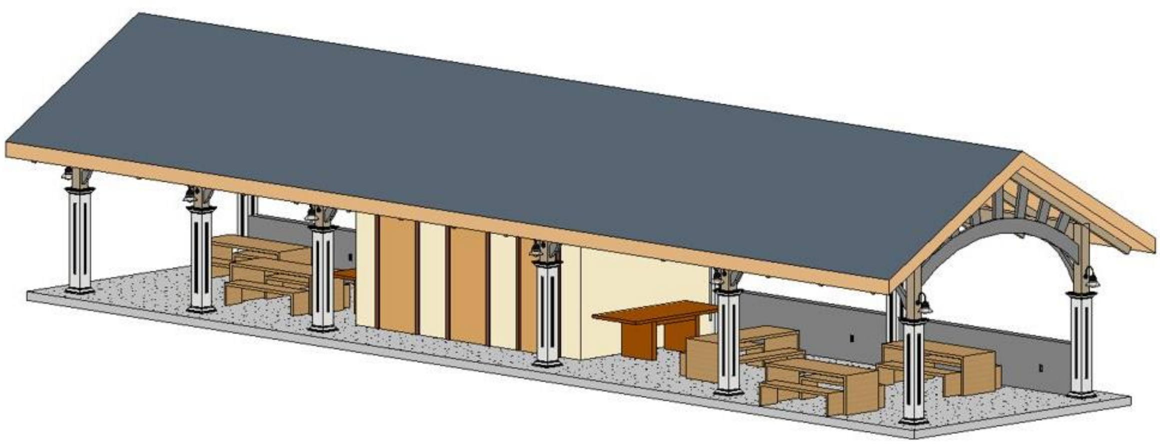
Sabula Municipal Boat Landing Project

Final Design Report

May 13th, 2022

Prepared for The City of Sabula



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Section I: Executive Summary

The city of Sabula, Iowa, is an island town situated on the Mississippi River. In recent years, the city has invested in its historic downtown to increase revenue from tourism. As part of this effort, this project has been designed to upgrade Sabula's municipal boat landing and park to create a welcoming front door to the Mississippi River for tourists and local residents to enjoy.

The current municipal boat landing faces an array of challenges that negatively impact the usability of the facility. The concrete surface of the boat ramp has degraded after years of use. The ramp also stops just two feet into the water, making it easy for trailers to get stuck in the muddy riverbed. The dock is also currently limited in size, reducing the efficiency of the site and increasing the time it takes boaters to put their boats in and out of the water. On land, the site features an outdated pavilion. The site also has limited parking options with no spaces for trailers to park. The lack of public restroom options also limits the current usability of the site for boaters.

The objective of the Sabula Municipal Boating Landing Project is to improve upon and add new amenities to the site to increase the overall usability of the site for recreational boaters. The project addresses four main areas of concern: the limitations of the current ramp and dock, the outdated pavilion with a lack of restroom facilities, the limited on-site parking options, and the lack of wayfinding resources.

Figure 1: Project Site

Our team has designed renovations and additions to resolve the areas of concern detailed above. Our recommendation for the boat ramp is to replace the concrete of the existing ramp, and to extend the length of the ramp underwater to 20 feet by anchoring a webbing of cable concrete into the end of the ramp. This solution will improve the usability of the ramp and prevent trailers from easily becoming stuck in the water.

For the boat dock, we have designed a layout featuring the same dock pieces the city currently uses at the site decreasing the initial costs of this portion of the project. This layout will increase the capacity of the dock, allowing up to five boats on the river facing side of the dock, with room for additional smaller boats along the land facing side. The sides of the dock will also be outfitted with a reflective material, increasing visibility at night. These additions to the boat dock will improve the usability of the site for boaters and provide additional space for boaters to tie off to and make use of the other site facilities or explore Sabula's downtown.

We recommend that the current pavilion be removed and replaced with a larger structure with more gathering space for visitors. While the current pavilion has no immediate structural concerns, we believe a new facility will create new opportunities for the park of Sabula's boat landing. The pavilion will include two separate areas, allowing for multiple groups to occupy the structure. Counterspace and electrical outlets will be included in the pavilion to accommodate the many groups of people using the space. Grills will also be located a short distance away from the pavilion. To improve accessibility, a sidewalk network will be created, running from the boat ramp on the north end of the property towards the pavilion on the south end.

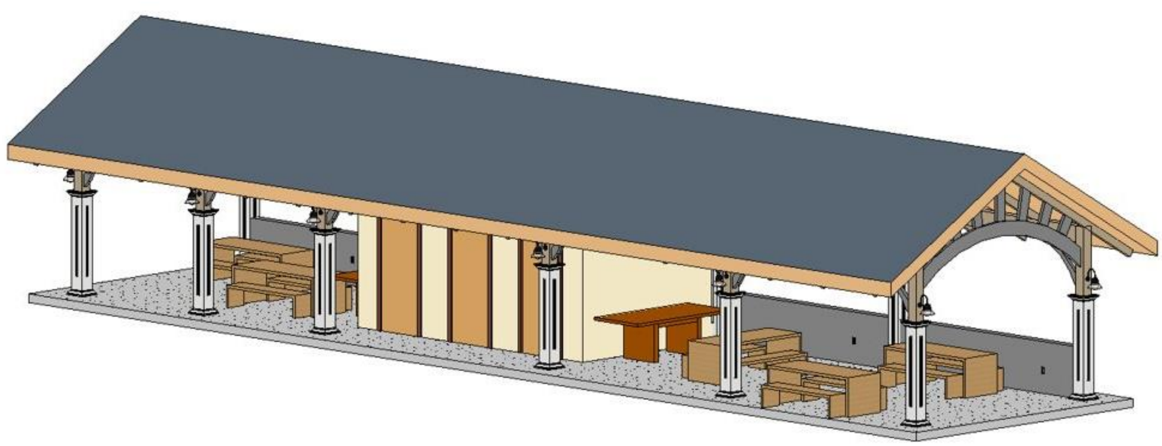

Figure 2: Pavilion and Restroom

Separating the two areas of the pavilion are the restroom facilities. The prefabricated structure will feature two single user restrooms and serve as a storm shelter capable of withstanding high winds up to 250 mph. While in use as a storm shelter, each restroom will have an expected capacity of 12 people. The dual use of this space will provide a much-needed resource for boaters and visitors to the site.

Improvements to the on-site parking options will also benefit boaters and visitors to the site. Temporary trailer parking will be positioned near the boat ramp, creating dedicated space for queued boaters to ensure the street remains accessible for drivers. In addition, accessible parking will be provided near the pavilion, further improving the functionality of the site.

For those visiting from out of town, the inclusion of wayfinding resources will help navigate them throughout the city of Sabula. A wayfinding board will be located at the corner of the boat ramp and River Street, providing directions to long-term trailer parking and to several restaurants and amenities around town. Extra space on the wayfinding board could be used to promote events and activities being held at the boat landing's park.

We have broken down the expected costs for the main areas of design. The estimated cost of the boat ramp is $48,300. The estimated cost of the dock is $24,800. The expected cost of the pavilion is $153,500. The expected cost of the restroom facilities is $78,400. The anticipated costs for all other site features—including sidewalks and landscaping—total to $52,000. Upon completion of all project elements, the total estimated cost comes to $357,000.

Most of the project's elements discussed are independent of each other and can be developed as funds are available. However, if the restrooms are developed prior to the pavilion, they will need to be located north of the existing pavilion. Once the new pavilion is installed, a partition wall can be added in place of the restrooms to maintain the two separate spaces of the original design.

As a lower cost option, it is possible to focus on the renovations to the boat ramp and the installation of the restroom and storm shelter facility. Both project elements address the more immediate concerns of the site that were previously addressed. Upon completion of the lower cost option, the total expected cost comes to $133,200.

Section II: Organization Qualifications and Experience

Organization and Design Team Description

The project was completed by a team of senior civil engineering students at the University of Iowa in the capstone design class. Isaac Mize specializes in structures, Larry Phan specializes in architecture, and Caleb Wright specializes in structures. The project was split into four main pieces, the dock and ramp, pavilion and restrooms, parking, and wayfinding resources. Working on the dock, ramp, and wayfinding resources was Isaac Mize. The parking was worked on by Caleb Wright. Finally, the Pavilion and restrooms were completed by Larry Phan with some assistance on the restrooms by Caleb Wright.

Section III: Design Services

Project Scope

The main objective of the Sabula Municipal Boat Landing Project is to improve the accessibility and amenities of the project site—attracting boaters and tourists to the city. Four main areas of design were the focus of development, improving the capacity and accessibility of the ramp and dock, developing an eye-catching pavilion with a restroom facility for visitors capable of acting as a storm shelter during severe weather, increasing the scope of the on-site parking area to allow for temporary boat trailer parking, and providing wayfinding resources for out-of-town boaters and visitors. Listed below are the desirables the client would like to see implemented.

Table 1: Client Desirables

Desireables		
Dock	General	Pavilion
Easier dock access	Playground stays	Rented space
Public access	Pavilion altered	Access point near pavilion to dock
Boat capacity of 3 to 4	Addition of restrooms	
Removable pieces	Wayfinding on site	
no wood	Handicap accessible	
Long lasting materials	Keep tree if possible	
Lighting	Public parking options	

The existing dock is limited in size and capacity, reducing the efficiency and usability of the site. By adding additional dock pieces, more boats will be able to tie off at the site, allowing more boaters to stop at the site and utilize its facilities.

The concrete boat ramp will be removed and replaced. In order to extend the ramp further into the water, a cable concrete system will be placed on the riverbed. This system will also be anchored into the end of the concrete ramp. This easy to construct option makes it easier for boaters to back their trailers into the river without getting stuff in the riverbed.

To improve the navigability of the site, a sidewalk system will extend from the dock's gangway, running parallel to the boat ramp, up to River Street. It will then run parallel to River Street towards the pavilion and parking spaces.

The redesigned pavilion structure focuses on creating additional space for visitors and provided amenities to accommodate a variety of events. The restroom facilities divide up the space into two separate areas, making it easier for multiple groups to use the pavilion simultaneously. Electric outlets and counter space also help accommodate events such as family gatherings or cookouts. A knee wall is also included around a portion of the exterior to help contain the space of the pavilion.

The restroom facilities are situated directly underneath the pavilion, providing a convenient location for boaters and visitors. The building features two single user restrooms and a utility closet. The structure also doubles as a storm shelter, providing a safe location for boaters during severe weather. The restrooms are a prefabricated design from Easi-Set Worldwide, and will accommodate wind speeds up to 250 mph.

Work Plan

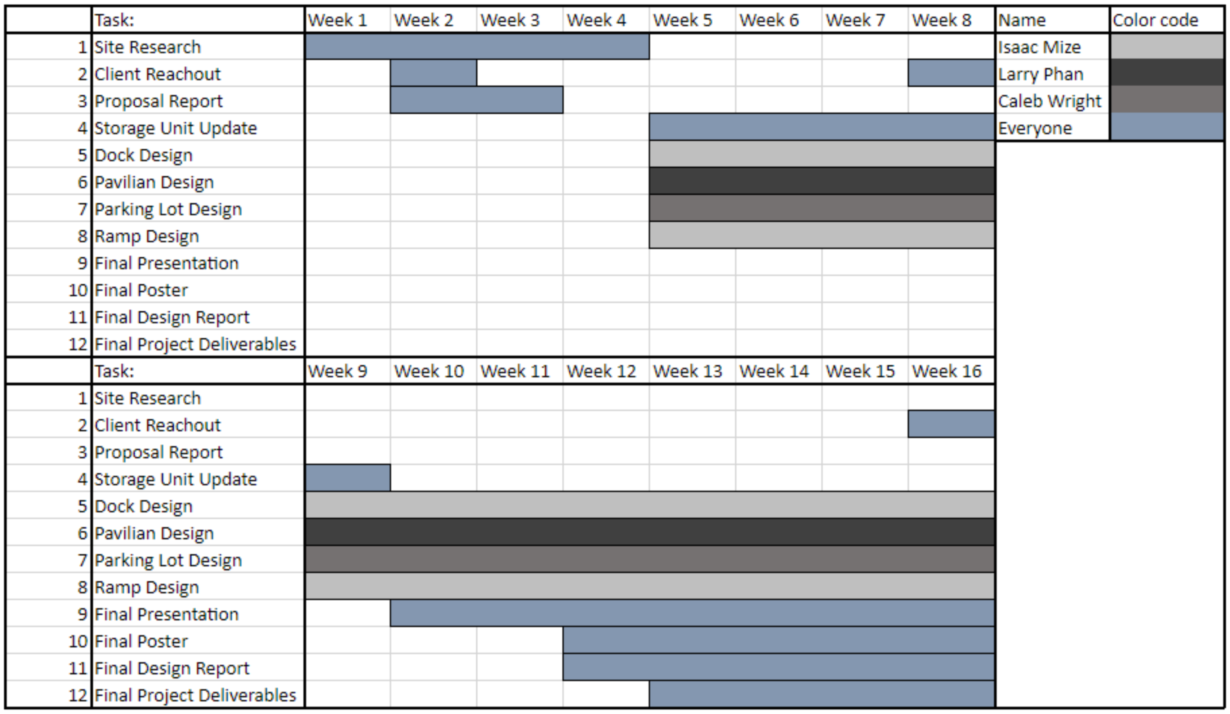

Figure 3: Gantt Chart of Work Schedule

Section IV: Constraints, Challenges, and Impacts

Constraints

Some of the constraints for the project ranged from specifications made by the client to those created by the environment and site layout. Another main constraint of every project is the deadlines for tasks. Deadlines must be met to keep both sides of the project in check and on schedule.

