EPICS PURDUE

Design Document

Spring House

Fall 2017

Table of Contents

2.1 Design Status

Phase 6: Service/Maintenance	**Status:** To be done **Semester:** Spring 2018

Phase 5: Delivery	**Status:** To be done **Semester:** Spring 2018

Phase 4: Detailed Design	**Status:** In Progress **Semester:** Fall 2017

Phase 3: Conceptual Design	**Status:** Completed **Semester:** Spring 2017

Phase 2 : Specification Development	**Status:** Completed **Semester:** Fall 2016

Phase 1: Project Identification	**Status:** Completed **Semester:** Spring 2016

3. Project Charter

3.1 Description of Community Partner

History of Bradford Woods

Bradford Woods, Indiana University's Outdoor Center, has a rich and interesting history. The Bradford family, who called the area home from the mid 1800's to the 1930's, donated 2,300 acres and the estate to Indiana University for the benefit of Riley Hospital's children with disabilities and other charitable, educational and recreational purposes. It is thanks to the generosity of the Bradford family that Bradford Woods is Indiana's largest preserved natural area outside the state and national park systems, and a national and international leader in outdoor education and summer camp programming. Bradford Woods currently serves over 25,000 people annually with diverse backgrounds and abilities; its mission is to be global leaders in the delivery of inclusive and experiential outdoor learning.

History of the Spring House

The focus of this project is the historic Spring House of Bradford Woods. The Bradford family made its fortune by discovering and then mining a valuable type of sand used for molding. This "molding sand" is no longer used in industry because companies can create better products than the natural equivalent. This natural molding sand is formed in an environment that is perpetually damp; springs create a perfect environment to form this sand. Bradford Woods has a large spring that comes to the surface on the property, where the Bradfords built a spring house. A spring house is a small building constructed over a spring, its purpose being to keep the spring water clean by excluding leaves, animals, and other contaminants. The structure was also used for refrigeration before the advent of ice houses, and later electricity. Food kept in a spring house could be kept at a constant temperature year-round, preventing spoilage of meats and dairy. While we do not know exactly which purposes the Bradfords used the Spring House, we can safely assume it was at the very least used to keep the spring water safe from contaminants. This spring water was then used for all manner of purposes; drinking, cleaning, etc. The Spring House was likely constructed before the turn of the 20th century, because the Bradfords first began living there in 1855. This puts the Spring House and its surroundings 120-160 years old.

Springs: How do they work?

Springs form when surface water from rain or overflow infiltrates the earth's surface. This water travels to underground aquifers, large bodies of rock that contain groundwater, and is stored there. A spring forms when the aquifer is filled to capacity, and water pressure differences force the water to the surface. Springs will come to the surface in an area that is lower than the aquifer, such as next to a hill or mountain, and water flow from a spring can vary from a small stream of water to huge pools flowing hundreds of millions of gallons per day. Figure 1, shown below, shows water traveling through a spring system. This process is not fast, it can take hundreds of thousands of years to completely fill some larger aquifers to the point where a spring will bubble up to the surface.

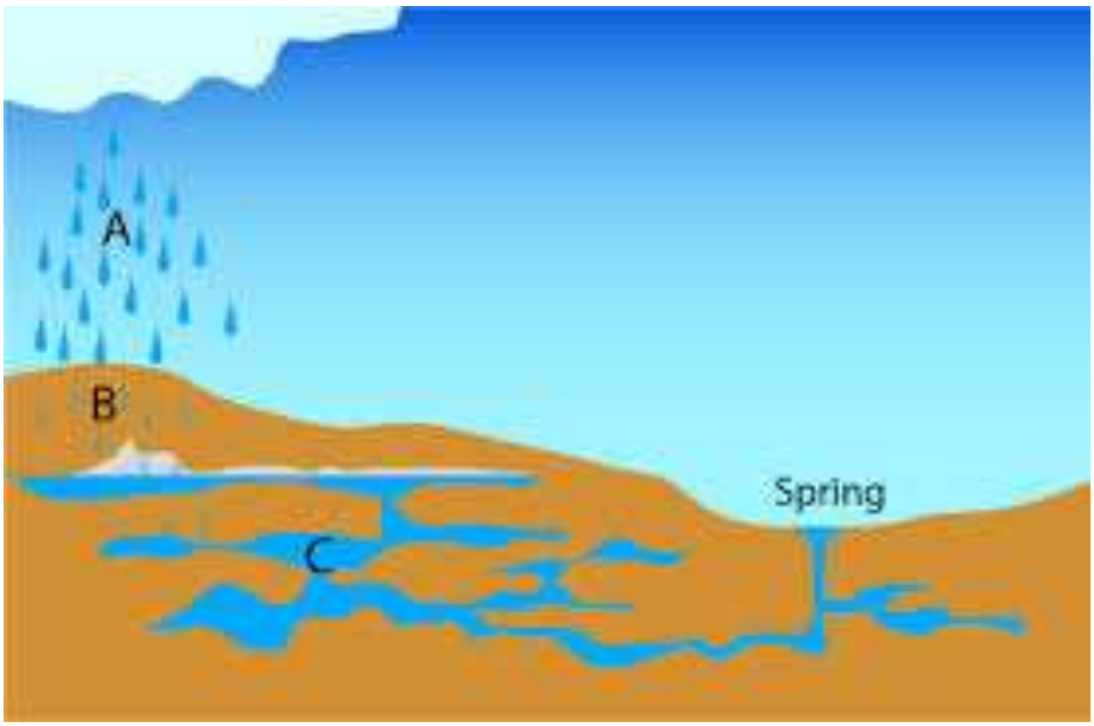


Figure 1: Technical Spring Description

The Spring House at Bradford Woods sits above the location where an underground spring emerges from the surface. The location of the aquifer which feeds the Spring House is likely in the hillside to the north of the Spring House, shown in Figure 1 as Point C. This aquifer has not been studied for the purposes of this report, so that is an assumption that has been backed by the previous explanation of springs.

3.2 Project History & Stakeholders

The Spring House team was formed in Spring 2016 from the EPICS Camp Riley team. The Camp Riley project partner, Tim Street, is the current director of Bradford Woods. In Spring of 2016, Tim approached the Camp Riley team with an idea for a ramp to ferry visitors from the road to the Spring House and back again. During the spring 2016 semester, the team surveyed the land to get an overview of the topography. The issue they encountered right off the bat was that the land was very wet and mucky and that it would be difficult to build on the land. Because of the nature of the house, the team knew that there was a spring underneath the house. It is unknown the exact locations of the underground spring, but the team believes they have identified the general location. During the summer of 2016 Tim attempted to bring in an excavator to fix the wetness issue and make the land more viable to build on; however, the excavator got stuck in the mucky land and was unable to fix the water issues.

The team went down and did soil probes of the land to see how deep down the muck goes. Then we plotted out the points. We designed our path so that the posts are spread over loads of concrete on the areas of land where the solid ground is at its highest points. This ensures that the posts will not sink as time goes on. In the Spring 2017 semester the team developed and implemented a drainage solution that would make the area both less muddy and more aesthetic. A swale, which is a small scale ditch, was dug through the middle of the site. A smaller swale was dug from the concrete pad of the spring house to the middle of the larger swale. This helped move water away from the concrete pad and out into the flow of water. The grass that was chosen is designed to grow in wet conditions and will soak up water; as well as make the area more aesthetically pleasing. The goal from is that the site will be dry enough to build a wheelchair accessible ramp upon in the Fall of 2017.

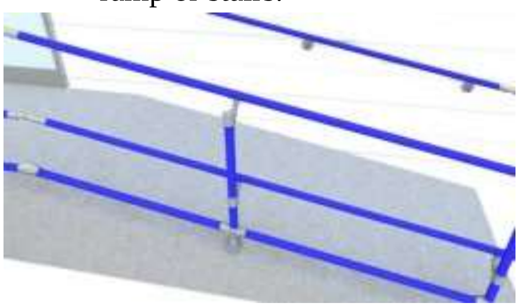
Stakeholders for this project are: Camp Riley visitors and campers, Bradford Woods employees and visitors, and Indiana University.

3.3 Project Objectives

- Accessibility to the Spring House
- Design and construct an ADA compliant ramp and landing area for visitors to approach the Spring House
- Interactive and informative path to educate visitors on the history and significance of the Spring House
- Spruce the Spring House up, make it more visually appealing

3.3.1 ADA Wheelchair Ramp Code

- ADA Ramp Specifications Require a 1:12 ramp slope ratio which equals 4.8 degrees slope or one foot of wheelchair ramp for each inch of rise. For instance, a 30 inch rise requires a 30 foot handicap wheelchair ramp.
- ADA Guidelines Require a Minimum 5' x 5' Flat, unobstructed area at the top and bottom of the ramp.
- ADA Standards Require wheelchair ramps to have a Minimum width of 36 inches of clear space across the wheelchair ramp. Massachusetts and California ADA code now require 48 inches ramp width to be an ADA compliant ramp.
- ADA Code Compliance Require a Minimum Turn Platform size of 5' x 5'. California ADA ramp code now requires a minimum 6 foot (in the direction of travel) platform size.
- ADA Guidelines for Wheelchair Ramps allow a Maximum run of 30 feet of wheelchair ramp before a rest or turn platform.
- ADA Ramp Guidelines Require ADA Ramp handrails that are between 34" and 38" in height on both sides of the wheelchair ramps.
- Railing: Railing must be a continuous smooth surface. A railing must be on both sides of ramp or stairs.



- Edge Protection: When there is a drop off, ramps require a curb or curb rail to prevent wheelchairs from slipping out from under the railing. In some cases a mid rail is sufficient to provide this protection.

