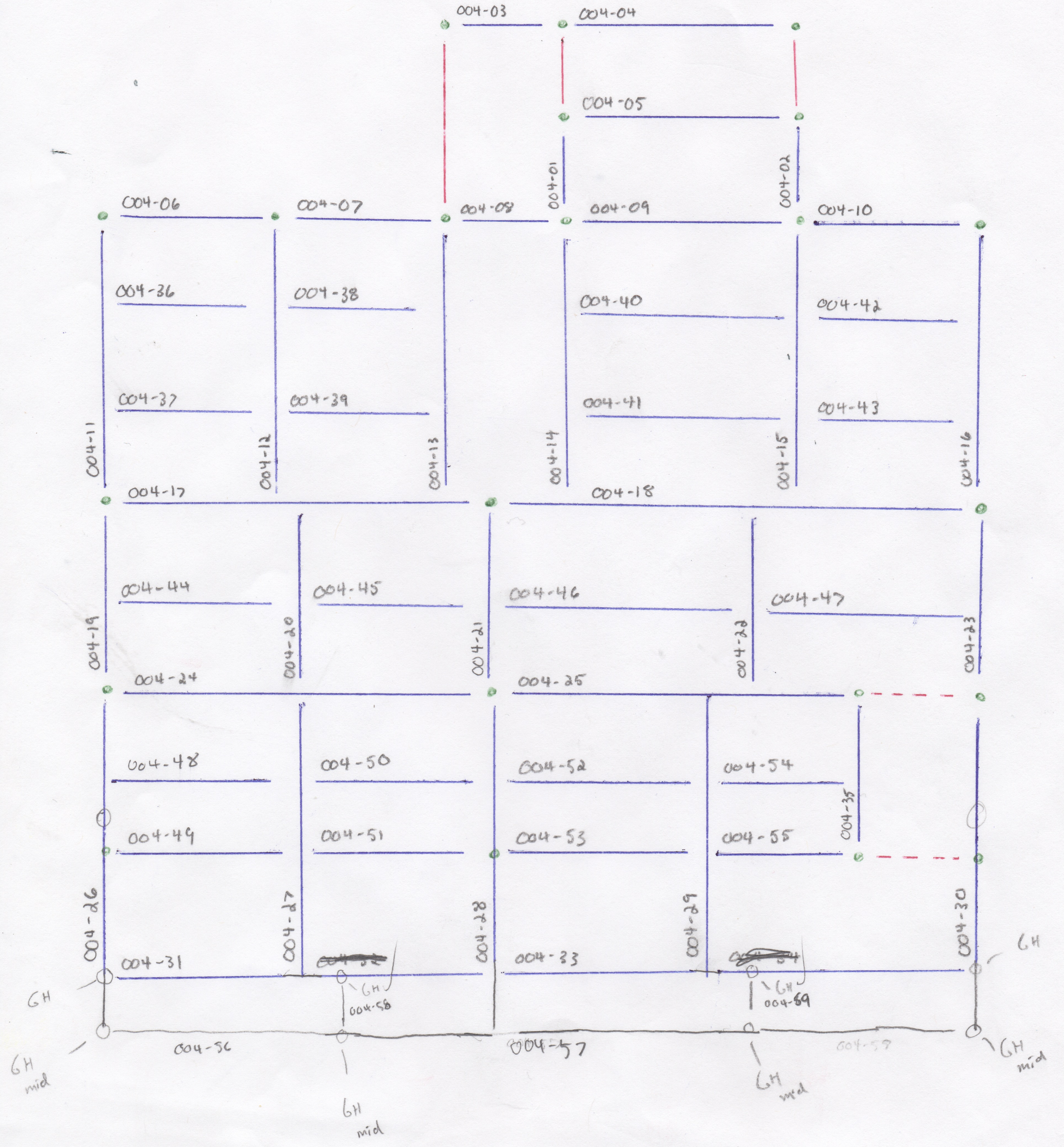
Level 2 - TOS - Steel 1 001-01 → 001-62

Level 3-TOS - Steel 2 002-01 → 002-82

Level 4 - TOS - Steel 3   003-01 → 003-70

Level 5 - TOS - Steel 4

004-01 → 004-55
-60



5th Floor	Beam	
Column	Start of	End of
002	004-03	
003	004-04	004-03
004		004-04
005	004-05	004-01
006		004-05 & 004-02
007	004-06	004-11
008	004-07	004-06 & 004-12
009	004-08	004-07 & 004-13
010	004-01 & 004-09	004-08 & 004-14
011	004-02 & 004-10	004-09 & 004-15
012		004-10 & 004-16
013	004-11 & 004-17	004-19
014	004-18	004-17 & 004-21
015	004-16	004-18 & 004-23
016	004-19 & 004-24	004-26
017	004-21 & 004-25	004-24 & 004-28
018		004-25 & 004-35
019	004-23	004-30
020	004-49 & 004-26*	004-26*
021		
022	004-53 & 004-28*	004-28*
023	004-35	004-55
024	004-30*	004-30*
025		
026		
027		
028		

4th Floor	Beam	
Column	Start of	End of
002	003-03	
003	003-04	003-03
004		003-04
005	003-05	003-01
006		003-02 & 003-05
007	003-06	003-11
008	003-07	003-06 & 003-12
009	003-08	003-07 & 003-13
010	003-01 & 003-09	003-08 & 003-14
011	003-02 & 003-10	003-09 & 003-15
012		003-10 & 003-16
013	003-11 & 003-17	003-19
014	003-18	003-17 & 003-21
015	003-16	003-18 & 003-23
016	003-19 & 003-24	003-26
017	003-21 & 003-25	003-24 & 003-28
018		003-25 & 003-30
019	003-23	003-31
020	003-26 & 003-32	003-34
021		
022	003-28 & 003-33	003-32 & 003-36
023	003-30	003-33
024	003-31	003-38
025	003-59 & 003-34*	003-34*
026		
027		
028	003-38*	003-68 & 003-38*

3rd Floor	Beam	
Column	Start of	End of
002	002-03	
003	002-04	002-03
004		002-04
005	002-05	002-01
006		002-02 & 002-05
007	002-06	002-11
008	002-07	002-06 & 002-12
009	002-08	002-07 & 002-13
010	002-01 & 002-09	002-08 & 002-14
011	002-02 & 002-10	002-09 & 002-15
012		002-10 & 002-16
013	002-11 & 002-17	002-19
014	002-18	002-17 & 002-21
015	002-16	002-18 & 002-23
016	002-19 & 002-24	002-26
017	002-21 & 002-25	002-24 & 002-28
018		002-25 & 002-30
019	002-23	002-31
020	002-26	002-34
021	002-32	002-35
022	002-28 & 002-33	002-32 & 002-37
023	002-30	002-33
024	002-31	002-39
025	002-34	002-42
026	002-35 & 002-40	
027	002-37 & 002-41	002-43
028	002-39	002-41 & 002-44

2nd Floor	Beam	
Column	Start of	End of
001	001-04	001-01
002	001-05	001-04
003	001-06	001-05
004		001-06
005	001-07	001-02
006		001-03 & 001-07
007	001-08	001-13
008	001-01 & 001-09	001-08 & 001-14
009	001-10	001-09 & 001-15
010	001-02 & 001-11	001-10 & 001-16
011	001-03 & 001-12	001-11 & 001-17
012		001-12 & 001-18
013	001-13 & 001-19	001-21
014	001-20	001-19 & 001-23
015	001-18	001-20 & 001-25
016	001-21 & 001-26	001-28
017	001-23 & 001-27	001-26 & 001-30
018		001-27 & 001-32
019	001-25	001-33
020	001-28	001-36
021	001-34	001-37
022	001-30 & 001-35	001-34 & 001-39
023	001-32	001-35
024	001-33	001-41
025	001-36	
026	001-37 & 001-42	
027	001-39 & 001-43	001-42
028	001-41	001-43

1st Floor	Beam	
Column	Start of	End of
001		000-01
002		
003		
004		
005	000-04	000-02
006		000-04 & 000-03
007	000-05	000-10
008	000-01 & 000-06	000-05 & 000-11
009	000-07	000-06 & 000-12
010	000-02 & 000-08	000-07 & 000-13
011	000-03 & 000-09	000-08 & 000-14
012		000-09 & 000-15
013	000-10 & 000-16	000-18
014	000-17	000-16 & 000-20
015	000-15	000-17 & 000-22
016	000-18 & 000-23	000-25
017	000-20 & 000-24	000-23 & 000-27
018		000-24 & 000-29
019	000-22	000-30
020	000-25	000-33
021	000-31	000-34
022	000-27 & 000-32	000-31 & 000-36
023	000-29	000-32
024	000-30	000-38
025	000-33	000-41
026	000-34 & 000-39	
027	000-36 & 000-40	000-39 & 000-43
028	000-38	000-40 & 000-45

Appendix X: Column Load Takedown

VERTICAL

from GH columns
from cantilevers

GRID LINES	COLUMN #	BASE LEVEL	TOP LEVEL	Level 1 - Steel G							Level 2 - Steel 1							Level 3 - Steel 2			
(NS-EW)		(Floor #)	(Floor #)	Beam 1 (k)	Beam 2 (k)	Beam 3 (k)	Beam 4 (k)	AXIAL LOAD (k)	TOP DOWN LOAD (k)	Min REQ COLUMN	Beam 1 (k)	Beam 2 (k)	Beam 3 (k)	Beam 4 (k)	AXIAL LOAD (k)	TOP DOWN LOAD (k)	Min REQ COLUMN	Beam 1 (k)	Beam 2 (k)	Beam 3 (k)	Beam 4 (k)
13-11	001	FOUNDATION	1	31.00				31.00	38.49	6x6x3/16	3.78	3.71			7.49	7.49	6x6x3/16	x			
14-11	002	FOUNDATION	ROOF					0.00	3.78	6x6x3/16	0.00	3.78			3.78	3.78	6x6x3/16	0.00			
15-11	003	FOUNDATION	ROOF					0.00	0.00	6x6x3/16	0.00	0.00			0.00	0.00	6x6x3/16	0.00	0.00		
16-11	004	FOUNDATION	ROOF					0.00	0.00	6x6x3/16	0.00				0.00	0.00	6x6x3/16	0.00			
15-18	005	FOUNDATION	ROOF	7.26	0.00			7.26	34.98	6x6x3/16	7.26	0.00			7.26	27.72	6x6x3/16	7.26	0.00		
16-18	006	FOUNDATION	ROOF	7.26	0.80			8.06	35.78	6x6x3/16	0.00	7.26			7.26	27.72	6x6x3/16	0.00	7.26		
12-10	007	FOUNDATION	4	10.80	0.80			11.60	79.44	6x6x3/16	5.40	10.80			16.20	67.84	6x6x3/16	5.40	6.75		
13-10	008	FOUNDATION	4	0.80	31.00	12.80	22.32	66.92	190.03	8x8x5/16	3.71	12.16	5.40	22.32	43.59	123.11	6x6x3/8	5.76	5.40	13.95	
14-10	009	FOUNDATION	4	12.80	22.32	0.00		35.12	143.04	6x6x3/8	0.00	12.16	22.32		34.48	107.92	6x6x3/8	0.00	5.76	18.00	
15-10	010	FOUNDATION	ROOF	13.20	22.68	0.00	0.00	35.88	170.16	8x8x5/16	0.00	12.54	0.00	22.68	35.22	134.28	6x6x3/8	0.00	12.54	0.00	22.68
16-10	011	FOUNDATION	4	13.20	20.88	5.01	4.50	43.59	188.77	8x8x5/16	0.00	4.60	12.54	20.88	38.02	145.18	6x6x3/8	0.00	4.50	12.54	20.88
17-10	012	FOUNDATION	4	9.00	4.50			13.50	80.76	6x6x3/16	4.60	9.00			13.60	67.26	6x6x3/16	4.50	9.00		
12-24	013	FOUNDATION	4	10.80	8.05	53.36		72.21	326.39	10x10x3/8	10.80	52.88	8.05		71.73	254.18	9x9x3/8	6.75	33.56	5.03	
23-24	014	FOUNDATION	4	67.39	64.30	16.10		147.79	682.46	16x16x1/2	63.97	67.06	16.10		147.13	534.67	14x14x1/2	55.79	45.45	13.08	
17-24	015	FOUNDATION	4	55.36	9.00	8.05		72.41	367.63	12x12x3/8	9.00	54.90	8.05		71.95	295.22	10x10x3/8	9.00	46.85	5.03	
12-19	016	FOUNDATION	4	8.05	7.00	45.86		60.91	283.12	9x9x3/8	8.05	45.85	7.00		60.90	222.21	8x8x3/8	5.03	36.09	7.00	
23-19	017	FOUNDATION	4	45.85	16.10	31.83	12.00	105.78	475.11	14x14x1/2	16.10	31.83	45.85	12.00	105.78	369.33	12x12x3/8	13.08	25.92	36.09	12.00
21-19	018	FOUNDATION	4	38.27	5.00			43.27	214.24	8x8x3/8	38.27	5.00			43.27	170.97	8x8x5/16	31.16	5.00		
17-19	019	FOUNDATION	4	8.05	0.00			8.05	27.85	6x6x3/16	8.05	0.00			8.05	19.80	6x6x3/16	5.03	0.00		
12-20	020	FOUNDATION	4	7.00	0.00			7.00	173.87	8x8x5/16	7.00	0.00			7.00	166.87	8x8x5/16	7.00	8.17		
31-20	021	FOUNDATION	2	10.62	30.01			40.63	130.09	6x6x3/8	30.05	10.62			40.67	89.46	6x6x3/8	30.01	18.78		
23-20	022	FOUNDATION	4	24.41	12.00	29.62	18.32	84.35	479.99	14x14x1/2	12.00	29.41	24.45	17.97	83.83	395.64	12x12x3/8	12.00	30.51	24.41	19.80
21-20	023	FOUNDATION	4	35.78	5.00			40.78	177.75	8x8x5/16	5.00	35.29			40.29	136.97	6x6x3/8	5.00	37.86		
17-20	024	FOUNDATION	4	7.70	0.00			7.70	95.94	6x6x3/8	0.00	7.35			7.35	88.24	6x6x3/8	0.00	9.19		
12-22	025	FOUNDATION	3	0.00	0.00			0.00	140.67	6x6x3/8	0.00				0.00	140.67	6x6x3/8	31.50	8.17		
31-22	026	FOUNDATION	2	10.62	23.21			33.83	173.07	8x8x5/16	10.62	10.25			20.87	139.24	6x6x3/8	18.78	99.59		
23-22	027	FOUNDATION	G	23.21	18.32	41.30	0.00	82.83	82.83	6x6x3/8											
17-22	028	FOUNDATION	3	41.30	7.70	0.00		49.00	318.98	10x10x3/8	7.35	25.35			32.70	269.98	9x9x3/8	31.50	9.19	95.29	
23-22	029	1	3								-10.25	-17.97	-25.35		-53.57	322.25	10x10x3/8	63.00	54.23	95.29	19.80
36-22	030	2	3																		
39-22	031	2	3																		
32-34	032	G	2					0.00	87.59	6x6x3/8					0.00	87.59	6x6x3/8	31.50	49.34		6.75
23-34	033	G	2					0.00	161.68	8x8x5/16					0.00	161.68	8x8x5/16	63.00	49.34	49.34	
33-34	034	G	2					0.00	87.59	6x6x3/8					0.00	87.59	6x6x3/8	31.50	49.34		6.75
							LOAD FROM THIS LEVEL-->	1109.47						LOAD FROM THIS LEVEL-->	894.85						LOAD FROM THIS LEVEL-->

			Level 4 - Steel 3							Level 5 - Steel 4							
AXIAL LOAD (k)	TOP DOWN LOAD (k)	Min REQ COLUMN	Beam 1 (k)	Beam 2 (k)	Beam 3 (k)	Beam 4 (k)	AXIAL LOAD (k)	TOP DOWN LOAD (k)	Min REQ COLUMN	Beam 1 (k)	Beam 2 (k)	Beam 3 (k)	Beam 4 (k)	AXIAL LOAD (k)	TOP DOWN LOAD (k)	Min REQ COLUMN	TOTAL AXIAL (k)
			x							x							38.493
0.00	0.00	4x4x1/4	0.000				0.000	0.000	4x4x1/4	0.000				0.000	0.000	4x4x1/4	3.780
0.00	0.00	4x4x1/4	0.000	0.000			0.000	0.000	4x4x1/4	0.000	0.0000			0.000	0.000	4x4x1/4	0.000
0.00	0.00	4x4x1/4	0.000				0.000	0.000	4x4x1/4	0.000				0.000	0.000	4x4x1/4	0.000
7.26	20.46	4x4x1/4	6.600	0.000			6.600	13.200	4x4x1/4	6.600	0.0000			6.600	6.600	4x4x1/4	34.980
7.26	20.46	4x4x1/4	0.000	6.600			6.600	13.200	4x4x1/4	6.600	0.0000			6.600	6.600	4x4x1/4	35.780
12.15	51.64	6x6x3/16	3.375	6.750			10.125	39.485	4x4x1/4	5.400	16.9600	7.000		29.360	29.360	4x4x1/4	79.435
25.11	79.52	6x6x3/16	3.600	3.375	13.950		20.925	54.405	6x6x3/16	5.760	22.3200	5.400		33.480	33.480	4x4x1/4	190.028
23.76	73.44	6x6x3/16	0.000	3.600	18.000		21.600	49.680	6x6x3/16	5.760	22.3200	0.000		28.080	28.080	4x4x1/4	143.040
35.22	99.06	6x6x3/8	0.000	12.540	0.000	22.680	35.220	63.840	6x6x3/16	5.940	22.6800	0.000	0.00	28.620	28.620	4x4x1/4	170.160
37.92	107.16	6x6x3/8	0.000	4.500	12.540	20.880	37.920	69.240	6x6x3/16	4.500	5.9400	20.880	0.00	31.320	31.320	4x4x1/4	188.765
13.50	53.66	6x6x3/16	4.500	9.000			13.500	40.156	4x4x1/4	4.500	15.1560	7.000		26.656	26.656	4x4x1/4	80.756
45.35	182.45	8x8x5/16	6.750	34.945	5.032		46.727	137.108	6x6x3/8	16.960	52.7550	20.666		90.381	90.381	6x6x3/16	326.391
114.32	387.54	12x12x3/8	63.699	46.837	16.100		126.636	273.220	9x9x3/8	63.699	66.7850	16.100		146.584	146.584	6x6x3/8	682.461
60.88	223.28	8x8x3/8	9.000	54.761	8.050		71.811	162.394	8x8x5/16	15.156	54.7610	20.666		90.583	90.583	6x6x3/8	367.632
48.13	161.31	8x8x5/16	5.032	44.341	7.000		56.373	113.189	6x6x3/8	20.666	52.8500	-16.700		56.816	56.816	6x6x3/16	283.125
87.10	263.55	9x9x3/8	16.100	31.830	44.341	12.000	104.271	176.451	8x8x5/16	16.100	36.8300	52.850	-33.6	72.180	72.180	6x6x3/16	475.109
36.16	127.70	6x6x3/8	38.270	5.000			43.270	91.540	6x6x3/8	43.270	5.0000			48.270	48.270	6x6x3/16	214.236
5.03	11.75	4x4x1/4	8.050	0.000			8.050	6.716	4x4x1/4	20.666	-22.0000			-1.335	-1.335	4x4x1/4	27.848
15.17	159.87	8x8x5/16	7.000	41.300	-24.100		24.200	144.700	6x6x3/8	14.000	106.5000			120.500	120.500	6x6x3/8	173.867
48.79	48.79	6x6x3/16	x							x							130.087
86.73	311.81	10x10x3/8	12.000	28.780	41.300	-26.500	55.580	225.080	8x8x3/8	14.000	145.5000	10.000		169.500	169.500	8x8x5/16	479.987
42.86	96.68	6x6x3/8	5.000	33.820			38.820	53.820	6x6x3/16	5.000	10.0000			15.000	15.000	4x4x1/4	177.753
9.19	80.89	6x6x3/16	0.000	-23.100			-23.100	71.700	6x6x3/16	94.800				94.800	94.800	6x6x3/8	95.938
39.67	140.67	6x6x3/8	12.600	88.400			101.000	101.000	6x6x3/8	x							140.667
118.37	118.37	6x6x3/8	x							x							173.067
			x							x							82.830
135.98	237.28	8x8x3/8	88.700	12.600			101.300	101.300	6x6x3/8	x							318.976
232.32	375.82	12x12x3/8	118.300	12.600	12.600		143.500	143.500	6x6x3/8								322.252
			50.400				50.400	50.400	6x6x3/16								50.400
			50.400				50.400	50.400	6x6x3/16								50.400
87.59	87.59	6x6x3/8															87.588
161.68	161.68	8x8x5/16															161.675
87.59	87.59	6x6x3/8															87.588
																	5115.189 <-- SUM OF AXIAL LOADS
1625.06						LOAD FROM THIS LEVEL-->	1151.728						LOAD FROM THIS LEVEL-->	1093.99			

VULCRAFT

Appendix Y: Steel Joist Specification

Design Guide Weight Table / Vulcraft Noncomposite Steel Joists, VLH-Series

Based on an Allowable Tensile Stress of 30,000 psi.

Joist Span (ft)	Joist Depth (in)	(plf)	200	250	300	350	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800	2000	2200	2400	2700	3000
			Total Uniformly Distributed Joist Load in Pounds Per Linear Foot																						
44	22	Wtj	10	11	14	15	16	20	24	27	31	35	41	44	50	51	57	60	64	72	87	88	97	108	126
		W360	104	121	153	177	195	245	283	331	365	415	477	507	584	584	659	682	709	800	978	978	1037	1140	1339
	24	Wtj	8	10	11	13	15	18	22	25	29	33	37	41	44	48	51	54	57	68	72	87	88	97	118
		W360	114	134	157	193	212	262	309	361	411	460	522	576	613	657	707	750	797	913	972	1188	1188	1264	1501
	26	Wtj	8	9	11	12	14	17	21	24	26	30	34	37	41	44	48	51	54	60	68	73	88	90	103
		W360	123	147	180	201	228	287	350	405	450	507	570	620	685	730	782	842	892	987	1090	1161	1420	1420	1585
	28	Wtj	8	9	10	12	13	16	18	22	24	28	32	35	38	42	45	48	51	58	61	69	81	89	95
		W360	130	157	194	216	254	313	363	429	473	554	614	668	727	804	857	918	989	1115	1160	1283	1504	1673	1727
	30	Wtj	7	9	10	11	13	16	18	21	24	26	29	32	35	38	42	44	48	51	58	64	69	81	89
		W360	136	174	214	243	270	348	402	474	548	609	661	712	774	842	931	994	1065	1147	1295	1406	1492	1749	1947
	33	Wtj	7	9	10	11	12	15	17	20	22	25	27	30	32	35	38	42	42	49	55	61	61	73	83
		W360	166	201	240	268	316	387	457	532	606	669	744	809	871	948	1032	1142	1142	1306	1493	1655	1655	1955	2153
	36	Wtj	8	9	9	10	11	14	16	18	21	24	26	29	30	34	36	38	42	49	50	57	61	69	82
		W360	198	226	262	299	346	429	509	588	665	765	842	921	972	1091	1139	1183	1315	1572	1572	1797	1995	2215	2599
	40	Wtj	12	12	10	10	12	14	16	18	20	22	24	27	29	32	33	35	38	42	49	51	57	63	71
		W360	336	336	319	354	409	494	594	678	761	864	953	1049	1149	1259	1311	1361	1477	1642	1966	1966	2248	2498	2776
	44	Wtj	8	9	9	10	11	13	15	17	20	21	24	26	28	30	32	34	37	42	44	51	56	60	65
		W360	299	334	363	402	442	568	664	746	890	964	1105	1214	1317	1401	1453	1599	1723	1907	2006	2403	2538	2862	3058
46	24	Wtj	9	11	12	14	16	20	24	27	31	35	41	44	48	51	57	59	64	72	87	88	97	108	126
		W360	109	127	153	186	205	259	298	349	386	439	504	536	574	618	697	723	752	850	1039	1039	1105	1215	1428
	26	Wtj	9	10	11	13	15	18	22	25	29	33	37	41	44	48	51	54	57	68	72	87	88	98	117
		W360	118	138	162	200	219	271	320	374	426	477	542	599	638	684	736	780	830	953	1015	1242	1242	1323	1573
	28	Wtj	8	9	11	12	14	17	21	24	26	30	35	37	42	44	48	51	54	60	68	72	88	89	103
		W360	126	149	184	211	233	293	358	414	460	519	584	636	703	749	803	865	916	1014	1122	1195	1463	1463	1635
	30	Wtj	8	9	11	12	14	17	19	22	25	29	32	35	38	42	44	48	51	58	64	69	81	89	95
		W360	139	173	202	236	269	328	381	433	507	578	622	677	736	814	869	931	1003	1132	1229	1304	1530	1702	1758
	33	Wtj	8	9	10	12	13	16	18	21	24	27	30	32	35	38	42	45	48	54	59	61	69	82	89
		W360	147	185	227	266	303	371	429	506	585	651	708	761	829	902	998	1065	1142	1305	1389	1447	1604	1883	2096
	36	Wtj	8	9	10	11	13	15	17	20	22	24	27	30	33	36	38	42	43	49	56	61	62	74	83
		W360	176	217	262	281	331	417	478	558	636	703	781	850	915	996	1084	1201	1201	1375	1571	1744	1744	2063	2273
	40	Wtj	8	9	10	11	12	15	17	20	21	24	27	29	32	34	37	38	42	47	51	57	62	67	80
		W360	215	252	284	335	390	464	573	665	723	833	917	1004	1101	1146	1234	1291	1435	1600	1719	1965	2184	2311	2657
	44	Wtj	13	13	11	11	12	15	16	19	20	23	25	27	30	31	34	38	41	43	48	54	58	64	72
		W360	357	357	351	387	450	555	631	721	810	966	1016	1118	1225	1271	1398	1506	1668	1754	1955	2219	2403	2673	2974
48	24	Wtj	9	11	13	15	17	21	26	30	34	38	44	48	51	57	60	68	72	87	88	97	107	126	137
		W360	99	120	149	168	194	237	291	328	369	418	472	505	544	613	636	702	747	913	913	972	1068	1256	1340
	26	Wtj	9	11	12	15	16	21	24	27	31	35	41	44	48	51	57	60	64	72	87	88	97	108	127
		W360	113	132	159	193	214	269	311	364	403	458	527	561	601	647	730	759	790	892	1092	1092	1164	1279	1506
	28	Wtj	9	10	12	14	15	18	23	26	30	34	37	42	44	48	51	55	58	68	73	88	89	98	118
		W360	121	149	173	205	232	279	347	404	456	514	559	618	659	706	760	806	858	986	1050	1286	1286	1373	1633
	30	Wtj	8	10	11	13	15	17	22	24	27	32	35	37	42	44	48	51	55	60	69	81	88	93	103
		W360	127	157	187	214	260	298	381	421	468	547	595	647	716	764	819	882	935	1036	1147	1345	1497	1546	1676
	33	Wtj	8	9	11	12	14	16	19	22	26	29	32	35	38	42	45	48	51	55	61	69	81	89	94
		W360	140	176	217	243	275	351	409	466	572	622	670	729	793	878	937	1004	1082	1148	1273	1411	1655	1843	1906
	36	Wtj	8	9	10	11	14	16	19	21	24	27	30	33	36	38	42	45	48	55	60	61	70	83	90
		W360	160	194	239	266	319	391	452	534	618	687	747	805	876	953	1056	1128	1209	1382	1534	1534	1703	1998	2225
	40	Wtj	9	9	10	11	13	15	18	20	22	26	29	32	34	36	38	42	44	50	56	61	63	72	83
		W360	211	236	272	314	362	456	521	611	664	806	883	968	1008	1093	1135	1262	1319	1511	1728	1921	1921	2134	2506
	44	Wtj	12	13	10	11	13	15	17	19	22	25	28	29	30	34	37	40	42	48	50	57	60	68	81
		W360	314	333	309	358	417	511	613	684	775	893	983	1077	1117	1229	1325	1466	1542	1719	1848	2113	2200	2487	2864
	48	Wtj	9	10	10	12	13	15	17	20	21	23	26	29	31	32	36	39	40	44	49	56	59	64	71
		W360	274	306	356	394	438	568	664	758	853	928	1070	1178	1291	1339	1473	1588	1662	1850	2062	2342	2536	2825	2989
50	26	Wtj	9	11	13	15	17	21	26	30	34	38	44	48	50	57	59	68	71	87	87	97	107	126	136
		W360	103	126	155	175	195	249	306	344	388	439	496	531	572	646	671	741	789	965	965	1029	1131	1331	1420
	28	Wtj	9	11	12	15	16	21	24	27	32	36	41	44	48	51	57	60	64	72	87	88	97	108	126
		W360	116	143	164	199	220	278	322	376	417	475	546	582	624	672	758	788	822	929	1137	1137	1214	1335	1573
	30	Wtj	9	10	12	14	15	18	23	26	30	35	37	42	44	51	51	57	60	68	72	88	89	103	118
		W360	123	152	184	209	237	285	354	414	467	526	572	633	675	780	780	880	916	1014	1080	1323	1323	1482	1684
	33	Wtj	8	10	12	13	15	18	21	24	27	30	34	37	42	44	48	51	54	60	68	80	88	89	103
		W360	137	170	207	236	263	334	393	455	506	571	644	701	776	828	888	957	1015	1125	1247	1463	1629	1629	1829
	36	Wtj	8	9	11	12	14	17	20	22	26	29	32	35	38	42	45	48	52	56	61	69	128	89	93
		W360	154	186	229	257	291	372	434	494	572	660	711	774	843	933	997	1068	1152	1221	1356	1505	2743	1967	2036
	40	Wtj	10	10	11	12	14	16	19	21	24	27	29	32	36	38	42	43	49	56	57	62	71	84	91
		W360	217	217	252	303	350	430	498	587	648	757	781	856	966	1052	1116	1166	1336	1527	1527	1698	1887	2216	2468
	44	Wtj	8	10	10	12	14	16	18	20	24	26	29	31	34	37	40	42	45	51	58	59	63	71	84
		W360	213	263	292	338	409	491	560	630	751	825	952	988	1087	1171	1296	1363	1424	1633	1868	1945	2078	2312	2716
	48	Wtj	9	9	11	12	13	15	18	20	22	25	28	30	32	35	38	39	43	49	52	60	64	68	75
		W360	264	271	327	378	440	525	648	724	820	899	1041	1141	1183	1302	1404	1469	1635	1823	1960	2242	2442	2643	2781
Bridging Rows			3		2									1											

Joists whose weight is shown to the left of the heavy red line have 2 1/2 inch deep bearings.