The main constraints given by the client are as follows: limited budget and having the playground to the south remain untouched. Of the constraints given by the client, arguably the most important is the limited budget. Due to the small size of the city, a project that is inexpensive is required to make sure the project can be completed.

Constraints tied to the location of the proposed site involve the total size of the site and the location of the site relative to the floodplain. The footprint of the site doesn't allow for much width to be added due to the shared boundary with the river. However, the site does provide ample space to stretch out the designs chosen and make up for the lost width. The site is located 1ft above the 100-year floodplain. Originally it was assumed that there would be extra building constraints because the site is located just off the river, and it was unsure where it sat relative to the floodplain. However, since the site is already 1 ft above the 100-year floodplain there should not be many constraints related to this.

Challenges

Along with constraints, the project has its fair share of challenges that come with it. As stated above in the constraints section, the limitations of a small city include a smaller budget. This is a major challenge for the project considering the requested changes to the boat ramp and parking lot. Both aspects of this design will require a lot of concrete which will account for a large portion of the cost. To combat this, we investigated adding an attached restroom facility which doubles as a safe room. If the restroom can meet the requirements of a safe room, part of the cost could potentially be funded by a hazard mitigation grant. Another way to bring the cost down was the implementation of a phase plan for the dock. The dock was presented in full and split into separate sections with multiple phases. The idea behind this was to provide the client with a way of stretching the dock expansion over a longer period, to allow for the client to choose how many pieces to add whenever they are needed.

A challenge related to the project location is the availability of space east to west on the project site. The location has plenty of space running north – south but doesn't provide much width. Because of this, the ramp slope is hard to adjust and will have to remain somewhat steep. This makes providing ADA access somewhat tricky. In order to combat this, the location of the dock to the north of the town can be pointed out for those in need of an accessible launch. This would tie into a wayfinding map for the project site.

One of the other challenges introduced to the project is how to maintain access along the road during the construction phase of the project. The road is one-way which further complicates things; however, it is a low traffic road and has a very large width to provide plenty of room for vehicles to pass by. If needed, the space to the north side of the existing pavilion can be used as a staging ground for the construction equipment rather than the road. It was stated by the client that the bar across the street utilizes this parking space for their business, so it would be beneficial to keep those parking spots open for public use while construction is happening.

Societal Impact within the Community and/or State of Iowa

This project will add to the community's enjoyment of the Mississippi River. The changes made by the project site will attract more people to Sabula. With the use of signs facing the river, it will provide those passing an opportunity to explore Sabula on a break. This should in turn bring in additional revenue for the community and local businesses.

Section V: Alternative Solutions

Throughout the planning phase of the project, several design alternatives were considered for each of the design objectives. While some of these designs were ultimately scrapped, others were used as a building block to develop the final designs detailed in the following section.

Restroom Facility

One of the main design objectives of the project is the addition of restroom facilities to the site. Several designs were considered that came with their own sets of features and limitations. The first design we conceptualized was the renovation of the existing city owned storage building, located just across the street from the project site. The building already included utilities for electrical and water, making it an excellent candidate for the location of the restrooms. The facility would feature two single user restrooms, as well as a welcome center and a storage room for city use.

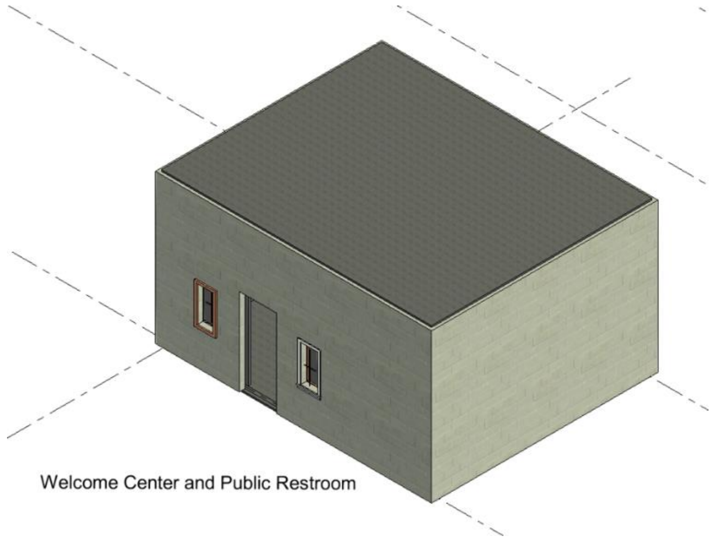

Figure 4: Restroom Alternative 1: Storage Room Renovation

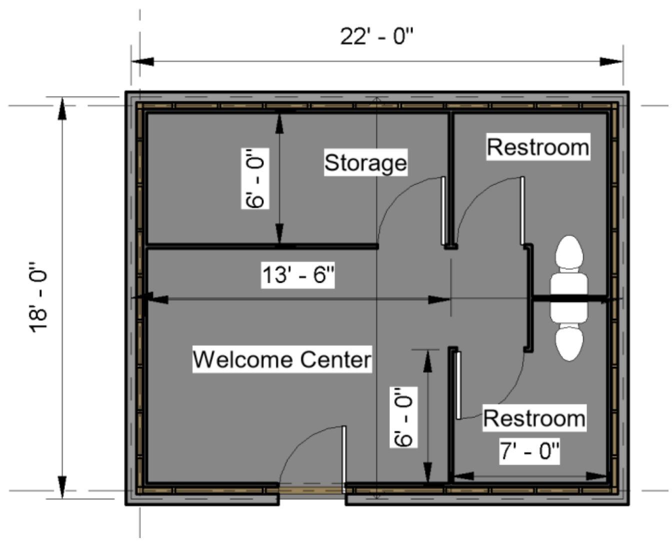

Figure 5: Restroom Alternative 1: Storage Room Renovation Floor Plan

While this option made good use of an existing structure and the utilities it included, its location across the road from the site would have been less convenient for boaters and other visitors to access. One other challenge with this design would have been building within the existing structure and getting it to the storm shelter requirements. To prioritize safety and user accessibility, we decided against this option for our final design.

The second design option for the restroom facility involved removing the existing storage facility and replacing it with an entirely new structure. By building from scratch, we would be able to increase the strength of the building to accommodate higher wind loads, allowing the restrooms to function as a saferoom during severe weather events. The facility would also feature two single user restrooms, a welcome center, and a storage room for city use.