- D Returns: Railing ends need to be rounded or return smoothly into a floor, wall or post.

sources:

https://www.adawheelchairramps.com/wheelchair-ramps/ada-guidelines.aspx

https://www.simplifiedbuilding.com/railing/ada-handrail/installation

3.4 Outcomes and Deliverables

Deliverables:

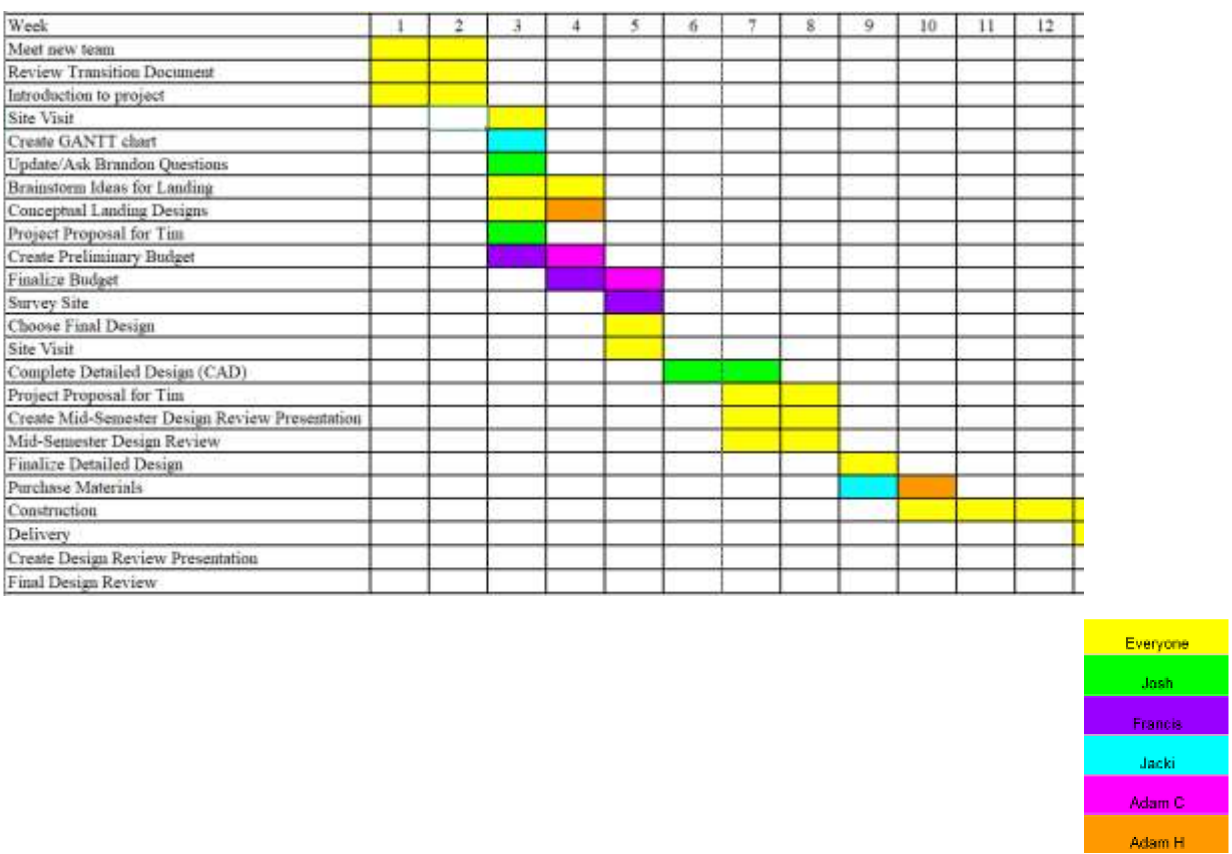
- ADA compliant ramp and landing
- Interactive and informative exhibits that highlight the significance of the Spring House

Outcomes:

- Transform the Spring House and its surroundings to a presentable and interesting version

3.5 Expected Semester Timeline

GANTT Chart



Milestones:

- Finalize Ramp Design
- Have footers and posts installed
- Ramp installed between posts
- Handrails and stringers installed
- Intended Completion Date: End of Fall 2017 Semester
- Completion Deadline: Prior to Summer 2018

4 Semester Documentation Fall 2017

4.1 Team Members

Josh Hernandez - MDE Design Lead
Jacki Knight - IM Project Partner Liaison
Adam Cameron - FYE Team Member
Francis Sullivan - MDE Team Member
Adam Harris - FYE Project Archivist

4.2 Project Status

The next step on the project is for a local construction contractor to install concrete footers in the ground where the supports for the walkway will be placed. The concrete pouring process is best done when the ground is cold and will thus occur in the winter. As the contractor pours the footers for the concrete, wooden deck posts will be placed in the footer. After this step is complete, construction of the ramp and landing can commence. This will involve constructing the walkway, using stringers as reinforcement, and finally installing hand rails.

4.3 Goals for the Semester

Goals: Design and build an ADA compliant ramp for campers and visitors of Camp Riley to be able to traverse the spring and visit the springhouse. This ramp would meet requirements set by the Project Partner and by the American Disabilities Act to ensure that this ramp is legal and reasonable for its end users. The team would design and construct a ramp using engineering and construction knowledge gained at Purdue. The team would be in charge of coordinating the construction of supporting developments in the area as well as evaluating the feasibility of the designed ramp in the given environment.

4.4 Semester Timeline

- 11/30 Finalized budget
- 10/18 Finalized initial design
- 9/20 Initially contacted contractor
- 10/13 Decided on contractor with project partner
- 11/15 Finalized new design
- 11/2 Finished the 3D model for the new design
- 11/3 Met with contractor and project partner

4.5 Semester Budget

Spring House Fall 2017 Purchasing Budget			
2 x 10 x 16' Ground Contact AC2® Green Pressure Treated Lumber	8	$22.49	$179.92
2 x 10 x 12' Ground Contact AC2® Green Pressure Treated Lumber	16	$19.27	$308.32
2 x 10 x 8' Ground Contact AC2® Green Pressure Treated Lumber	31	$11.47	$355.57
2 x 10 x 4' Ground Contact AC2® Green Pressure Treated Lumber	1	$7.29	$7.29
USP Structural Connectors 2" x 8-10" Triple Zinc Slant Nail Joist Hanger	41	$1.11	$45.51
USP Structural Connectors 10D x 1-1/2" Hot Dipped Galvanized Nail - 5 lb. Box	1	$19.28	$19.28
4 x 6 x 10' #2 Ground Contact AC2® Green Pressure Treated Timber	14	$17.97	$251.58
4 x 6 x 12' #2 Critical Structural AC2® Green Pressure Treated Timber	8	$25.27	$202.16
Total			**$1,369.63**

Spring House- Spring 2018 Purchasing Budget #1			
Grip Fast® HDG Carriage Bolts 1/2" x 8" - 10lb Box	3	$21.99	$65.97
Grip Fast® HDG Carriage Bolts 1/2" x 6" - 10lb Box	4	$21.99	$87.96
Grip Fast® 1/2" Grade 2 Hot-Dipped Galvanized Flat Washer - 26 Count	8	$2.99	$23.92
Grip Fast® 1/2" Grade 2 Hot-Dipped Galvanized Split Lock Washer - 12 Count	17	$1.39	$23.63
Grip Fast 1/2"-13 Hot-Dipped Galvanized Hex Nuts (28 Pieces)	8	$2.99	$23.92
4" x 6" Post Pro-Anchor	5	$39.00	$195.00
Total			**$420.40**

Spring House- Spring 2018 Purchasing Budget #2			
5/4 in. x 6 in. x 8 ft.	156	$4.77	$744.12
5/4 in. x 6 in. x 12 ft.	26	$7.37	$191.62
2 in. Star Flat-Head Wood Deck Screws (5 lb.-Pack)	3	$19.96	$59.88
Total			**$995.62**

4.6 Transition Report

4.6.1 Summary of Semester Progress / Comparison of Actual Semester Timeline to Proposed Semester Timeline

Our original timeline did not leave enough time to properly prepare the area. It was assumed that the process would start quickly because there was an existing design. In reality it took multiple weeks to gather measurements and prepare the swampy spring area for construction. The previous design was also unsatisfactory and required changes to meet new Project Partner demands. In addition, the need to hire an outside contractor added a dimension of work that was previously unaccounted for. Advice from the contractor contradicted our original assumption that footers would be best installed during the warm season, and that instead implementing the footers would be best done in the winter after the ground has solidified.

The need for a significant redesign to the ramp as well as the needs of the contracted work meant that the original timeline of completion by the end of Fall 2017 Semester was quickly made impossible. However the specific and robust nature of the design that was finalized this semester and the concrete plans to prepare the area for construction of the walkway are testament to the large amount of progress that has been made this semester.

4.6.2 Draft Timeline for Spring 2018 and Relationship to Overall Project Timeline

January 27	- Transition in new team and get footers installed by contractor
	- Validate Design, wait for warmer weather to begin construction
February	- Finalize build day schedules
March	- Build Days, attach stringers and being laying walkway across beams
	- 3/05 Recruit help for build days in April
	- 3/30 Finish stringers
April	- Build Days, attach handrails and finish laying walkway
	- 4/23 Last week of April, ramp should be finished
May	- Finalize Phase 6: Service/Maintenance

5 Current Design

5.1 Project Identification

Progress from previous semesters left a ramp design that follows the path shown in Figure 1 in the Appendix. This design allowed for the ramp to move visitors from the street to the Spring House and back the same path. The design called for 6’ width and slopes that were in accordance with ADA requirements. However, the design that was being followed was taking visitors to the edge of the existing concrete pad so that the pad could be used for viewing the Spring House. This became no longer feasible, as the condition that the pad was in was not suitable for people to use; site visits made this apparent early, both to team members and the project partner, prompting the project partner to ask for a revamped design that included a landing made out of the same materials which would allow for safe viewing of the Spring House. This landing was asked to be designed to hold 10-15 people at once.

5.2 Initial Brainstorming

In order to satisfy the project partner’s new requirements, three designs were considered by the team and ultimately presented to the project partner. These three designs can be found in the appendix, Figures 3-5. Initial Design #1 (Figure 3) is a simple landing against the Spring House, similar in length to the house and initially thought to be 10’ wide. This design kept the same width used by the previous ramp design. It is the simplest of the three designs, and ultimately the one chosen by the project partner. Initial Design #2 (Figure 4) was a slightly more intricate design; the landing shown is in L-shape that encompasses the Spring House and could allow for viewing of the house through both windows on the Spring House. It was also thought to be 10’ wide and kept the same initial ramp design width. Initial Design #3 (Figure 5) is the most complicated of the three designs, but also could allow for better viewing practices. The design shows one-way traffic from the north-south street to the Spring House, and the exit would be to the east-west street. As shown, the landing contains the L-shape from Design #2, but would be thinner in width. The reason for this is because there would be one-way traffic on the ramp/landing; visitors would enter from one side and exit from the other, and would not need to turn around and return the same direction.

The three designs were presented to the project partner, and the project partner chose Design #1 as the best design. Reasons for this include: Design #1 would be the cheapest design, it does not interfere with views of the Spring House from the street, and any presentations done about the Spring House on the landing could be easiest with this design. This choice was expected, as it best fulfills the needs that the project partner had stated. The other designs were chosen because they could be variations that the project partner had not originally thought of, and were thought to be viable by the team.

5.3 Redesign of the Ramp

Once the design had been chosen by the project partner, the team began initial design of the ramp. This process involved using the previous ramp design approved by the project partner from an earlier iteration of the team, and incorporating the chosen landing configuration. A survey was done on the site, and was matched with previous surveys in order to get an accurate representation of the current land conditions. This survey was used to check slopes used by the previous ramp iteration, and to set the landing at a height of 2.5’ above ground level in order to maintain a slope less than 8.3% slope in accordance with ADA guidelines. The ramp was also redesigned to use 8’ board lengths, which allowed for 7.5’ of width for two-way traffic along the ramp. The landing was chosen to be 150 sq. ft, in order to hold 10-15 people comfortably. The landing would be 15’ in length, matching the length of the Spring House, and 10’ wide, spanning the concrete pad that had fallen apart. In order to stabilize the ramp, the previous design iteration had used a rectangular concrete footer at each set of posts that would be installed and hold both posts in it. This footer design was originally used in the redesign as well, but would be changed at a later point, explained in Section 5.5. This redesign was submitted to the project partner who asked for the landing to be set at a lower height, which is explained in section 5.5.