Joists whose weight is shown between the heavy red and black lines have 5 inch deep bearings.

Joists whose weight is shown between the heavy black and blue lines have 7 1/2 inch deep bearings.

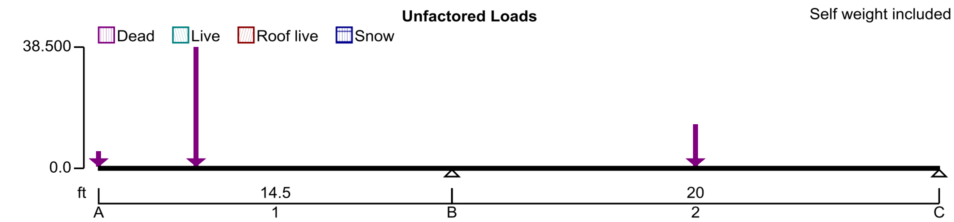
Joists whose weight is shown to the right of the heavy blue line have 10 inch deep bearinngs.

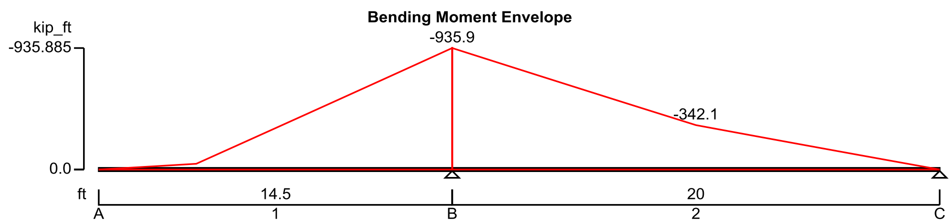
Appendix Z: TEDDS Canteliver Analysis

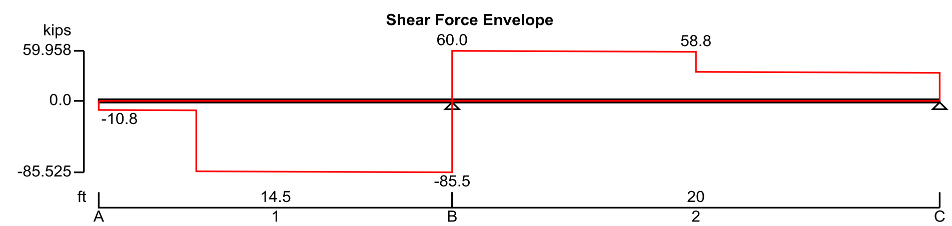
STEEL BEAM ANALYSIS & DESIGN (AISC360-10)

In accordance with AISC360 14th Edition published 2010 using the ASD method

Tedds calculation version 3.0.09







Support conditions

Support A	Vertically free
	Rotationally free
Support B	Vertically restrained
	Rotationally free
Support C	Vertically restrained
	Rotationally free

Applied loading

Beam loads	Dead point load 5.419 kips at 0.00 in
	Dead point load 5.419 kips at 0.00 in

Dead point load 38.5 kips at 48.00 in
Dead point load 34.5 kips at 48.00 in
Dead point load 14 kips at 294.00 in
Dead self weight of beam × 1
Dead point load 10 kips at 294.00 in

Load combinations

Load combination 1	Support A	Dead × 1.00
		Live × 1.00
		Roof live × 1.00
		Snow × 1.00
	Span 1	Dead × 1.00
		Live × 1.00
		Roof live × 1.00
		Snow × 1.00
	Support B	Dead × 1.00
		Live × 1.00
		Roof live × 1.00
		Snow × 1.00
	Span 2	Dead × 1.00
		Live × 1.00
		Roof live × 1.00
		Snow × 1.00
	Support C	Dead × 1.00
		Live × 1.00
		Roof live × 1.00
		Snow × 1.00

Analysis results

Maximum moment;	M_{max} = **0** kips_ft;	M_{min} = **-935.9** kips_ft
Maximum moment span 1;	M_{s1_max} = **0** kips_ft;	M_{s1_min} = **-935.9** kips_ft
Maximum moment span 1 segment 1;	$M_{s1\_seg1\_max}$ = **0** kips_ft;	$M_{s1\_seg1\_min}$ = **-40.1**
kips_ft		
Maximum moment span 1 segment 2;	$M_{s1\_seg2\_max}$ = **0** kips_ft;	$M_{s1\_seg2\_min}$ = **-318.9**
kips_ft		
Maximum moment span 1 segment 3;	$M_{s1\_seg3\_max}$ = **0** kips_ft;	$M_{s1\_seg3\_min}$ = **-626.6**
kips_ft		
Maximum moment span 1 segment 4;	$M_{s1\_seg4\_max}$ = **0** kips_ft;	$M_{s1\_seg4\_min}$ = **-935.9**
kips_ft		
Maximum moment span 2;	M_{s2_max} = **0** kips_ft;	M_{s2_min} = **-935.9** kips_ft
Maximum shear;	V_{max} = **60** kips;	V_{min} = **-85.5** kips
Maximum shear span 1;	V_{s1_max} = **-10.8** kips;	V_{s1_min} = **-85.5** kips
Maximum shear span 1 segment 1;	$V_{s1\_seg1\_max}$ = **0** kips;	$V_{s1\_seg1\_min}$ = **-11.3** kips
Maximum shear span 1 segment 2;	$V_{s1\_seg2\_max}$ = **0** kips;	$V_{s1\_seg2\_min}$ = **-84.7** kips
Maximum shear span 1 segment 3;	$V_{s1\_seg3\_max}$ = **0** kips;	$V_{s1\_seg3\_min}$ = **-85.1** kips
Maximum shear span 1 segment 4;	$V_{s1\_seg4\_max}$ = **0** kips;	$V_{s1\_seg4\_min}$ = **-85.5** kips
Maximum shear span 2;	V_{s2_max} = **60** kips;	V_{s2_min} = **33.6** kips

Deflection;	δ_{max} = **0** in;	δ_{min} = **0** in
Deflection span 1;	δ_{s1_max} = **0** in;	δ_{s1_min} = **0** in
Deflection span 2;	δ_{s2_max} = **0** in;	δ_{s2_min} = **0** in
Maximum reaction at support A;	R_{A_max} = **0** kips;	R_{A_min} = **0** kips
Maximum reaction at support B;	R_{B_max} = **145.5** kips;	R_{B_min} = **145.5** kips
Unfactored dead load reaction at support B;	R_{B_Dead} = **145.5** kips	
Maximum reaction at support C;	R_{C_max} = **-33.6** kips;	R_{C_min} = **-33.6** kips
Unfactored dead load reaction at support C;	R_{C_Dead} = **-33.6** kips	

Section details

Section type; **W 30x116**

ASTM steel designation; **A992**

Steel yield stress; F_y = **50** ksi

Steel tensile stress; F_u = **65** ksi

Modulus of elasticity; E = **29000** ksi

Safety factors

Safety factor for tensile yielding; Ω_{ty} = **1.67**

Safety factor for tensile rupture; Ω_{tr} = **2.00**

Safety factor for compression; Ω_c = **1.67**

Safety factor for flexure; Ω_b = **1.67**

Safety factor for shear; Ω_v = **1.50**

Lateral bracing

Span 1 has lateral bracing at supports plus quarter points

Span 2 has continuous lateral bracing

Cantilever tip is unbraced

Cantilever support is continuous with lateral and torsional restraint

Classification of sections for local buckling - Section B4.1

Classification of flanges in flexure - Table B4.1b (case 10)

Width to thickness ratio; $b_f / (2 \times t_f)$ = **6.18**

Limiting ratio for compact section; $\lambda_{pff} = 0.38 \times \sqrt{[E / F_y]}$ = **9.15**

Limiting ratio for non-compact section; $\lambda_{rff} = 1.0 \times \sqrt{[E / F_y]}$ = **24.08**; Compact

Classification of web in flexure - Table B4.1b (case 15)

Width to thickness ratio; $(d - 2 \times k) / t_w$ = **47.79**

Limiting ratio for compact section; $\lambda_{pwf} = 3.76 \times \sqrt{[E / F_y]}$ = **90.55**

Limiting ratio for non-compact section; $\lambda_{rwf} = 5.70 \times \sqrt{[E / F_y]}$ = **137.27**; Compact

Section is compact in flexure

Design of members for shear - Chapter G

Required shear strength; $V_r = \max(\text{abs}(V_{max}), \text{abs}(V_{min}))$ = **85.525** kips

Web area; $A_w = d \times t_w$ = **16.95** in^2

Web plate buckling coefficient; k_v = **5**

Web shear coefficient - eq G2-2; C_v = **1.000**

Nominal shear strength - eq G2-1; $V_n = 0.6 \times F_y \times A_w \times C_v$ = **508.500** kips

Allowable shear strength; $V_c = V_n / \Omega_v$ = **339.000** kips

PASS - Allowable shear strength exceeds required shear strength

Design of members for flexure in the major axis at span 1 segment 4 - Chapter F

Required flexural strength; $M_r = max(abs(M_{s1\_seg4\_max}), abs(M_{s1\_seg4\_min}))$ = **935.885** kips_ft

Yielding - Section F2.1

Nominal flexural strength for yielding - eq F2-1; $M_{nyld} = M_p = F_y \times Z_x$ = **1575** kips_ft

Lateral-torsional buckling - Section F2.2

Unbraced length; $L_b = L_{s1\_seg4}$ = **43.5** in

Limiting unbraced length for yielding - eq F2-5; $L_p = 1.76 \times r_y \times \sqrt{[E / F_y]}$ = **92.826** in

Distance between flange centroids; $h_o = d - t_f$ = **29.15** in

c = **1**

$r_{ts} = \sqrt{[\sqrt{(I_y \times C_w)} / S_x]}$ = **2.697** in

Limiting unbraced length for inelastic LTB - eq F2-6

$L_r = 1.95 \times r_{ts} \times E / (0.7 \times F_y) \times \sqrt{[(J \times c / (S_x \times h_o)) + \sqrt{((J \times c / (S_x \times h_o))^2 + 6.76 \times (0.7 \times F_y / E)^2)}]}$ = **271.367** in

Nominal flexural strength; $M_n = M_{nyld}$ = **1575.000** kips_ft

Allowable flexural strength; $M_c = M_n / \Omega_b$ = **943.114** kips_ft

PASS - Allowable flexural strength exceeds required flexural strength

Design of members for vertical deflection

Consider deflection due to live loads

Limiting deflection; $\delta_{lim} = L_{s2} / 360$ = **0.667** in

Maximum deflection span 2; $\delta = max(abs(\delta_{max}), abs(\delta_{min}))$ = **0** in

PASS - Maximum deflection does not exceed deflection limit

Appendix AA: USGS Seismi Report

Design Maps Summary Report

User–Specified Input

Report Title Growing Power Milwaukee
Tue February 24, 2015 03:49:08 UTC

Building Code Reference Document ASCE 7-10 Standard
(which utilizes USGS hazard data available in 2008)

Site Coordinates 43.035°N, 87.922°W

Site Soil Classification Site Class E – "Soft Clay Soil"

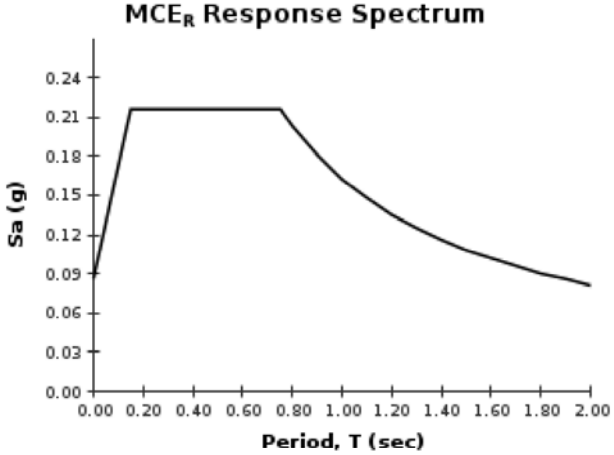
Risk Category I/II/III

USGS–Provided Output

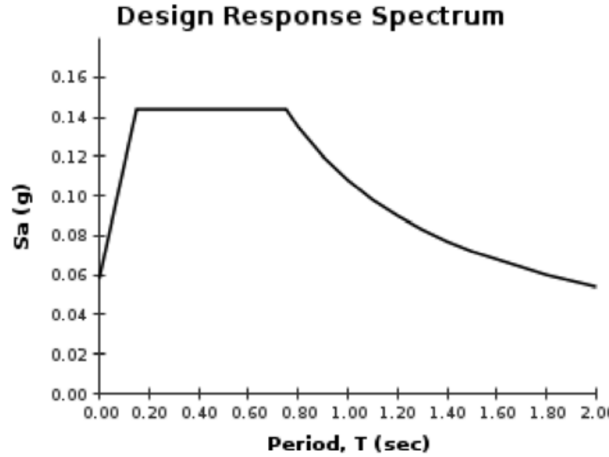
S_S =	0.086 g	S_{MS} =	0.216 g	S_{DS} =	0.144 g
S_1 =	0.046 g	S_{M1} =	0.162 g	S_{D1} =	0.108 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.

MCE_R Response Spectrum



Design Response Spectrum

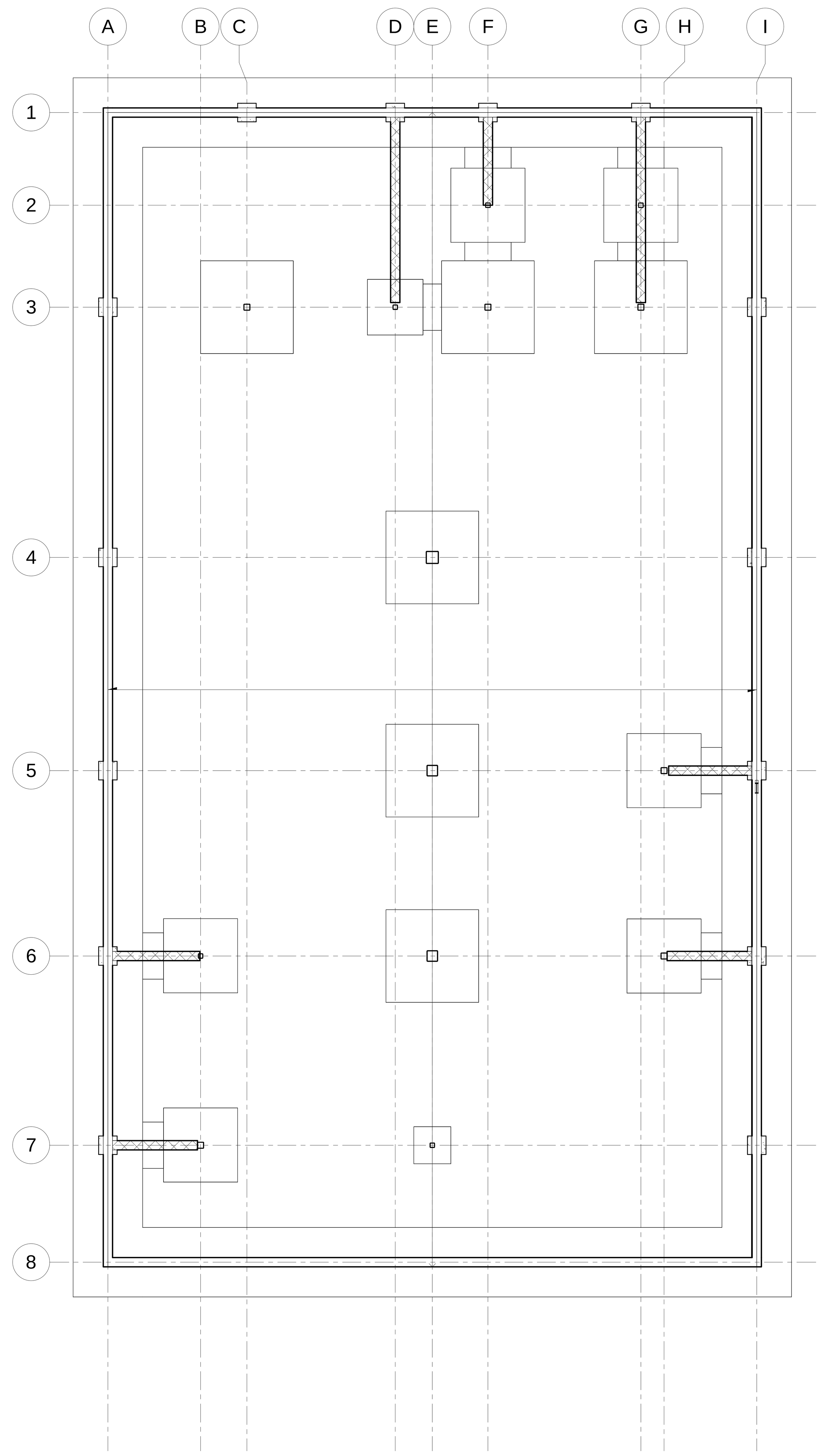


For PGA_M, T_L, C_{RS}, and C_{R1} values, please view the detailed report.

Appendix AB: Greenhouse Framing Log

Greenhouse Framing

Member	Quantity	Level	IFF Column, Top Level	Length (ft)	trib ft	area load ksf	uniform load k/ft	load k	Total moment k-ft	Axial from above k	Total Axial force k	start shear	end shear	Size ZZxYYxWW	mom. Capacity k-ft	Weight (lb/ft)	Total Weight (lb)
Framing																	
	1	5 top		20.25	9.75	0.03	0.2925	5.923125	14.99291016					5.5x5.5x3/16	16.4	13.25	268.3125
	1	5 top		20.25	9.75	0.03	0.2925	5.923125	14.99291016					5.5x5.5x3/16	16.4	13.25	268.3125
	1	5 top		20.25	9.75	0.03	0.2925	5.923125	14.99291016					5.5x5.5x3/16	16.4	13.25	268.3125
	1	5 top		20.25	9.75	0.03	0.2925	5.923125	14.99291016					5.5x5.5x3/16	16.4	13.25	268.3125
	1	5 top		20.25	15	0.03	0.45	9.1125	23.06601563					5.5x5.5x5/16	25.9	21.21	429.5025
	1	5 top		20.25	15	0.03	0.45	9.1125	23.06601563					5.5x5.5x5/16	25.9	21.21	429.5025
	2	5 top		30	12.5	0.03	0.375	11.25	42.1875			5.625	5.625	7x7x3/8	50.7	32.58	1954.8
	1	5 top		30	20.25	0.03	0.6075	18.225	68.34375			9.1125	9.1125	7x7x5/8	75.9	50.81	1524.3
	8	5 top		15	6.75	0.03	0.2025	3.0375	5.6953125					4x4x3/16	8.42	9.42	1130.4
	24	5 top		6.75	5	0.03	0.15	1.0125	0.854296875					4x4x3/16	8.42	9.42	1526.04
	2	5 slope		30	12	0.03	0.36	10.8	40.5			5.4	5.4	7x7x3/8	50.7	32.58	1954.8
	8	5 slope		20	5	0.03	0.15	3	7.5					4x4x3/16	8.42	9.42	1507.2
	1	5 slope		22.36	12.5	0.03	0.375	8.385	23.436075			4.1925	4.1925	5.5x5.5x5/16	25.9	21.21	474.2556
	1	5 slope		22.36	15	0.03	0.45	10.062	28.12329					5.5x5.5x3/8	30	24.93	557.4348
	1	5 slope		22.36	12.5	0.03	0.375	8.385	23.436075			4.1925	4.1925	5.5x5.5x5/16	25.9	21.21	474.2556
	1	5 slope		22.36	15	0.03	0.45	10.062	28.12329			5.031	5.031	5.5x5.5x3/8	30	24.93	557.4348
	1	5 slope		22.36	20	0.03	0.6	13.416	37.49772			6.708	6.708	7x7x5/16	43.4	27.59	616.9124
	1	5 slope		22.36	15	0.03	0.45	10.062	28.12329			5.031	5.031	5.5x5.5x3/8	30	24.93	557.4348
	1	5 slope		22.36	12.5	0.03	0.375	8.385	23.436075			4.1925	4.1925	5.5x5.5x5/16	25.9	21.21	474.2556
	1	5 slope		22.36	15	0.03	0.45	10.062	28.12329					5.5x5.5x3/8	30	24.93	557.4348
	1	5 slope		22.36	12.5	0.03	0.375	8.385	23.436075			4.1925	4.1925	5.5x5.5x5/16	25.9	21.21	474.2556
	1	5 slope		22.36	15	0.03	0.45	10.062	28.12329			5.031	5.031	5.5x5.5x3/8	30	24.93	557.4348
	1	5 slope		22.36	20	0.03	0.6	13.416	37.49772			6.708	6.708	7x7x5/16	43.4	27.59	616.9124
	1	5 slope		22.36	15	0.03	0.45	10.062	28.12329			5.031	5.031	5.5x5.5x3/8	30	24.93	557.4348
	4	5 slope		31	10	0.03	0.3	9.3	36.0375					7x7x5/16	43.4	27.59	3421.16
	12	5 slope		15	5.5	0.03	0.165	2.475	4.640625					4x4x3/16	8.42	9.42	1695.6
	12	5 slope		20.25	5.5	0.03	0.165	3.34125	8.457539063					4x4x1/4	10.8	12.21	2967.03
	4	5 slope		20.25	5	0.03	0.15	3.0375	7.688671875					4x4x3/16	8.42	9.42	763.02
	112	5 slope		5.5	5	0.03	0.15	0.825	0.5671875					4x4x3/16	8.42	9.42	5802.72
	8	5 slope		16.5	5.5	0.03	0.165	2.7225	5.61515625					4x4x3/16	8.42	9.42	1243.44
	8	5 slope		11	5.5	0.03	0.165	1.815	2.495625					4x4x3/16	8.42	9.42	828.96
	8	5 slope		5.5	5	0.03	0.15	0.825	0.5671875					4x4x3/16	8.42	9.42	414.48
Framing																	
	4	5 wall		20.25	6.25	0.03	0.1875	3.796875	9.610839844					4x4x1/4	10.8	12.21	989.01
	8	5 wall		20	6.25	0.03	0.1875	3.75	9.375					4x4x1/4	10.8	12.21	1953.6
	2	5 wall		30	6.25	0.03	0.1875	5.625	21.09375					5.5x5.5x5/16	25.9	21.21	1272.6
	24	5 wall		6.75	4.1667	0.03	0.125001	0.84375675	0.711919758					2x2x3/16	2.21	4.32	699.84
	72	5 wall		5	4.1667	0.03	0.125001	0.625005	0.390628125					2x2x3/16	2.21	4.32	1555.2
	8	5 wall		12.5	6.75	0.03	0.2025	2.53125	0		2.53125			2.5x2.5x1/4	10	7.11	711
	34	5 wall		12.5	5	0.03	0.15	1.875	0		1.875			2.5x2.5x1/4	10	7.11	3021.75
Columns																	
001	1	5 wall		12.5	5	0.03	0.15	1.875	0	5.109	6.984			4x4x3/16	36	9.42	117.75
002	1	5 wall		12.5	5	0.03	0.15	1.875	0	19.1	20.975			4x4x3/16	36	9.42	117.75
003	1	5 wall		12.5	5	0.03	0.15	1.875	0	19.1	20.975			4x4x3/16	36	9.42	117.75
004	1	5 wall		12.5	5	0.03	0.15	1.875	0	5.109	6.984			4x4x3/16	36	9.42	117.75
005	1	5 wall		12.5	6	0.03	0.18	2.25	0	10.06	12.31			4x4x3/16	36	9.42	117.75
006	1	5 wall		12.5	6	0.03	0.18	2.25	0	10.06	12.31			4x4x3/16	36	9.42	117.75
007	1	5 wall		12.5	6.75	0.03	0.2025	2.53125	0	22.7	25.23125			4x4x3/16	36	9.42	117.75
008	1	5 wall		12.5	6.75	0.03	0.2025	2.53125	0	22.7	25.23125			4x4x3/16	36	9.42	117.75
009	1	5 wall		12.5	6	0.03	0.18	2.25	0	10.06	12.31			4x4x3/16	36	9.42	117.75
010	1	5 wall		12.5	6	0.03	0.18	2.25	0	10.06	12.31			4x4x3/16	36	9.42	117.75
011	1	5 wall		12.5	5	0.03	0.15	1.875	0	5.109	6.984			4x4x3/16	36	9.42	117.75
012	1	5 wall		12.5	5	0.03	0.15	1.875	0	19.1	20.975			4x4x3/16	36	9.42	117.75
013	1	5 wall		12.5	5	0.03	0.15	1.875	0	19.1	20.975			4x4x3/16	36	9.42	117.75
014	1	5 wall		12.5	5	0.03	0.15	1.875	0	5.109	6.984			4x4x3/16	36	9.42	117.75
								29.0625		182.476	211.5385						
Framing	4	4 slope		20	11.75	0.03	0.3525	7.05	17.625					5x5x5/16	21	19.08	1526.4
	2	4 slope		30	11.75	0.03	0.3525	10.575	39.65625					7x7x5/16	43.4	27.59	1655.4
	2	4 slope		23.5	10	0.03	0.3	7.05	20.709375			3.525	3.525	5.5x5.5x5/16	25.9	21.21	996.87
	2	4 slope		23.5	17.5	0.03	0.525	12.3375	36.24140625			8.8125	8.8125	7x7x5/16	43.4	27.59	1296.73
	1	4 slope		23.5	15	0.03	0.45	10.575	31.0640625			5.2875	5.2875	7x7x5/16	43.4	27.59	648.365
	6	4 slope		20	5.875	0.03	0.17625	3.525	8.8125					4x4x1/4	10.8	12.21	1465.2
	6	4 slope		15	5.875	0.03	0.17625	2.64375	4.95703125					4x4x3/16	8.42	9.42	847.8
	40	4 slope		5.875	5	0.03	0.15	0.88125	0.647167969					4x4x3/16	8.42	9.42	2213.7
	42	4 wall		5	4	0.03	0.12	0.6	0.375					4x4x3/16	8.42	9.42	1978.2
	42	4 wall		5	3.375	0.03	0.10125	0.50625	0.31640625					4x4x3/16	8.42	9.42	1978.2
	11	4 wall		16	5	0.03	0.15	2.4	0		2.4			2.5x2.5x1/4	10	7.11	1251.36
	11	4 wall		13.5	5	0.03	0.15	2.025	0		1.875			2.5x2.5x1/4	10	7.11	1055.835
Columns																	
001	1	4 wall		13.5	5	0.03	0.15	2.025	0	3.525	5.55			3x3x1/4	16	8.81	118.935
002	1	4 wall		13.5	5	0.03	0.15	2.025	0	8.8125	10.8375			3x3x1/4	16	8.81	118.935
003	1	4 wall		13.5	5	0.03	0.15	2.025	0	8.8125	10.8375			3x3x1/4	16	8.81	118.935
004	1	4 wall		13.5	5	0.03	0.15	2.025	0	3.525	5.55			3x3x1/4	16	8.81	118.935
005	1	4 wall		16	5	0.03	0.15	2.4	0	3.525	5.925			3x3x1/4	12.3	8.81	140.96
006	1	4 wall		16	5	0.03	0.15	2.4	0	8.8125	11.2125			3x3x1/4	12.3	8.81	140.96
007	1	4 wall		16	5	0.03	0.15	2.4	0	8.8125	11.2125			3x3x1/4	12.3	8.81	140.96
008	1	4 wall		16	5	0.03	0.15	2.4	0	3.525	5.925			3x3x1/4	12.3	8.81	140.96
											67.05						
										49.35							
Framing	4	3 slope		20	14.5	0.03	0.435	8.7	21.75					5.5x5.5x5/16	25.9	21.21	1696.8
	2	3 slope		30	14.5	0.03	0.435	13.05	48.9375					8x8x5/16	57.6	31.84	1910.4
	2	3 slope		29	10	0.03	0.3	8.7	31.5375			4.35	4.35	7x7x5/16	43.4	27.59	1600.22
	2	3 slope		29	17.5	0.03	0.525	15.225	55.190625			10.875	10.875	8x8x5/16	57.6	31.84	1846.72
	1	3 slope		29	15	0.03	0.45	13.05	47.30625			6.525	6.525	8x8x5/16	57.6	31.84	923.36
	8	3 slope		20	5.8	0.03	0.174	3.48	8.7					4x4x1/4	10.8	12.21	1953.6
	8	3 slope		15	5.8	0.03	0.174	2.61	4.89375					4x4x3/16	8.42	9.42	1130.4
	50	3 slope		5.8	5	0.03	0.15	0.87	0.63075					4x4x3/16	8.42	9.42	2731.8
	42	3 wall		5	4	0.03	0.12	0.6	0.375					4x4x3/16	8.42	9.42	1978.2
	42	3 wall		5	4	0.03	0.12	0.6	0.375					4x4x3/16	8.42	9.42	1978.2
	11	3 wall		16	5	0.03	0.15	2.4	0		2.4			2.5x2.5x1/4	10	7.11	1251.36
	11	3 wall		16	5	0.03	0.15	2.4	0		2.4			2.5x2.5x1/4	10	7.11	1251.36
Columns																	
001	1	3 wall		16	5	0.03	0.15	2.4	0	4.35	6.75			3x3x5/16	14	10.58	169.28
002	1	3 wall		16	5	0.03	0.15	2.4	0	10.875	13.275			3x3x5/16	14	10.58	169.28
003	1	3 wall		16	5	0.03	0.15	2.4	0	10.875	13.275			3x3x5/16	14	10.58	169.28
004	1	3 wall		16	5	0.03	0.15	2.4	0	4.35	6.75			3x3x5/16	14	10.58	169.28
005	1	3 wall		16	5	0.03	0.15	2.4	0	4.35	6.75			3x3x5/16	14	10.58	169.28
006	1	3 wall		16	5	0.03	0.15	2.4	0	10.875	13.275			3x3x5/16	14	10.58	169.28
007	1	3 wall		16	5	0.03	0.15	2.4	0	10.875	13.275			3x3x5/16	14	10.58	169.28
008	1	3 wall		16	5	0.03	0.15	2.4	0	4.35	6.75			3x3x5/16	14	10.58	169.28
											80.1						
										60.9							