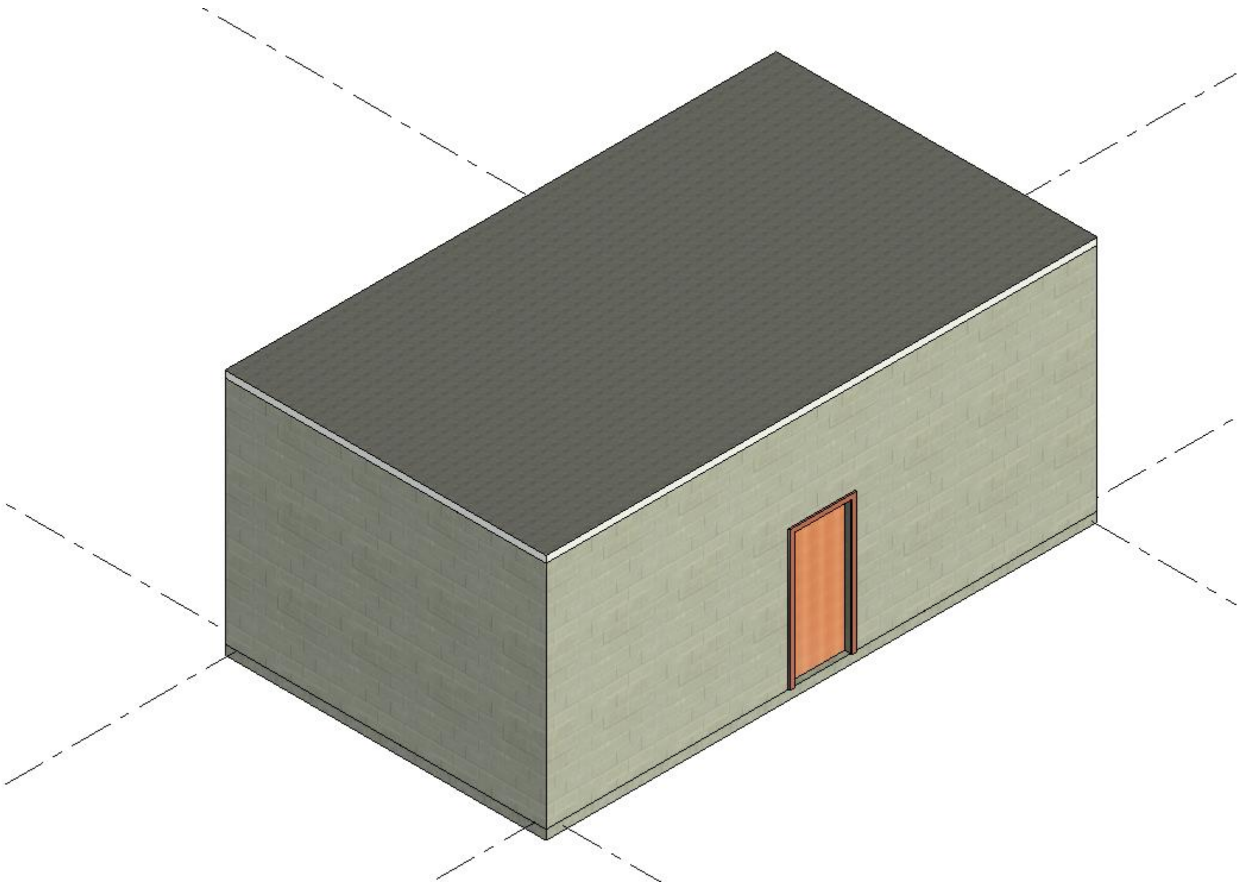

Figure 6: Restroom Alternative 2: Storage Room Replacement

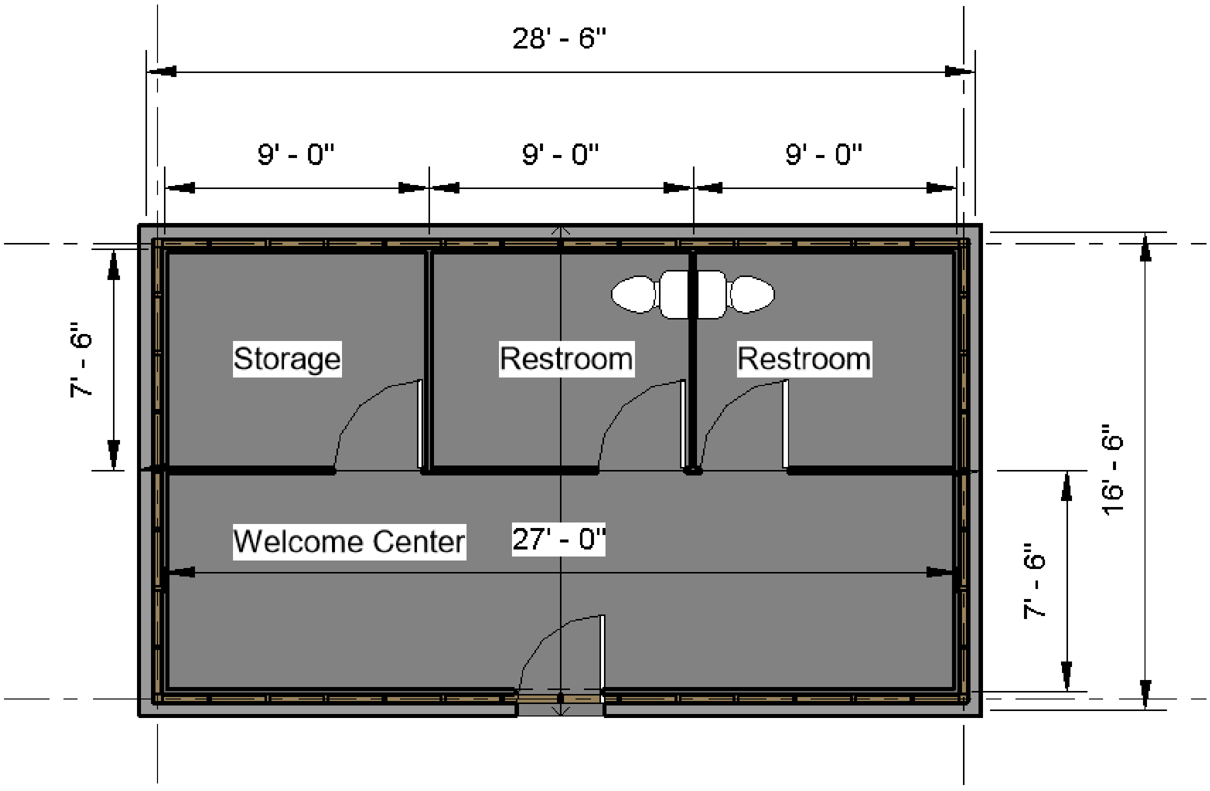

Figure 7: Restroom Alternative 2: Storage Room Replacement Floor Plan

While this concept allowed us to implement additional features such as the saferoom, it ultimately suffered the same flaw as the previous option: not being in an ideal location for visitors. While this design was not selected, the saferoom concepts would be carried over into the final design.

The final design alternative we considered was incorporating the restrooms directly into the pavilion design. This restroom design features two single user restrooms and is conveniently located for visitors at the pavilion and playground.

Figure 8: Final Restroom Design

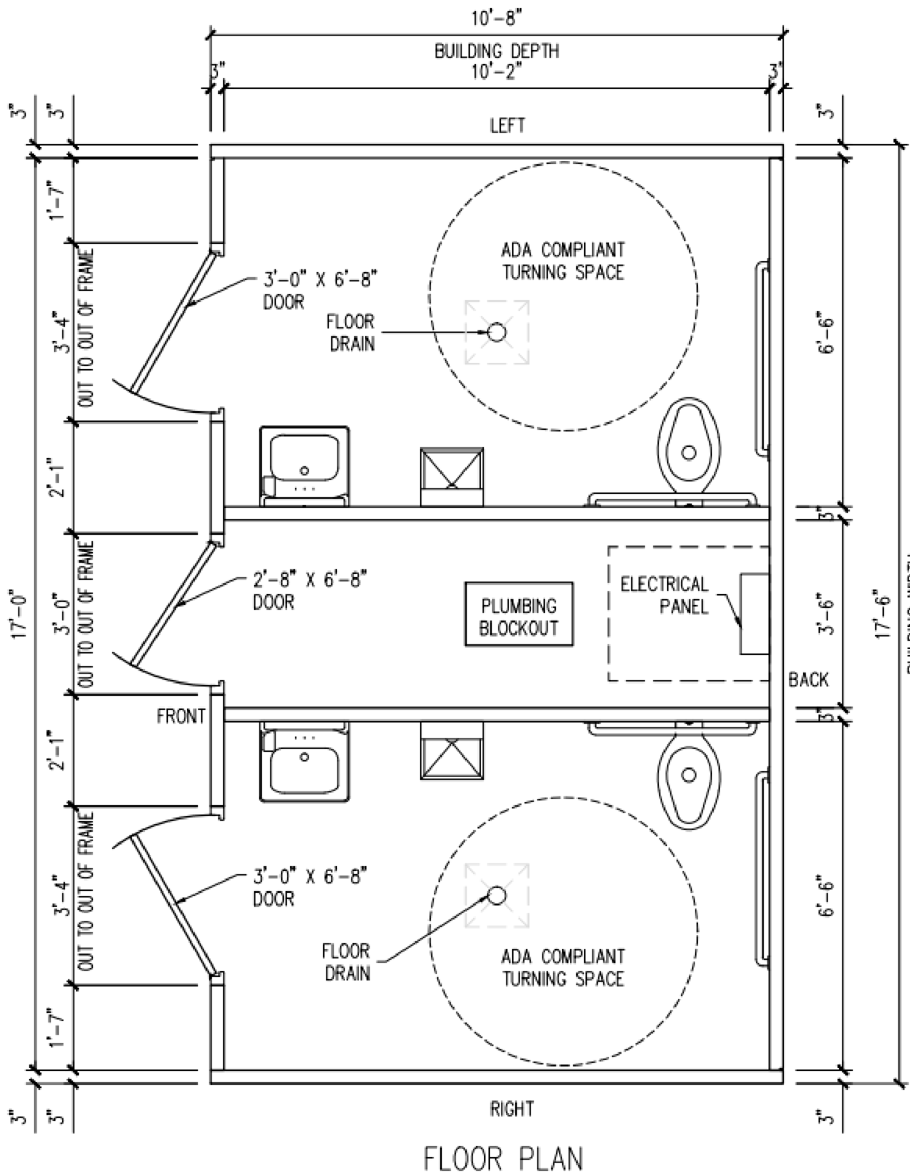

Figure 9: Final Restroom Floor Plan

This design solved the main design flaw of the previous two options. However, it is not without its drawbacks. While the current pavilion has utilities for electricity, it does not currently have plumbing, requiring additional construction underneath River Street. In addition, the facility does not include an indoor welcome center.

Pavilion Design

Multiple design options were explored for the pavilion, including original concepts, renovations, and amenities. The first design is an original construction, featuring a modern design the resembles the waves of the river. The design also incorporates the roof to naturally gather water into a gutter and disperse it into nearby greenery, potentially a small garden. The roofing would be limited in structure, with a minimalist vision, having its support within the roof itself instead of using beams and joists.

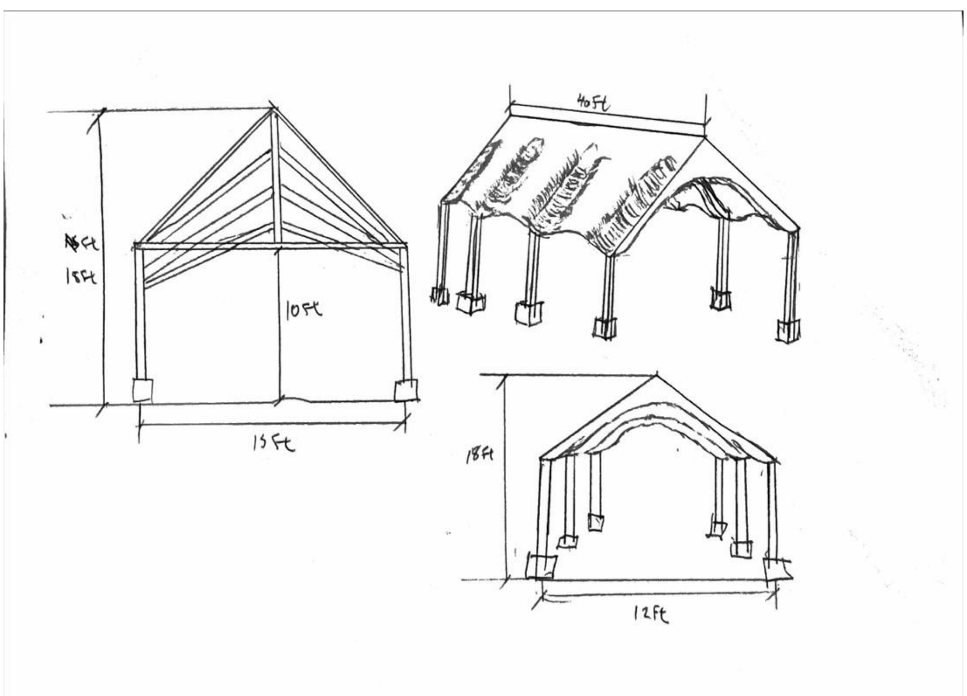

Figure 10: Pavilion Alternative 1

The final design alternative is a rebuild of the existing pavilion. This would be the most cost-effective option and would focus on incorporating multiple amenities, such as including the bathroom within the pavilion, which will double as a storm shelter. The addition of knee walls will help keep small children from wandering to the riverbank and provide some protection from winds off the river.