5.4 Section Designs and Concrete Footers

Figure 6 shows the section designs of the ramp, a top and bottom view to show the stringers that are used to support the ramp. 1”x6”x8’ boards are used for the decking of each section, 2”x10” boards are used for the stringers. These board sizes were chosen because they are standard sizes for deck boards, and then were proved to be able to carry the loads using structural analysis. The structural analysis is explained in Section 5.8. The stringers are spaced with one on each side of the ramp, and two that are evenly spaced underneath the ramp. The deck boards will be laid on top of the stringers as shown in the figure. The posts were originally chosen to be 4”x4” deck posts, but were later changed to 4”x6” as explained in section 5.8. These posts will be set into concrete footers. The original concrete footer design was a rectangular box which would hold both posts, one at each end. After consulting with a contractor, Greystone Concrete, a new footer design was chosen, which is shown in Figure 10. This design allowed for less concrete to be used, and is also a more standard footer design. Each post along the long, straight section of ramp will have its own footer, as well as each post for the east side of the landing. The posts after the turn will not require a concrete footer, because the ground there is more stable and not as wet. The concrete footers are to be installed by the contractor after the ground has hardened over the winter.

5.5 Finalized Ramp Design

The landing at a height of 2.5’ above the ground was undesirable to the project partner, as a landing at this height would have disrupted the view of the Spring House. The window of the Spring House would have been partially blocked making it hard for viewers to observe the inside of the Spring House. In order to lower this landing to 1.5’ the ramp needed to be redesigned to comply with the ADA ramp slope requirements. This redesign required the ramp to be longer in length to stay below ADA maximum ramp slope. The previous design went directly to the road and because the ramp needed to be lowered a turn to the south was added. Ramp slope, which is consistent through every sloped section, was determined to be 7.4% based on the landing height and ground elevations. ADA regulations required there to be a maximum of 30’ of sloped ramp before a flat rest area; to follow this regulation it was decided to create two 15’ sections since 2”x10” boards come in standard maximum length of 16’. This was later changed to two 14’ 7.5” sections due to the decking of the ramp using 1” by 6” boards. A 14’ 7.5” section was the closest length to 15’ the section could be in order to use a whole number of decking boards. The rest area section on the straight section of the ramp was designed to be 6’ to comply with ADA regulations. The rest area section on the turns were designed to be 8’x8’, dictated by 8’ wide throughout. The ramp section parallel to the eastbound road was a copy of the closest section to the Spring House. The section of ramp connecting to the road had to be 6’ to reach the turn platform closest to the road. 2” by 10” stringers were chosen to support the ramp based on statics testing explained in Section 5.8. Turning to the south side was a choice of the project partner because it would be easier to access the ramp closer to the intersection. The dog leg turn comprised of a 15’ section with a slope of 7.4%, an 8’ flat rest area that facilitated the turn back to the road, and a 6’ section with a slope of 7.4% in order to connect to the road as shown in Figure 7 & 8. This redesign would include splices along the outside stringers on the sloped sections; splicing specifications will be covered in section 5.7. The landing was altered to be 12’ by 12’ for reasons explained in section 5.6.

5.6 Landing Design

Initially, the landing was designed to be 15’ by 10’ as specified in section 5.3. This was changed because the length of 15’ would not allow for a support post to be placed on the southwest corner of the landing. The support post needed to move locations because its original position was where all the water drained and the land had no structural support. The 12’ by 12’ design offered more support points and still allowed for the capacity specified by the project partner. This redesign also cut down greatly on the cost of the overall project, as it changed the board length from 16’ to 12’. This also helped the overall safety of the ramp because it shortened the length of the stringers which allowed for them to support a high load, as described in section 5.8 and shown in figures #13-25 and tables #1-3. The posts chosen for the project are 6”x4” to allow for maximum support for each stringer as the boards will be bolted to the six inch side and will share the six inches between the two boards. The landing will include eight posts and each one will be supported by either the pad or concrete footers. The posts closest to the Spring House will not have concrete footers, and will instead be supported by the existing concrete pad. This will be accomplished using post brackets, drilling them into the concrete pad and securing the deck post to the post bracket. The posts along the east side of the landing will be secured using the concrete footers explained in section 5.4

5.7 Splicing

Splicing is a construction technique used to secure two wooden boards together. This is used when a wooden beam needs to span between two posts but is not long enough or when one board spanning the distance between posts is not strong enough to carry the exerted force. The design uses splices to give the supporting wooden beams below the decking more strength. Splicing the wooden boards between the post avoids splicing them together on the posts. This causes the exerted force to be dispersed among the spliced section and posts as opposed to all on the posts. The bolt formation on the spliced sections of stringers was determined based off of Historic Home’s ramp they built in back in Fall of 2015. The formation includes 10 bolts with 5 bolts on each splice connected on the backside to a 4 foot board splicing them together, as shown in Figures 11 & 12. Splices occur every 5.85’ on the 30’ decline section and every 7.3125’ on the 15’ decline sections. The Historic Home’s ramp stringers were fastened by either a splice or to a post every 6’. This was used to determine the Spring House’s ramps splices, keeping a similar width where possible. Splices were chosen to be of equal length on each section and did not occur on a post.

5.8 Structural Mechanics Calculations

The wooden ramp will have to support an increased load due to the needs of Camp Riley. Campers are often in heavy motorized wheelchairs and often have an adult chaperone accompanying them. To ensure that the ramp would remain solid, thick beams were used to support the weight. In order to ensure that the design was adequate for the task a simple statics analysis of the beam under heavy load was performed. Specifications of the beams from the manufacturer were used to calculate the Moment of Inertia, and obtained the Young's Modulus of Elasticity for our material from Engineering Toolbox to set up our calculation. The beam was set up with a fixed end and a roller which is necessary for statics analysis. An illustration of this is available in the Appendix as Figure 24. In reality the beam would be pinned on both sides. Governing equations for displacement, slope, moment, and shear were put into Microsoft Excel and can be found below.

$$\delta = \frac{qx}{24EI}(L^3 - 2Lx^2 + x^3)$$

$$\theta = \frac{q}{24EI}(L^3 - 6Lx^2 + 4x^3)$$

$$M = \frac{qx}{2}(x - L)$$

$$V = -\frac{q}{2}(L + x)$$

Equations 1-4: Governing equations for static beam loading

In the image above, the list of variables used in the equations is as follows: δ = displacement of board, θ = slope of board, M = moment along board, V = shear force along the board, q = load weight, E = Young's Modulus, I = Moment of Inertia, L = length of board, x = Point of Interest (midpoint).

For the load on the beam in the model, a distributed load was chosen rather than point loads. This assumes that the load is applied evenly across the beam, which roughly approximates the campers and adults spread out over the ramp. This model assumes that the walkway is evenly distributing the load and that the people are spaced apart. The distributed load was made to be 800lbs total. This would be the approximate weight of two campers in heavy wheelchairs and two adults. It is worth noting that this calculation is for a single beam. The actual ramp is designed with two beams with reinforcing stringers running between them. A similar load in reality would be 4 children in wheelchairs and 4 adults standing on a 8ft or 12ft section of the walkway.

In the first scenario the ramp had no issues supporting the weight and showed minimal displacement and a completely acceptable shear force for the wood. Graphs of the deflection, slope, moment, and shear are available in the Appendix as Figures 12-15.

The second case featured a longer beam.; the first case was done with an 8ft section, and since the ramp also contains 12 foot sections, another model was done. The load was kept the same in order to check the relative stresses against each other. The graphs of each of the loads are available in the Appendix as Figures 16-19. The longer section showed greater displacement and moment by about 50%, maximum shear force was also increased by about 25%. These forces are still well within the limits of a single beam. The maximum shear force parallel to the grain was found on Engineering Toolbox to be approximately 1,500 psi, the maximum shear in the 800lb case was found to be 0.5kips over 16 square inches or 31.25 psi.

The final test was two point loads on the beam. The same total force was used for ease of comparison, but we placed two 400lb loads at 25% and 75% of the beam's length. This test assumes that the walkway and planks that line the beam and distribute load across the length are not working at all and that each camper and adult pair are standing right next to each other. This slightly decreased the maximum loads across the beam, but changed the shapes of the graphs. These graphs are available in the Appendix as Figures 20-23.

Structural analysis of the beams gave us confidence that even without the structural reinforcements, the stringers, the walkway would support the heaviest loads that it would see. Adding the stringers to the design reinforces the ramp to a point where no beam deflection can be felt by a human.