1 Basement TOS
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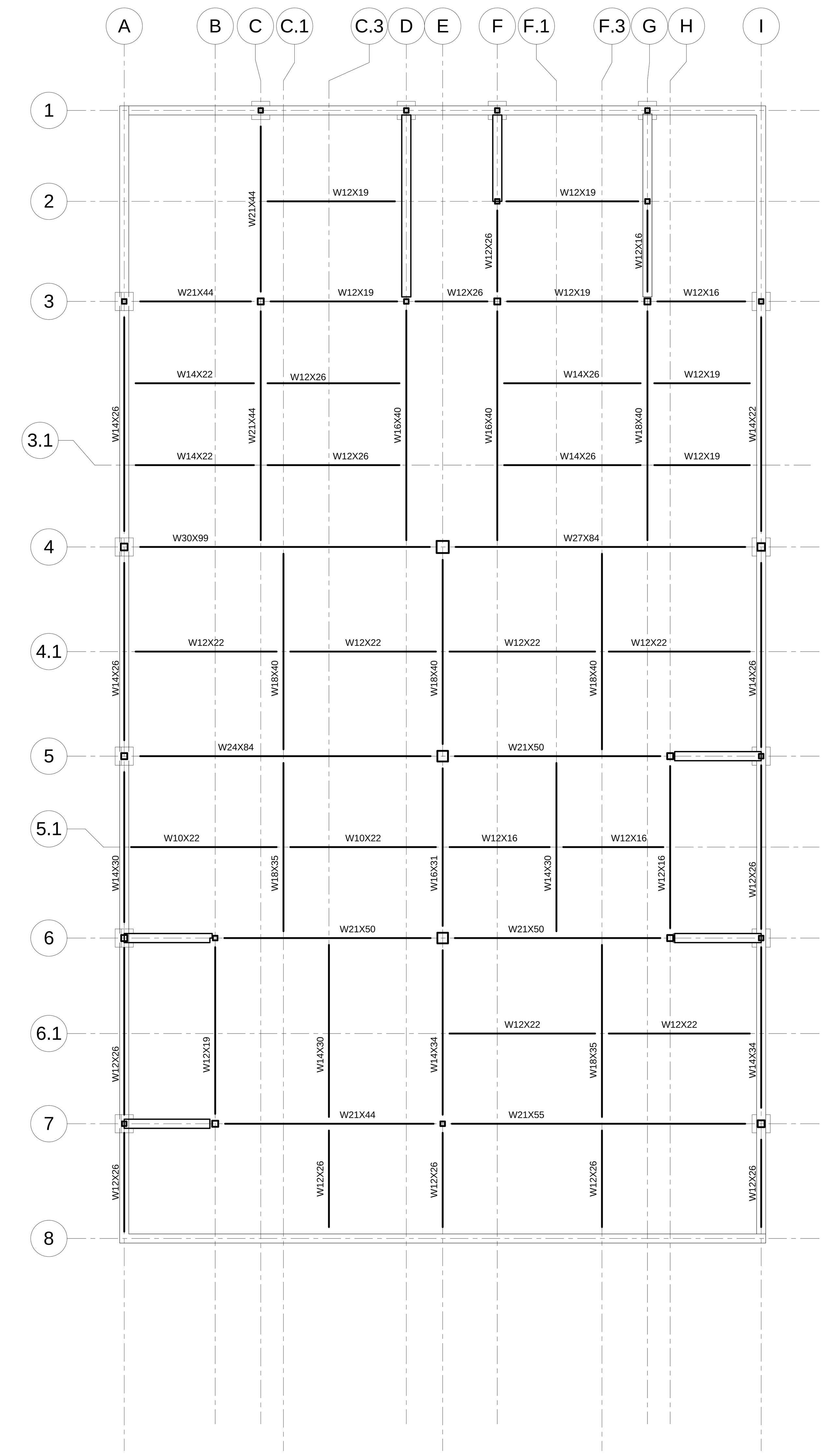

2 Level G
1/8" = 1'-0"

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

Foundation Plan/ Level G Framing Plan

Project Number	
Date	2/25/2015
Drawn By	WM
Checked By	JA

S.100

Scale 1/8" = 1'-0"

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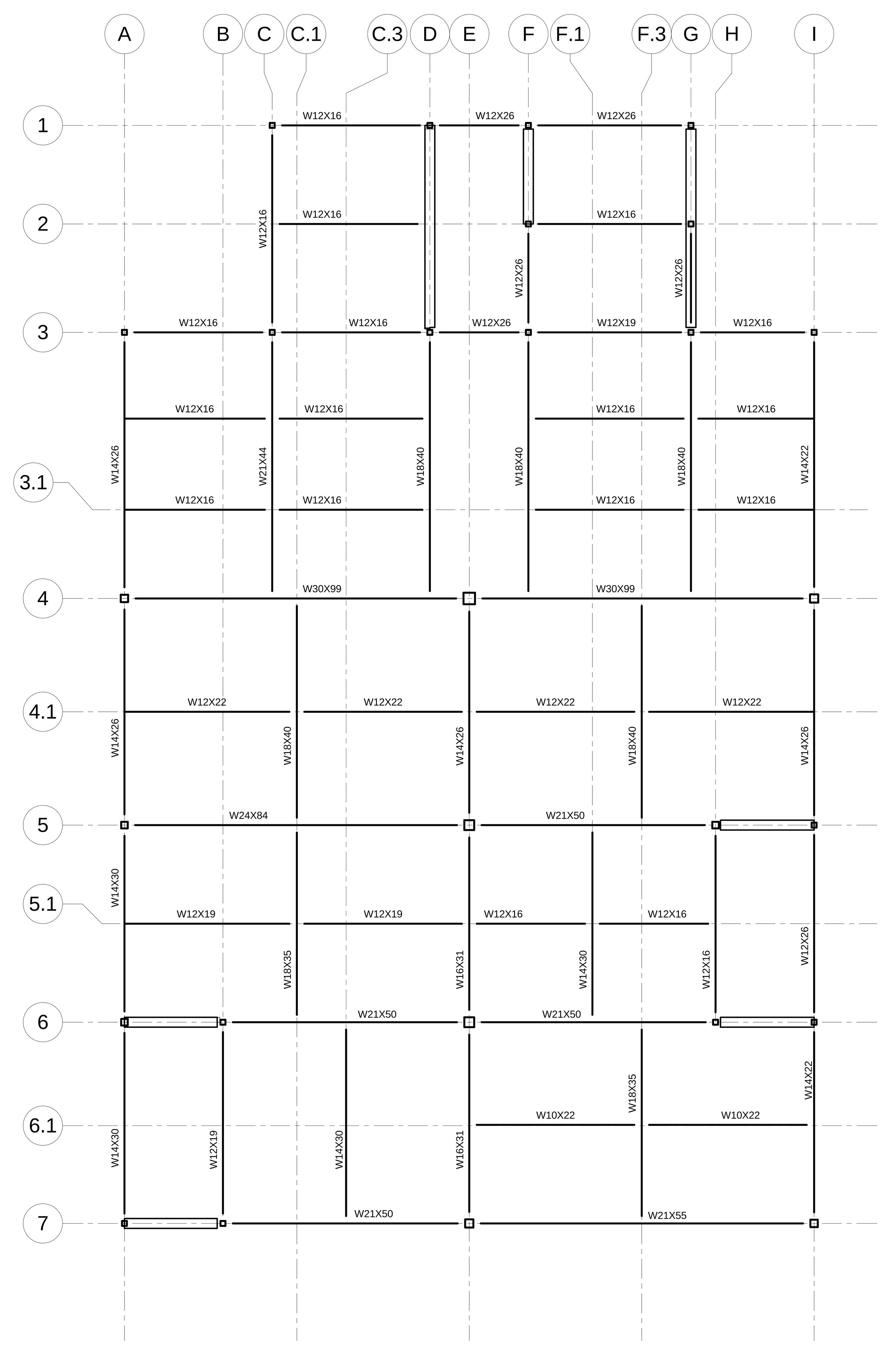

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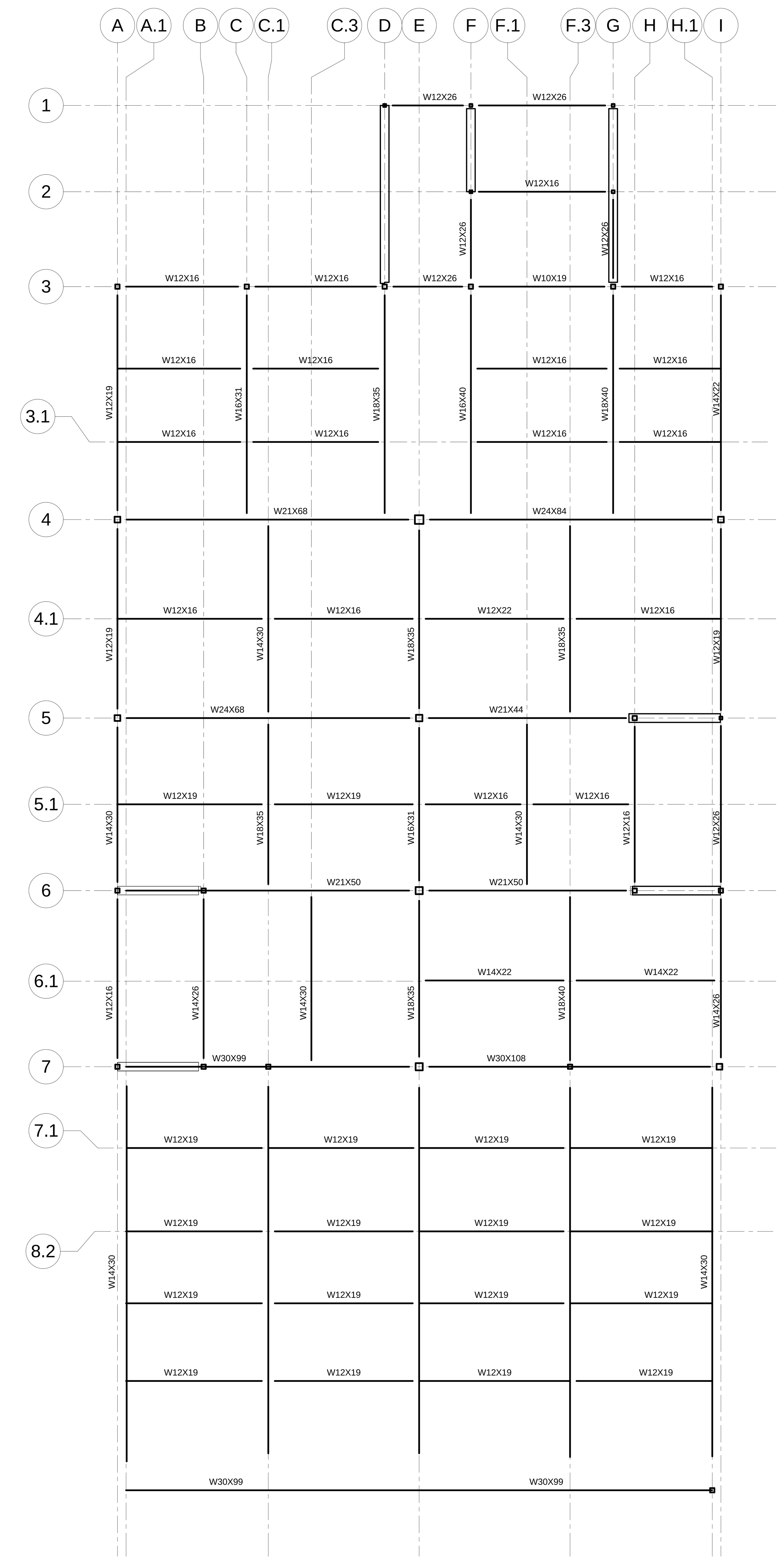

2 Level 2
1/8" = 1'-0"

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

Level 1 and 2 Framing Plans

Project Number

Date 2/25/2015

Drawn By WM

Checked By JA

S.101

Scale 1/8" = 1'-0"

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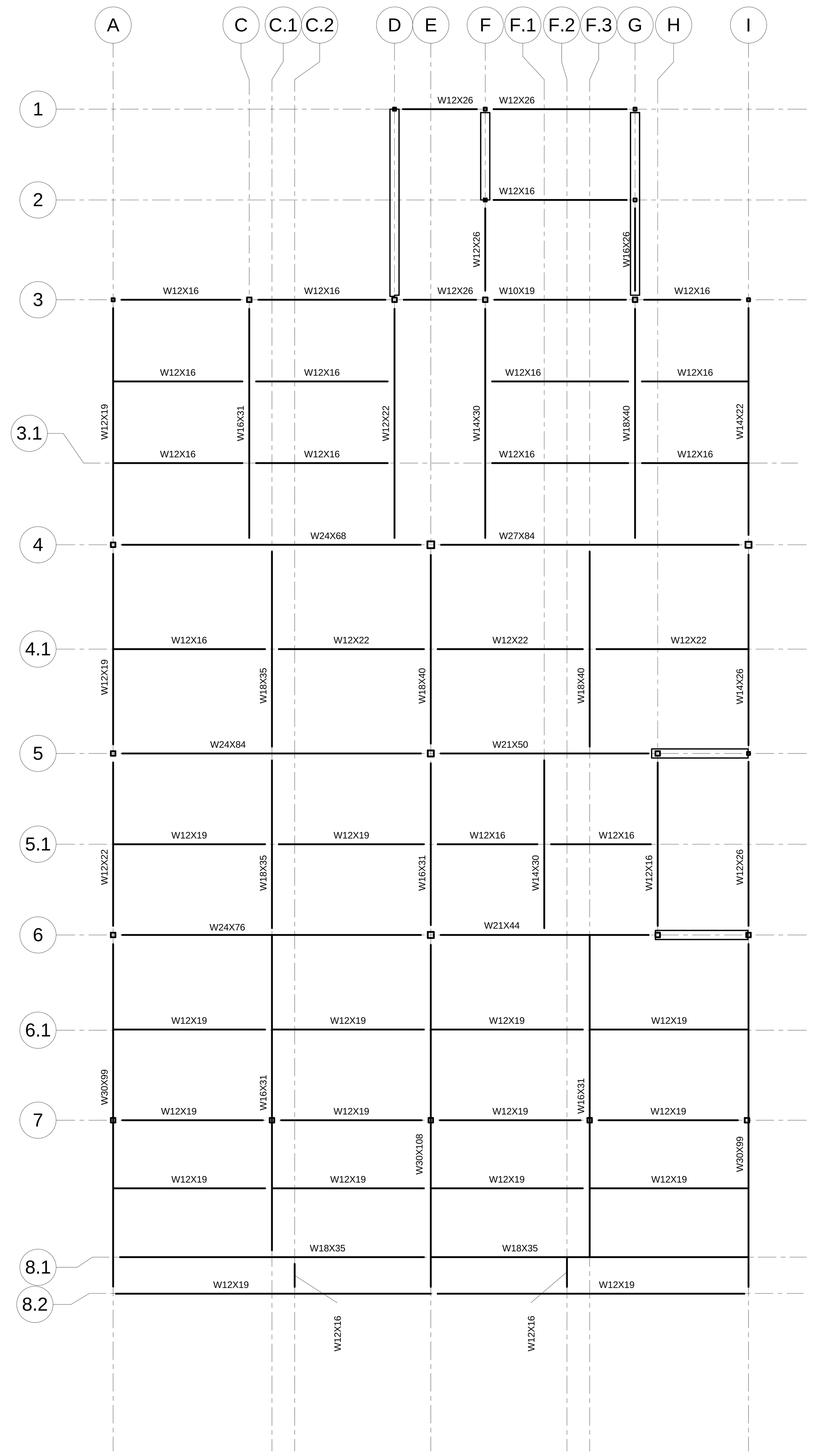

1 Level 3
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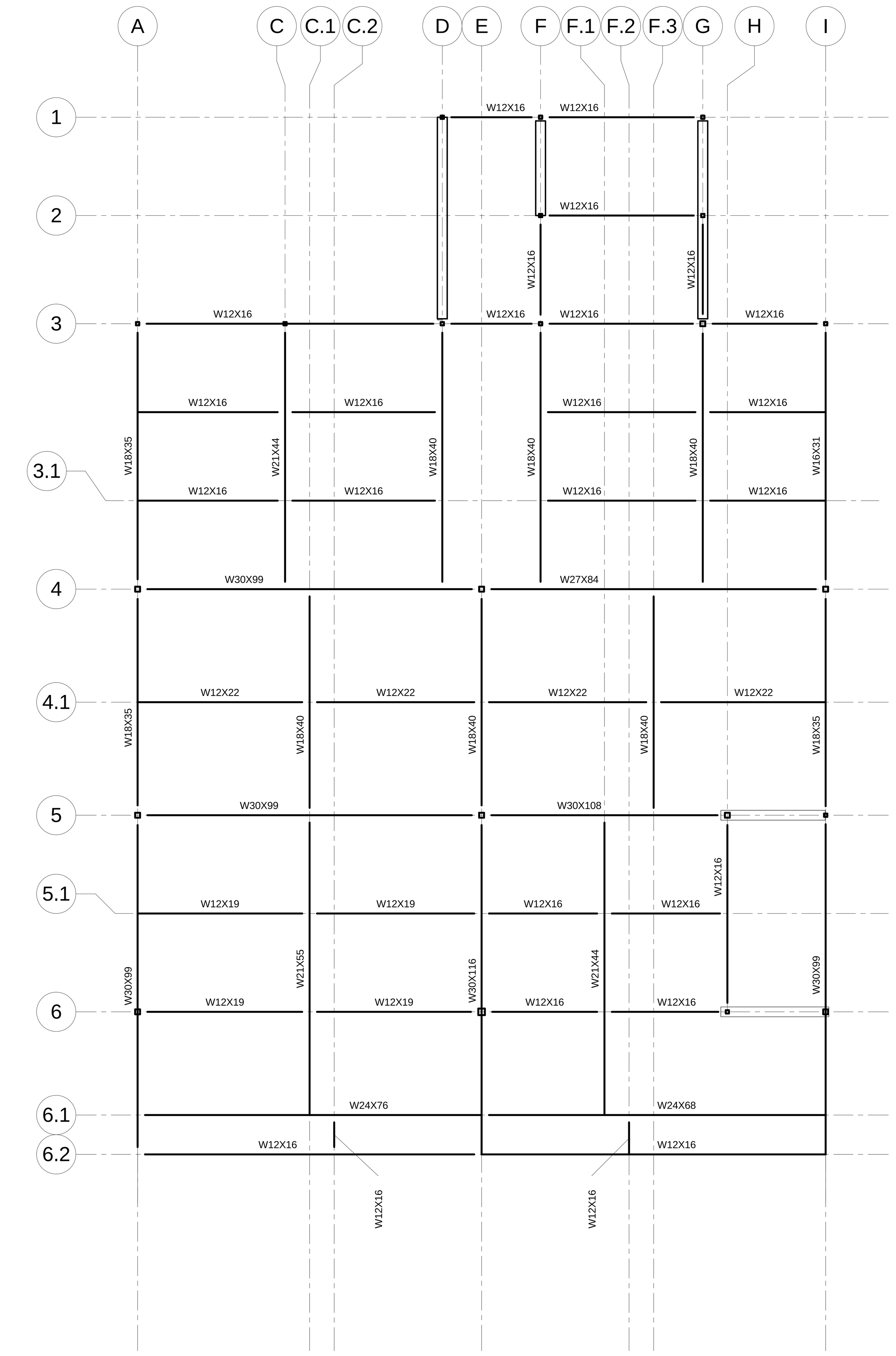

2 Level 4
1/8" = 1'-0"

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

Level 3 and 4 Framing Plans

Project Number	
Date	2/25/2015
Drawn By	WM
Checked By	JA

S.102

Scale	1/8" = 1'-0"

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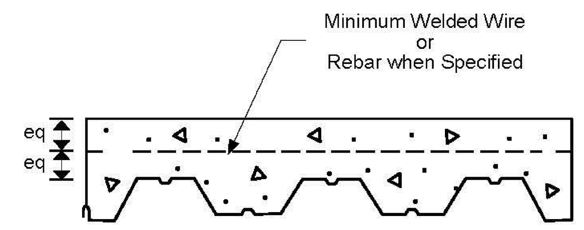

Figure 1.17.1: TYPICAL PLACEMENT OF TEMPERATURE & SHRINKAGE REINFORCEMENT

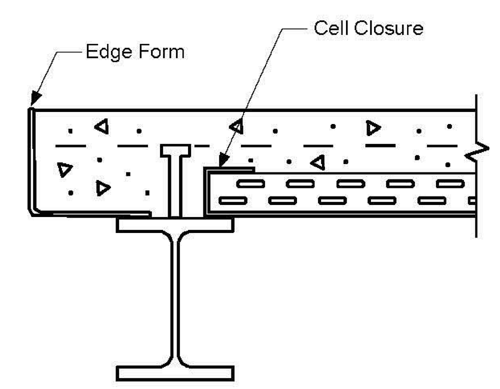

Figure 1.17.3: SINGLE PIECE EDGE FROM PERPENDICULAR TO DECK ON WIDE FLANGE BEAM

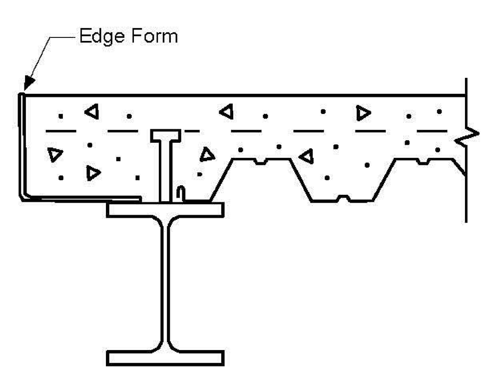

Figure 1.17.2: SINGLE PIECE EDGE FROM PARALLEL TO DECK ON WIDE FLANGE BEAM

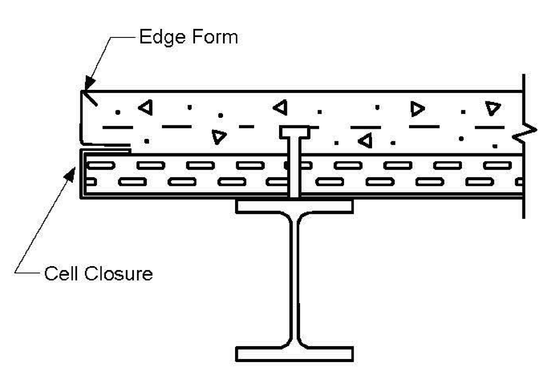

Figure 1.17.4: TWO PIECE EDGE FORM WITH DECK CANTILEVER ON WIDE FLANGE BEAM

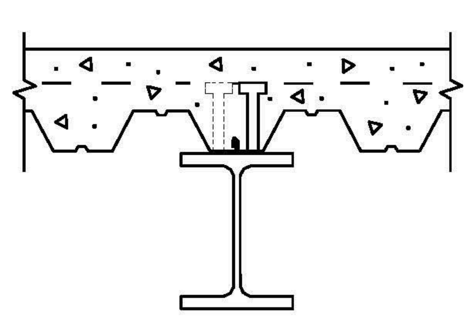
Figure 1.17.5: DECK PARALLEL TO WIDE FLANGE BEAM