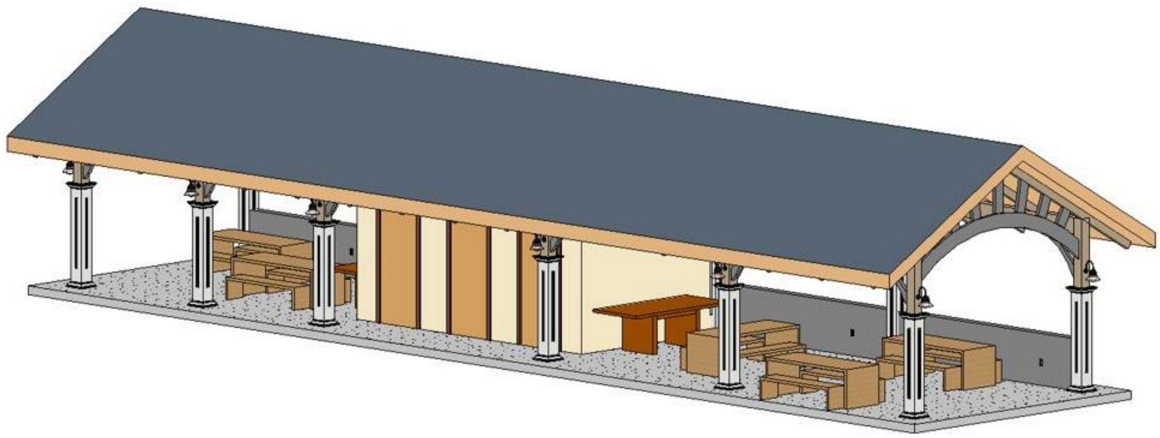

Figure 11: Architectural Render of Final Pavilion Design

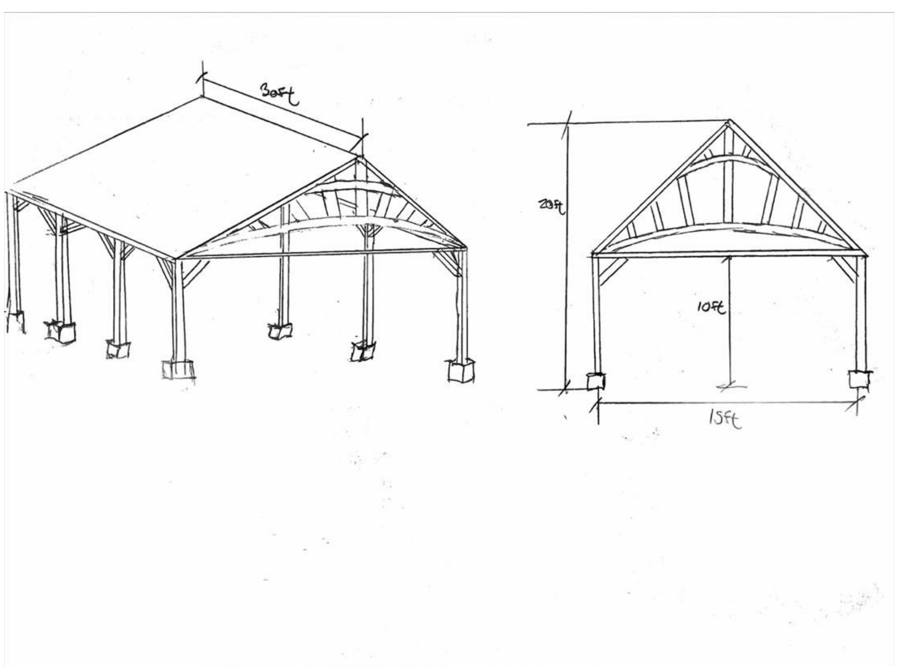

Figure 12: Pavilion Alternative 2

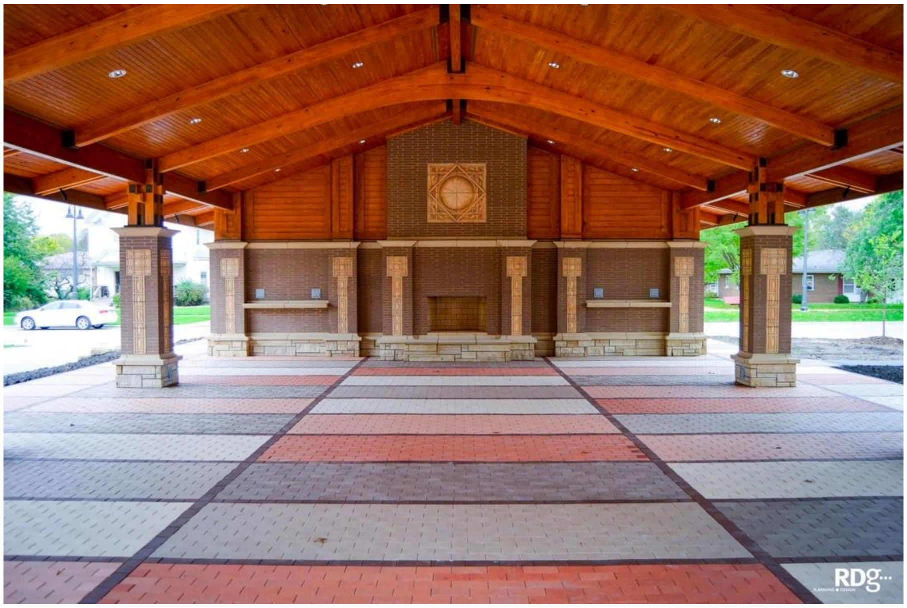

Figure 13: Pavilion Reference Image

Figure 14: Knee Wall Example

Dock and Ramp Design

The city of Sabula recently purchased two floating docks from Hewitt Machine and Manufacturing Inc. Due to the modular nature of these docks, we decided the most simple and cost-effective approach was to build upon what the city is already using. The design options for the dock focused on the extension of the current facility and the order that new additions should be completed to maximize the use of city funding.

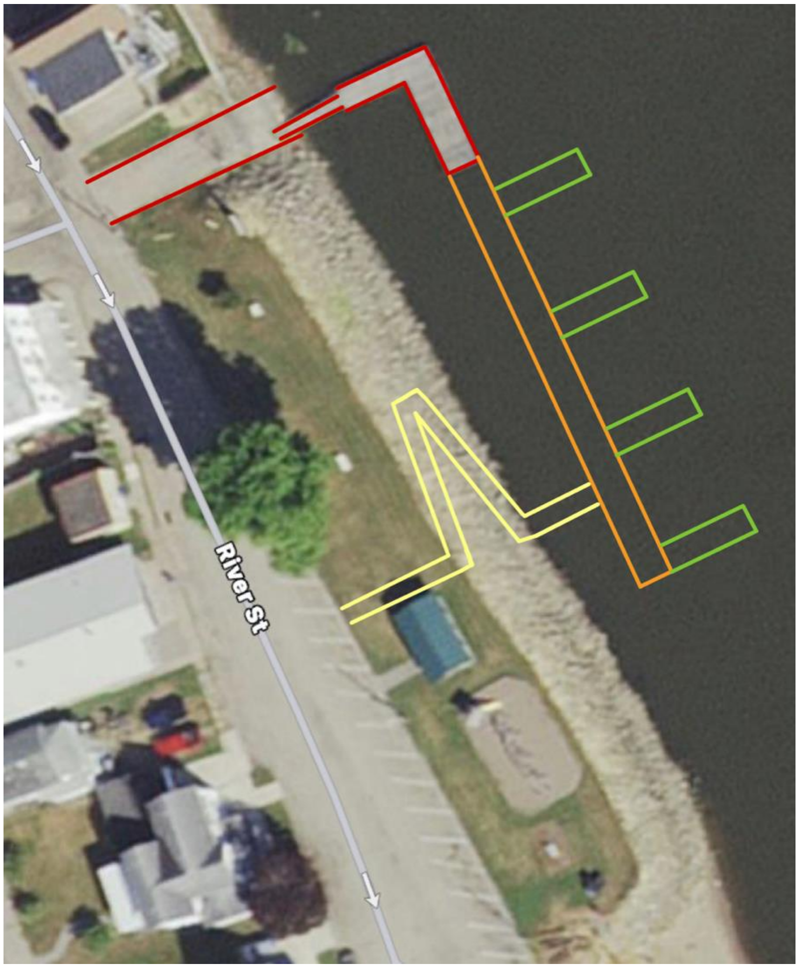

Figure 15: Dock and Ramp Alternative 1

Building off the original dock outlined in red, the main body of the new dock—outlined in orange—would extend downstream parallel to the shoreline. This allows us to increase the dock's boater capacity while also building downstream towards the pavilion and the secondary access point, outlined in yellow. Finally, if the need for further capacity arises, additional sections can be installed running perpendicular to the main dock. This design layout is very flexible and can be adjusted depending on demand and weather conditions.

The largest drawback with this layout is the overall scale of the project. In order to complete each phase, over 20 dock pieces would be required. At this size, the dock far exceeds the foreseeable dock capacity requirements for the site.

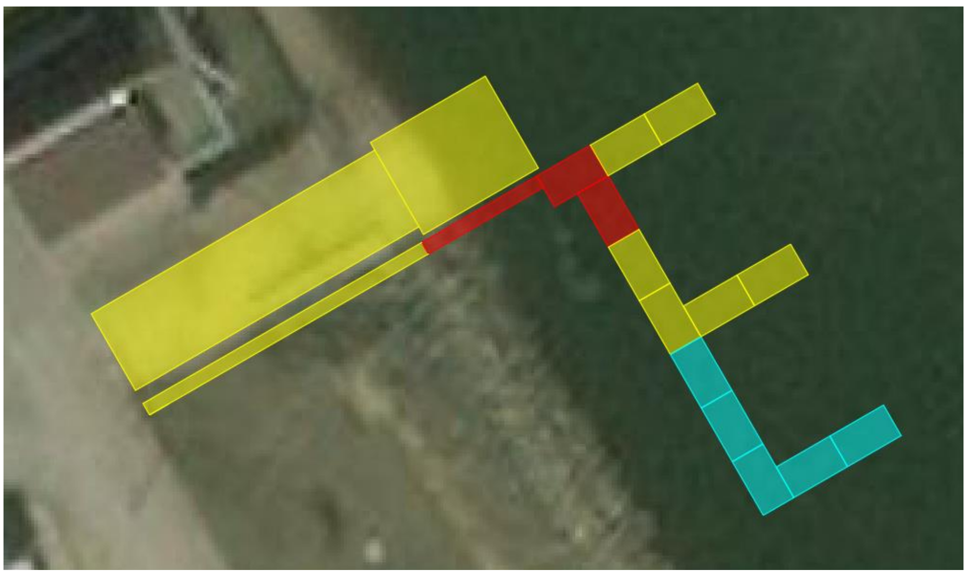

Figure 16: Dock and Ramp Final Design

Reassessing the previous option led us to reduce the overall size of the dock in order to more closely match the expected capacity of three or four boats. The river facing side of the dock while have a capacity of five boats, with the end dock capable of accommodating larger boats.

This option is significantly more cost effective for the city of Sabula and better fits the needs of the site. Should the dock's capacity become a limitation in the future, additional dock pieces can always be added further downstream in a similar pattern. The plan does remove the secondary access point planned in the original phase plan, but an additional sidewalk network on land will still allow boaters to move between the docks and pavilion facilities.

On-site Parking

Several parking alternatives were also developed with the objective of increasing parking capacity for visitors. In these alternatives, temporary trailer parking spots were included north of the car parking.

Parking design 1 is a redesign of alternatives explored during the preliminary phase. The on street parking stays relatively similar to the current parking conditions. Accessible parking options were added to the location. The one main addition that this design adds is trailer parking next to the boat ramp. Enough space was left for two trailers to park on the site. This idea was eventually scrapped as the trailer parking just did not seem feasible for the location and would be very hard for the community to use.

Figure 17: Parking Design 1

The second and final design shown below is an improvement of design 1. ADA parking was added to the location as well as a sidewalk up to the boat ramp. The temporary trailer parking provides enough space to fit two trailers comfortably. Some space is left between the trailer parking and car parking. This provides an opportunity to add an additional parking space or expand the parking stall widths.

Figure 18: Parking Design 2

Section VI: Final Design Details

Pavilion

The ultimate recommendation for the pavilion was to incorporate a bathroom facility within the pavilion to have easy access without the need to risk crossing the road. This new design will feature a redesigned pavilion with a bathroom facility located underneath. The total area will take up an approximate 75' x 15' of land with length of the structure run North to South. The construction of the pavilion will be primarily made of up of Southern Pine No.1 as the wood is both strong and cost effective for this project.

The bathroom will be a precast structure, with the predetermined dimensions of 10'-8" x 17'-6". It will serve two symmetrical, unisex bathrooms with ADA compliant turning spaces with a utility room in between. The south wall of the casting shall be placed approximately 20' from the first columns on the south side of the pavilion.

Currently, there is a grill in the current pavilion that would need to be removed during construction. However, to keep this amenity, it is suggested to purchase an in-ground charcoal grill to replace the current one. A 4 in. commercial park bi-level charcoal grill with post selected as the recommended grill, however, other equivalent products can be selected if desired.

The pavilion will be classified as an open building with risk category II, and exposure level D, as it sits next to a body of water. These categorizations will be used to determine the structural analysis as well as the standards that the pavilion must meet. Using ASCE 7-16 procedures can calculate the design loads and deflections for the systems of the building. Loads that will be applied onto the structure shall be considered as dead load, wind load, and snow load, from ASCE 7-16 Section 2.3.1.