Appendix

Figure 1: Existing Site Conditions

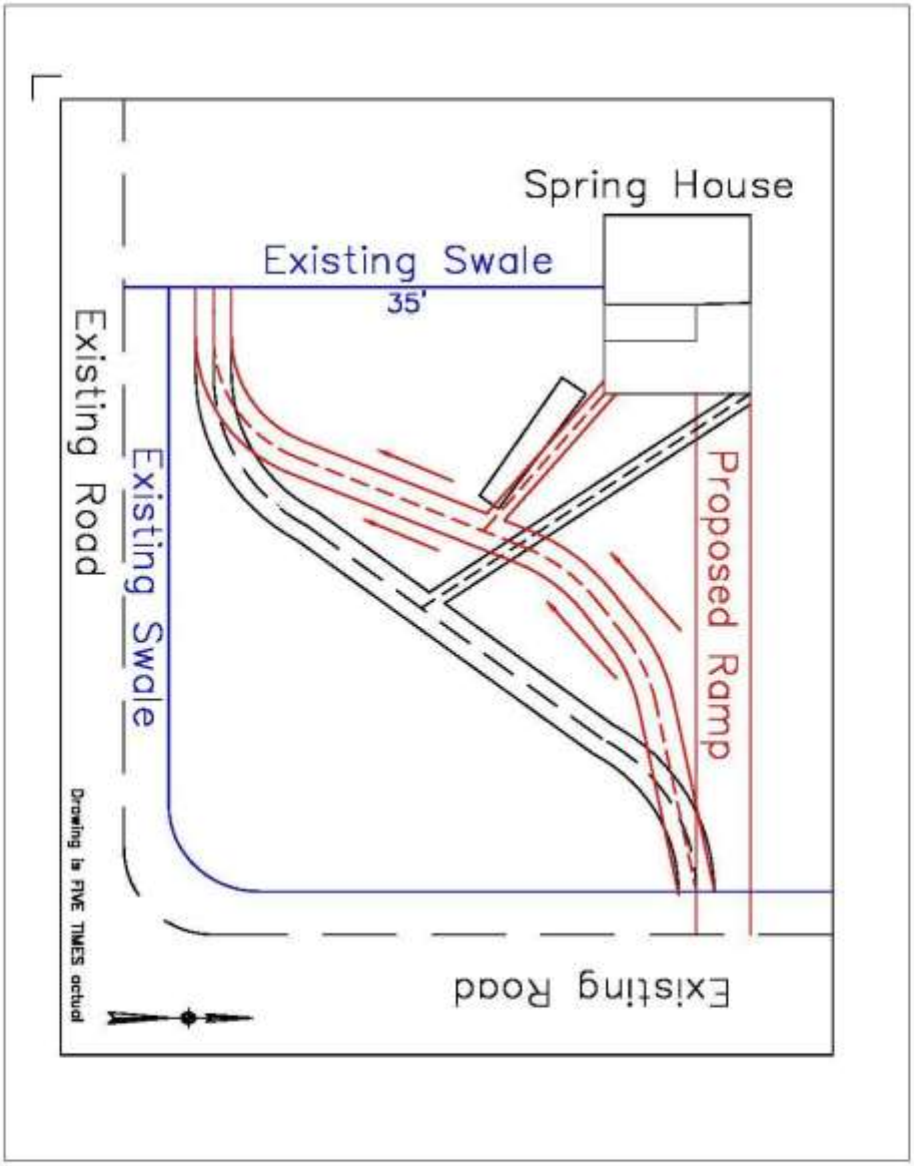


Figure 2: Proposed Site Conditions

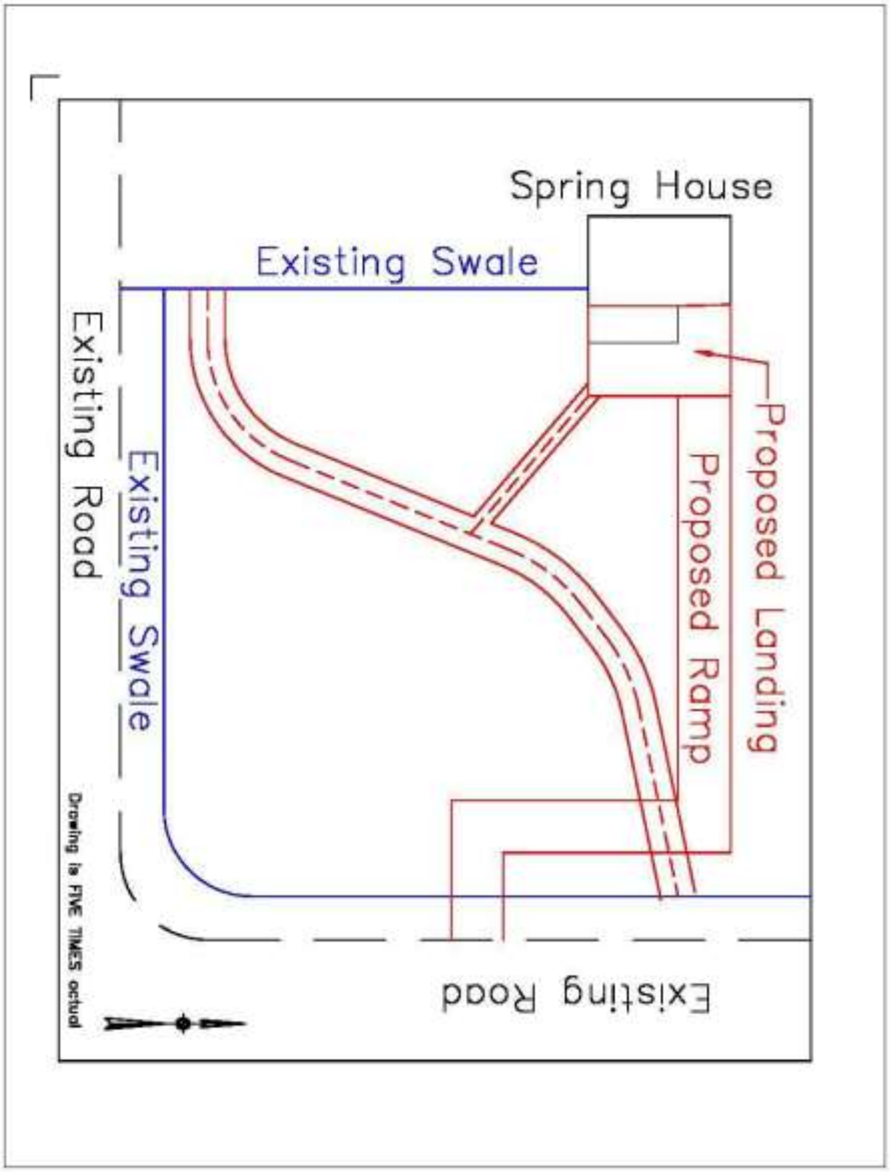


Figure 3: Initial Brainstorm Design #1

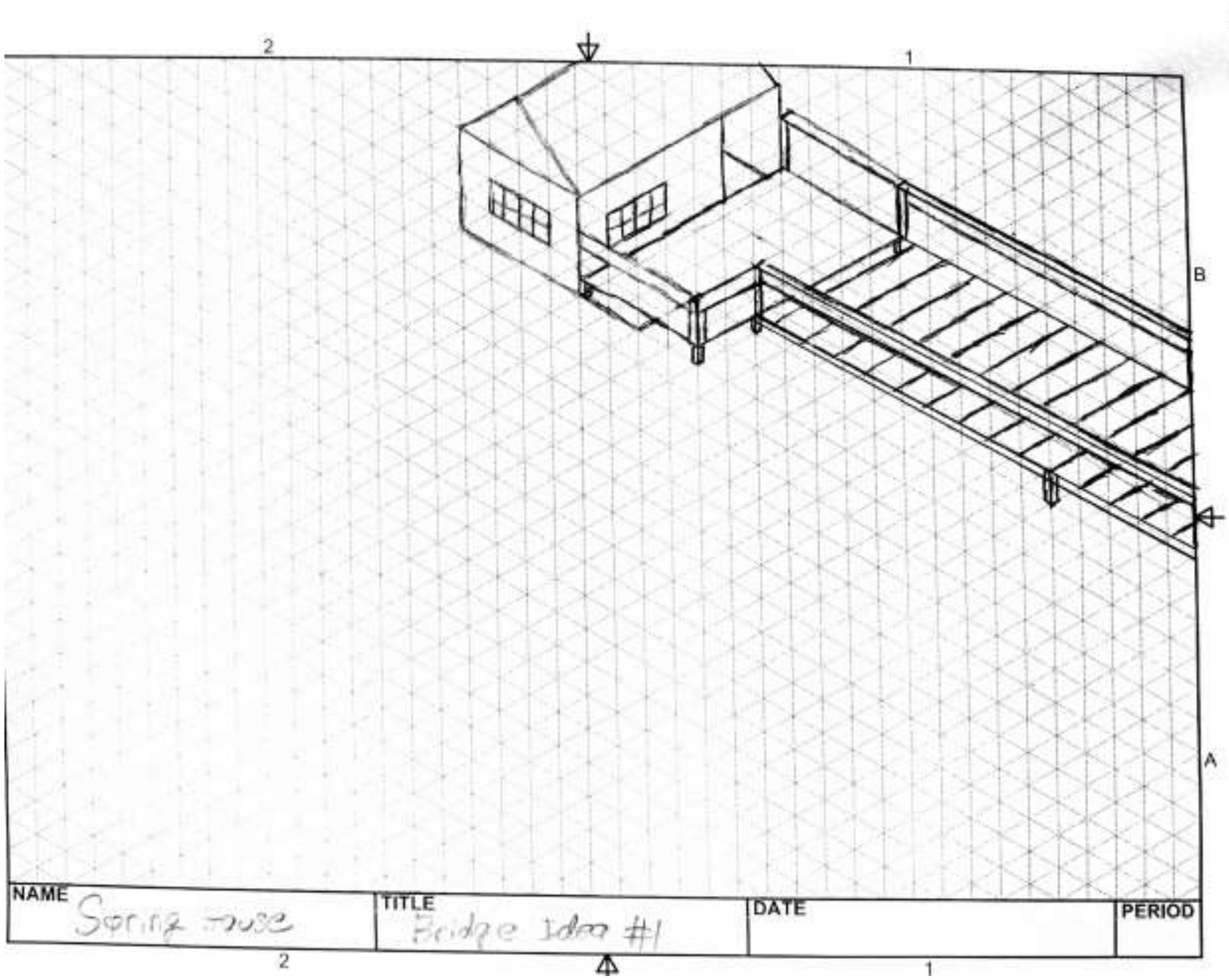


Figure 4: Initial Brainstorm Design #2

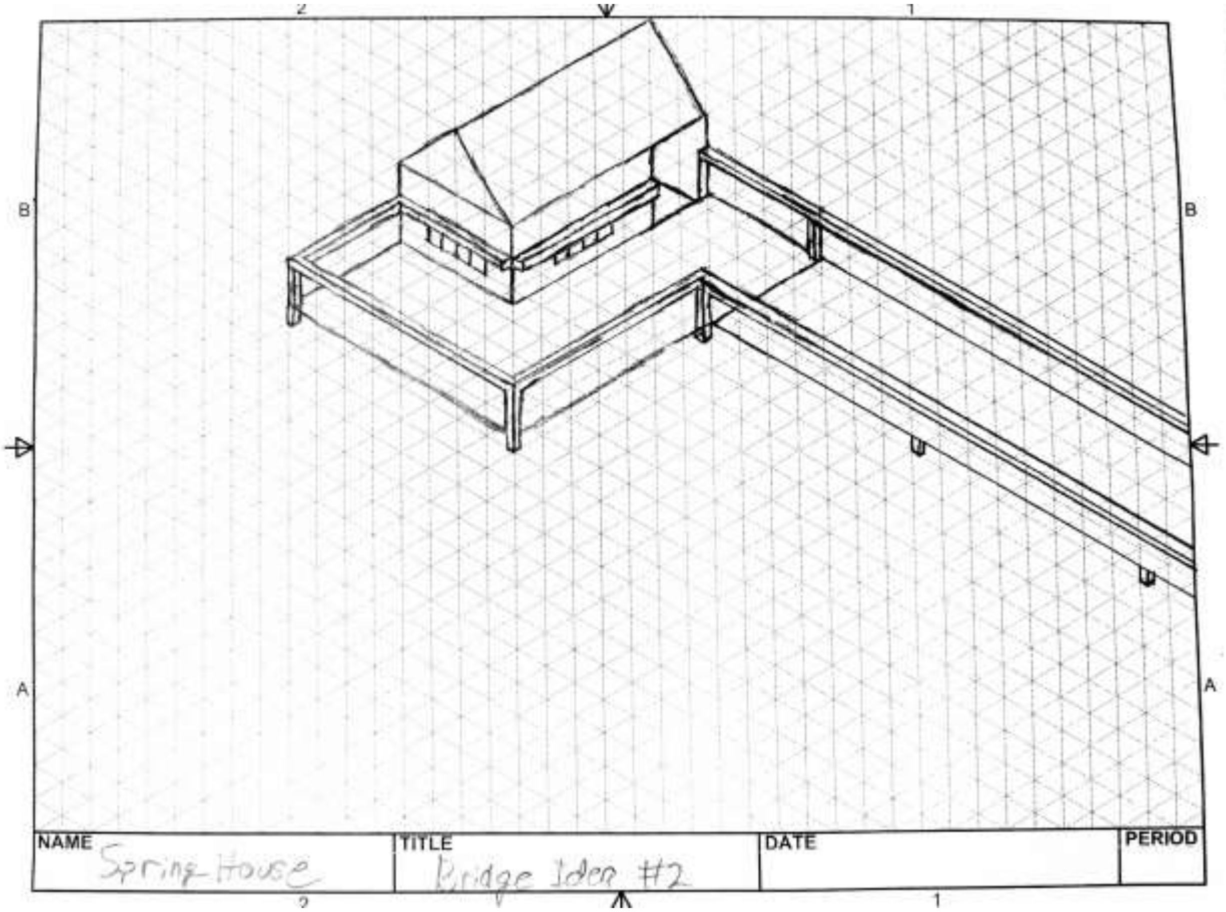