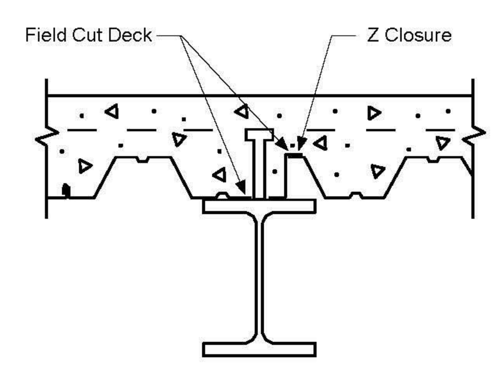

Figure 1.17.8: DECK PARALLEL TO WIDE FLANGE BEAM CUT WITH ZEE FLASHING TO ACCOMMODATE DECK MODULE

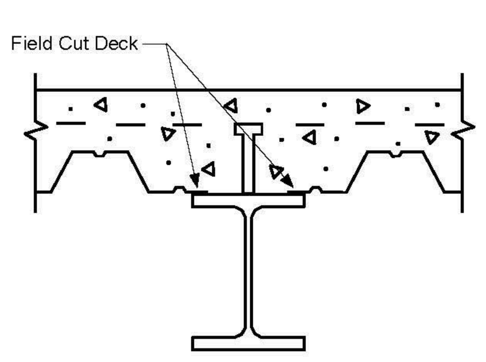

Figure 1.17.6: DECK PARALLEL TO WIDE FLANGE BEAM CUT TO ACCOMMODATE DECK MODULE

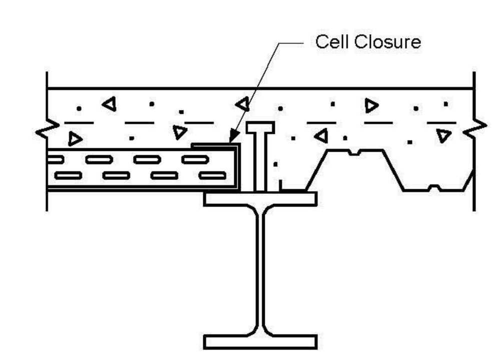

Figure 1.17.9: DECK TRANSITION ON WIDE FLANGE BEAM

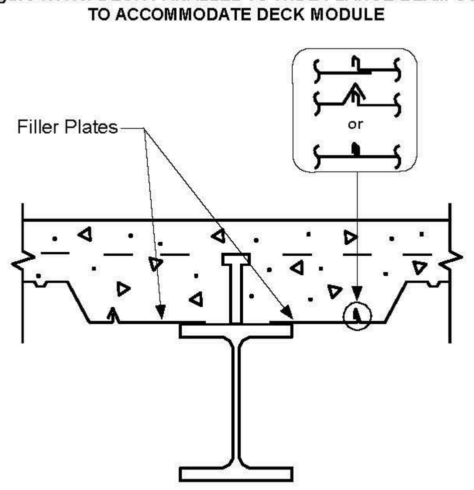

Figure 1.17.7: DECK PARALLEL TO WIDE FLANGE BEAM WITH FILLER PLATES

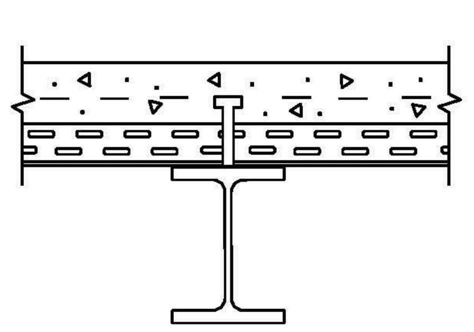
Figure 1.17.10: DECK PERPENDICULAR TO WIDE FLANGE BEAM

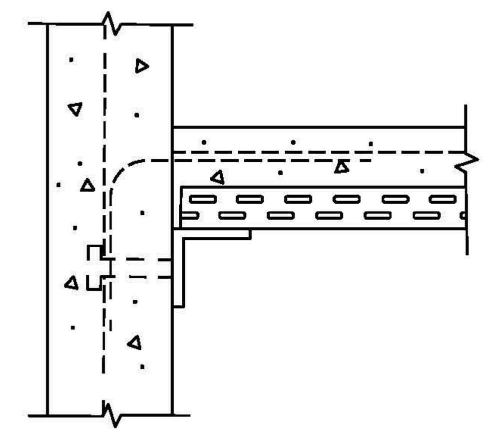
Figure 1.17.11: CONCRETE OR CMU WALL LEGER DECK PERPENDICULAR

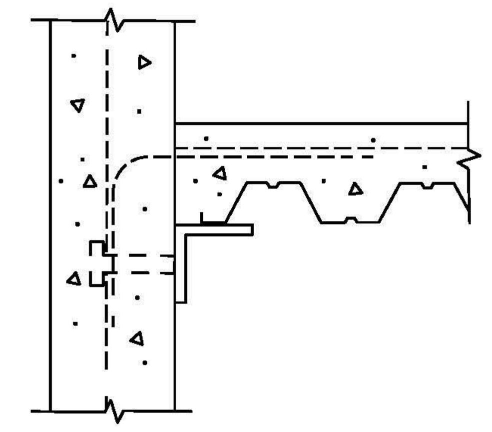
Figure 1.17.12: CONCRETE OR CMU WALL LEGER DECK PARALLEL

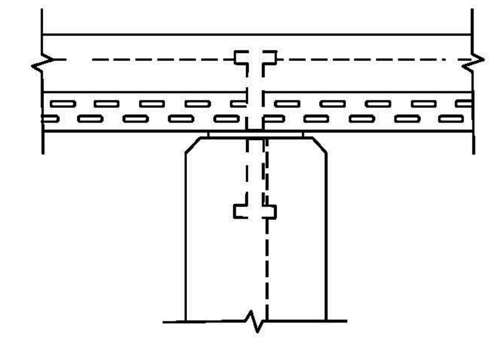
Figure 1.17.13: CONCRETE OR CMU WALL WITH EMBED PERPENDICULAR

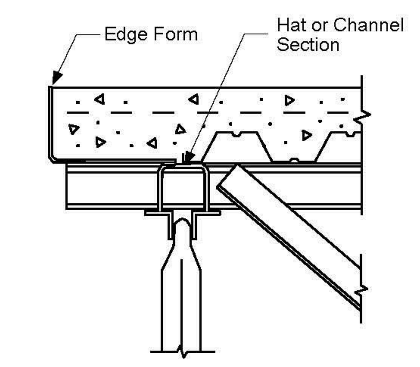

Figure 1.17.14: SINGLE PIECE EDGE FROM PARALLEL TO DECK ON OPEN WEB JOIST GIRDER

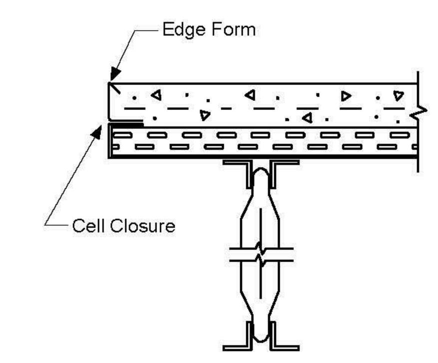

Figure 1.17.15: TWO PIECE EDGE FORM WITH DECK CANTILEVER ON WIDE FLANGE BEAM

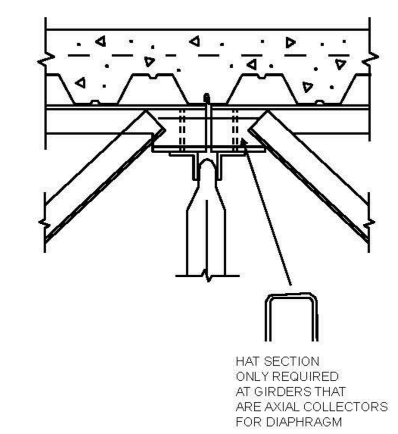

Figure 1.17.16: DECK ON OPEN WEB STEEL JOISTS AND OPEN WEB STEEL JOIST GIRDER

Column Flashings

Columns may require deck support angles depending on web support. Smaller columns often do not require deck support angles because there are no unsupported webs as shown in Figure 1.17.17. Large columns will create a condition in which one or more webs are unsupported, as shown in Figure 1.17.18. When the webs are unsupported, deck support angles are required to limit localized deflections during concrete placement. The Detail in Figure 1.17.18 is a common example of how deck may be supported when required. Using the thinnest support angles practical, when installed as shown, makes fitting and attaching the deck easier.

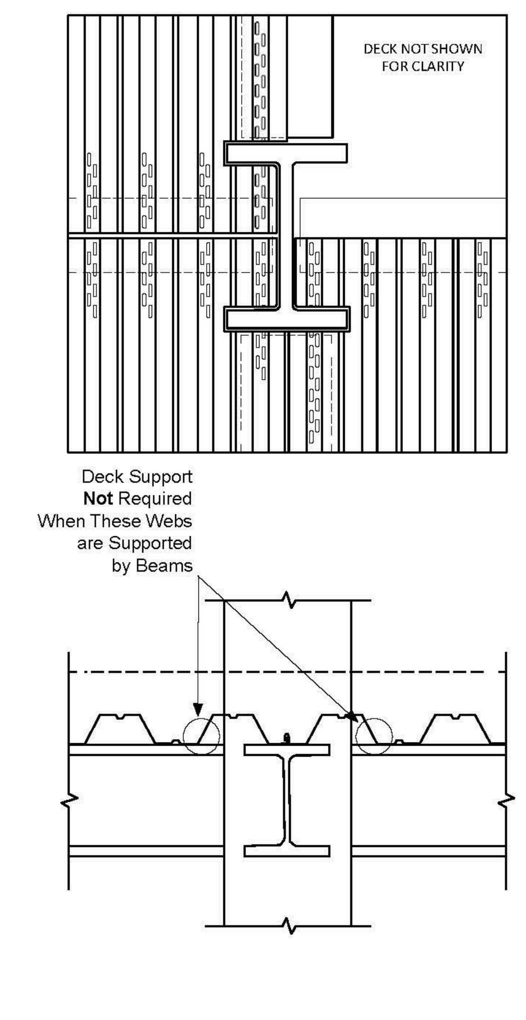

Figure 1.17.17: COLUMN DETAIL NOT REQUIRING DECK SUPPORT ANGLES

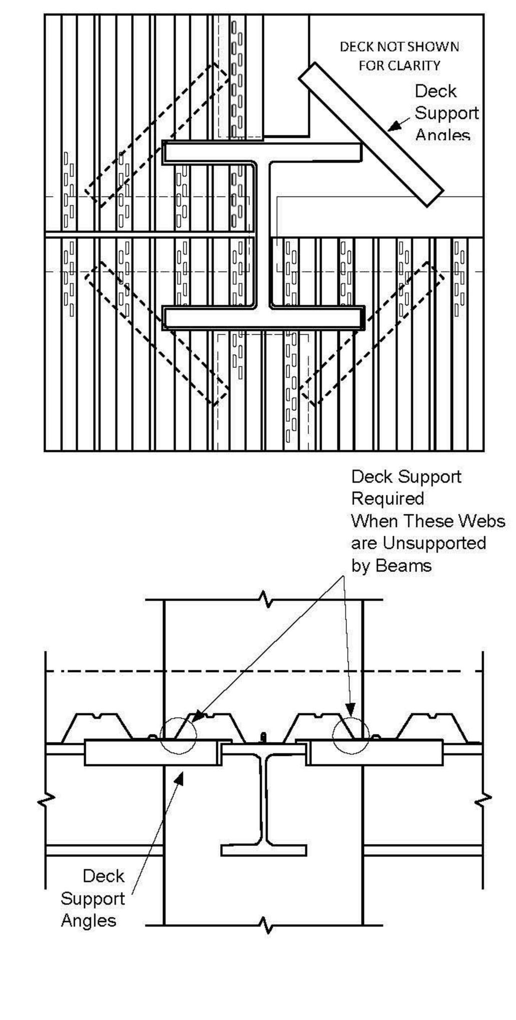

Figure 1.17.18: COLUMN DETAIL REQUIRING DECK SUPPORT ANGLES

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

Metal Deck Details

Project Number	
Date	2/25/2015
Drawn By	Author
Checked By	Checker

S.200

Scale

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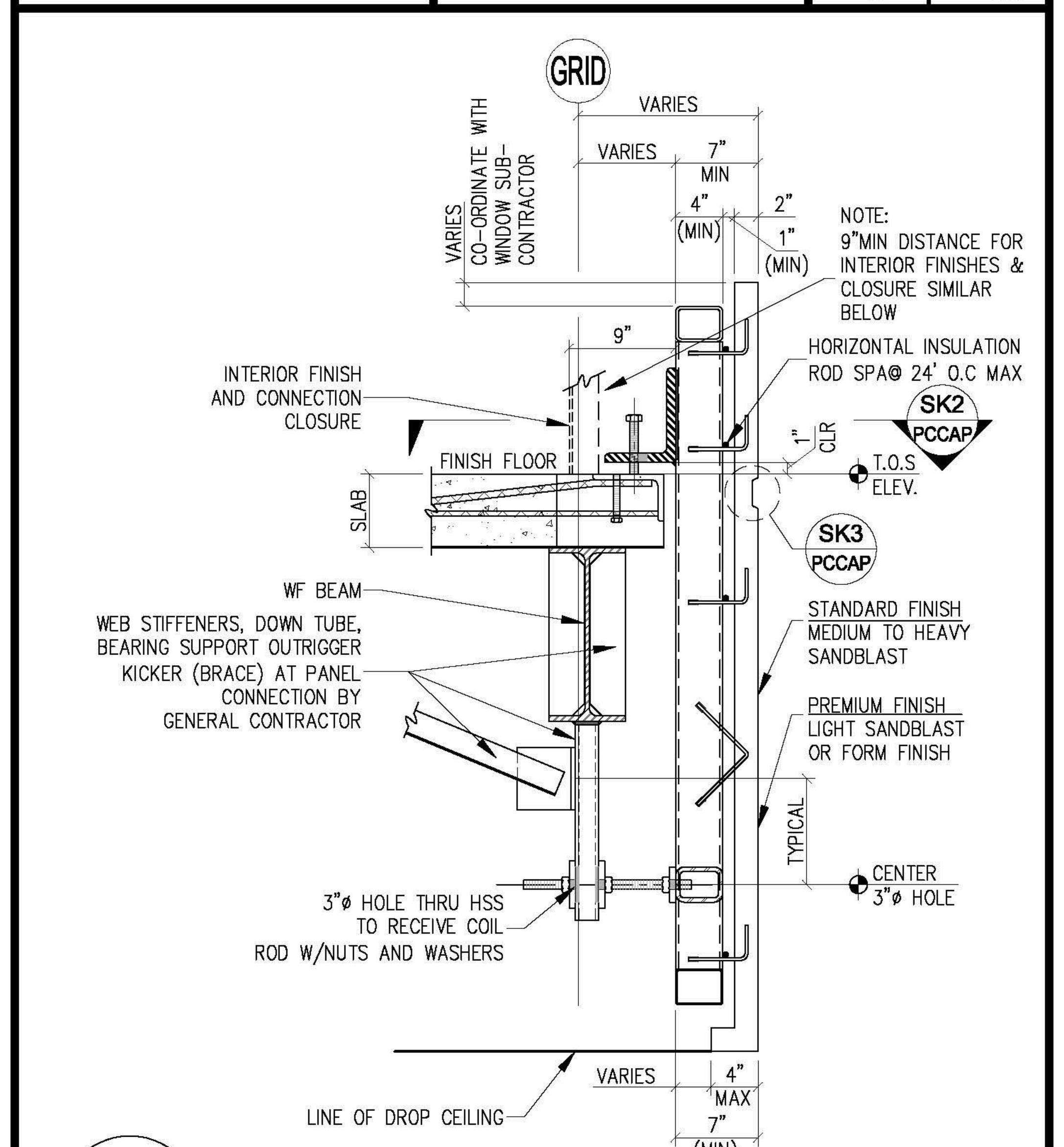
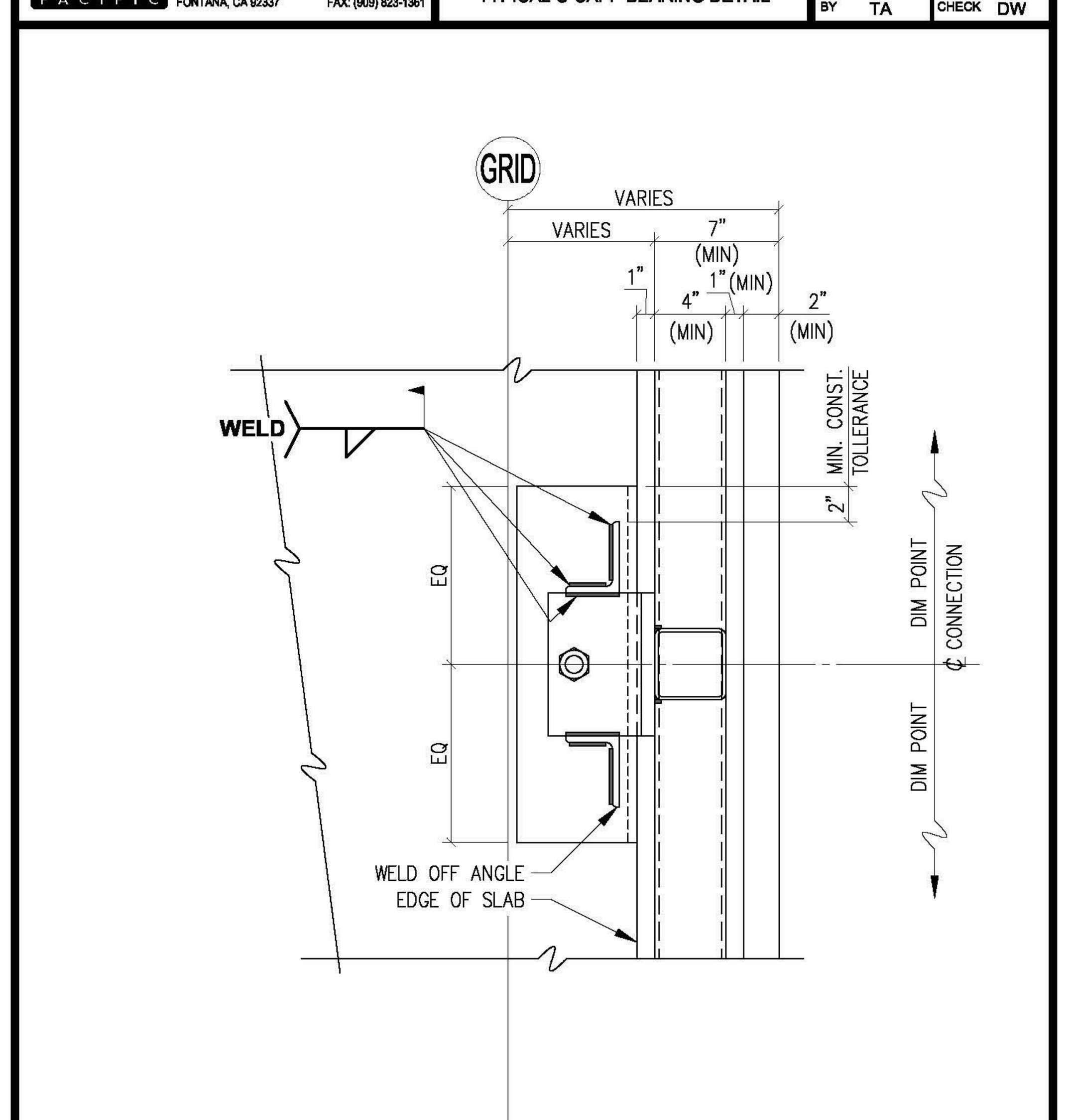
CLARK PACIFIC	PROJECT	JOB
1980 SOUTH RIVER ROAD, W SACRAMENTO, CA 95691, TEL: (916) 371-0305, FAX: (916) 372-0323; 13592 SLOVER AVENUE, FONTANA, CA 92337, TEL: (909) 823-1433, FAX: (909) 823-1361	CONTRACTOR: TYPICAL C-CAPP SECTION AT STEEL STRUCTURE	SHEET PCCAP-SK1; DATE 3/15/07; BY TA; CHECK DW



SK1 TYPICAL C-CAPP PANEL CONNECTIONS (FLOOR SECTION)
SCALE: 1" = 1'-0"

S:\By Employee\tony arroyo\WEBSITE.dwg, 3/16/2007 3:50:26 PM

CLARK PACIFIC	PROJECT	JOB
1980 SOUTH RIVER ROAD, W SACRAMENTO, CA 95691; 13592 SLOVER AVENUE, FONTANA, CA 92337	CONTRACTOR: TYPICAL C-CAPP BEARING DETAIL	SHEET PCCAP-SK2; DATE 3/15/07; BY TA; CHECK DW



SK2 TYPICAL BEARING CONNECTION (C-CAPP)
SCALE: 1 1/2" = 1'-0"

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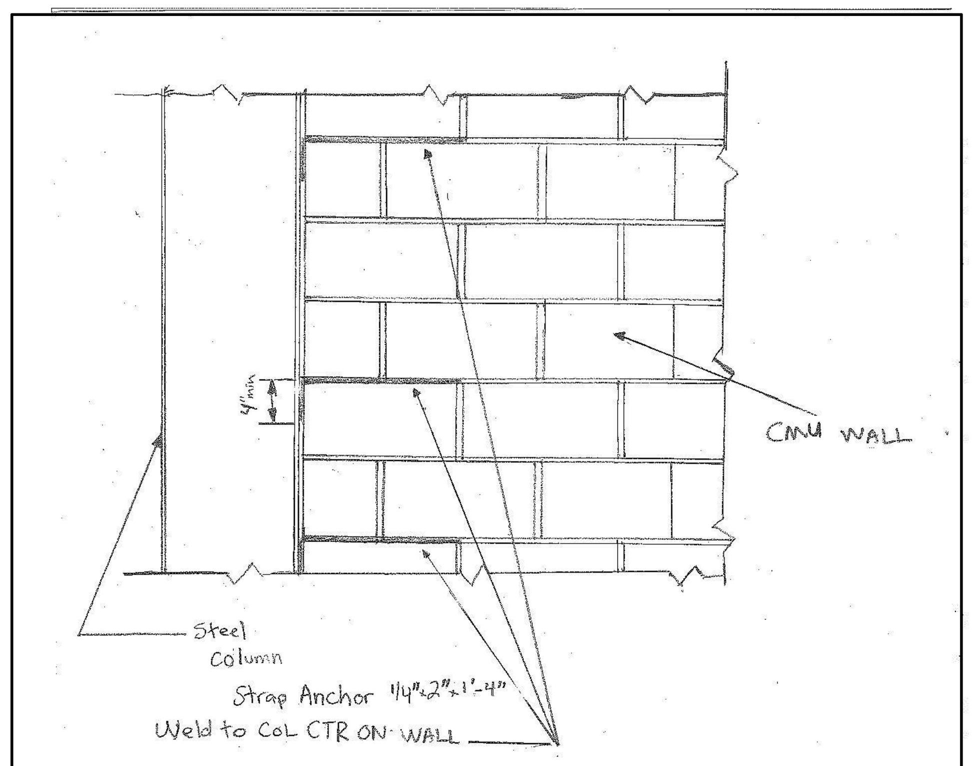
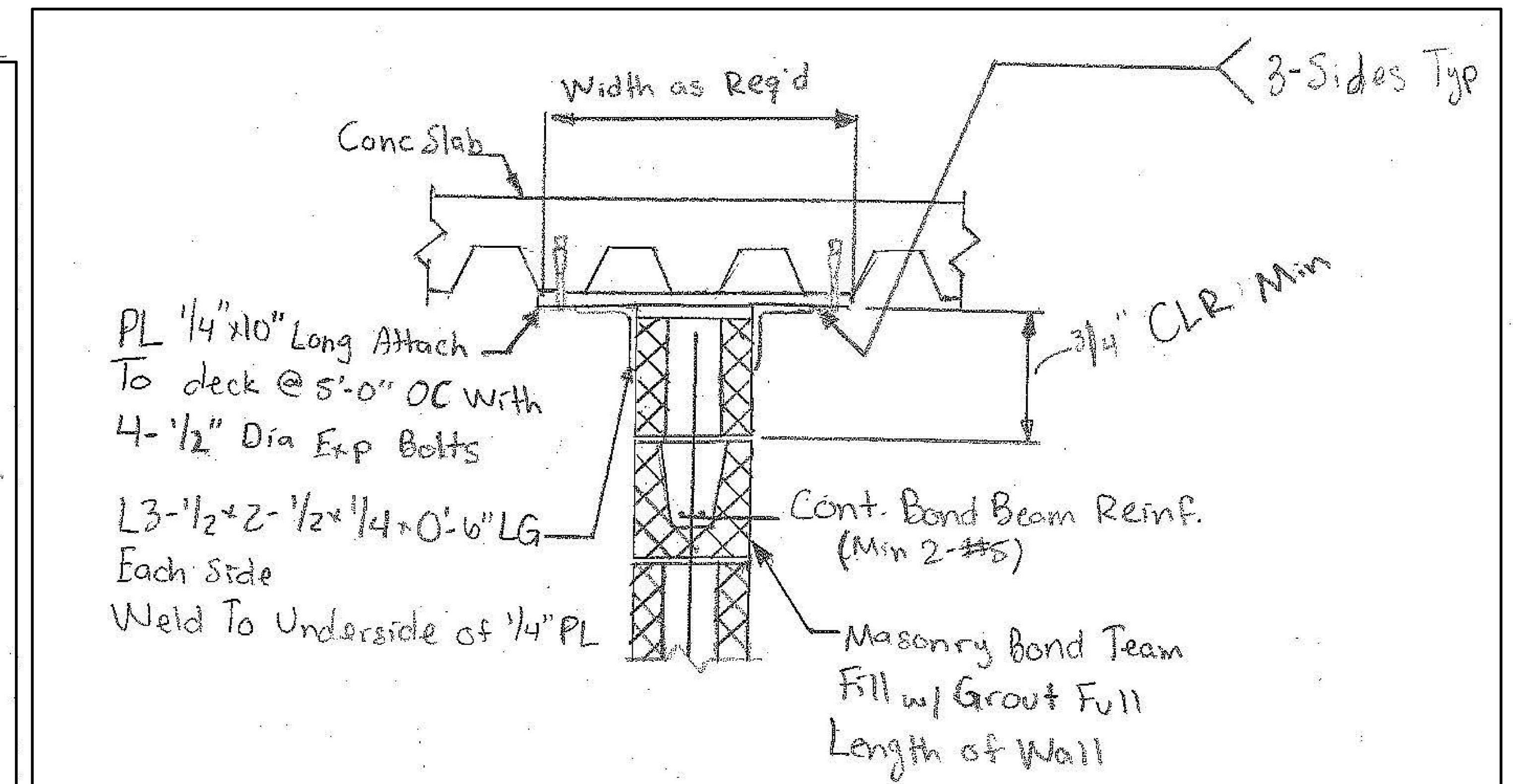
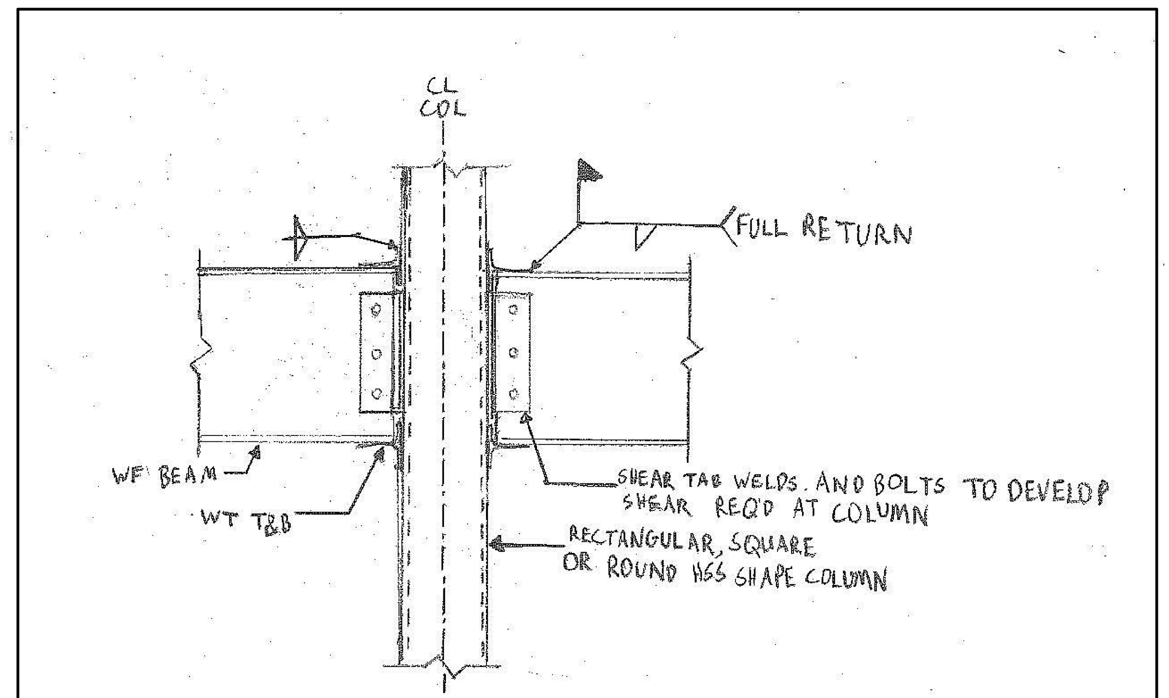