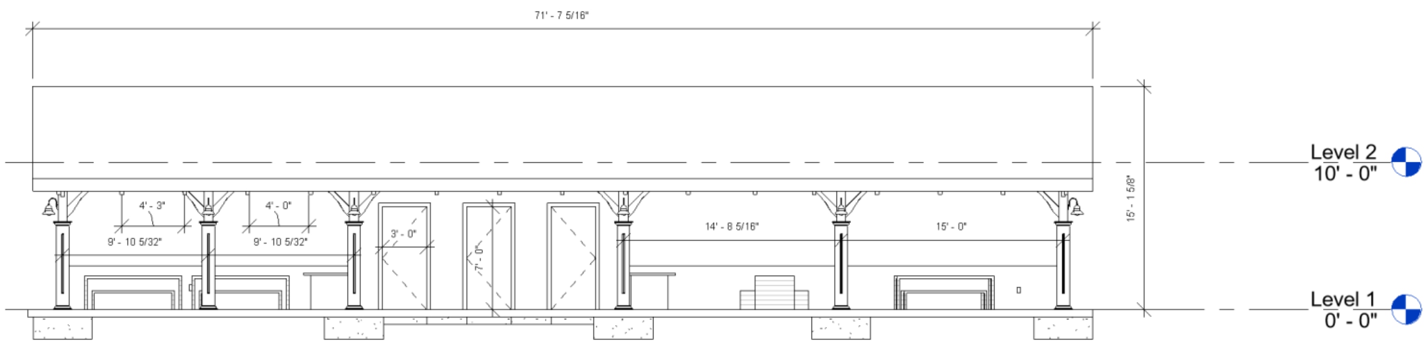

Figure 19: Final Pavilion Design Front Elevation

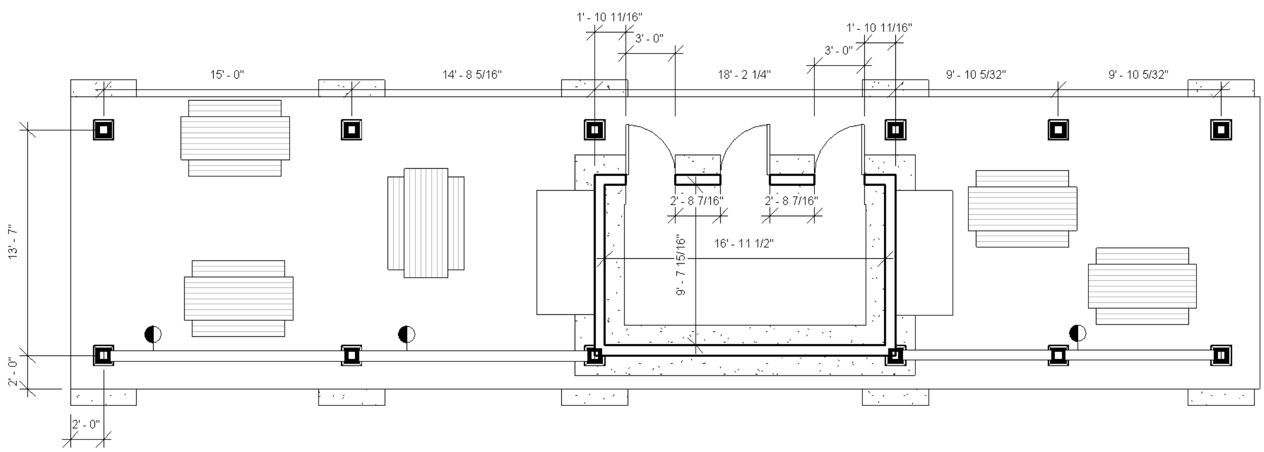

Figure 20: Final Pavilion Design Floor Plan

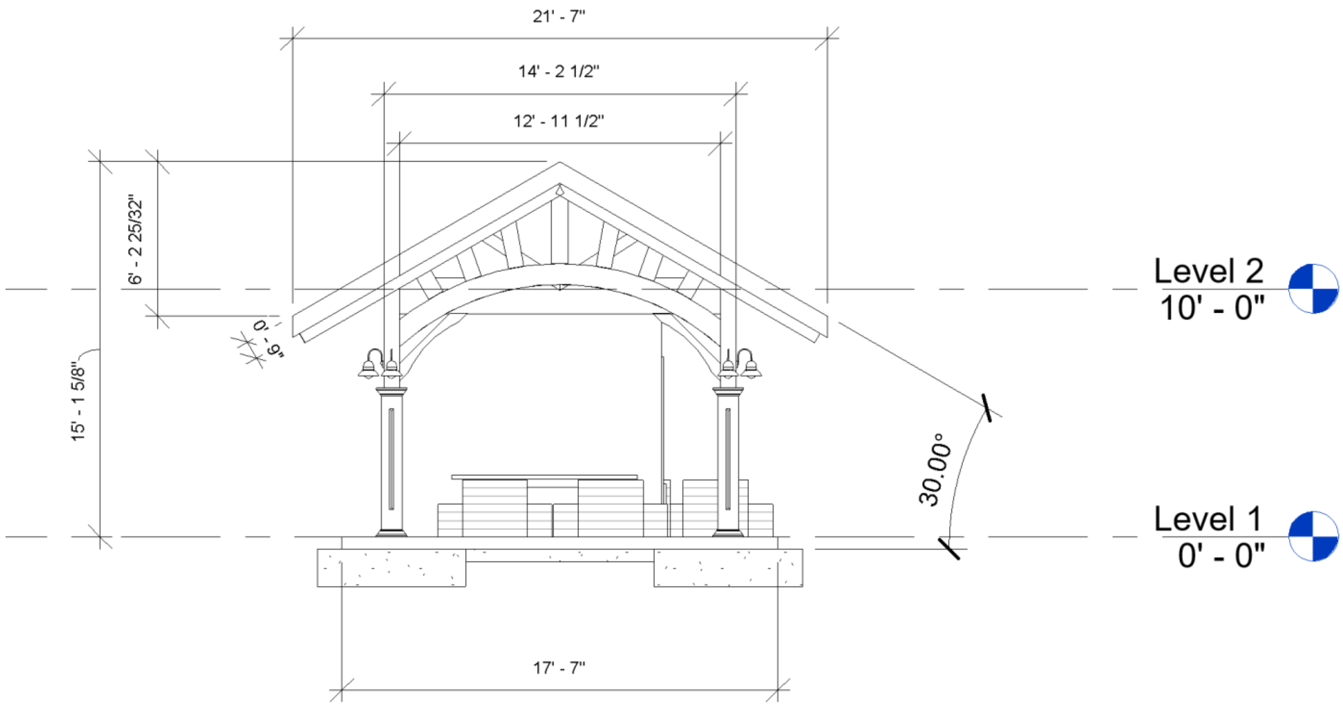

Figure 21: Final Pavilion Design Side View

Dock and Ramp

In order to reduce the number of dock pieces required for the new layout, the same dock style and dimensions as the city's current docks were selected. The Floating Truss Dock manufactured by Hewitt Machine and Manufacturing features an aluminum deck, aluminum truss framing around the sides, and a floatation tank underneath. Each dock piece is 14 feet long by 8 feet wide and is assembled using hinges to allow the structure to adjust with the waves. To keep the docks from drifting, a steel pole is attached to each dock piece and dropped into the riverbed.

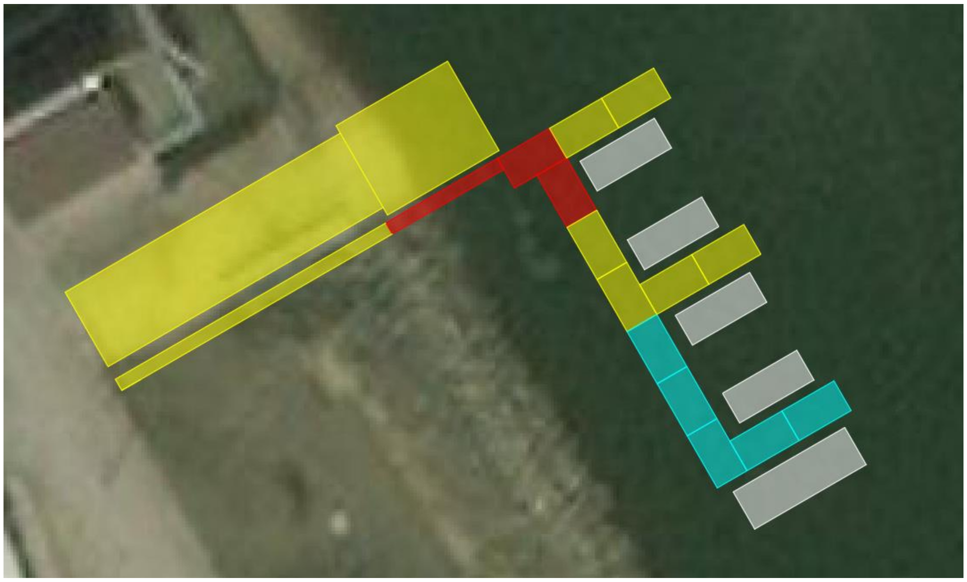

Figure 22: Dock and Ramp Final Design. The grey rectangles represent average sized boats.

The implementation of the dock and ramp design has been broken down into two main phases; the first phase is focused on addressing the limitations discussed previously, and the second phase is focused on the future growth of the project site.

The portions outlined in red depict the existing infrastructure, consisting of two dock pieces and a gangway. The first phase, represented in yellow, adds six additional dock pieces, implements a sidewalk to access the dock from River Street, and reconstructs and extends the boat ramp's underwater length to 20 feet. The second phase, represented in blue, adds five additional dock pieces to the end of the docks from the first phase. The second phase can be repeated downstream as necessary, with each repeat increasing the total boat capacity by two.

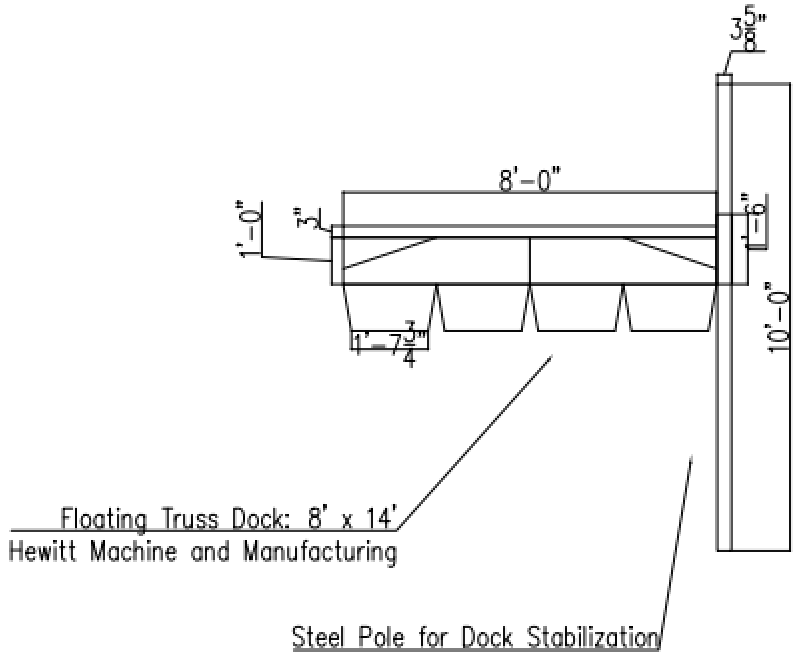

Figure 23: Dock Piece Section View

The gangway will be connected to the dock with a hinge connection, and a sliding hinge connection on land to allow the gangway to adapt to changes in water elevation.

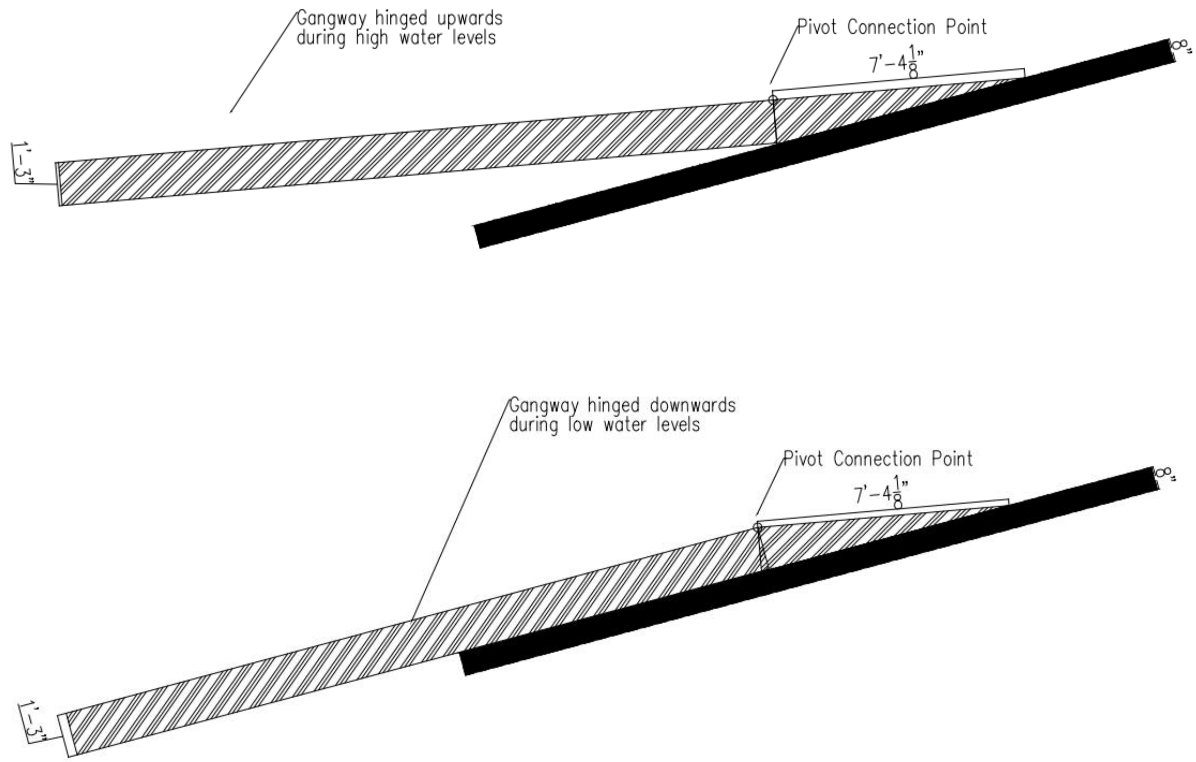

Figure 24: Gangway View

The boat ramp is to be reconstructed, with the addition of cable concrete laid out for the underwater portion of the ramp. The cable concrete is composed of concrete pieces weaved together using a netting material. Each concrete piece measures 15.5” x 15.5. The total area of cable concrete is 600 square feet, with the sheer extending out 2 extra feet on the sides of the ramp. The last two end pieces of concrete are embedded in the end of the ramp, keeping the sheet in place.