Figure 5: Initial Brainstorm Design #3

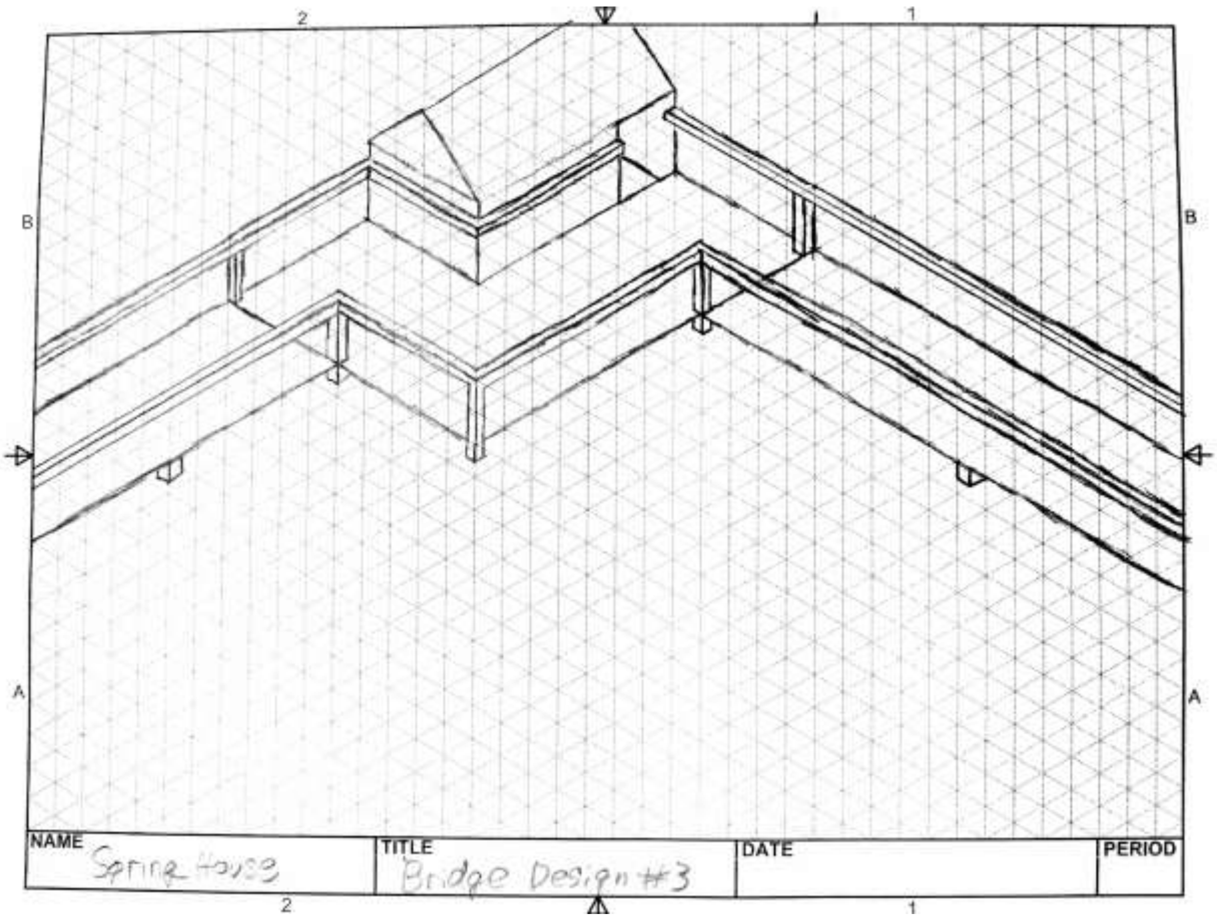


Figure 6: Ramp Section Views

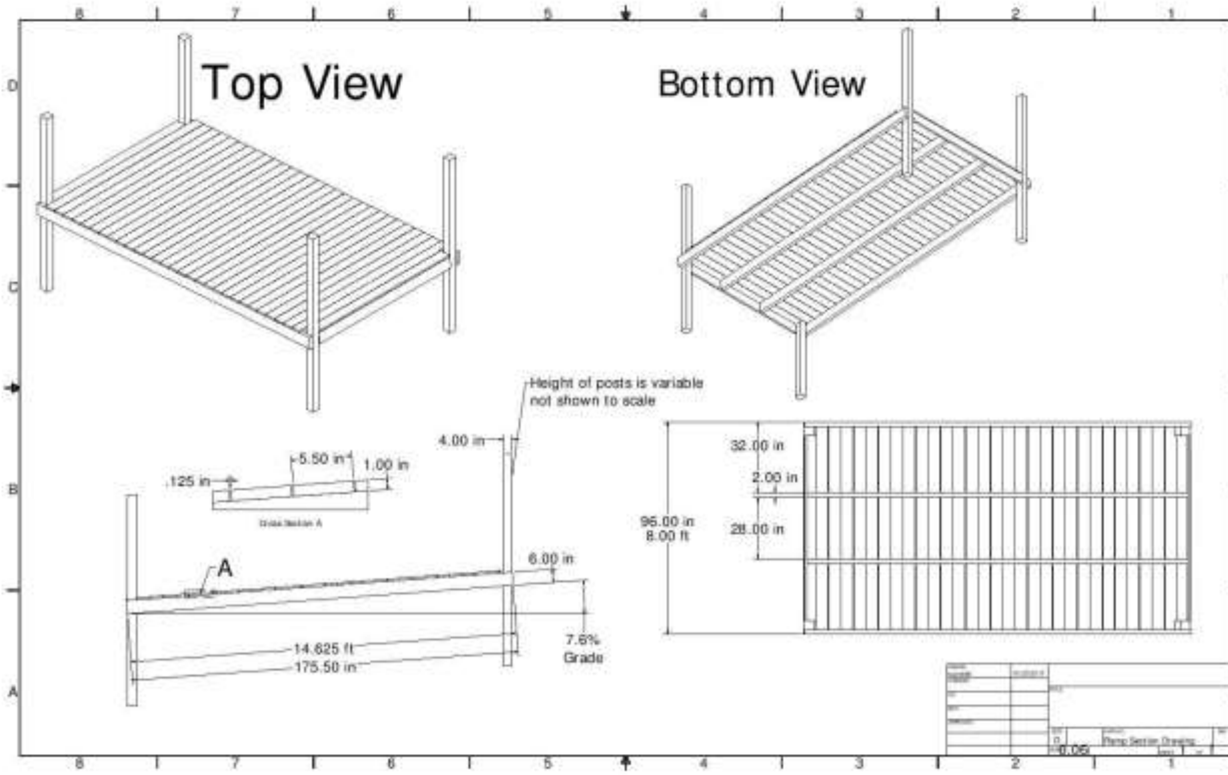


Figure 7: Top/Bottom Views

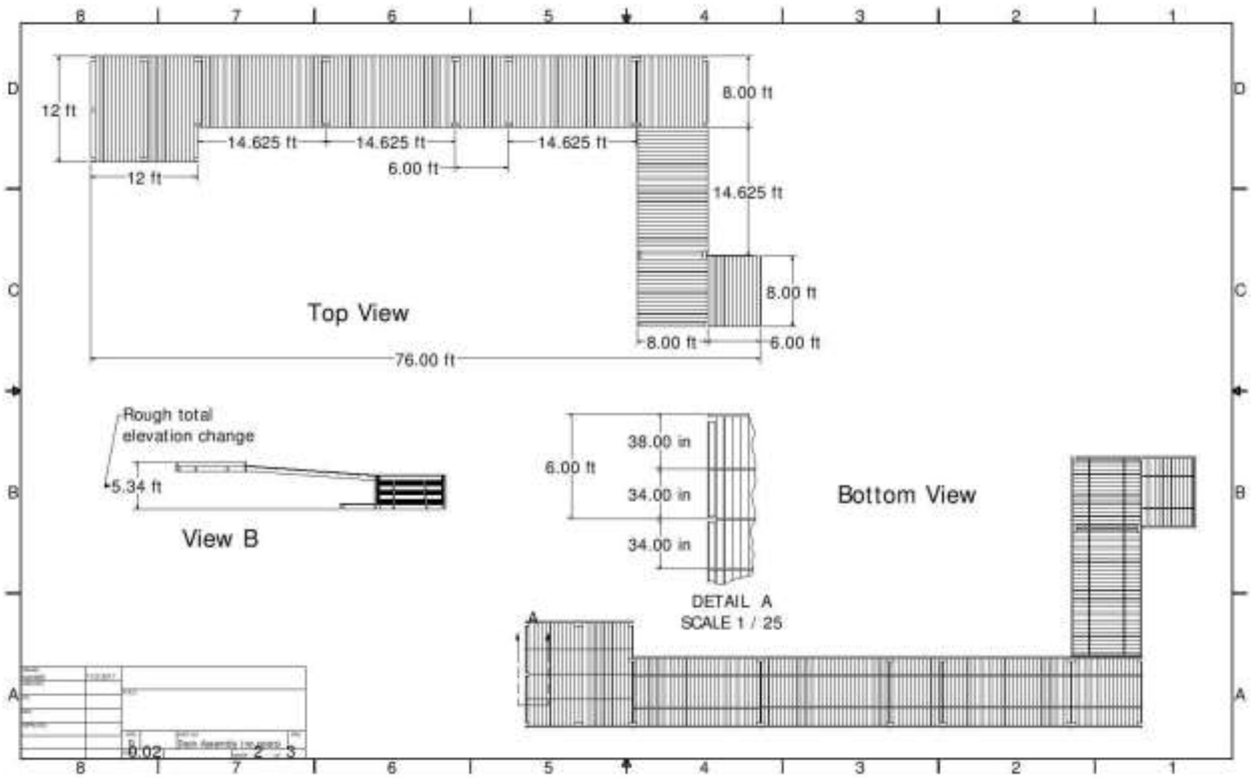


Figure 8: Ramp Slope Design

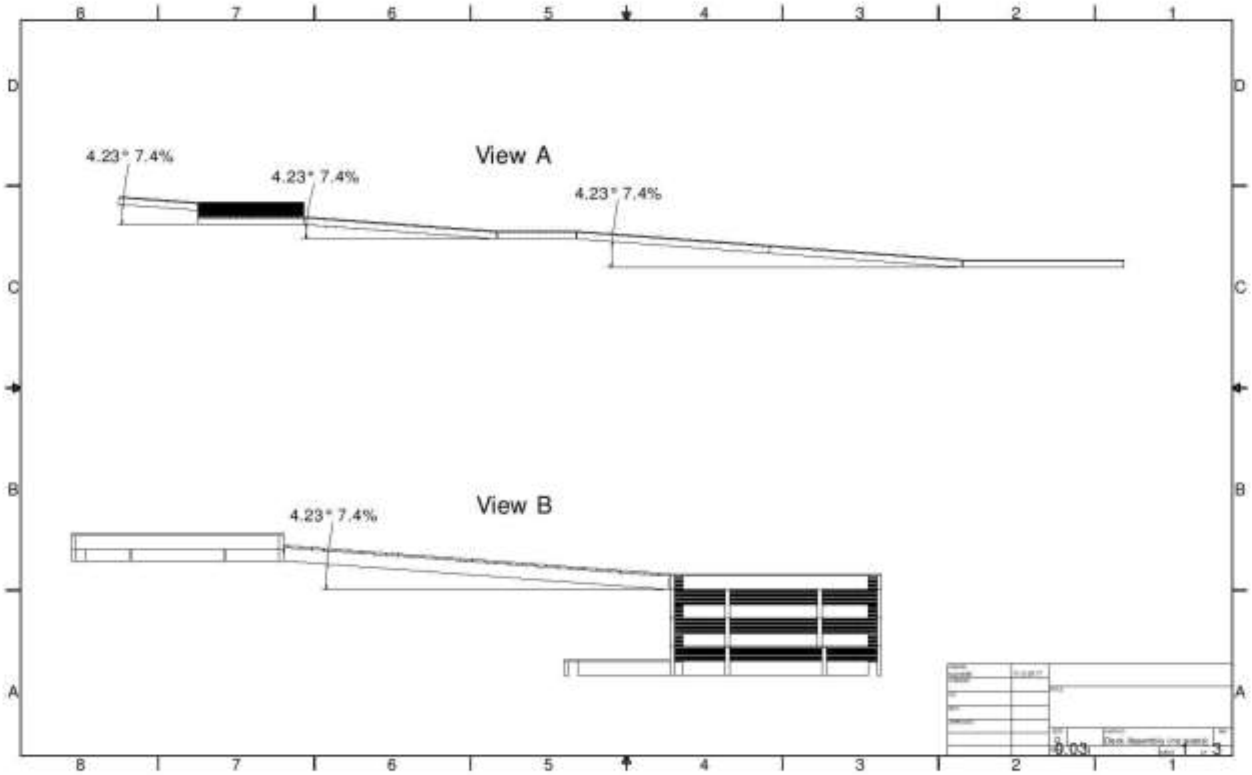


Figure 9: Full Ramp View

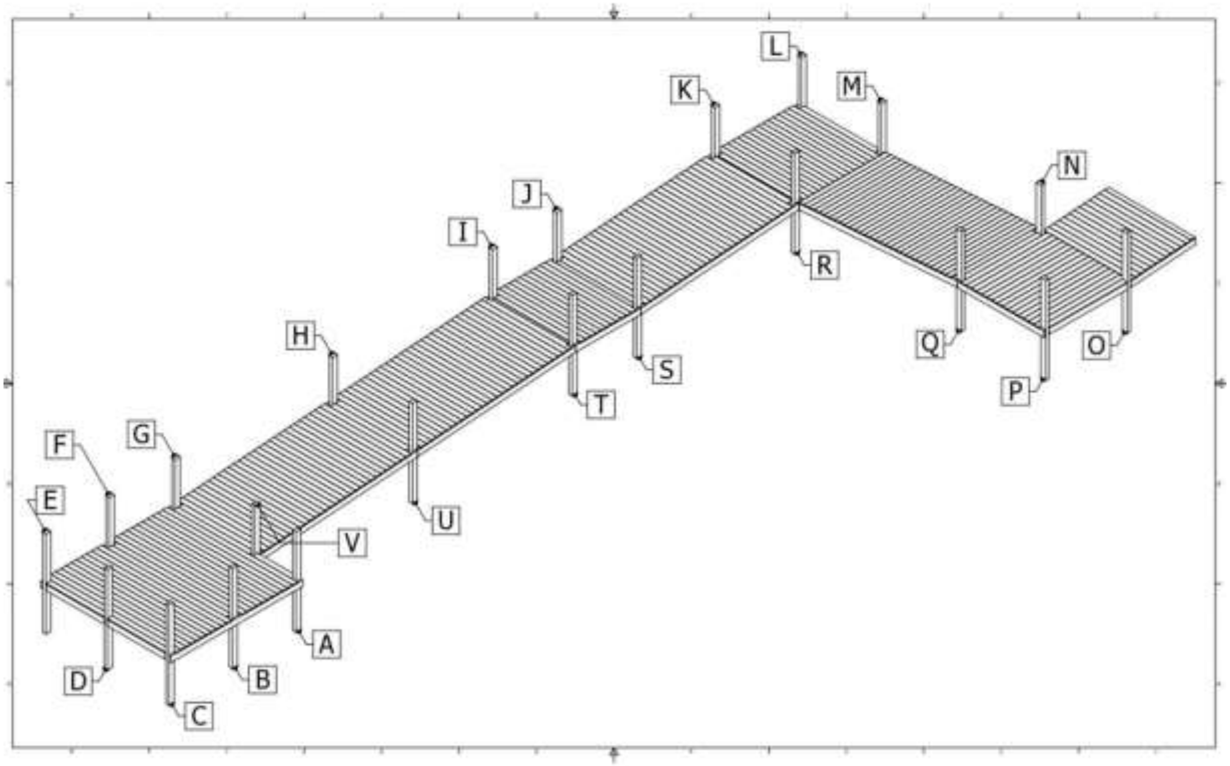