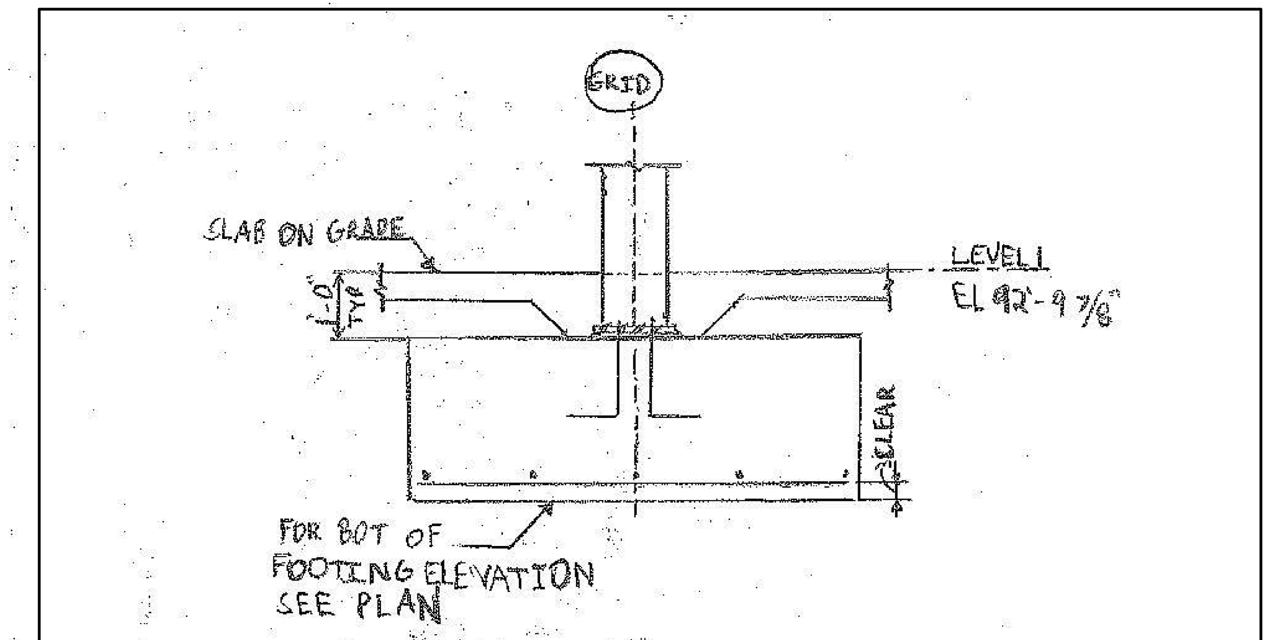
CONNECTION OF CMU TO STEEL COLUMNS



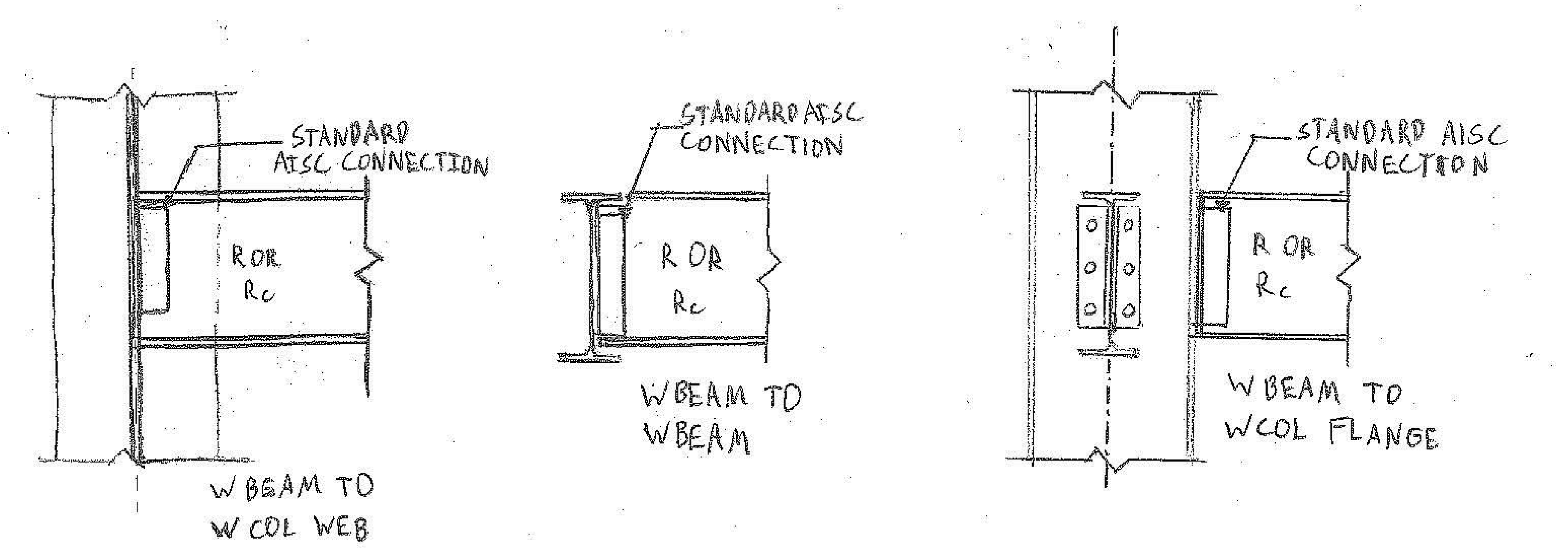
TOP OF CONCRETE MASONRY PARTITION AT COMPOSITE METAL DECK



W BEAM TO HSS COLUMN MOMENT



TYPICAL INTERIOR COLUMN FOOTING



TYPICAL BEAM CONNECTIONS

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

Typical Details

Project Number	
Date	2/25/2015
Drawn By	Author
Checked By	Checker

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Scale

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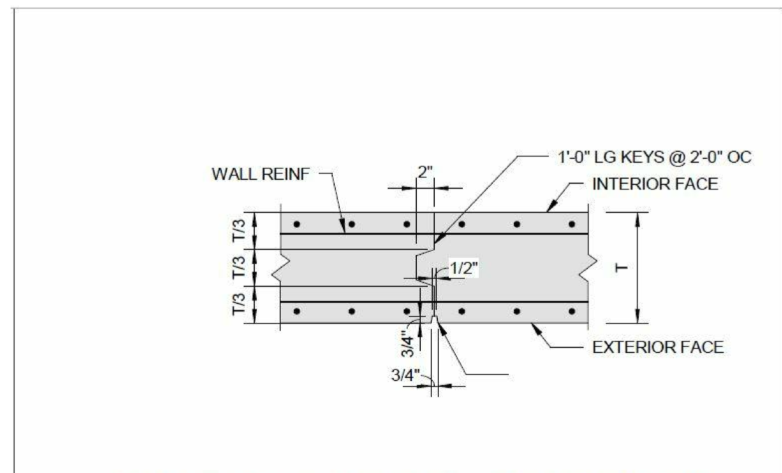
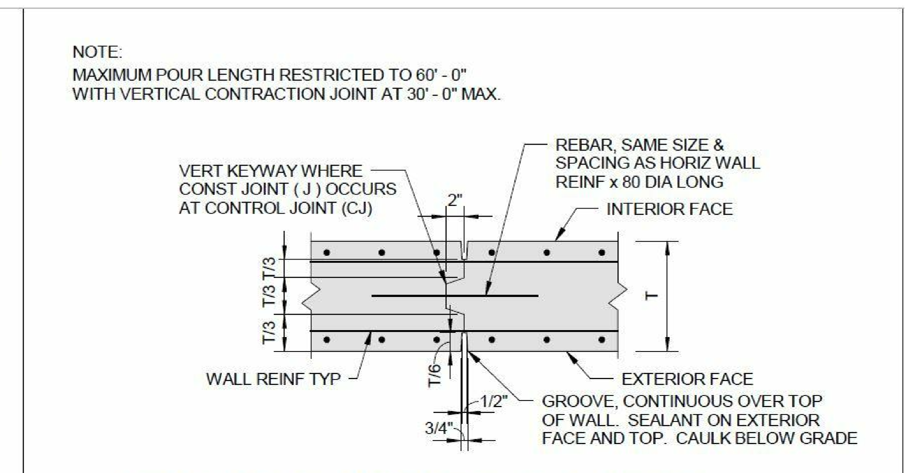
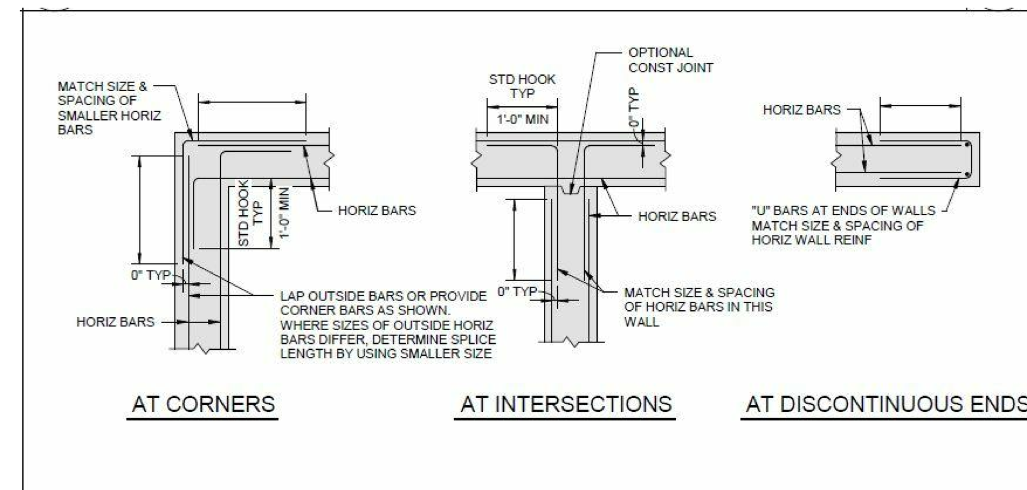
234



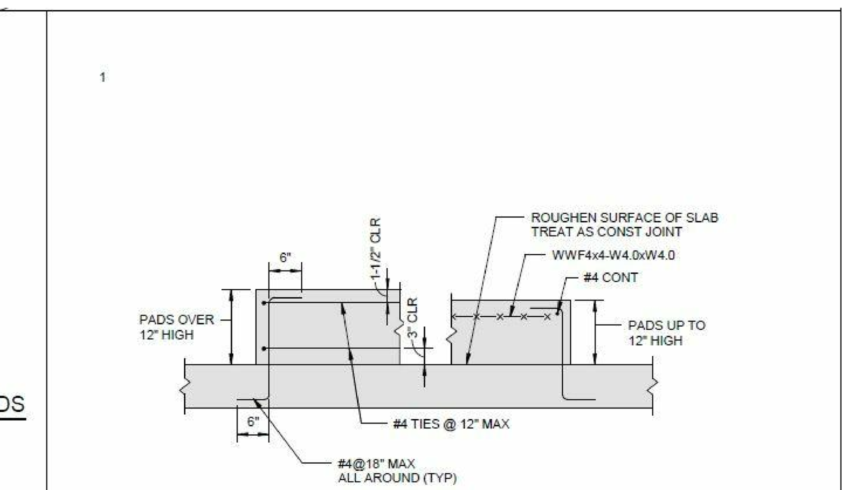
1 VERTICAL CONSTRUCTION JOINT IN CONCRETE WALLS



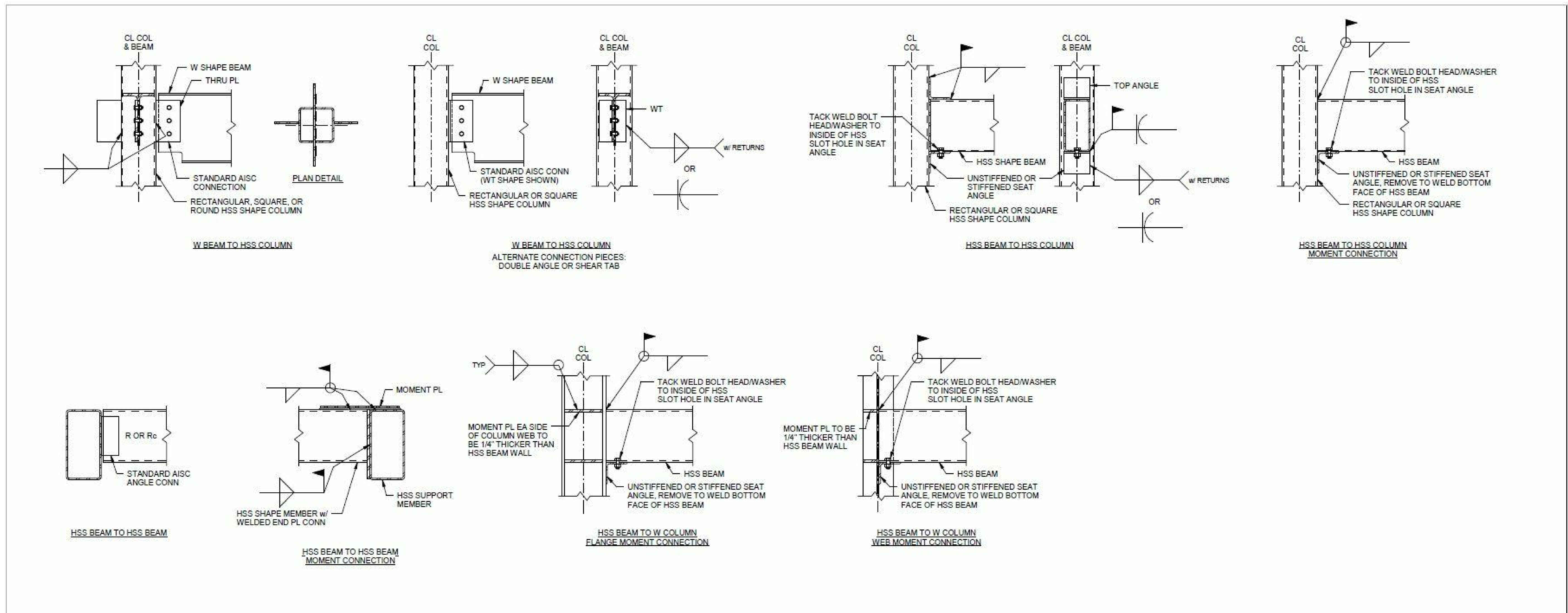
2 VERTICAL CONTRACTION JOINT IN CONCRETE WALLS



3 HORIZONTAL WALL REINFORCING PLANS

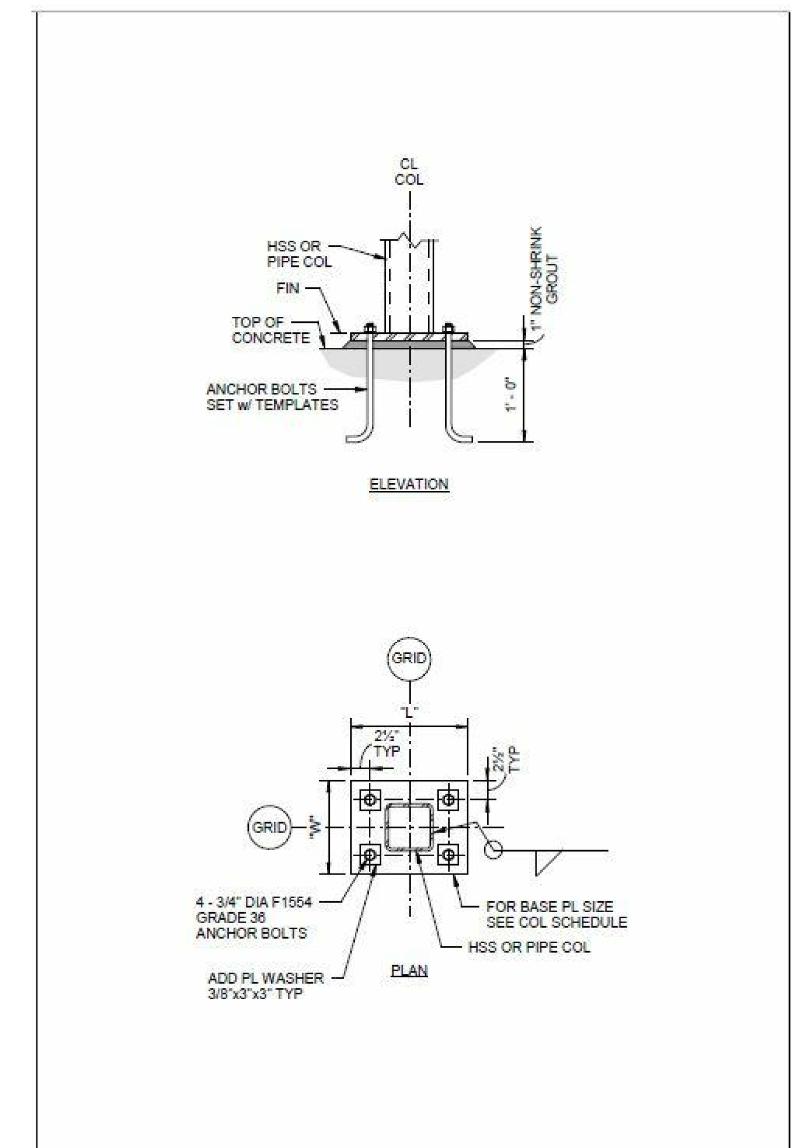


4 CONCRETE EQUIPMENT PAD

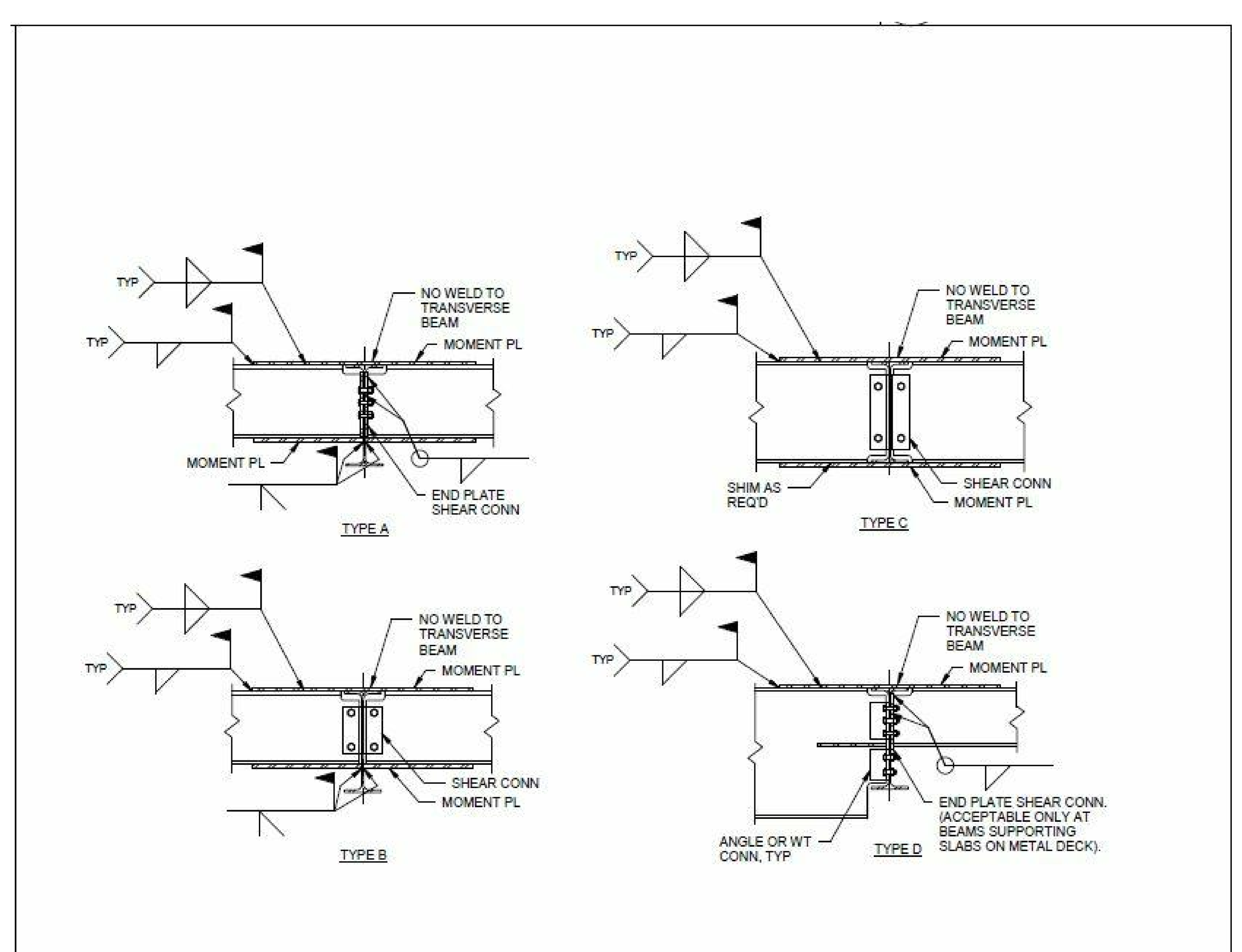


5 TYPICAL HSS CONNECTIONS

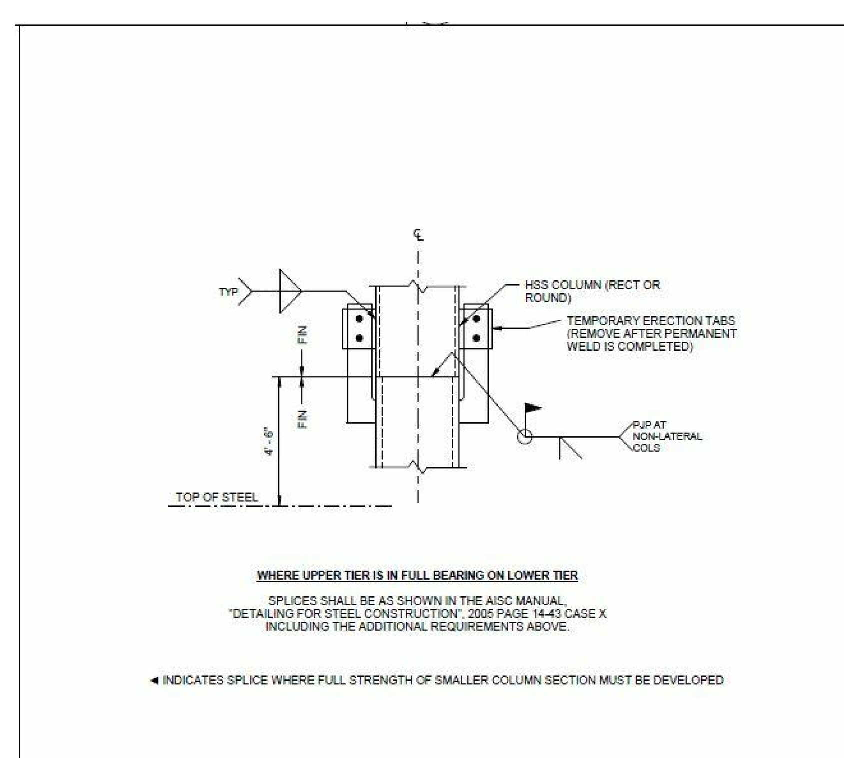
SCALE: 1" = 1'-0"