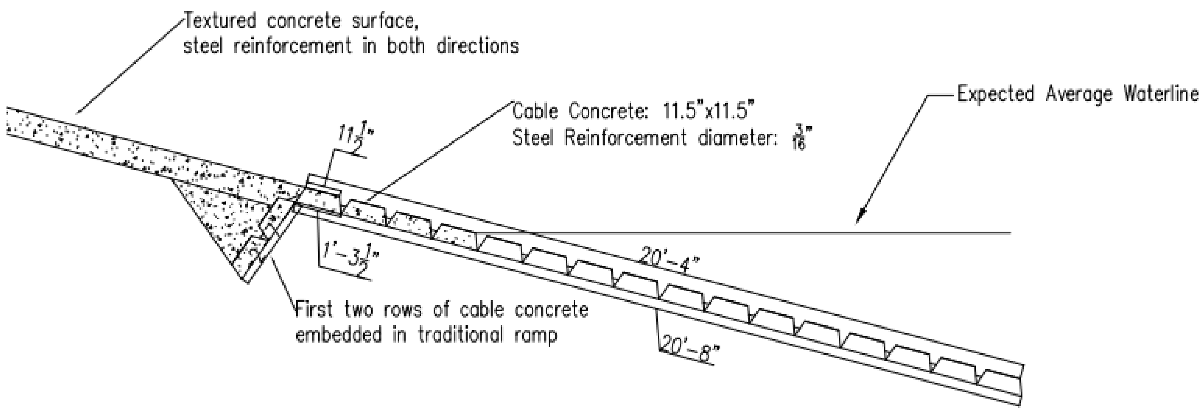

Figure 25: Cable Concrete connection detail

Restroom Facility

The restroom facility will be located underneath the pavilion and act as a partition between the larger and smaller sides. For the restroom design a precast restroom was chosen for its low maintenance, vandal resistance, durability, strength and ease of construction. The precast restroom already was built to withstand the winds required by FEMA for a storm shelter in Iowa. However, the chosen unit does need to be upgraded to handle speeds of 250 mph, which after reaching out to the company is a possibility.

The restroom unit will contain two single user units with a utility closet in the middle for maintenance. Both sides will be ADA accessible. On top of being a restroom, it will double as a safe room for the park. According to FEMA (Federal Emergency Management Agency), a safe room in this location must be designed to withstand 250 mph winds and the impact of a 15lb 2x4 at 100 mph. Anchor systems will come with the construction of the restroom where it shall be installed into the foundation of the new pavilion if being constructed simultaneously. One of the other requirements has the building being anchored to the foundation. Shown below are the dimensions of the building. These plans were taken by Easi-Set Worldwide as they will be the company used for the precast restrooms, however other manufacturers providing an equal product should also be considered when bidding. The building chosen is titled the Morgan Series and a floor plan and side view are shown with dimensions. Both will be linked in the references section. The Final Design will have a flat roof rather than the gable roof shown below. A remote unlocking system is recommended to keep the facility open during disasters.

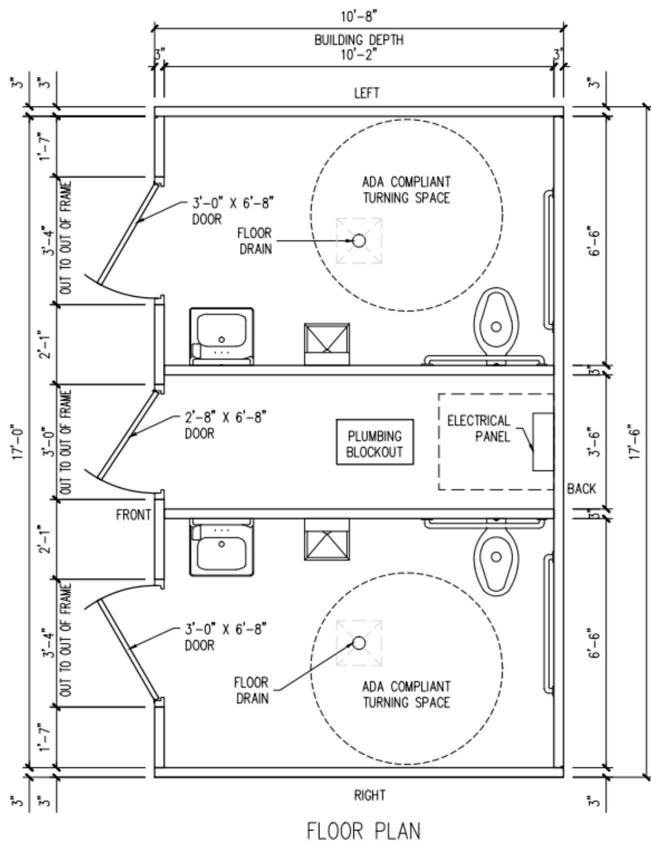

Figure 26: Final Restroom Floor Plan

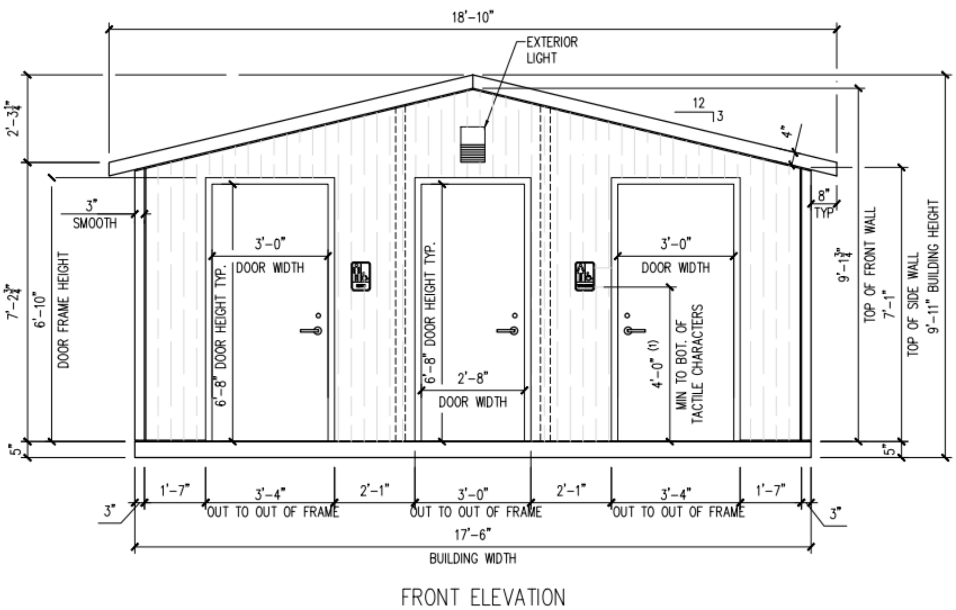

Figure 27: Final Restroom Front Elevation

On-Site Parking

The final parking option chosen was a redesign of the current parking. This option keeps the on-street parking and adds room to the north for temporary trailer parking. These two trailer spots will act as a queue for the boat ramp in the chance that more than one vehicle shows up at a time. Permanent trailer parking is located at the north of town and will be pointed out on a wayfinding map posted on the project site. Some space is left between the trailer spots and car parking. This allows for an additional stall to be added or stalls to be widened.

All dimensions for the parking lot and sidewalks were pulled from SUDAS (Statewide Urban Design and Standards) for Iowa. Each parking stall must be 9’ in width and 18’ in length. Additionally, for every 20 parking spaces one accessible zone must be included. If only one accessible parking space is necessary, it must be designed to the standards for a van. The accessible space must be 9’x18’ and include a safety zone on one side. The safety zone for a van requires 8’ to one side.

Figure 28: Final Parking Design 2

Wayfinding Board

A wayfinding board is an important addition to the boat landing and will enable visitors to find and utilize local businesses. This board will be located next to the temporary trailer parking and boat ramp on our project site. Figure 21 shows a map of what we would suggest being included. The main location that should be pointed out is the long-term trailer parking on the north side of Sabula. Some other prime locations are included on the map such as the bank and convenience store. Alongside the map, emergency contact information would be included such as the local police department, weather radio channels, and the Iowa DNR.

Figure 29: Wayfinding Board Map

<u>Section VII:</u> Engineer's Cost Estimate

		Material	Material	Labor	labor	Delivery	Total
Item	Quantity	Count	Unit Price	Cost	Hours	Cost	Cost
Pavilion				$18.75/hr	400		$ 90,000.00
8"x8"x10' Southern Pine columns	-	10	$112	-	-	$100	$ 1,120.00
8"x12"x20' Southern Pine beams	-	140	$86.80	-	-	$100	$ 12,152.00
6-3/4"x10-1/2" GLB	648 lf	-	$34.85/lf	-	-	$100	$ 22,582.80
Foundation (4' Thick)	24ft^2	10	$5.25/$ft^2$	-	-	-	$ 1,260.00
Concrete Slab (6" Thick)	1264ft^2	-	$5.25/$ft^3$	-	-	-	$ 6,636.00
LUS310 Face Mount Hanger	-	8	$5			$100	$ 140.00
LSSR210-2Z Rafter Hanger	-	15	$30	-	-	$100	$ 550.00
CCQ88SDS2.5 Column Cap	-	12	$200	-	-	$100	$ 2,500.00
Column Cover	-	12	$400	-	-	$100	$ 4,900.00
Lighting	-	12	$100	-	-	$100	$ 1,300.00
In Ground Grill	-	1	$1,300			$100	$ 1,400.00
EPDM Roofing	1785ft^2	-	$5/$ft^2$	-	-	$100	$ 8,925.00
						Sub-Total:	$153,465.80

Table 2-1: Pavilion Cost Estimate

		Material	Material	Labor	labor	Delivery	Total
Item	Quantity	Count	Unit Price	Cost	Hours	Cost	Cost
Ramp				$18.75/hr	150		$ 33,750.00
Concrete (Ramp 7" Thick)	1580 ft^2	-	$5.25/$ft^2$	-	-	-	$ 8,295.00
Cable Concrete	720 ft^2	-	$6.25/$ft^2$	-	-	-	$ 4,500.00
Form Work	1580 ft^2	-	$1.10/$ft^2$	-	-	-	$ 1,738.00
						Sub-Total:	$ 48,283.00

Table 2-2: Ramp Cost Estimate

		Material	Material	Labor	labor	Delivery	Total
Item	Quantity	Count	Unit Price	Cost	Hours	Cost	Cost
Dock							
Phase 1	112 ft^2	6	$20/$ft^2$	-	-	$100	$ 13,440.00
Phase 2	112 ft^2	5	$20/$ft^2$				$ 11,200.00
						Sub-Total:	$ 24,640.00

Table 2-3: Ramp Dock Cost Estimate

		Material	Material	Labor	labor	Delivery	Total
Item	Quantity	Count	Unit Price	Cost	Hours	Cost	Cost
Restrooms							
Precast Restroom	228 ft^2	1	$300/$ft^2$	-	-	-	$ 68,400.00
Utility Services	-	-	$10,000	-	-	-	$10,000.00
						Sub-Total:	$ 78,400.00