Figure 10: Greystone Footer Design

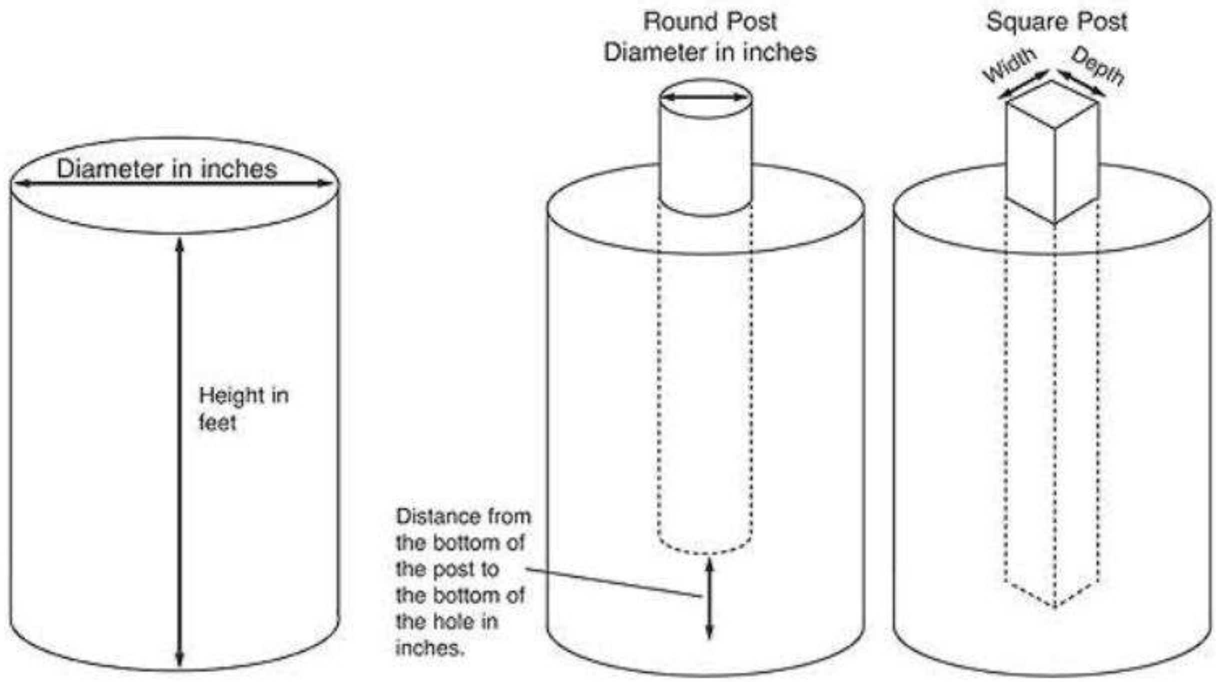


Figure 11: Splicing Technique A

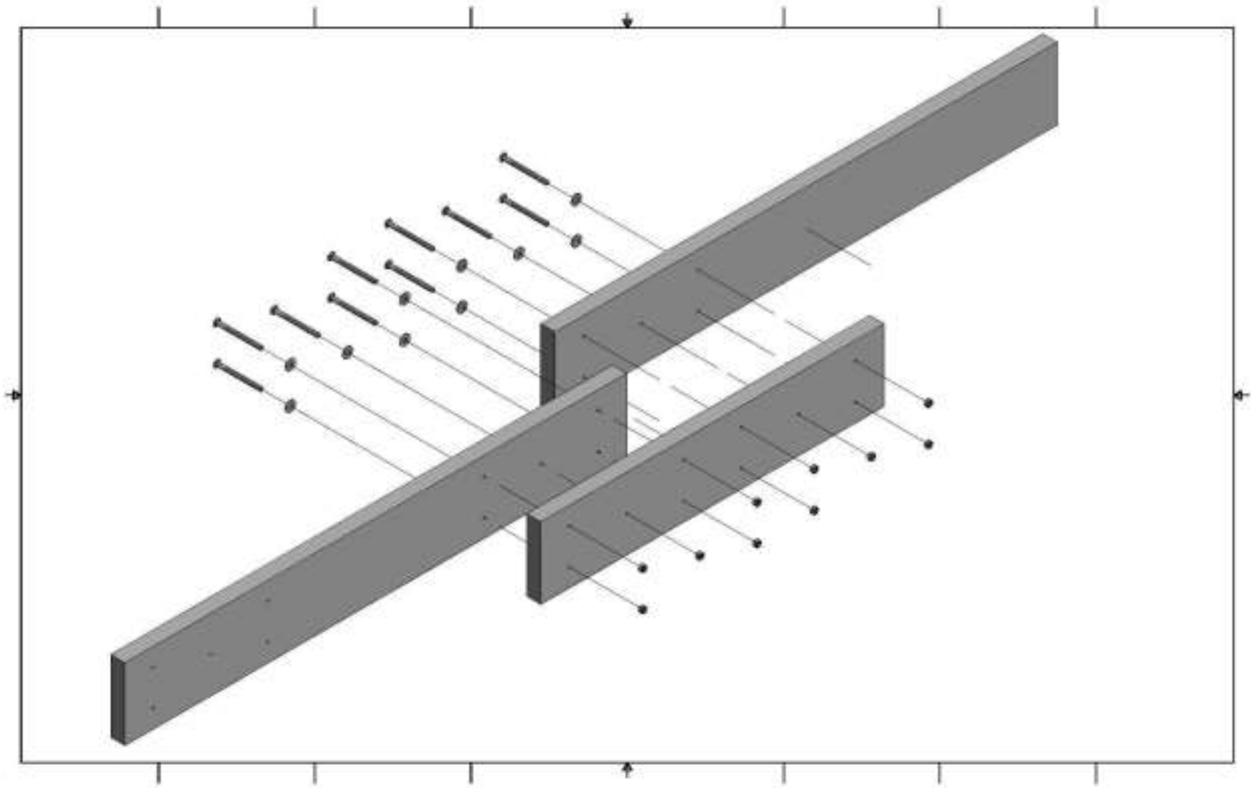


Figure 12: Splicing Technique B

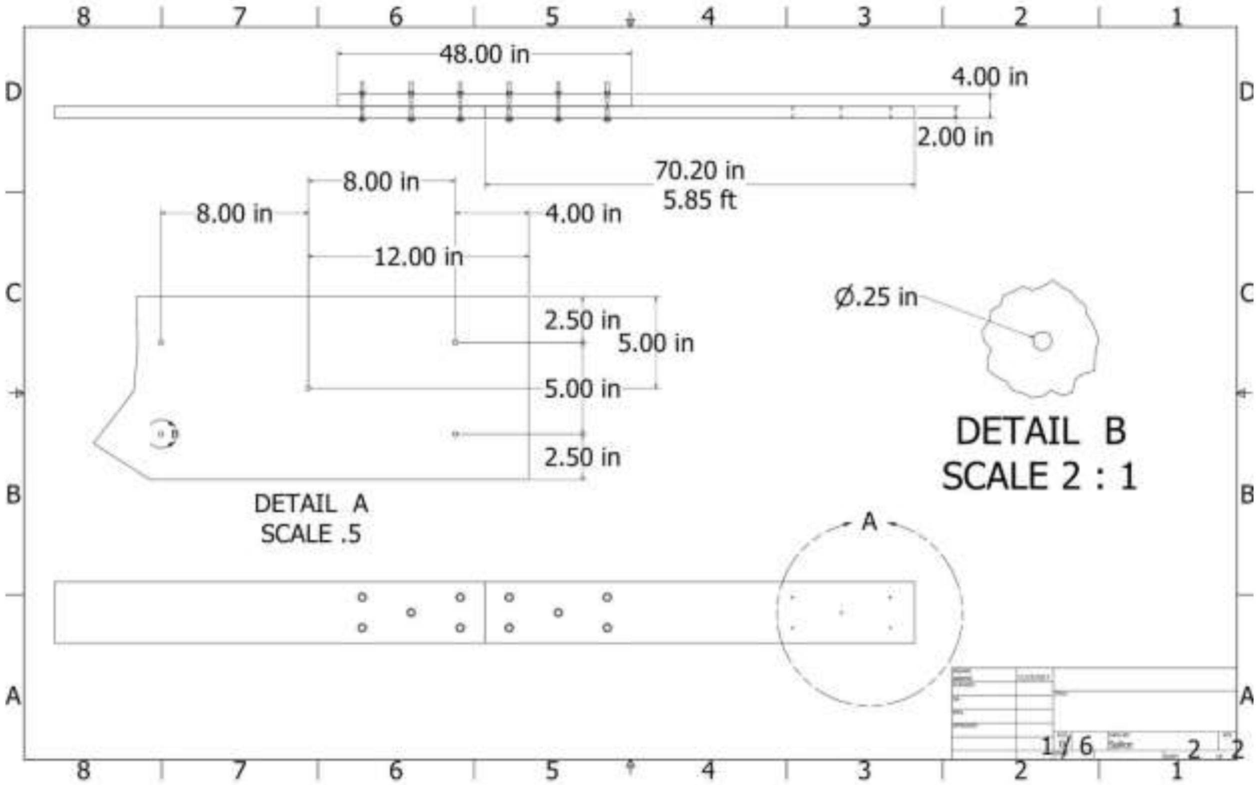


Figure 13: Displacement along Beam, Load Condition #1

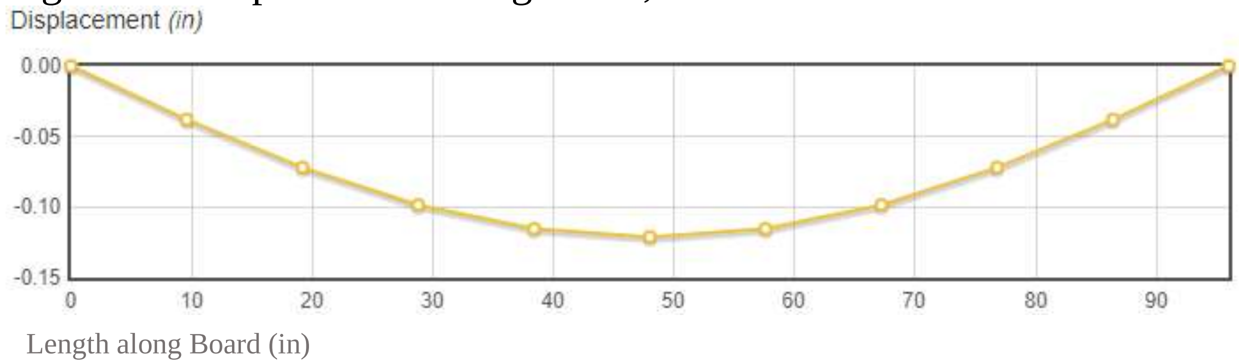