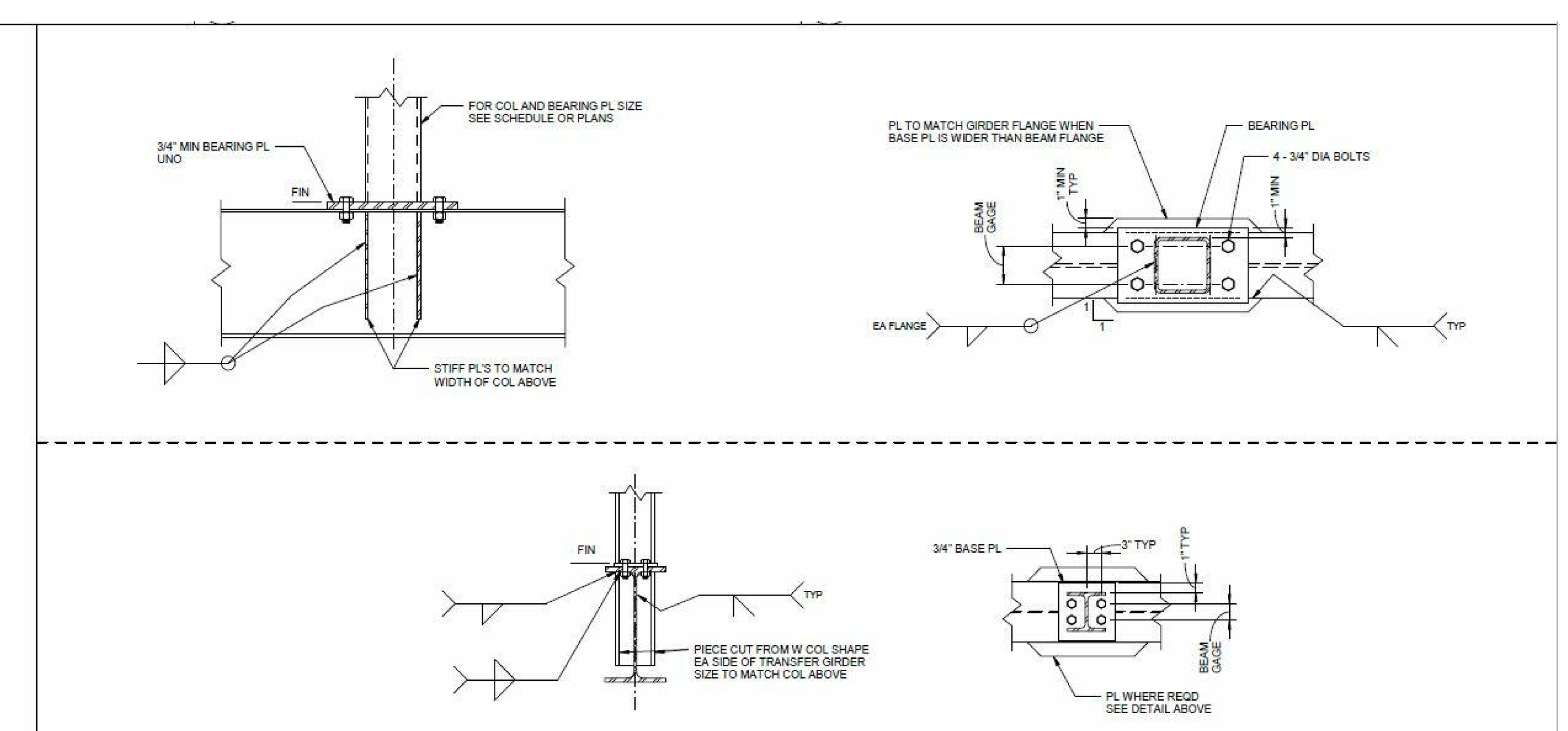
7 COLUMN BASE PLATE



6 BEAM TO BEAM MOMENT CONNECTION



8 TYPICAL HSS COLUMN SPLICE DETAILS



9 BASE PLATE OF COLUMN TRANSFER BEAM

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Team 08 - 2015

Growing Power Vertical Farm

Typical Details

Project Number	
Date	2/25/2015
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Checked By	Checker

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Scale

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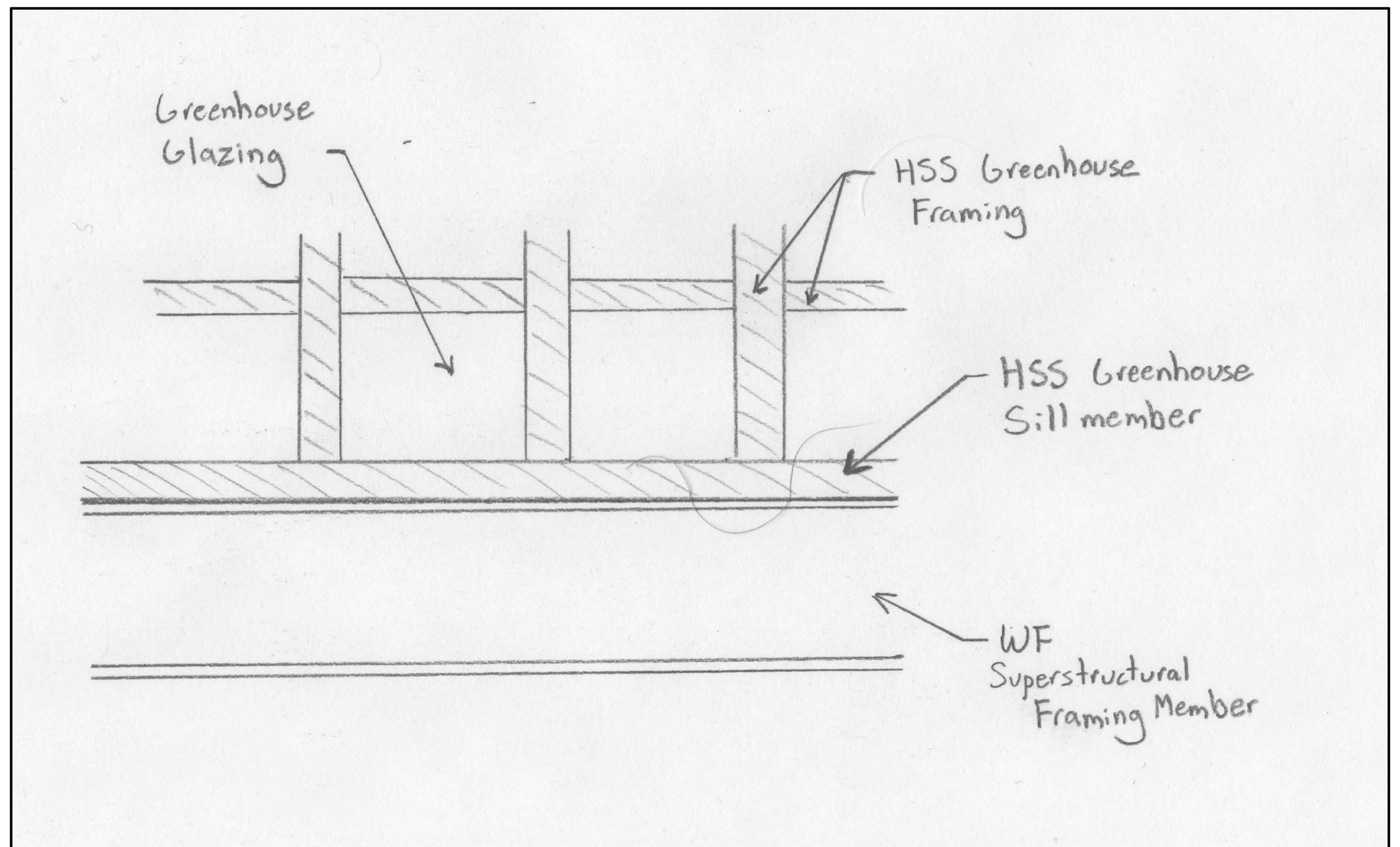
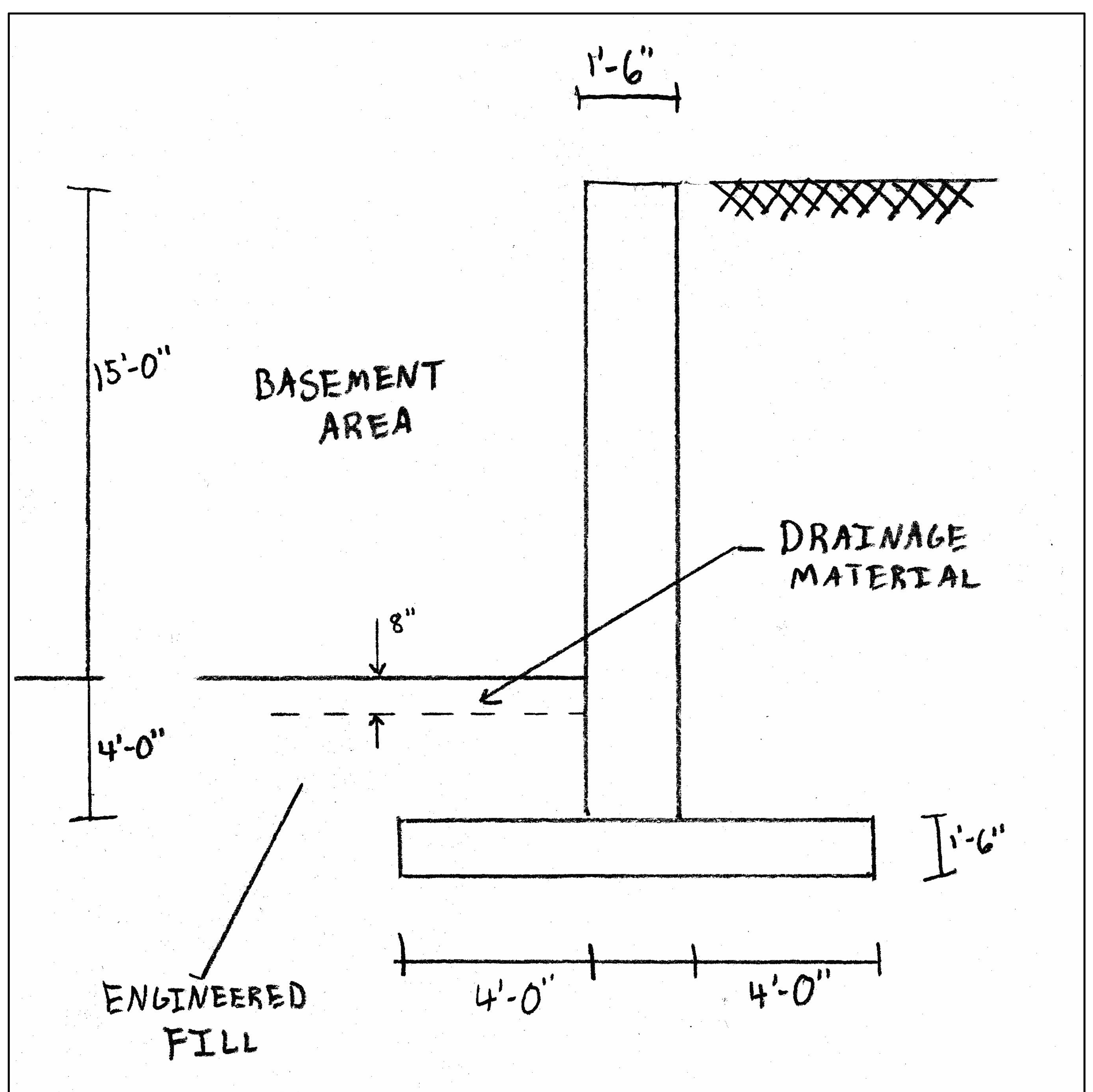
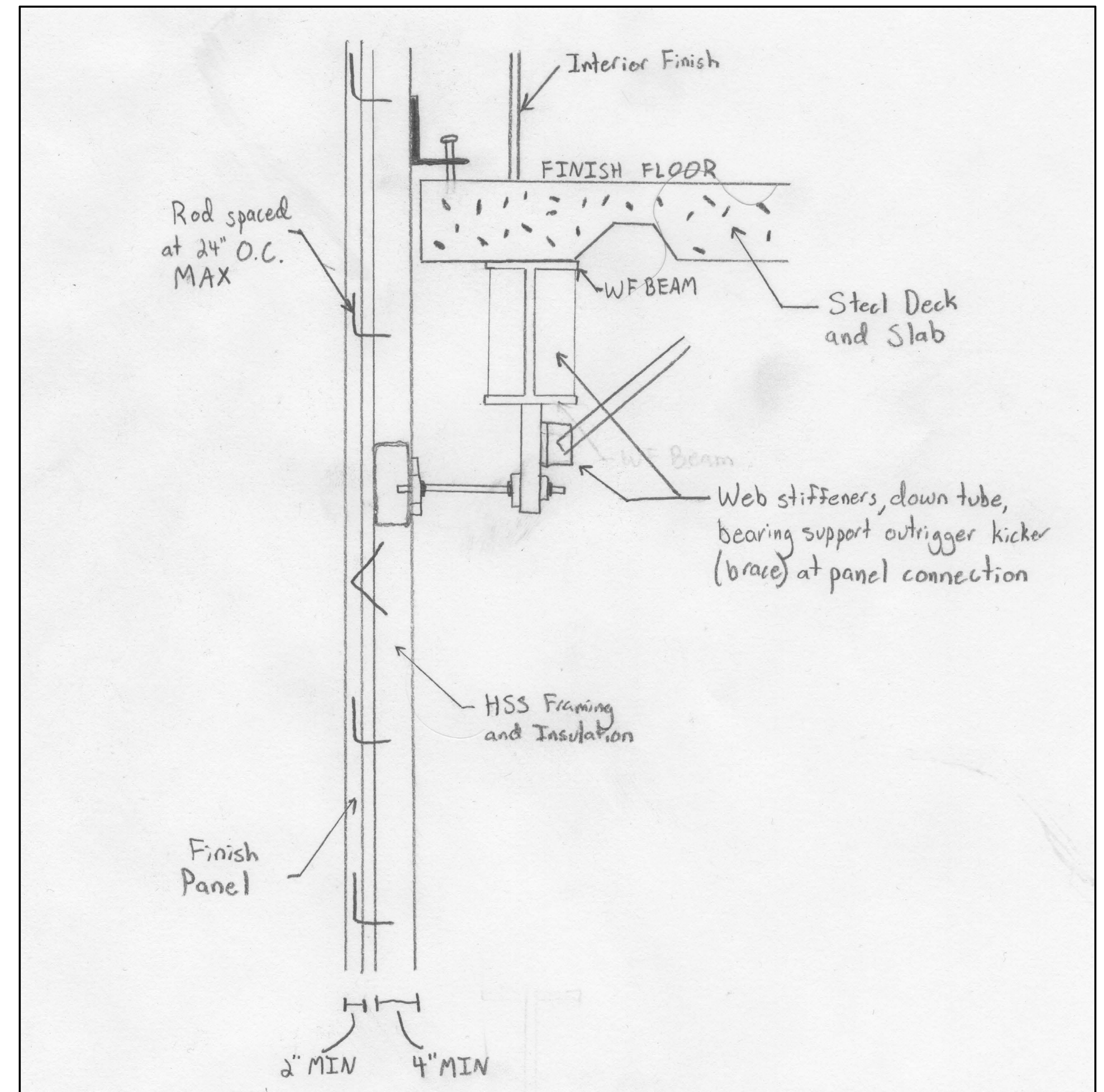


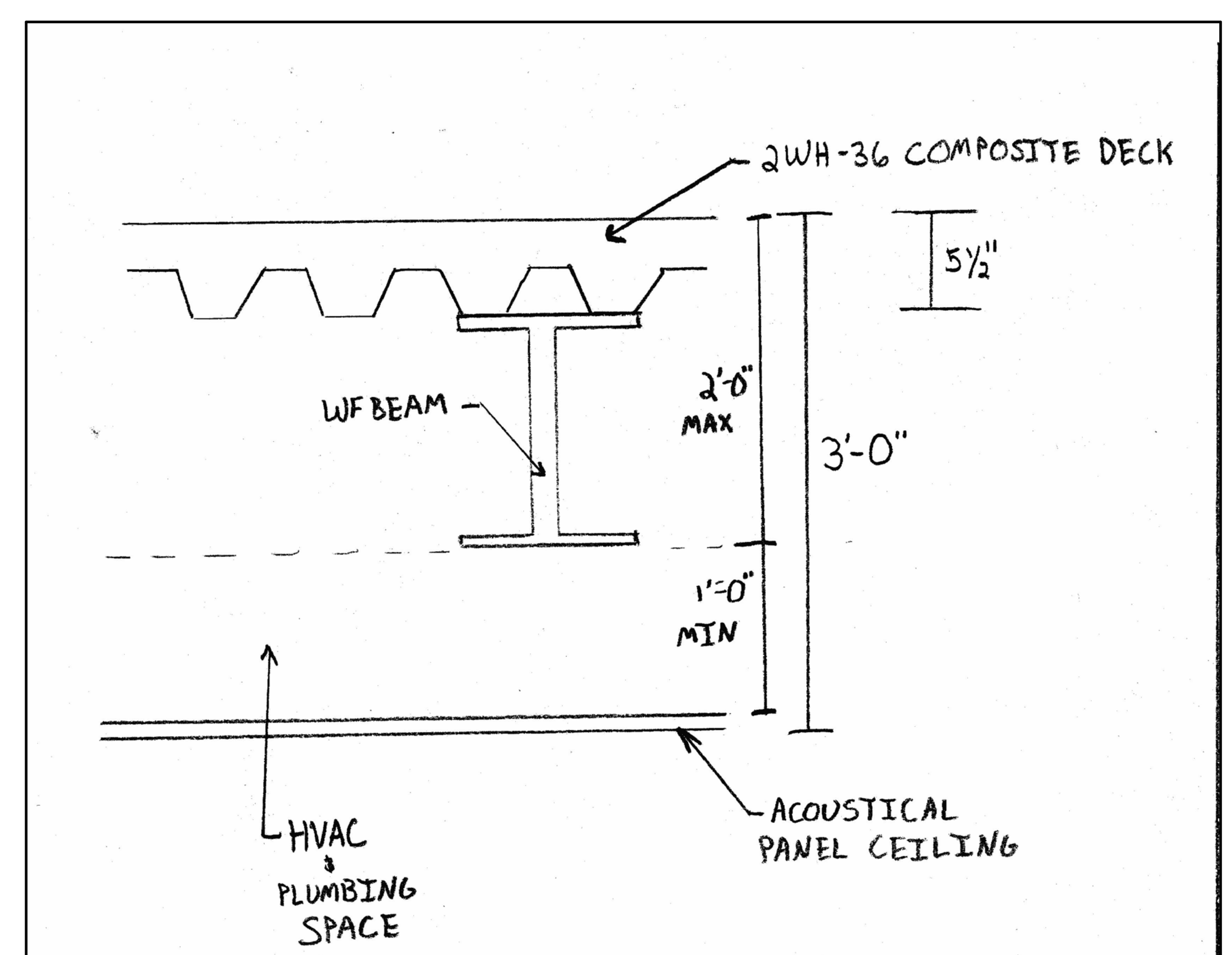
GREENHOUSE SILL FEATURE



FOUNDATION WALL



FINISH PANEL CONNECTION TO BUILDING STRUCTURE



CEILING SECTION

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

Typical Details

Project Number	
Date	2/25/2015
Drawn By	Author
Checked By	Checker

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Scale

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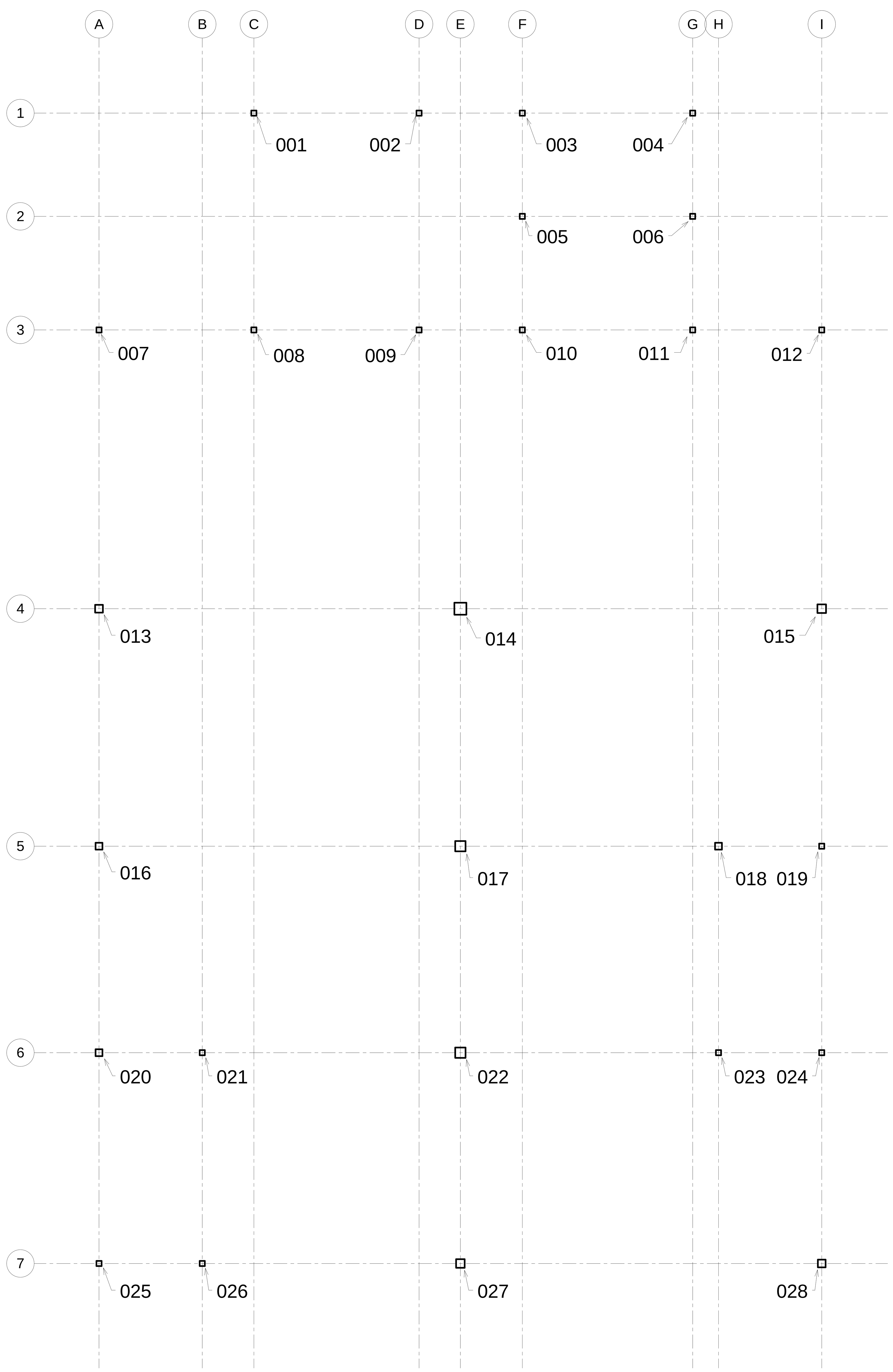

1 Level 1
3/16" = 1'-0"

Column Schedule

Height	Levels	001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	016	017	018	019	020	021	022	023	024	025	026	027	028	029	030	031	032	033	034
	Roof (65'-0")																																		
13'	4 (52'-0")		4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4				4x4x1/4																								
13'	3 (39'-0")		4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	6x6x3/16	6x6x3/8	6x6x3/8	6x6x3/16	6x6x3/16	6x6x3/16	4x4x1/4	6x6x3/8		8x8x5/16	4x4x1/4	6x6x3/8										
13'	2 (26'-0")		4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/16	4x4x1/4	6x6x3/8	9x9x3/8	8x8x5/16	6x6x3/8	8x8x5/16	6x6x3/8	4x4x1/4	6x6x3/8		8x8x3/8	6x6x3/16	6x6x3/16	6x6x3/8			6x6x3/8	6x6x3/8	6x6x3/16	6x6x3/16			
13'	1 (13'-0")		4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/8	6x6x3/8	6x6x3/16	8x8x5/16	12x12x3/8	8x8x3/8	8x8x5/16	9x9x3/8	6x6x3/8	4x4x1/4	8x8x5/16	6x6x3/16	10x10x3/8	6x6x3/8	6x6x3/16	6x6x3/8	6x6x3/8		8x8x3/8	6x6x3/8			8x8x5/16	8x8x5/16	8x8x5/16
13'	G (0'-0")	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/16	6x6x3/8	6x6x3/8	6x6x3/8	6x6x3/8	6x6x3/16	9x9x3/8	14x14x1/2	10x10x3/8	8x8x3/8	12x12x3/8	8x8x5/16	6x6x3/16	8x8x5/16	6x6x3/8	12x12x3/8	6x6x3/8	6x6x3/8	6x6x3/8	6x6x3/8		9x9x3/8				8x8x5/16	8x8x5/16	8x8x5/16
15'	Basement (-15'-0")					6x6x3/16	6x6x3/16		8x8x5/16	6x6x3/8	8x8x5/16	8x8x5/16			16x16x1/2			14x14x1/2	8x8x3/8			6x6x3/8	14x14x1/2	8x8x5/16			8x8x5/16	6x6x3/8							
	Grid Lines	C-1	D-1	F-1	G-1	F-2	G-2	A-3	C-3	D-3	F-3	G-3	I-3	A-4	E-4	I-4	A-5	E-5	H-5	I-5	A-6	B-6	E-6	H-6	I-6	A-7	B-7	E-7	I-7	E-7	C.1-7	F.3-7	A.1-9	E-9	H.1-9
	Column Number	001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	016	017	018	019	020	021	022	023	024	025	026	027	028	029	030	031	032	033	034
	Footing Type	A*	A*	D*	D*	D	D	A*	A	A	A	A	A*	B*	C	B*	B*	C	D	D*	D*	D	C	D	D*	D*	D	A	B*	/	/	/	/	C	C
	Baseplate Type	A	A	A	A	A	A	A	B	A	B	B	A	B	F	C	B	E	B	A	B	A	E	B	A	A	B	A	B	/	/	/	/	/	/

*=indicates part of foundation wall

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No.	Description	Date

Team 08 - 2015

Growing Power Vertical Farm

Column Layout

Project Number

Date 2/25/2015

Drawn By WM

Checked By JA

S.300

Scale 3/16" = 1'-0"

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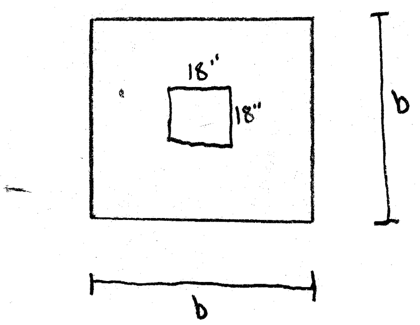
Footing C



$f'_c = 4\,ksi$

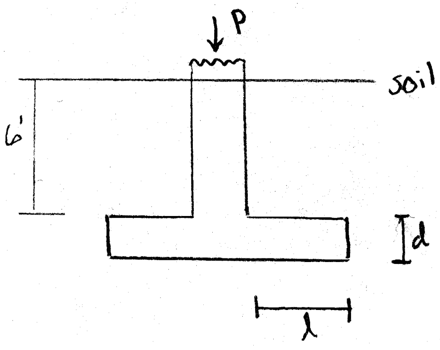
$f_y = 60\,ksi$

factored $P = 685^k$

unfactored $P = 410.2^k$

$q_a = 3{,}000\ lb/ft^2$

$3\ k/ft^2$



assume avg density soil & concrete

1) q_e

$$q_e = q_a - q_{soil+footing} = 3\ k/ft^2 - 0.125\,kcf(6') = 2.25\ k/ft^2$$

2) A_{req}

$$A_{req} = \frac{D+L}{q_e} = \frac{411^k}{2.25} = 183\ ft^2$$

$$b \geq 13.5 \longrightarrow 13'\text{-}6"$$

3) q_u Factored design

$$q_u = \frac{685^k}{(13.5\ ft)^2} = 3.76\ k/ft^2$$

Find d for shear punching

$$b_o = 4(18+d)$$

$$V_c = \min \begin{bmatrix} 4 \\ 2 + 4/\beta_c \approx 6 \\ \frac{40 \cdot b_o}{d} + 2 \end{bmatrix} \cdot \sqrt{f'_c}\, b_o d$$

$$\phi V_c = (0.75)(4)\frac{\sqrt{4000}}{1000}\left[4(18+d)\right]d$$

$$\phi V_c = 0.759\,(18+d)d$$

$$V_u = q_v\left[13.5^2 - \frac{(18+d)^2}{12^2}\right]$$

$$V_u = 3.76\left[13.5^2 - \frac{(18+d)^2}{12^2}\right]$$

$$= 685 - 0.0261(18+d)^2$$

$$V_u \leq \phi V_c$$

$$685 - 0.0261(18+d)^2 = 0.759(18+d)d$$

$d = 24$ $V_u = 638.96$

$\phi V_c = 765.072$

Beam Shear

$$\phi V_c = (0.75)(2)\frac{\sqrt{4000}}{1000}\left(13.5' \times 12''/_{ft}\right)(24\,in) = 369^k$$

$$V_u = q_v\left(\frac{13.5 - 18/12}{2} - \frac{24}{12}\right)13.5 = 203^k$$

$\phi V_c > V_u$ 24" works for beam shear

Check $\frac{40 \cdot b_o}{d} + 2 > 4$ OK

Find A_s

$$M_u = (q_u b)\frac{l^2}{2}$$

$$l = \frac{13.5 - 24/12}{2} = 5.75'$$

$$M_u = (3.76)(13.5)\frac{5.75^2}{2} = 839 \text{ k-ft}$$

$$10{,}069 \text{ k-in}$$

guess $a = 2$

$$A_s = \frac{M_u}{\phi f_y (d - a/2)} = \frac{10{,}069}{(0.9)(60)(24-1)} = 8.11 \text{ in}^2$$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{8.11 \text{ in}^2 (60)}{(0.85)(4)(13.5 \times 12)} = 0.883''$$