Table 2-4: Restroom Cost Estimate

		Material	Material	Labor	labor	Delivery	Total
Item	Quantity	Count	Unit Price	Cost	Hours	Cost	Cost
Other				$18.75/hr	150		$ 33,750.00
Concrete (Walkways 4" Thick)	1520 ft^2	-	$5.25/$ft^2$	-	-	-	$ 7,980.00
Form Work	1520 ft^2	-	$1.10/$ft^2$	-	-	-	$ 1,672.00
Concrete Removal	1264ft^2	-	$5/$ft^2$	-	-	-	$ 6,320.00
Pavilion Removal	-	-	$2,000	-	-	-	$ 2,000.00
						Sub-Total:	$ 51,722.00

Table 2-5: Additional

Item	Cost
Pavilion	$153,465.80
Ramp	$ 48,283.00
Dock	$ 24,640.00
Restrooms	$ 78,400.00
Other	$ 51,722.00
Total	$356,510.80

Table 2-6: Totals

Appendices

References

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Design Calculations

To find the snow load, ASCE 7-16 Section 7 shall be used. Figure 31 determines the

$$1.2D + 1.6S + .5W \text{ (Equation 1, ASCE 7-16 Load Combination 3)}$$

ground snow load, p_g, to be 25 psf for the site. The flat roof snow load, p_f, can then be determined using Equation 2, where:

C_e = 0.8 from Table 3

C_t = 1.2 from Table 4

I_s = 1.0 from Table 5

$$p_f = 0.7 C_e C_t I_s p_g \text{ (Equation 2, ASCE 7-16 Equation 7.3-1)}$$

The sloped roof snow load, p_s, can then be determined from Equation 3, where:

C_s = 0.74 from Figure 32

This gives p_s a value of 17.76 psf, which shall be multiplied by the tributary width of 4 ft to get a value of 0.07 kip/ft, which shall be used as S in Equation 1.

$$p_s = C_s p_f \text{ (Equation 3, ASCE 7-16 Equation 7.4-1)}$$

The wind load shall be determined using ASCE 7-16 Section 26 and 27. Velocity pressure, q_h, is to be determined using Equation 4, where:

K_z = 1.03 from Table 6

K_{zt} = 1.0 from Figure 33

K_d = 0.85 from Table 7

K_e = 0.976 from Table 8 with ground elevation at 182 m

V = 107 mph from Figure 34

$$q_h = 0.00256 K_z K_{zt} K_d K_e V^2$$ (Equation 4, ASCE 7-16 Equation 26.10-1)

The wind load on the roof, p, can then be determined using Equation 5, with the dependency of the direction of the wind, as indicated in Figure 36, where:

G = 0.85 from ASCE 26.11.1 with the fact of the structure being a rigid building

CN is dependent on the case indicated in Figure 35, where case A is the wind blown from E-W and case B is the wind blown from W-E.

$$p = q_h GCN$$ (Equation 5, ASCE 7-16 Equation 27.3-2)

The results of Equation 5 were tabulated into a spreadsheet, Table 12. Using the highest value of 27.67 psf, it will be multiplied by a tributary width of 4 ft to give a value of 0.11 kip/ft, which shall be used as the load of W for Equation 1.

Dead load, D, shall be predetermined from the used software.

With the use of Autodesk Robot Structural Analysis, criteria to meet the National Design Specification for Wood Construction was achieved. Design values were calculated using Table 10 where variables for each load design were pulled from NDS Supplement. Reference design values for southern pine are shown in Table 11 and Table 12. Adjustment factors are also needed and provided throughout the NDS Supplement as well as the NDS Manual. Figures 36 and 37 determines the size factor, C_F, flat use factor, C_{fu}, repetitive member factor, C_r, and wet service factor, C_M. Load duration factor, C_D, and temperature factor, C_t are found in section 2.3 of the NDS Manual, specifically shown in Table 13 and 14. The beam stability factor, C_L is determined in the NDS Manual section 3.3.3 to be a value of 1. Incising factor, C_i is determined using Table

15. Column stability factor, C_P is determined using NDS Manual section 3.7. Buckling stiffness factor, C_T is calculated using Equation 6 where:

K_M = 1200 from NDS Manual section 4.4.2

l_e = 96

K_T = .59 from NDS Manual section 4.4.2

$$C_T = 1 + \frac{K_M l_e}{K_T E}$$ (Equation 6, NDS for Wood Construction Equation 4.4-1)

Bearing area factors are determined using Table 16. All design values for each type of sawn lumber are tabulated into a spreadsheet and are given as Table 17, 18, 19, and 20. Table 21 gives the equations for each design value and its adjustment factor.

Inputting previously determined load combinations into Robot, automatic calculations are made for the structure of the pavilion, giving actual stresses and deformation that can be compared to design values. On the analysis of the 15 ft beam on the south end of the pavilion, results give an actual deflection of -0.054 in. Standards require structural members to have an allowable deflection of L/240, which for a 15 ft beam, gives an allowable deflection of 0.0625 in, therefore, this beam meets requirements. Looking at the same beam, results give a bending stress of 50 psi. Compared to the bending design value of 919.08 psi from Table 17-1, bending stress for the beam is okay. Actual tensile stress of the same beam resulted in 150 psi, and when compared to the tensile design value of 828 psi, tensile stress is okay. NDS Manual specifies combined bending and axial tension members to meet the requirement of $\frac{f_t}{F_t{}'} + \frac{f_b}{F_b{}^*} \leq 1.0$.

Using the recently mentioned actual stresses, the ratio of combined stresses comes to 0.236, which meets NDS standards.

To find the snow load, ASCE 7-16 Section 7 shall be used. Figure 31 determines the

$$1.2D + 1.6S + .5W \text{ (Equation 1, ASCE 7-16 Load Combination 3)}$$

ground snow load, p_g, to be 25 psf for the site. The flat roof snow load, p_f, can then be determined using Equation 2, where:

C_e = 0.8 from Table 3

C_t = 1.2 from Table 4

I_s = 1.0 from Table 5

$$p_f = 0.7C_eC_tI_sp_g \text{ (Equation 2, ASCE 7-16 Equation 7.3-1)}$$

The sloped roof snow load, p_s, can then be determined from Equation 3, where:

C_s = 0.74 from Figure 32

This gives p_s a value of 17.76 psf, which shall be multiplied by the tributary width of 4 ft to get a value of 0.07 kip/ft, which shall be used as S in Equation 1.

$$p_s = C_sp_f \text{ (Equation 3, ASCE 7-16 Equation 7.4-1)}$$

The wind load shall be determined using ASCE 7-16 Section 26 and 27. Velocity pressure, q_h, is to be determined using Equation 4, where:

K_z = 1.03 from Table 6

K_{zt} = 1.0 from Figure 33

K_d = 0.85 from Table 7

K_e = 0.976 from Table 8 with ground elevation at 182 m

V = 107 mph from Figure 34

$$q_h = 0.00256K_zK_{zt}K_dK_eV^2$$ (Equation 4, ASCE 7-16 Equation 26.10-1)

The wind load on the roof, p, can then be determined using Equation 5, with the dependency of the direction of the wind, as indicated in Figure 36, where:

G = 0.85 from ASCE 26.11.1 with the fact of the structure being a rigid building

CN is dependent on the case indicated in Figure 35, where case A is the wind blown from E-W and case B is the wind blown from W-E.

$$p = q_hGCN$$ (Equation 5, ASCE 7-16 Equation 27.3-2)

The results of Equation 5 were tabulated into a spreadsheet, Table 12. Using the highest value of 27.67 psf, it will be multiplied by a tributary width of 4 ft to give a value of 0.11 kip/ft, which shall be used as the load of W for Equation 1.

Dead load, D, shall be predetermined from the used software.

With the use of Autodesk Robot Structural Analysis, criteria to meet the National Design Specification for Wood Construction was achieved. Design values were calculated using Table 10 where variables for each load design were pulled from NDS Supplement. Reference design values for southern pine are shown in Table 11 and Table 12. Adjustment factors are also needed and provided throughout the NDS Supplement as well as the NDS Manual. Figures 36 and 37 determines the size factor, C_F, flat use factor, C_{fu}, repetitive member factor, C_r, and wet service factor, C_M. Load duration factor, C_D, and temperature factor, C_t are found in section 2.3 of the NDS Manual, specifically shown in Table 13 and 14. The beam stability factor, C_L is determined in the NDS Manual section 3.3.3 to be a value of 1. Incising factor, C_i is determined using Table

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K_M = 1200 from NDS Manual section 4.4.2

l_e = 96

K_T = .59 from NDS Manual section 4.4.2

$$C_T = 1 + \frac{K_M l_e}{K_T E}$$ (Equation 6, NDS for Wood Construction Equation 4.4-1)

Bearing area factors are determined using Table 16. All design values for each type of sawn lumber are tabulated into a spreadsheet and are given as Table 17, 18, 19, and 20. Table 21 gives the equations for each design value and its adjustment factor.

Inputting previously determined load combinations into Robot, automatic calculations are made for the structure of the pavilion, giving actual stresses and deformation that can be compared to design values. On the analysis of the 15 ft beam on the south end of the pavilion, results give an actual deflection of -0.054 in. Standards require structural members to have an allowable deflection of L/240, which for a 15 ft beam, gives an allowable deflection of 0.0625 in, therefore, this beam meets requirements. Looking at the same beam, results give a bending stress of 50 psi. Compared to the bending design value of 919.08 psi from Table 17-1, bending stress for the beam is okay. Actual tensile stress of the same beam resulted in 150 psi, and when compared to the tensile design value of 828 psi, tensile stress is okay. NDS Manual specifies combined bending and axial tension members to meet the requirement of $\frac{f_t}{F_t'} + \frac{f_b}{F_b*} \leq 1.0$.

Using the recently mentioned actual stresses, the ratio of combined stresses comes to 0.236, which meets NDS standards.

Table and Figures

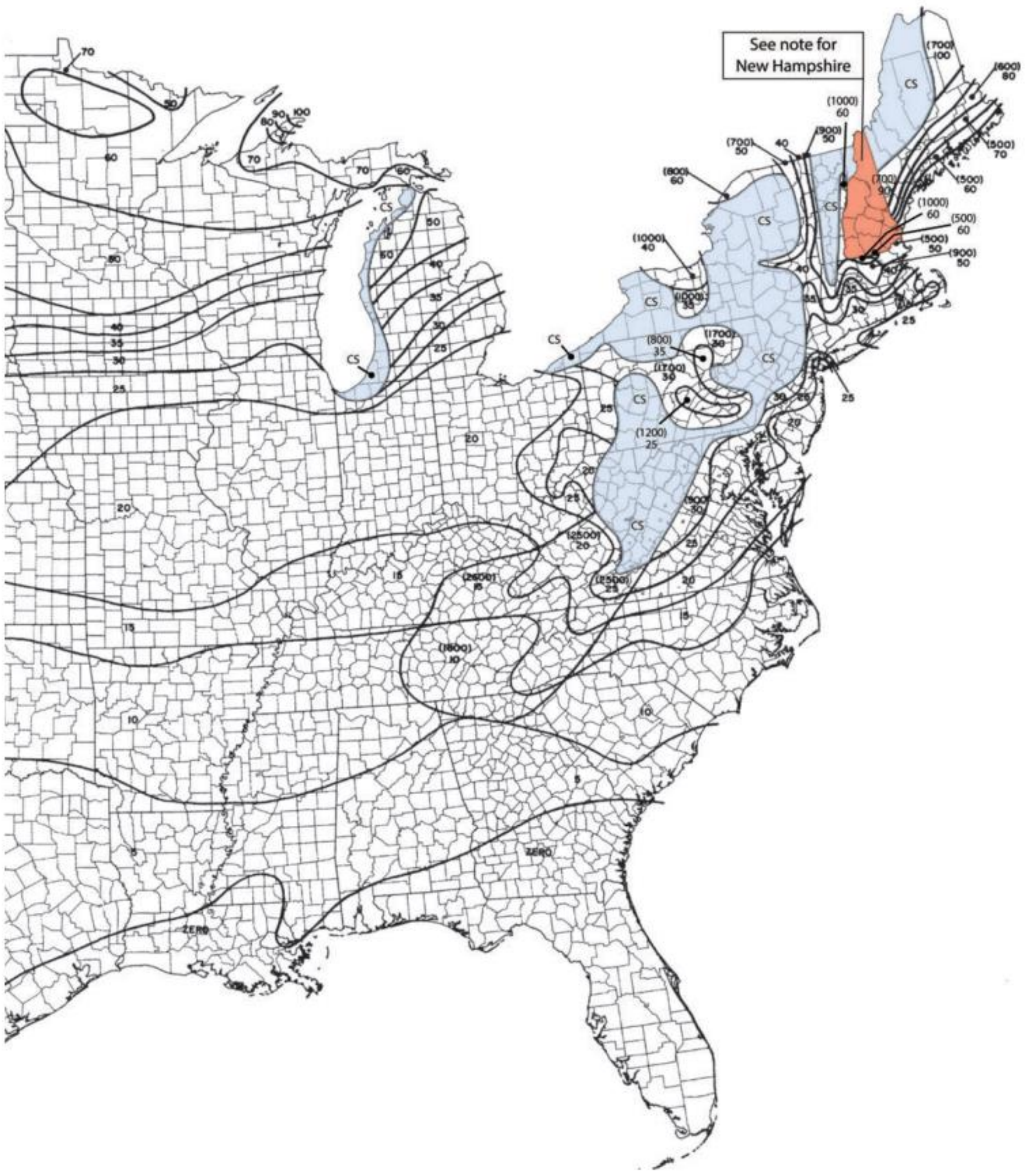


FIGURE 7.2-1 (*Continued*)