Figure 14: Moment Along Beam Graph, Load Condition #1

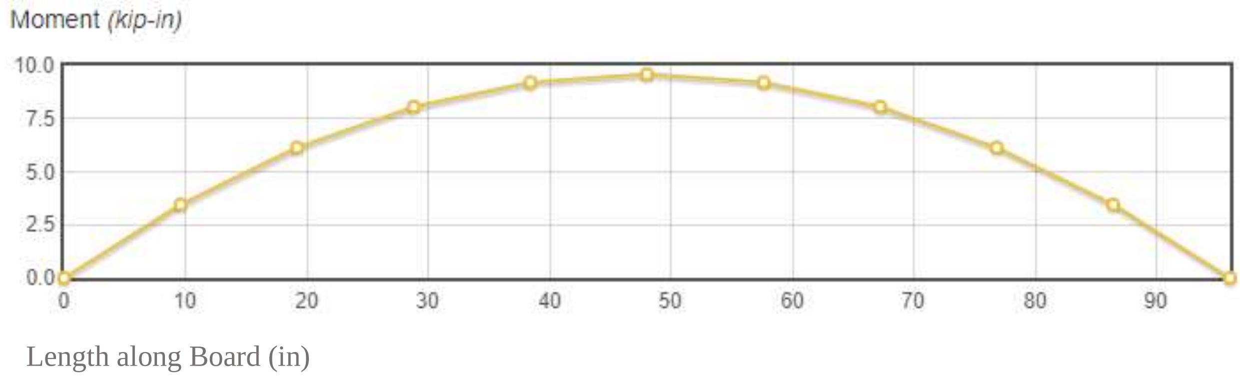


Figure 15: Slope of the Beam, Load Condition #1

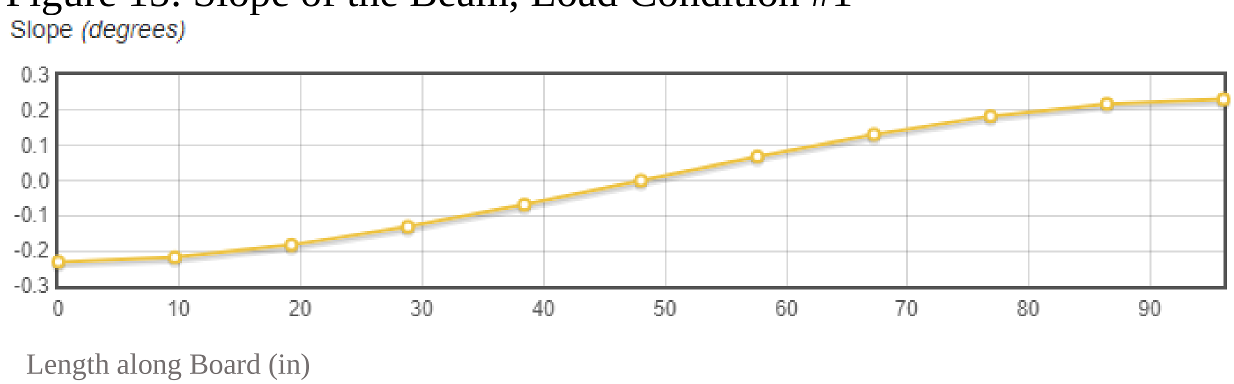


Figure 16: Shear Force along Beam, Load Condition #1

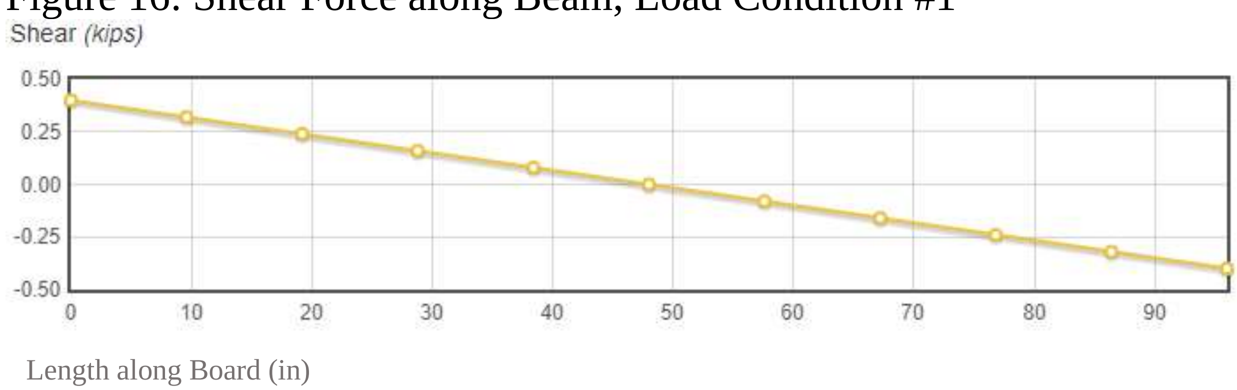
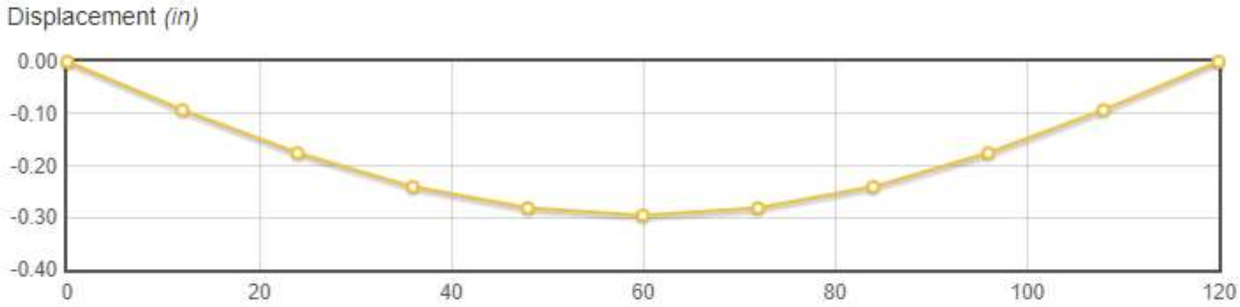
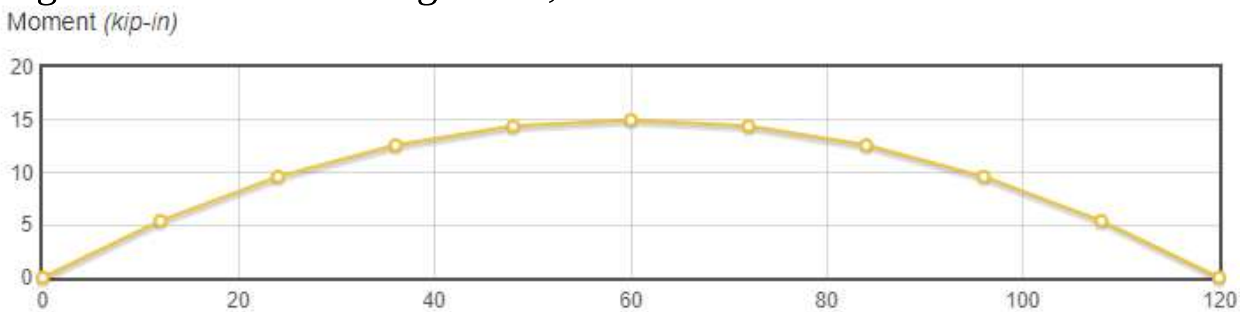