Check

$$A_{s\,min} = \frac{3\sqrt{f'_c}}{f_y} \qquad \frac{200 \cdot 13.5 \cdot 12 \cdot 24}{60}$$

$$6.67 \text{ in}^2 \geq \frac{200 b_w d}{f_y}$$

12.96 in^2 controls

Design for $A_s = 13 \text{ in}^2$

Spacing
#8 @ 10"

Appendix AE: Conceptual Design Estimate in Uniformat Categories

Conceptual Estimate - Modified Model					
			Unit	Cost per SF	% of Subtotal
A. STRUCTURE					
110	Standard Foundations	Poured Concrete, stip and spread footings	S.F. Ground	3.03	
120	Special Foundations	N/A			
130	Slab on Grade	4" reinforced concrete with vapor barrier and granular base	S.F. Slab	5.07	9%
2010	Basement Excavation	Site preparation for slab and trentch for foundation wall and footing	S.F of Ground	0.17	
2020	Basement Walls	4" foundation wall	L.F. of Wall	6.05	
B. SHELL					
	B10 Superstucture				
1010	Floor Construction	Open web steel joists, slab form, concrete, columns	S.F. Floor	1.92	
1020	Roof Construction	Metal deck, open steeel joists, beams, exterior columns	S.F. Roof	6.66	5%
	B20 Exterior Enclosure				
2010	Exterior Walls	Face brick with concrete block backup	S.F. Wall	8.82	
2020	Exterior Windows	Window wall	Each	4.36	9%
2030	Exterior Doors	Glass and metal doors and entrances with transom	Each	2.12	
	B30 Roofing				
3010	Roof Coverings	Built up tar and gravel with flashing	S.F. Roof	5.40	
3020	Roof Openings	Skylight	S.F. Roof	0.33	3%
C. INTERIORS					
1010	Partitions	Concrete Block	S.F. Partition	7.75	
1020	Interior Doors	Single leaf hollow metal	Each	5.65	
1030	Fittings	Chalk boards, counters, cabinets	S.F. Floor	5.10	
2010	Stair Construction	Concrete filled metal pan	Fleight	3.99	25%
3010	Wall Finishes	60% paint, 40% epoxy coating	S.F. Surface	5.75	
3020	Floor Finishes	60% epoxy, 20% carpet, 20% vinyl compsition tile	S.F. Floor	5.72	
3030	Ceiling Finishes	Mineral fiber tile on concealed zee bars	S.F. Ceiling	7.04	
D. SERVICES					
	D10 Conveying				
1010	Elevator & Lifts	Two hydrolic passenger elevatos	Each	3.32	
1020	Escalators & Moving Walks	N/A			2%
	D20 Plumbing				
2010	Plumbing Fixtures	Toilet and service fixtures, supply and drainage 1 fixture per 1320 sf floor	Each	3.08	
2020	Domestic Water Distribution	Gas fired water heater	S.F. Floor	2.56	4%
2040	Rain Water Drainage	Roof drains	S.F. Roof	0.86	
	D30 HVAC				
3010	Energy Supply	Oil fired hot water, unit heaters	S.F. Floor	4.98	
3020	Heat Generating Systems	Included in D3050			
3030	Cooling Generating Systems	Chilled water, air cooled condensed system	S.F. Floor	12.58	
3050	Thermal & Package Units	Multizone units, gas heating, electric cooling	S.F. Floor	20.37	23%
3090	Other HVAC Syst. & Equipment	N/A			
	D40 Fire Protection				
4010	Sprinklers	Wet pipe splinker system	S.F. Floor	3.93	
4020	Stand pipes	Standpipes and hose systems	S.F. Floor	0.76	3%
	D50 Electrical				
5010	Electrical Service/Distribution		S.F. Floor	4.91	
5020	Lighting & Wiring		S.F. Floor	13.50	
5030	Communications & Security		S.F. Floor	7.26	16%
5090	Other Electrical Systems		S.F. Floor	0.73	
E. EQUIPMENT & FURNISHINGS					
F. SPECIAL COSNTRUCTION					
G. BUILDING SITEWORK					
			Subtotal	163.77	100%

25%	40.94
6%	12.28
Total	216.99
Location factor	1.04
Inflation factor	1.13
Total sf cost	**$ 255.74**
Project Total Cost	**$ 12,452,530.37**

Appendix AF: Design Development Estimate in MasterFormat Division

Building Name: GROWING
Project Name: AEI STUDENT DESIGN COMPETITION
Building Square Footage: 50000
Date of Estimate: 2/5/2015

MASTERFORMAT ESTIMATE

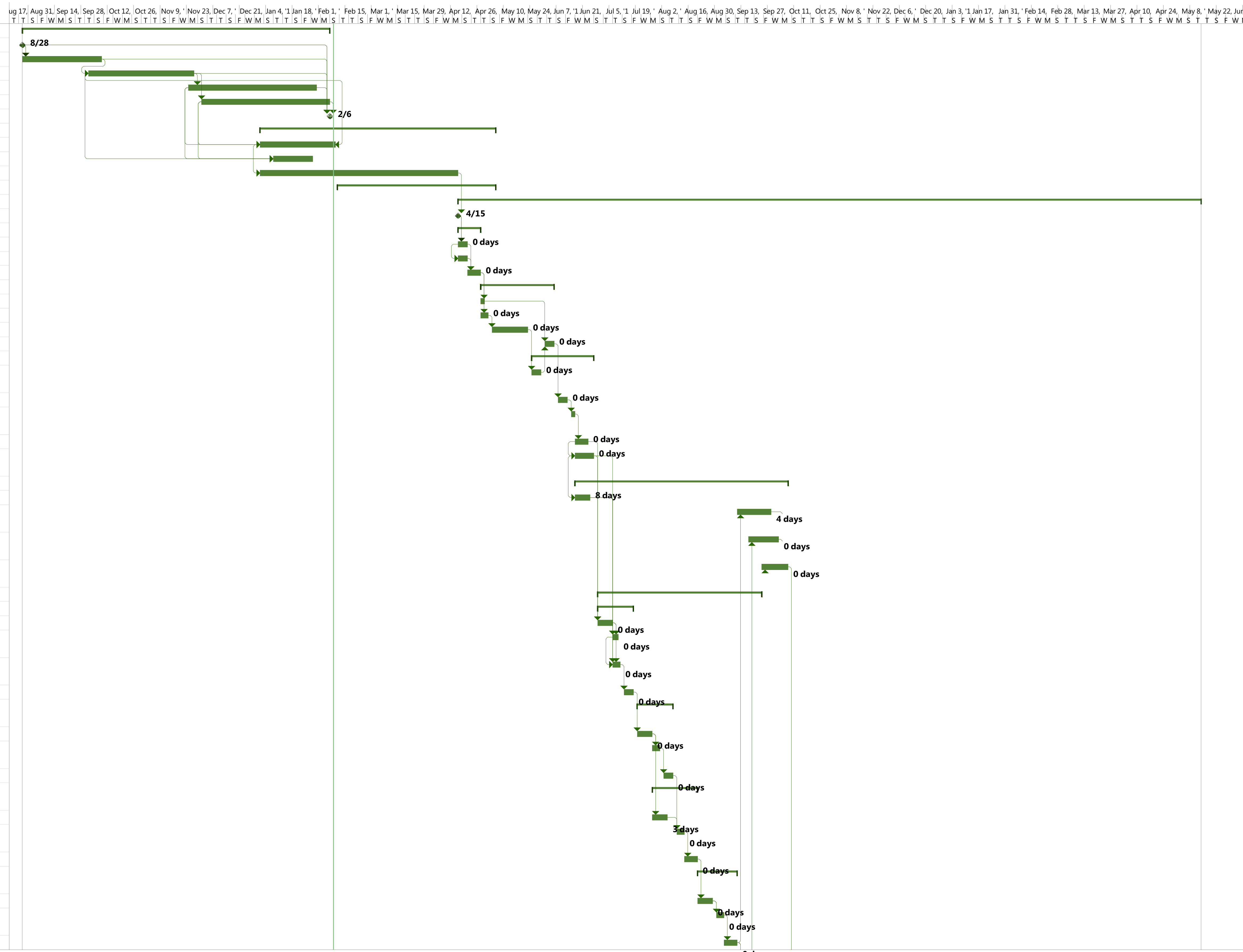
Division		Crew	Daily Output	Qnty. of Crews	Unit	Cost Inc O&P ($ per unit)	Quantity	Extra Labor Cost ($)	Total Cost
Division 1	**General Requirements**								
01 11 31.10 0010	Architectural Fees	-	-	-	Project	6.6%	12000000	$ -	792000
01 11 31.20 0110	Construction Management Fees to $10,000,000	-	-	-	Project	4.0%	12000000	$ -	480000
01 11 31.30 0200	Electrical Engineering Fees	-	-	-	Contract	4.8%	2000000	$ -	96000
01 11 31.30 1000	Mechanical (plumbing & HVAC) Fees	-	-	-	Contract	4.8%	2000000	$ -	96000
01 11 31.30 1300	Structural Engineering Fees	-	-	-	Project	2.5%	12000000	$ -	300000
01 21 16.50 0150	Contingencies, 5%	-	-	-	Project	5.0%	12000000	$ -	600000
01 56 26.50 0200	Temporary Fencing, chain link, 11 ga., 4' hight	2 Clab	400	3.00	L.F.	$ 5.50	2250	$ 8,270.55	$ 20,648.25
Division 2	**Existing Conditions**								
02 41 16.13 0100	Building Demolition, urban project, mixture of types.	B-8	20100	1.00	C.Y.	$ 0.50	2851.9	$ -	$ 1,425.93
02 41 16.13 1000	Building Demolition, urban project, single family house, wood 1600 S.F.	B-3	1	1.00	Ea.	$ 5,725.00	1.0	$ -	$ 5,725.00
Division 3	**Concrete**								
03 30 53.40 4700	Slab on grade (3500 psi), not including finish, 6" Thick	C-14-E	92	2.00	C.Y.	$ 186.00	161.4	$ 10,848.87	$ 40,875.54
03 30 53.40 4700	Slab on grade (3500 psi), not including finish, 6" Thick	C-14-E	92	1.00	C.Y.	$ 186.00	30.0	$ -	$ 5,582.41
03 30 53.40 6350	16' High	C-14-D	91	1.00	C.Y.	$ 320.00	231.1	$ -	$ 73,955.56
03 31 13.35 0150	Normal Weight Concrete, ready mix delivered, 3000 psi	-	-	1.00	C.Y.	$ 109.00	569.0	$ -	$ 62,025.40
03 31 13.70 1400	Concrete Placing, elevated slabs, less than 6" thick, pumped	C-20	140	1.00	C.Y.	$ 33.50	125.2	$ -	$ 4,194.56
03 31 13.70 1400	Concrete Placing, elevated slabs, less than 6" thick, pumped	C-20	140	1.00	C.Y.	$ 33.50	97.4	$ -	$ 3,262.45
03 31 13.70 1400	Concrete Placing, elevated slabs, less than 6" thick, pumped	C-20	140	1.00	C.Y.	$ 33.50	146.1	$ -	$ 4,893.95
03 31 13.70 1400	Concrete Placing, elevated slabs, less than 6" thick, pumped	C-20	140	1.00	C.Y.	$ 33.50	113.7	$ -	$ 3,808.29
03 31 13.70 1400	Concrete Placing, elevated slabs, less than 6" thick, pumped	C-20	140	1.00	C.Y.	$ 33.50	86.7	$ -	$ 2,903.59
03 31 13.70 2650	Concrete Placing, footings, spread, pumped	C-20	150	1.00	C.Y.	$ 31.00	230.3	$ -	$ 7,140.33
Division 4	**Masonry**								
04 22 10.24 0300	Concree Block, Exterior, C90, 2000 psi, Normal weight, 8" x 16" x 12" thick	D-9	250	1.00	S.F	$ 17.25	6876.9		$ 118,627.04
Division 5	**Metals**								
05 12 23.15 1000	Lightweight steel pipe members, 3-1/2" diameter	E-2	780	1.00	L.F.	$ 17.50	970.5	$ -	$ 16,983.75
05 12 23.77 0300	Stuctural Steel Projects, Office, steel bearing, 3 to 6 stories	E-5	10.3	1.00	Ton	$ 3,850.00	20.6	$ -	$ 79,117.50
05 12 23.77 0300	Stuctural Steel Projects, Office, steel bearing, 3 to 6 stories	E-5	10.3	1.00	Ton	$ 3,850.00	19.5	$ -	$ 75,190.50
05 12 23.77 0300	Stuctural Steel Projects, Office, steel bearing, 3 to 6 stories	E-5	10.3	1.00	Ton	$ 3,850.00	25.2	$ -	$ 96,908.35
05 12 23.77 0300	Stuctural Steel Projects, Office, steel bearing, 3 to 6 stories	E-5	10.3	1.00	Ton	$ 3,850.00	26.1	$ -	$ 100,523.50
05 12 23.77 0300	Stuctural Steel Projects, Office, steel bearing, 3 to 6 stories	E-5	10.3	1.00	Ton	$ 3,850.00	25.1	$ -	$ 96,481.00
05 12 23.77 3500	Stuctural Steel Projects,Welded construction, commercial buildings.,	E-9	8.3	1.00	Ton	$ 5,100.00	25.3	$ -	$ 129,093.93
05 12 23.77 3500	Stuctural Steel Projects,Welded construction, commercial buildings.,	E-9	8.3	1.00	Ton	$ 5,100.00	9.0	$ -	$ 45,798.00
05 12 23.77 3500	Stuctural Steel Projects,Welded construction, commercial buildings.,	E-9	8.3	1.00	Ton	$ 5,100.00	10.8	$ -	$ 55,131.00
05 12 23.77 3500	Stuctural Steel Projects,Welded construction, commercial buildings	E-9	8.3	1.00	Ton	$ 5,100.00	23.5	$ -	$ 119,832.56
05 21 13.50 3360	Steel Joist Framing, deep longspan joists, 37 lb./ft	E-7	220	1.00	L.F.	$ 43.50	90.0	$ -	$ 3,915.00
05 21 13.50 3120	Steel Joist Framing, deep longspan joists, 70 lb./ft	E-7	220	1.00	L.F.	$ 78.50	135.0	$ -	$ 10,597.50
05 31 33.50 6700	Steel Form Decking, 22 gauge, 2" deep uncoated	E-4	3600	1.00	S.F.	$ 3.60	8113.7	$ -	$ 29,209.21
05 31 33.50 6700	Steel Form Decking, 22 gauge, 2" deep uncoated	E-4	3600	1.00	S.F.	$ 3.60	6310.7	$ -	$ 22,718.41
05 31 33.50 6700	Steel Form Decking, 22 gauge, 2" deep uncoated	E-4	3600	1.00	S.F.	$ 3.60	9466.5	$ -	$ 34,079.40
05 31 33.50 6700	Steel Form Decking, 22 gauge, 2" deep uncoated	E-4	3600	1.00	S.F.	$ 3.60	7366.5	$ -	$ 26,519.40
05 31 33.50 6700	Steel Form Decking, 22 gauge, 2" deep uncoated	E-4	3600	1.00	S.F.	$ 3.60	5616.5	$ -	$ 20,219.40
05 51 16.50 0300	Metal Pan Stairs, cement fill metal pan, picket rail, 4' wide	E-4	30	1.00	Riser	$ 715.00	242.0	$ -	$ 173,030.00
05 51 16.50 1500	Metal Pan Stairs, Landing, steel pan , conventional	E-4	160	1.00	S.F.	$ 92.00	440.0	$ -	$ 40,480.00
Division 6	**Wood, Plastics, and Composites**								
06 11 10.14 0400	Columns and Fraiming, 4" x 4"	2 Carp.	0.52	1.00	M.B.F	$ 3,600.00	1.7	$ -	$ 6,264.00
Division 7	**Thermal & Moisture Protection**								
07 24 13.10 0105	Exterior Insulation and Finish Systems, field applied, 2" EPS insulation, with 1/2" cement board sheati	J-1	268	2.00	S.F	$ 12.75	2675.8	$ 25,654.85	$ 59,770.66
07 24 13.10 0105	Exterior Insulation and Finish Systems, field applied, 2" EPS insulation, with 1/2" cement board sheati	J-1	268	2.00	S.F	$ 12.75	2619.5	$ 25,115.44	$ 58,513.93
07 24 13.10 0105	Exterior Insulation and Finish Systems, field applied, 2" EPS insulation, with 1/2" cement board sheati	J-1	268	2.00	S.F	$ 12.75	2304.5	$ 22,095.15	$ 51,477.27
07 24 13.10 0105	Exterior Insulation and Finish Systems, field applied, 2" EPS insulation, with 1/2" cement board sheati	J-1	268	2.00	S.F	$ 12.75	1962.2	$ 18,813.78	$ 43,832.34
07 24 13.10 0105	Exterior Insulation and Finish Systems, field applied, 2" EPS insulation, with 1/2" cement board sheati	J-1	268	2.00	S.F	$ 12.75	1845.8	$ 17,696.89	$ 41,230.20
07 46 46.10 0070	Panel siding, 5/16" thick, smooth texture	2 Carp	750	1.00	S.F	$ 2.95	2675.8	$ -	$ 7,893.46
07 46 46.10 0070	Panel siding, 5/16" thick, smooth texture	2 Carp	750	1.00	S.F	$ 2.95	2619.5	$ -	$ 7,727.50
07 46 46.10 0070	Panel siding, 5/16" thick, smooth texture	2 Carp	750	1.00	S.F	$ 2.95	2304.5	$ -	$ 6,798.22
07 46 46.10 0070	Panel siding, 5/16" thick, smooth texture	2 Carp	750	1.00	S.F	$ 2.95	1962.2	$ -	$ 5,788.61
07 46 46.10 0070	Panel siding, 5/16" thick, smooth texture	2 Carp	750	1.00	S.F	$ 2.95	1845.8	$ -	$ 5,444.96
Division 8	**Openings**								
08 14 16.09 0210	Flush, interior 1-3/8", 7 ply, hollow core. Birch face, 3'-0" x 7'	2 Carp	16	1.00	Ea.	$ 191.00	40.0	$ -	$ 7,640.00
08 14 16.09 0210	Flush, interior 1-3/8", 7 ply, hollow core. Birch face, 3'-0" x 7'	2 Carp	16	1.00	Ea.	$ 191.00	6.0	$ -	$ 1,146.00
08 32 13.10 0450	Aluminum, 5/8" tempered insulated glass, 6' wide	2 Carp	4	1.00	Ea.	$ 1,275.00	3.0	$ -	$ 3,825.00
08 36 13.10 2650	Steel, 24 ga. Sectional, manual 10' x 10' high	2 Carp	1.8	1.00	Ea.	$ 1,825.00	1.0	$ -	$ 1,825.00
08 42 26.10 0100	Swingin Glass DoorsIncluding hardware, 1/2" thick, tempered, 6' x 7' opening	2 Glaz	1.4	1.00	Opng.	$ 5,500.00	1.0	$ -	$ 5,500.00
08 44 13.10 0200	Glazed Curtain Wall, aluminum stock, including glazing, maximum single glazed	H-1	160	1.00	S.F.	$ 209.00	267.9	$ -	$ 55,980.65
08 54 13.10 0280	Fiberglass single hung windows, 36" x 72"	2 Carp	16	1.00	Ea.	$ 585.00	49.0	$ -	$ 28,665.00
08 71 20.15 1000	Door hardware interior	-	-	1.00	Ea	$ 640.00	46.0	$ -	$ 29,440.00
08 81 30.10 0700	Instulating Glass, 1" thick dbl. glazed, 1/4" float, 1/4" tempered	2 Glaz	75	3.00	S.F.	$ 48.00	1225.0	$ 23,030.00	$ 81,830.00
08 81 30.10 0700	Instulating Glass, 1" thick dbl. glazed, 1/4" float, 1/4" tempered	2 Glaz	75	5.00	S.F.	$ 48.00	3557.2	$ 133,749.59	$ 304,493.75
08 81 30.10 0700	Instulating Glass, 1" thick dbl. glazed, 1/4" float, 1/4" tempered	2 Glaz	75	10.00	S.F.	$ 48.00	6220.5	$ 526,254.30	$ 824,838.30
08 81 30.10 0700	Instulating Glass, 1" thick dbl. glazed, 1/4" float, 1/4" tempered	2 Glaz	75	10.00	S.F.	$ 48.00	5126.3	$ 433,688.36	$ 679,752.68
08 81 30.10 0700	Instulating Glass, 1" thick dbl. glazed, 1/4" float, 1/4" tempered	2 Glaz	75	10.00	S.F.	$ 48.00	9680.6	$ 818,982.14	$ 1,283,652.86
Division 9	**Finishes**								
09 21 16.33 1200	1/2" interior, gypsum board, std, tape & finish 2 sides, metal studs 16" O.C., 3-5/8" wide, 6" wide	2 Carp	330	2.00	S.F.	$ 4.75	13759.0	$ 42,762.97	$ 108,118.22
09 30 13.10 3000	Ceramic tailing, floors, natural clay, random or uniform, thin set, color group 1	D-7	183	2.00	S.F.	$ 9.40	649.7	$ 3,148.38	$ 9,255.56
09 30 13.10 3000	Ceramic tailing, floors, natural clay, random or uniform, thin set, color group 1	D-7	183	3.00	S.F.	$ 9.40	265.6	$ 2,574.05	$ 5,070.59
09 30 13.10 3000	Ceramic tailing, floors, natural clay, random or uniform, thin set, color group 1	D-7	183	3.00	S.F.	$ 9.40	408.0	$ 3,953.77	$ 7,788.50
09 30 13.10 3000	Ceramic tailing, floors, natural clay, random or uniform, thin set, color group 1	D-7	183	3.00	S.F.	$ 9.40	455.3	$ 4,412.48	$ 8,692.12
09 30 13.10 3000	Ceramic tailing, floors, natural clay, random or uniform, thin set, color group 1	D-7	183	3.00	S.F.	$ 9.40	277.4	$ 2,688.89	$ 5,296.83
09 30 13.10 5810	Walls, interior, thin set, 8" x 8" tile	D-7	170	3.00	S.F.	$ 9.90	1547.5	$ 16,144.98	$ 31,465.23
09 30 13.10 5810	Walls, interior, thin set, 8" x 8" tile	D-7	170	3.00	S.F.	$ 9.90	880.0	$ 9,180.99	$ 17,892.99
09 30 13.10 5810	Walls, interior, thin set, 8" x 8" tile	D-7	170	3.00	S.F.	$ 9.90	1247.5	$ 13,015.09	$ 25,365.34
09 30 13.10 5810	Walls, interior, thin set, 8" x 8" tile	D-7	170	3.00	S.F.	$ 9.90	1255.0	$ 13,093.34	$ 25,517.84
09 30 13.10 5810	Walls, interior, thin set, 8" x 8" tile	D-7	170	3.00	S.F.	$ 9.90	930.0	$ 9,702.64	$ 18,909.64
09 51 23.30 1125	Mineral Fiber, on 15/16" T bar sup. 2' x 2' x 3/4" lay-in board	1 Carp	345	5.00	S.F.	$ 4.46	5290.0	$ 14,843.68	$ 38,436.99
09 51 23.30 1125	Mineral Fiber, on 15/16" T bar sup. 2' x 2' x 3/4" lay-in board	1 Carp	345	5.00	S.F.	$ 4.46	4671.2	$ 13,107.36	$ 33,940.87
09 51 23.30 1125	Mineral Fiber, on 15/16" T bar sup. 2' x 2' x 3/4" lay-in board	1 Carp	345	5.00	S.F.	$ 4.46	5753.1	$ 16,143.20	$ 41,802.02
09 51 23.30 1125	Mineral Fiber, on 15/16" T bar sup. 2' x 2' x 3/4" lay-in board	1 Carp	345	5.00	S.F.	$ 4.46	5610.9	$ 15,744.21	$ 40,768.87
09 51 23.30 1125	Mineral Fiber, on 15/16" T bar sup. 2' x 2' x 3/4" lay-in board	1 Carp	345	5.00	S.F.	$ 4.46	4185.5	$ 11,719.34	$ 30,386.58
09 51 23.30 1125	Mineral Fiber, on 15/16" T bar sup. 2' x 2' x 3/4" lay-in board	1 Carp	345	5.00	S.F.	$ 4.46	576.1	$ 1,612.94	$ 4,182.12
09 64 29.10 0020	Floor, Fir, vertical grain, 1" x 4", not incl. finish, C grade & better	1 Carp	255	4.00	S.F.	$ 5.25	1899.9	$ 8,207.48	$ 18,181.85
09 64 29.10 7500	Refinish wood floor, sand, 2 cts poly, wax	1 Carp	400	4.00	S.F.	$ 2.10	1899.9	$ 4,160.74	$ 8,150.49
09 65 16.10 8000	Vinyl, sheet goods, backed, 0,065 thick, minimum"	1 Tilf	250	6.00	S.F.	$ 6.50	3647.2	$ 24,436.44	$ 48,143.44
09 65 16.10 8000	Vinyl, sheet goods, backed, 0,065 thick, minimum"	1 Tilf	250	6.00	S.F.	$ 6.50	6876.1	$ 46,069.54	$ 90,763.86
09 91 23 40 0160	Concrete paint, latex , Roll, 1st coat	1 Pord	2600	2.00	S.F.	$ 0.40	19646.3	$ 2,357.55	$ 10,216.06
09 91 23.72 1670	Painting walls, complete, including surface prep, primer & 2 coats finish, on drywall or plaster, with ro	1 Pord	325	8.00	S.F.	$ 1.67	13759.0	$ 130,793.05	$ 153,770.58
Division 13	**Special Construction**								
13 21 26.50 6100	Cold Stroage Rooms, Prefab walk-in 8'-6" high, aluminum, incl. refrigeration, door & roomm, not incl. p	2 Carp	54.8	5.00	S.F. Flr.	$ 205.00	1182.9	$ 88,761.06	$ 331,245.31
Division 14	**Conveying Equipment**								
14 21 23.10 1700	Electric traction Passenger Elevator, base unit, 3500 lbs, 200 fpm, 5 stop, std, fin.	2 Elev	0.5	1.00	Ea.	$ 139,270.00	1.0	$ -	$ 139,270.00
Division 21	**Fire Suppression**								
21 13 13.50 3730	Wet-Pipe Sprinkler System, Sprinklers heads, standard spray, pendent or upright, brass	1 Spri	16	4.00	Ea.	$ 139,270.00	1.0	$ 41,250.00	$ 70,250.00
Division 22	**Plumbing**								
22 41 23.20 4000	Shower Stall, with drain only. Polypropylene w/ molded-stone floor, 30" x 30"	Q-1	2	1.00	Ea.	$ 1,325.00	2.0	$ -	$ 2,650.00
22 42 13.30 3140	Urinal wall hung, vitreous china, with hanger & sel-closing valve. Water saving 0.5 gpf	Q-1	3	1.00	Ea.	$ 1,050.00	4.0	$ -	$ 4,200.00
22 42 13.40 3360	Water closet, bowl only, with flush valve, seat, with floor outlet, 1.28 gpf	Q-1	5.8	1.00	Ea.	$ 860.00	12.0	$ -	$ 10,320.00
22 42 13.40 3362	Water closet bowl only, with flush valve, seat, with floor outlet, 1.28 gpf, ADA	Q-1	5.8	1.00	Ea.	$ 900.00	8.0	$ -	$ 7,200.00
22 42 16.40 7000	Lavatory fixture, sevice, all, P.E. on C.I. , roll rim, 22" x 18"	1 Plum	4	1.00	Ea.	$ 1,150.00	16.0	$ -	$ 18,400.00
22 42 39.10 2800	Faucets for lavatories, Self-closing, center set	1 Plum	10	1.00	Ea.	$ 240.00	16.0	$ -	$ 3,840.00
Division 23	**Heating, Ventilating, & Air Conditioning**								
23 52 13.10 2220	Electric Boiler, ASME, standard controls and trim, 296 KW, 1010 MBH	Q-19	0.55	1.00	Ea.	$ 21,200.00	1.0	$ -	$ 21,200.00
23 65 13.10 0150	Forced-draft Type Cooling Tower, Galvanized steel, induced draft, crossflow, vertical, belt drive, 100 to	Q-6	100	1.00	TonAC	$ 244.00	88.0	$ -	$ 21,472.00
23 65 13.10 3500	Cooling tower, pumps and piping	Q-6	38	1.00	TonAC	$ 168.00	88.0	$ -	$ 14,784.00
23 81 46.10 2220	Water Source Heat Pumps, not incl. connecting tubing. Water source to air, single package. 5 ton cool	Q-5	0.9	3.00	Ea.	$ 4,750.00	22.0	$ 62,186.67	$ 166,686.67
Division 26	**Electrical**								
26 51 13.55 0160	Interior LED Fixtures, cylinder, 7.8 watts	1 Elec	8	5.00	Ea.	$ 565.00	80.0	$ 17,120.00	$ 62,320.00
26 51 13.55 1200	Interior LED Fixtures, troffers, volumetric recess mounted, 2' x 2'	1 Elec	5.7	5.00	Ea.	$ 720.00	236.0	$ 70,800.00	$ 240,720.00
26 51 13.55 2000	Strip, surface mounted, one light bar 4' long, 40 watt	1 Elec	8.5	5.00	Ea.	$ 865.00	72.0	$ 14,400.00	$ 76,680.00
26 51 13.55 2010	Strip, surface mounted, one light bar 4' long, 60 watt	1 Elec	8	5.00	Ea.	$ 900.00	30.0	$ 6,420.00	$ 33,420.00
26 51 13.55 2020	Strip, surface mounted, two light bar 4' long, 80 watt	1 Elec	7	5.00	Ea.	$ 1,175.00	18.0	$ 4,392.00	$ 25,542.00
26 51 13.55 3000	Linear, suspended mountedd, one light bar 4' long, 37 watt	1 Elec	6.7	5.00	Ea.	$ 460.00	87.0	$ 22,098.00	$ 62,118.00
26 51 13.55 6000	Greenhouse LED Lighting, 103 Watt	2 Elec	650	2.00	Ea.	1281	107.0	$ 14,017.00	$ 158,467.00
Division 31	**Earthwork**								
31 13 13.20 1750	Tree removal, 24" to 36" diameter, hardwood	B-10M	50	1.00	Ea.	$ 56.50	14.0	$ -	$ 791.00
31 23 16.16 6030	Machine excavation, for spread and mat footings, elevator pits, and small buildin foundations, comme	B-12-E	55	8.00	B.C.Y.	$ 28.50	4666.7	$ 923,456.97	$ 1,056,456.97
31 23 23.13 2300	Compactig backfill, 6" to 12" lifts, vibrating roller	B-10-L	700	3.00	E.C.Y.	$ 3.90	1805.6	$ 6,956.55	$ 13,998.21
31 23 23.14 2420	Backfill Structural, Dozer or F.E. loader, no compaction, 80 H.P., 300' haul, common earth	B-10-L	370	3.00	L.C.Y.	$ 3.64	1805.6	$ 13,161.04	$ 19,733.26
Division 32	**Interior Improvements**								
32 11 23.23 0303	Base course drainage layer, crushed 1-1/2" stone base, compacted to 8" deep	B-36-B	4500	1.00	S.Y.	$ 10.45	2222.2	$ -	$ 23,222.22
32 12 16.13 0200	Plant-mix Asphalt Paving, binder course, 4" thick	B-25	4140	1.00	S.Y.	$ 18.30	2222.2	$ -	$ 40,666.67
Miscelaneous									
50 17 00.61 3100	Total: Mechanical & Electrical, Interior space			1.00	S.F.	$ 23.00	36643	$ -	$ 341,989.00
50 17 00.69 3100	Total: Mechanical & Electrical, Greenhouse Space			1.00	S.F.	$ 57.50	12050	$ -	$ 468,732.33
Miscelaneous	Rotating Vertical Towers				Ea.	$ 1,250.00	21	$ -	$ 26,250.00
Miscelaneous	Rotating Vertical Towers				Ea.	$ 1,250.00	23	$ -	$ 28,750.00
Miscelaneous	ZipGrow Towers				Ea.	$ 57.00	462	$ -	$ 26,334.00

Appendix AG: Design Development Estimate in Uniformat Categories

	Building Name:	GROWING POWER - VERTICAL FARM				
	Project Name:	AEI STUDENT DESIGN COMPETITION 2015				
	Building Square Footage:	48693				
	Date of Estimate:	2/5/2015				
		UNIFORMAT ESTIMATE				
				TOTAL	**COST /**	**% OF**
	LEVEL 1 INFORMATION	**LEVEL 2 INFORMATION**	**LEVEL 3 INFORMATION**	**COST**	**S. F.**	**TOTAL**
A	**SUBSTRUCTURE**	**A10 - FOUNDATIONS**	A1010 - STANDARD FOUNDATIONS	$ 7,140.33		
		A20 - BASEMENT CONSTRUCTION	A1030 - SLAB ON GRADE	$ 40,875.54		
			A2010 - BASEMENT EXCAVATION	$ 1,090,188.44		
			A2020 - BASEMENT WALLS	$ 73,955.56		
			SUBTOTAL SUBSTRUCTURE	**$ 1,212,159.87**	24.89392462	**10.27%**
B	**SHELL**	**B10 - SUPERSTRUCTURE**	B1010 - FLOOR CONSTRUCTION	$ 811,243.77		
			B1020 - ROOF CONSTRUCTION	$ 220,761.56		
		B20 - EXTERIOR CLOSURE	B2010 - EXTERIOR WALLS	$ 2,224,099.84		
			B2020 - EXTERIOR WINDOWS & EXTERIOR DOORS	$ 117,820.00		
		B30 - ROOFING	B3010 - ROOF COVERING & OPENINGS	**$ 1,275,741.95**		
			SUBTOTAL SHELL	**$ 4,649,667.12**	95.48943622	**39.41%**
C	**INTERIORS**	**C10 - INTERIOR CONSTRUCTION**	C1010 - PARTITIONS	$ 164,098.87		
			C1020 - INTERIOR DOORS	$ 42,051.00		
			C1030 - FITTINGS / SPECIALTIES	$ -		
		C20 - STAIRCASES	C2010 - STAIR CONSTRUCTION	$ 213,510.00		
		C30 - INTERIOR FINISHES	C3010 - WALL FINISHES	$ 272,921.62		
			C3020 - FLOOR FINISHES	$ 211,559.29		
			C3030 - CEILING FINISHES	$ 189,517.47		
			SUBTOTAL INTERIORS	**$ 1,093,658.25**	22.46027656	**9.27%**
D	**SERVICES**	**D10 - CONVEYING SYSTEMS**	D1010 - ELEVATORS & LIFTS	$ 139,270.00		
		D20 - PLUMBING	D2010 - PLUMBING FIXTURES	$ 46,610.00		
		D30 - HVAC	D3020 - HEAT GENERATING SYSTEMS	$ 187,886.67		
			D3040 - HVAC DISTRIBUTION SYSTEMS	$ 504,988.33		
		D40 - FIRE PROTECTION	D4010 - FIRE PROTECTION SPRINKLER SYSTEM	$ 70,250.00		
		D50 - ELECTRICAL	D5010 - ELECTRICAL SERVICE & DISTRIBUTION	$ 341,989.00		
			D5020 - LIGHTING & BRANCH WIRING	$ 659,267.00		
			SUBTOTAL SERVICES	**$ 1,950,261.00**	40.05218409	**16.53%**
E	**EQUIPMENT & FURNISHINGS**	**E10 - EQUIPMENT**	E1090 - OTHER EQUIPMENT	$ 104,581.75		
			SUBTOTAL EQUIPMENT & FURNISHINGS	**$ 104,581.75**	2.147777915	**0.89%**
F	**SPECIAL CONSTRUCTION & DEMOLITION**	**F10 - SPECIAL CONSTRUCTION**	F1020 - INTEGRATED CONSTRUCTION	$ 331,245.31		
			SUBTOTAL SPECIAL CONST. & DEMO	**$ 331,245.31**	6.802729633	**2.81%**
G	**BUILDING SITE WORK**	**G10 - SITE PREPARATION**	G1010 - SITE CLEARING	$ 20,648.25		
			G1020 - SITE DEMOLITION & RELOCATIONS	$ 7,941.93		
		G20 - SITE IMPROVEMENTS	G2020 - PARKING LOTS	$ 63,888.89		
			SUBTOTAL BUILDING SITE WORK	**$ 92,479.06**	1.899227005	**0.78%**
			TOTAL PRELIMINARY BUDGET	**$ 9,434,052.36**	193.745556	**79.96%**
			DESIGN CONTINGENCY	$ 600,000.00		
			TOTAL ESTIMATED TRADE COSTS	**$ 10,034,052.36**		
			ARCHITECTURAL FEES	$ 792,000.00		
			CONSTRUCTION MANAGEMENT FEES	$ 480,000.00		
			ELECTRICAL ENGINEERING FEES	$ 96,000.00		
			MECHANICAL ENGINEERING FEES	$ 96,000.00		
			STRUCTURAL ENGINEERING FEES	$ 300,000.00		
			SUBTOTAL AE DESIGN COSTS	**$ 1,764,000.00**		
			PROJECT SUBTOTAL	**$ 11,798,052.36**		
			CM CONTINGENCY	$ -		
			SUBTOTAL CM FIXED LIMIT OF CONSTRUCTION	**$ -**		
			PROJECT SUBTOTAL	**$ 11,798,052.36**		
			ALLOWANCES	$ 500,000.00		
			SUBTOTAL ALLOWANCES	**$ 500,000.00**		
			PROJECT SUBTOTAL	**$ 12,298,052.36**		
Z	**ALTERNATES**		ALTERNATE #1: MILWAUKEE WI			
			MILWAUKEE, WI. LOCATION FACTOR	1.04		
			SUBTOTAL ALTERNATE #1	**$ 12,789,974.45**		
			MILWAUKEE PROJECT TOTAL	**$ 12,789,974.45**	$ 262.67	
			ALTERNATE #2: MIAMI, FL			
			MIAMI, FL. LOCATION FACTOR	0.876		
			SUBTOTAL ALTERNATE #2	**$ 10,773,093.87**	221.2452276	
			MIAMI PROJECT TOTAL	**$ 10,773,093.87**	$ 221.25	
			PROJECT TOTAL	**$ 12,789,974.45**	**$ 262.67**	**100%**

Appendix AH: Project Schedule

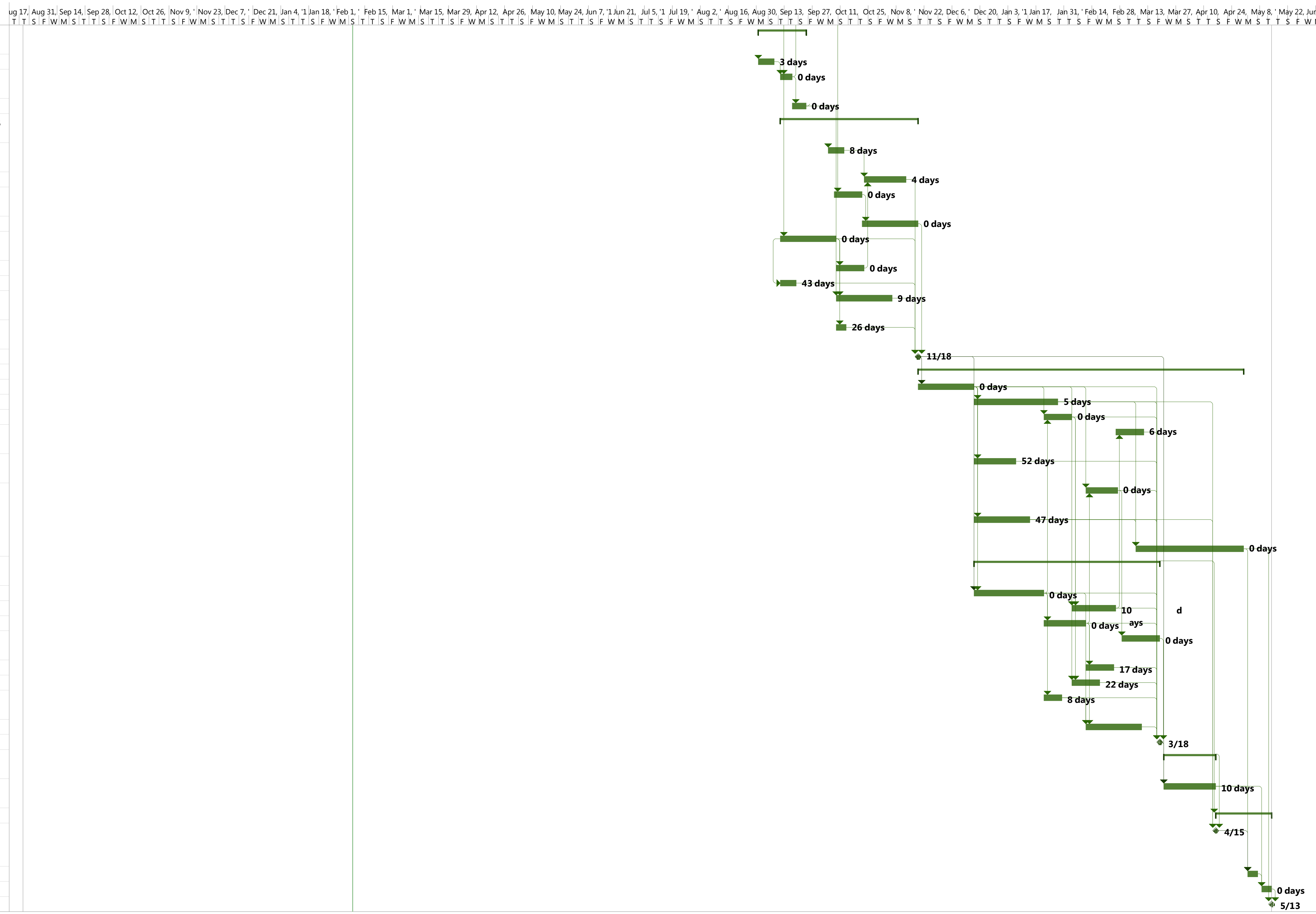
ID	Task Mode	Task Name	Duration	Start	Finish
1		**Design Phase**	**117 days**	**Thu 8/28/14**	**Fri 2/6/15**
2		Project Start	0 days	Thu 8/28/14	Thu 8/28/14
3		Project Study	30 days	Thu 8/28/14	Wed 10/8/14
4		Architectural Design	40 days	Thu 10/2/14	Wed 11/26/14
5		Mechanical Design	50 days	Mon 11/24/14	Fri 1/30/15
6		Structural Engineer Design	50 days	Mon 12/1/14	Fri 2/6/15
7		Substancial Copletion	0 days	Fri 2/6/15	Fri 2/6/15
8		**Preconstruction Phase**	**89 days**	**Thu 1/1/15**	**Tue 5/5/15**
9		Estimate Complete	28 days	Thu 1/1/15	Mon 2/9/15
10		Scopes of Work Defined	15 days	Thu 1/8/15	Wed 1/28/15
11		Permits	75 days	Thu 1/1/15	Wed 4/15/15
12		**Delivery Times**	**60 days**	**Wed 2/11/15**	**Tue 5/5/15**
16		**Construction Phase**	**282 days**	**Wed 4/15/15**	**Fri 5/13/16**
17		Construction Starts	0 days	Wed 4/15/15	Wed 4/15/15
18		**Start Up - Site Work**	**8 days**	**Thu 4/16/15**	**Mon 4/27/15**
19		Fencing	3 days	Thu 4/16/15	Mon 4/20/15
20		Movilization	3 days	Thu 4/16/15	Mon 4/20/15
21		Site Work	5 days	Tue 4/21/15	Mon 4/27/15
22		**Excavation & Demolition**	**29 days**	**Tue 4/28/15**	**Fri 6/5/15**
23		Tree Removal	2 days	Tue 4/28/15	Wed 4/29/15
24		Demolition	4 days	Tue 4/28/15	Fri 5/1/15
25		Excavation	15 days	Mon 5/4/15	Fri 5/22/15
26		Backfill	5 days	Mon 6/1/15	Fri 6/5/15
27		**Substructure**	**25 days**	**Mon 5/25/15**	**Fri 6/26/15**
28		Foundations - Footings	5 days	Mon 5/25/15	Fri 5/29/15
29		Basement Slab	5 days	Mon 6/8/15	Fri 6/12/15
30		Steel Framing Basement	2 days	Mon 6/15/15	Tue 6/16/15
31		Foundation Walls	5 days	Wed 6/17/15	Tue 6/23/15
32		Basement Cooler Walls	8 days	Wed 6/17/15	Fri 6/26/15
33		**Services & Equipment**	**81 days**	**Wed 6/17/15**	**Wed 10/7/15**
34		Elevator Installation	6 days	Wed 6/17/15	Wed 6/24/15
35		Greenhouse Systems Installation (3rd floor)	12 days	Fri 9/11/15	Mon 9/28/15
36		Greenhouse Systems Installation (4th floor)	12 days	Thu 9/17/15	Fri 10/2/15
37		Greenhouse Systems Installation (5th floor)	10 days	Thu 9/24/15	Wed 10/7/15
38		**Superstructure**	**63 days**	**Mon 6/29/15**	**Wed 9/23/15**
39		**1st Floor Structure**	**15 days**	**Mon 6/29/15**	**Fri 7/17/15**
40		Framing 1st Floor	6 days	Mon 6/29/15	Mon 7/6/15
41		Slab on Grade F1st Floor	3 days	Tue 7/7/15	Thu 7/9/15
42		Metal Decking 1st floor	4 days	Tue 7/7/15	Fri 7/10/15
43		Slab 1st Floor	5 days	Mon 7/13/15	Fri 7/17/15
44		**2nd Floor Superstructure**	**15 days**	**Mon 7/20/15**	**Fri 8/7/15**
45		Framing 2nd Floor	6 days	Mon 7/20/15	Mon 7/27/15
46		Metal Decking 2nd Floor	4 days	Tue 7/28/15	Fri 7/31/15
47		Slab 2nd Floor	5 days	Mon 8/3/15	Fri 8/7/15
48		**3rd Floor Superstructure**	**18 days**	**Tue 7/28/15**	**Thu 8/20/15**
49		Framing 3rd Floor	6 days	Tue 7/28/15	Tue 8/4/15
50		Metal Decking 3rd floor	4 days	Mon 8/10/15	Thu 8/13/15
51		Slab 3rd Floor	5 days	Fri 8/14/15	Thu 8/20/15
52		**4th Floor Superstructure**	**15 days**	**Fri 8/21/15**	**Thu 9/10/15**
53		Framing 4th Floor	6 days	Fri 8/21/15	Fri 8/28/15
54		Metal decking 4th floor	4 days	Mon 8/31/15	Thu 9/3/15
55		Slab 4th floor	5 days	Fri 9/4/15	Thu 9/10/15



Project: MQP Schedule 01.28.20

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

ID	Task Mode	Task Name	Duration	Start	Finish
56		**5th Floor Superstructure**	**18 days**	**Mon 8/31/15**	**Wed 9/23/15**
57		Framing 5th Floor	6 days	Mon 8/31/15	Mon 9/7/15
58		Metal decking 5th Floor	4 days	Fri 9/11/15	Wed 9/16/15
59		Slab 5th Floor	5 days	Thu 9/17/15	Wed 9/23/15
60		**Roofing & Exterior Enclosure**	**49 days**	**Fri 9/11/15**	**Wed 11/18/15**
61		Roofing Structure 3rd & 4th Floor	6 days	Mon 10/5/15	Mon 10/12/15
62		Glazing 3rd & 4th Floor	15 days	Fri 10/23/15	Thu 11/12/15
63		Roofing Structure 5th Floor	10 days	Thu 10/8/15	Wed 10/21/15
64		Glazing 5th Floor	20 days	Thu 10/22/15	Wed 11/18/15
65		Panels Installation 1st & 2nd Floor	20 days	Fri 9/11/15	Thu 10/8/15
66		Glazing 1st & 2nd Floor	10 days	Fri 10/9/15	Thu 10/22/15
67		Windows Installation	6 days	Fri 9/11/15	Fri 9/18/15
68		Panels Installation 3rd & 4th Floor	20 days	Fri 10/9/15	Thu 11/5/15
69		Exterior Door Installation	3 days	Fri 10/9/15	Tue 10/13/15
70		Building Enclosed	0 days	Wed 11/18/15	Wed 11/18/15
71		**MEP Installation**	**117 days**	**Thu 11/19/15**	**Fri 4/29/16**
72		Duct & Pipe Work	20 days	Thu 11/19/15	Wed 12/16/15
73		HVAC Installation	30 days	Thu 12/17/15	Wed 1/27/16
74		Electric Installaions	10 days	Thu 1/21/16	Wed 2/3/16
75		Interior Lighting Installatin	10 days	Fri 2/26/16	Thu 3/10/16
76		Greenhouse Lighting Installation	15 days	Thu 12/17/15	Wed 1/6/16
77		Plumbing Fixtures Installation	12 days	Thu 2/11/16	Fri 2/26/16
78		Fire Protection Systems Installation	20 days	Thu 12/17/15	Wed 1/13/16
79		Commisioning	40 days	Mon 3/7/16	Fri 4/29/16
80		**Interior Construction & Finishes**	**67 days**	**Thu 12/17/15**	**Fri 3/18/16**
81		Interior Walls	25 days	Thu 12/17/15	Wed 1/20/16
82		Ceiling Installation	16 days	Thu 2/4/16	Thu 2/25/16
83		Flooring Installation	15 days	Thu 1/21/16	Wed 2/10/16
84		Toillet Wall ceramic tile installation	15 days	Mon 2/29/16	Fri 3/18/16
85		Floor Painting Finish	10 days	Thu 2/11/16	Wed 2/24/16
86		Interior Walls Paint	10 days	Thu 2/4/16	Wed 2/17/16
87		Interior Door Installation	7 days	Thu 1/21/16	Fri 1/29/16
88		Furniture	20 days	Thu 2/11/16	Wed 3/9/16
89		Interiors Complete	0 days	Fri 3/18/16	Fri 3/18/16
90		**Site Work & Improvements**	**20 days**	**Mon 3/21/16**	**Fri 4/15/16**
91		Loading and Parking area Paving	20 days	Mon 3/21/16	Fri 4/15/16
92		**Turn Over & Move In**	**20 days**	**Fri 4/15/16**	**Fri 5/13/16**
93		Construction Substancial Completion	0 days	Fri 4/15/16	Fri 4/15/16
94		Demovilization	5 days	Mon 5/2/16	Fri 5/6/16
95		Move In	5 days	Mon 5/9/16	Fri 5/13/16
96		Project Finish	0 days	Fri 5/13/16	Fri 5/13/16



Project: MQP Schedule 01.28.20

Task		Summary		Inactive Milestone		Duration-only		Start-only		External Milestone		Manual Progress	
Split		Project Summary		Inactive Summary		Manual Summary Rollup		Finish-only		Deadline			
Milestone		Inactive Task		Manual Task		Manual Summary		External Tasks		Progress			

Appendix AI: LEED Checklist

LEED v4 for BD+C: New Construction and Major Renovation

Project Checklist

Project Name: Growing Power Vertical Farm
Date: 02/11/2015

Y	?	N			
1			Credit	Integrative Process	1

9	0	5		Location and Transportation	16
			Credit	LEED for Neighborhood Development Location	16
1			Credit	Sensitive Land Protection	1
		2	Credit	High Priority Site	2
4		1	Credit	Surrounding Density and Diverse Uses	5
3			Credit	Access to Quality Transit	5
1			Credit	Bicycle Facilities	1
		1	Credit	Reduced Parking Footprint	1
		1	Credit	Green Vehicles	1

5	0	5		Sustainable Sites	10
Y			Prereq	Construction Activity Pollution Prevention	Required
1			Credit	Site Assessment	1
		2	Credit	Site Development - Protect or Restore Habitat	2
		1	Credit	Open Space	1
3			Credit	Rainwater Management	3
		2	Credit	Heat Island Reduction	2
1			Credit	Light Pollution Reduction	1

4	5	2		Water Efficiency	11
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
		2	Credit	Outdoor Water Use Reduction	2
3	3		Credit	Indoor Water Use Reduction	6
	2		Credit	Cooling Tower Water Use	2
1			Credit	Water Metering	1

11	4	18		Energy and Atmosphere	33
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
6			Credit	Enhanced Commissioning	6
3	2	13	Credit	Optimize Energy Performance	18
	1		Credit	Advanced Energy Metering	1
		2	Credit	Demand Response	2
		3	Credit	Renewable Energy Production	3
1			Credit	Enhanced Refrigerant Management	1
1	1		Credit	Green Power and Carbon Offsets	2

9	2	2		Materials and Resources	13
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
3		2	Credit	Building Life-Cycle Impact Reduction	5
1	1		Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
2			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
1	1		Credit	Building Product Disclosure and Optimization - Material Ingredients	2
2			Credit	Construction and Demolition Waste Management	2

10	0	6		Indoor Environmental Quality	16
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
		2	Credit	Enhanced Indoor Air Quality Strategies	2
2		1	Credit	Low-Emitting Materials	3
1			Credit	Construction Indoor Air Quality Management Plan	1
1		1	Credit	Indoor Air Quality Assessment	2
1			Credit	Thermal Comfort	1
2			Credit	Interior Lighting	2
1		2	Credit	Daylight	3
1			Credit	Quality Views	1
1			Credit	Acoustic Performance	1

3	0	1		Innovation	6
3			Credit	Innovation	5
		1	Credit	LEED Accredited Professional	1

3	0	0		Regional Priority	4
1			Credit	Regional Priority: Sensitive land protection	1
1			Credit	Regional Priority: Access to quality transit	1
1			Credit	Regional Priority: Rainwater management	1
			Credit	Regional Priority: Specific Credit	1

55	11	39		TOTALS	Possible Points: 110

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110