Figure 17: Displacement along Beam, Load Condition #2



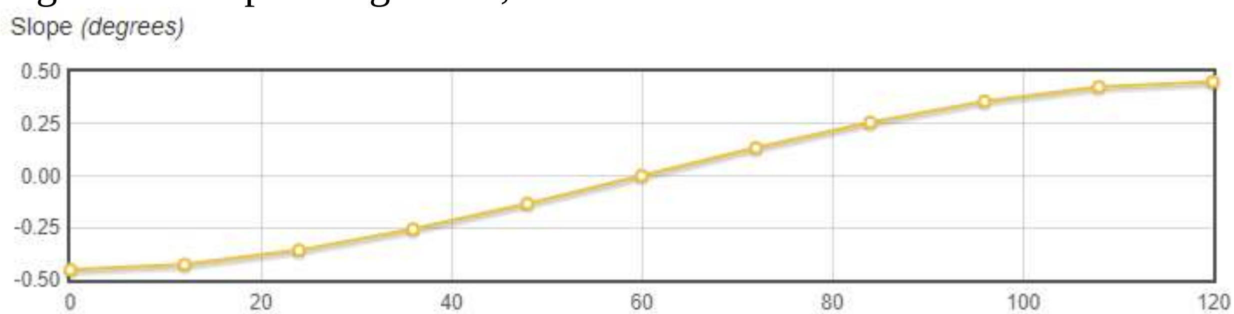
Length along Board (in)

Figure 18: Moment along Beam, Load Condition #2



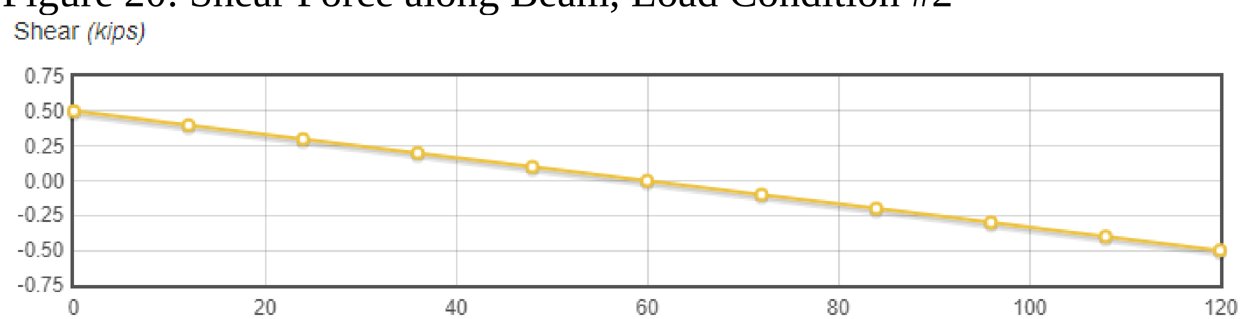
Length along Board (in)

Figure 19: Slope along Beam, Load Condition #2



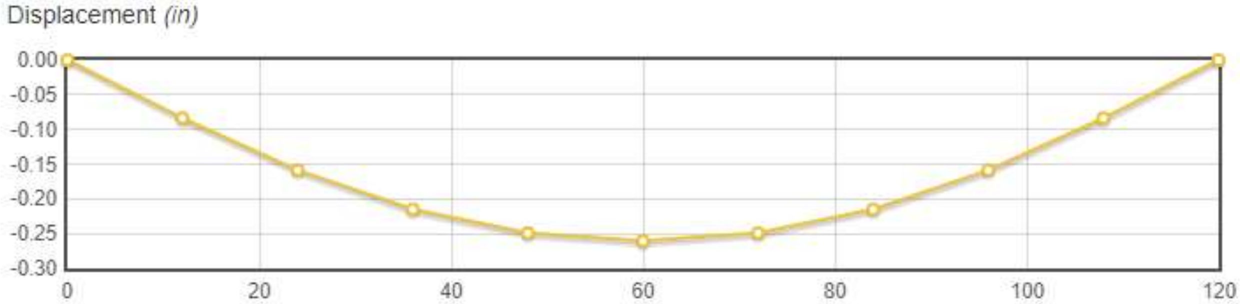
Length along Board (in)

Figure 20: Shear Force along Beam, Load Condition #2



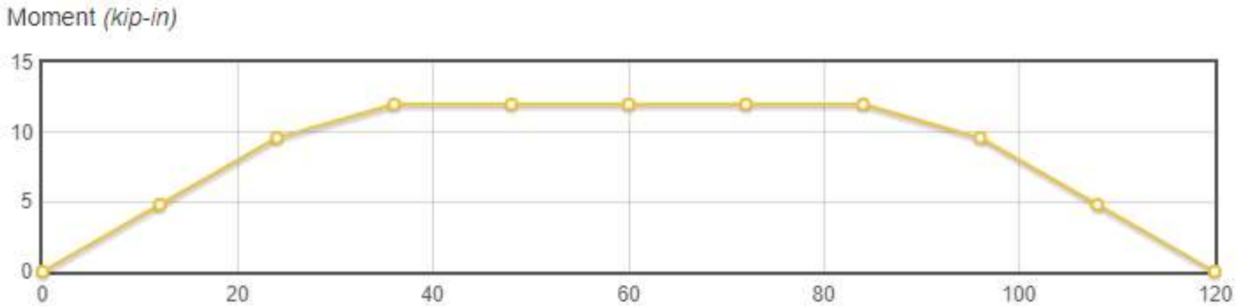
Length along Board (in)

Figure 21: Displacement along Beam, Load Condition #3



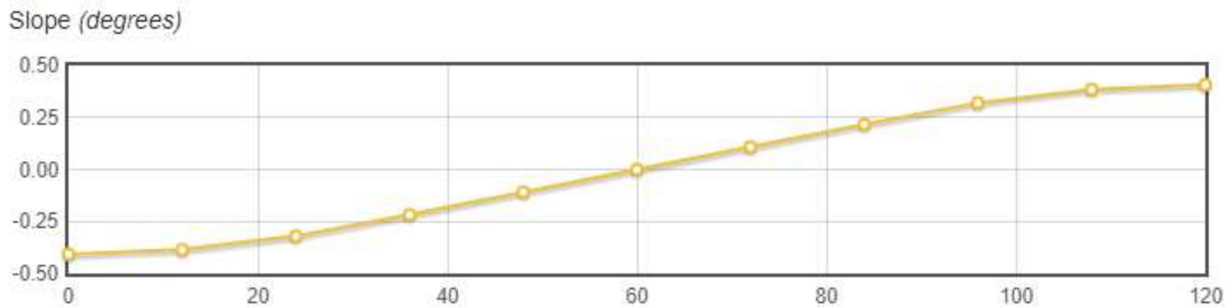
Length along Board (in)

Figure 22: Moment along Beam, Load Condition #3



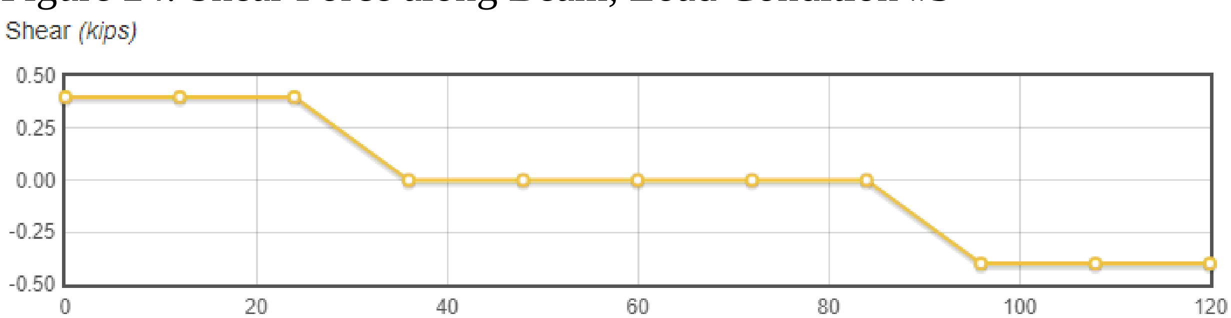
Length along Board (in)

Figure 23: Slope along Beam, Load Condition #3



Length along Board (in)

Figure 24: Shear Force along Beam, Load Condition #3



Length along Board (in)

Figure 25: Beam Model #1,2

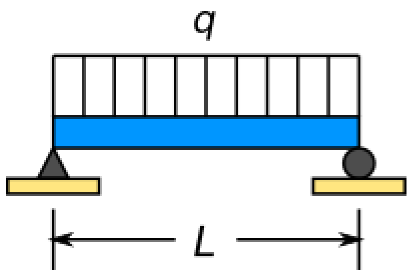


Figure 26: Beam Model #3

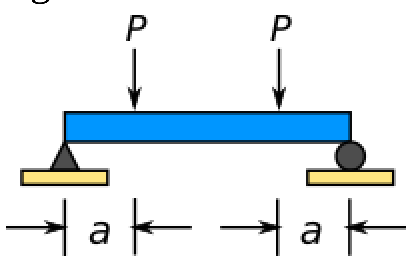


Table 1

Load Condition #1: 8 ft. Board with Uniform Distributed Load					
Moment of Inertia		Board Dimensions		Dist. Load	
M of board (lbs)	46.3	Young's Modulus (ksi)	1595.4	800	lbs
a (in)	2	L (in)	96	0.8	kips
b (in)	96	POI (in)	48	0.008333	ksi
Moment of Inertia (in^4)	35573.83				

Table 2

Load Condition #2: 12 ft. Board with Uniform Distributed Load					
Moment of Inertia		Board Dimensions		Dist. Load	
M of board (lbs)	46.3	Young's Modulus (ksi)	1595.4	800	lbs
a (in)	2	L (in)	120	0.8	kips
b (in)	120	POI (in)	60	0.00667	ksi
Moment of Inertia (in^4)	55575.43				

Table 3

Load Condition #3: 12 ft. Board with Evenly Spaced Point Loads					
Moment of Inertia		Board Dimensions		Point Loads	
M of board (lbs)	46.3	Young's Modulus (ksi)	1595.4	P1	400
a (in)	2	L (in)	120	P2	400
b (in)	120	POI (in)	60	D1	30
Moment of Inertia (in^4)	55575.43			D2	90

Table 4

Load Condition #1 Results		Location
Max Displacement (in)	0.001623	48 in
Max Shear (kips)	0.39984	0 in
Max Moment (kip-in)	95.962	48 in

Table 5

Load Condition #2 Results		Location
Max Displacement (in)	0.000254	60 in
Max Shear (kips)	0.4998	0 in
Max Moment (kip-in)	14.994	60 in

Table 6

Load Condition #3 Results		Location
Max Displacement (in)	0.000223	60 in
Max Shear (kips)	0.4	0 in
Max Moment (kip-in)	12	36 in