Figure 30 (ASCE 7-16 Figure 7.2-1)

Table 7.3-1 Exposure Factor, C_e

Surface Roughness Category	Exposure of Roof[a]		
	Fully Exposed	Partially Exposed	Sheltered
B (see Section 26.7)	0.9	1.0	1.2
C (see Section 26.7)	0.9	1.0	1.1
D (see Section 26.7)	0.8	0.9	1.0
Above the tree line in windswept mountainous areas	0.7	0.8	NA
In Alaska, in areas where trees do not exist within a 2-mi (3-km) radius of the site	0.7	0.8	NA

Table 3 (ASCE 7-16 Table 7.3-1)

Table 7.3-2 Thermal Factor, C_t

Thermal Condition[a]	C_t
All structures except as indicated below	1.0
Structures kept just above freezing and others with cold, ventilated roofs in which the thermal resistance (R-value) between the ventilated space and the heated space exceeds $25°F \times h \times ft^2/Btu$ ($4.4\ K \times m^2/W$)	1.1
Unheated and open air structures	1.2
Freezer building	1.3
Continuously heated greenhouses[b] with a roof having a thermal resistance (R-value) less than $2.0°F \times h \times ft^2/Btu$ ($0.4\ K \times m^2/W$)	0.85

Table 4 (ASCE 7-16 Table 7.3-2)

Table 1.5-2 Importance Factors by Risk Category of Buildings and Other Structures for Snow, Ice, and Earthquake Loads

Risk Category from Table 1.5-1	Snow Importance Factor, I_s	Ice Importance Factor—Thickness, I_i	Ice Importance Factor—Wind, I_w	Seismic Importance Factor, I_e
I	0.80	0.80	1.00	1.00
II	1.00	1.00	1.00	1.00
III	1.10	1.15	1.00	1.25
IV	1.20	1.25	1.00	1.50

Note: The component importance factor, I_p, applicable to earthquake loads, is not included in this table because it depends on the importance of the individual component rather than that of the building as a whole, or its occupancy. Refer to Section 13.1.3.

Table 5 (ASCE 7-16 Table 1.5-2)

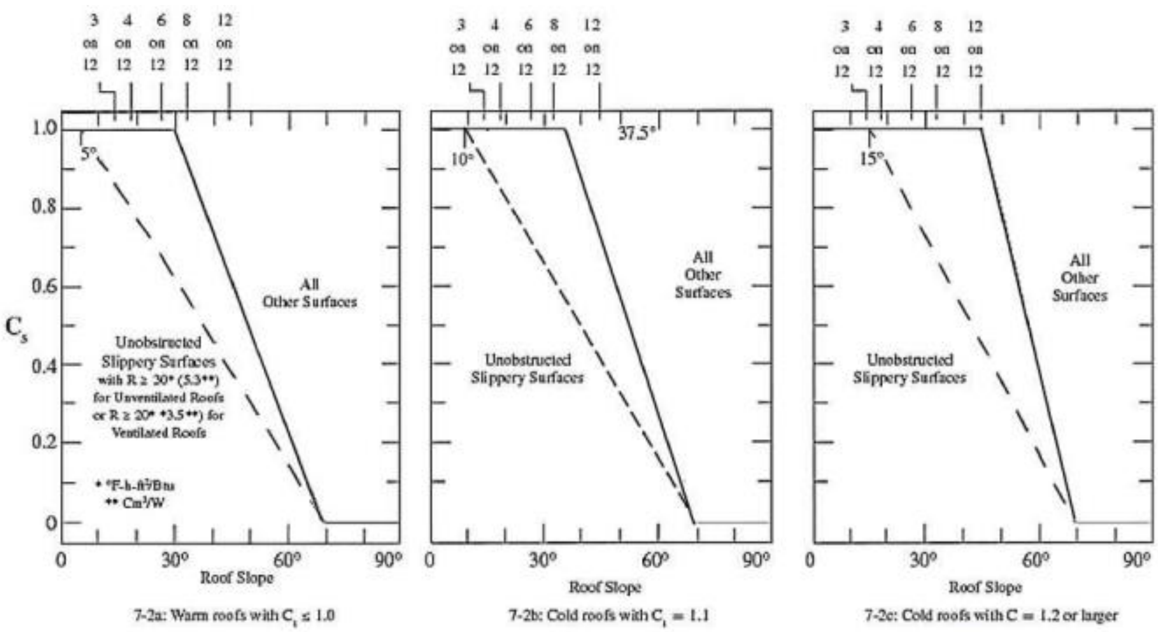


FIGURE 7.4-1 Graphs for Determining Roof Slope Factor, C_s, for Warm and Cold Roofs (See Table 7.3-2 for C_t Definitions)

Figure 31 (ASCE 7-16 Figure 7.4-1)

Table 26.10-1 Velocity Pressure Exposure Coefficients, K_h and K_z

Height above Ground Level, z		Exposure		
ft	m	B	C	D
0–15	0–4.6	0.57 (0.70)[a]	0.85	1.03
20	6.1	0.62 (0.70)[a]	0.90	1.08
25	7.6	0.66 (0.70)[a]	0.94	1.12
30	9.1	0.70	0.98	1.16
40	12.2	0.76	1.04	1.22
50	15.2	0.81	1.09	1.27
60	18.0	0.85	1.13	1.31
70	21.3	0.89	1.17	1.34
80	24.4	0.93	1.21	1.38
90	27.4	0.96	1.24	1.40
100	30.5	0.99	1.26	1.43
120	36.6	1.04	1.31	1.48
140	42.7	1.09	1.36	1.52
160	48.8	1.13	1.39	1.55
180	54.9	1.17	1.43	1.58
200	61.0	1.20	1.46	1.61
250	76.2	1.28	1.53	1.68
300	91.4	1.35	1.59	1.73
350	106.7	1.41	1.64	1.78
400	121.9	1.47	1.69	1.82
450	137.2	1.52	1.73	1.86
500	152.4	1.56	1.77	1.89

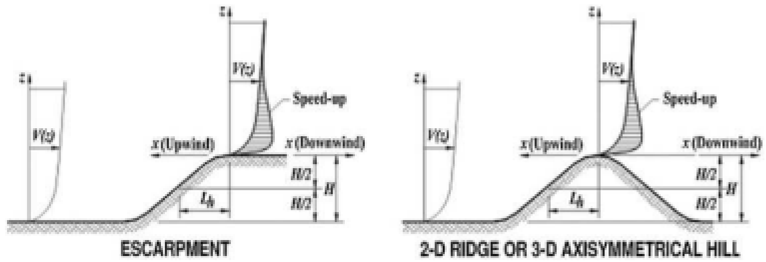
[a]Use 0.70 in Chapter 28, Exposure B, when $z < 30$ ft (9.1 m).

Notes

1. The velocity pressure exposure coefficient K_z may be determined from the following formula:
   For 15 ft (4.6 m) $\leq z \leq z_g$ $\quad K_z = 2.01(z/z_g)^{2/\alpha}$
   For $z <$ 15 ft (4.6 m) $\quad K_z = 2.01(15/z_g)^{2/\alpha}$
2. α and z_g are tabulated in Table 26.11-1.
3. Linear interpolation for intermediate values of height z is acceptable.
4. Exposure categories are defined in Section 26.7.

Table 6 (ASCE 7-16 Table 26.10-1)

Diagrams



Topographic Multipliers for Exposure C[a,b,c]

	K_1 Multiplier				K_2 Multiplier			K_3 Multiplier		
H/L_h	2D Ridge	2D Escarpment	3D Axisym-metrical Hill	x/L_h	2D Escarpment	All Other Cases	z/L_h	2D Ridge	2D Escarpment	3D Axisym-metrical Hill
0.20	0.29	0.17	0.21	0.00	1.00	1.00	0.00	1.00	1.00	1.00
0.25	0.36	0.21	0.26	0.50	0.88	0.67	0.10	0.74	0.78	0.67
0.30	0.43	0.26	0.32	1.00	0.75	0.33	0.20	0.55	0.61	0.45
0.35	0.51	0.30	0.37	1.50	0.63	0.00	0.30	0.41	0.47	0.30
0.40	0.58	0.34	0.42	2.00	0.50	0.00	0.40	0.30	0.37	0.20
0.45	0.65	0.38	0.47	2.50	0.38	0.00	0.50	0.22	0.29	0.14
0.50	0.72	0.43	0.53	3.00	0.25	0.00	0.60	0.17	0.22	0.09
				3.50	0.13	0.00	0.70	0.12	0.17	0.06
				4.00	0.00	0.00	0.80	0.09	0.14	0.04
							0.90	0.07	0.11	0.03
							1.00	0.05	0.08	0.02
							0.50	0.01	0.02	0.00
							2.00	0.00	0.00	0.00

[a]For values of H/L_h, x/L_h, and z/L_h other than those shown, linear interpolation is permitted.
[b]For $H/L_h > 0.5$, assume that $H/L_h = 0.5$ for evaluating K_1 and substitute $2H$ for L_h for evaluating K_2 and K_3.
[c]Multipliers are based on the assumption that wind approaches the hill or escarpment along the direction of maximum slope.

Notation

H = Height of hill or escarpment relative to the upwind terrain, in ft (m).
K_1 = Factor to account for shape of topographic feature and maximum speed-up effect.
K_2 = Factor to account for reduction in speed-up with distance upwind or downwind of crest.
K_3 = Factor to account for reduction in speed-up with height above local terrain.
L_h = Distance upwind of crest to where the difference in ground elevation is half the height of hill or escarpment, in ft (m).
x = Distance (upwind or downwind) from the crest to the site of the building or other structure, in ft (m).
z = Height above ground surface at the site of the building or other structure, in ft (m).
μ = Horizontal attenuation factor.
γ = Height attenuation factor.

Equations

$K_{zt} = (1 + K_1 K_2 K_3)^2$
K_1 = determined from table below
$K_2 = (1 - |x|/\mu L_h)$
$K_3 = e^{-\gamma z/L_h}$

Parameters for Speed-Up over Hills and Escarpments

	$K_1/(H/L_h)$				μ	
	Exposure					
Hill Shape	B	C	D	γ	Upwind of Crest	Downwind of Crest
2D ridges (or valleys with negative H in $K_1/(H/L_h)$)	1.30	1.45	1.55	3	1.5	1.5
2D escarpments	0.75	0.85	0.95	2.5	1.5	4
3D axisymmetrical hill	0.95	1.05	1.15	4	1.5	1.5

FIGURE 26.8-1 Topographic Factor, K_{zt}

Figure 32 (ASCE 7-16 Figure 26.8-1)

Table 26.6-1 Wind Directionality Factor, K_d

Structure Type	Directionality Factor K_d
Buildings	
Main Wind Force Resisting System	0.85
Components and Cladding	0.85
Arched Roofs	0.85
Circular Domes	1.0[a]
Chimneys, Tanks, and Similar Structures	
Square	0.90
Hexagonal	0.95
Octagonal	1.0[a]
Round	1.0[a]
Solid Freestanding Walls, Roof Top Equipment, and Solid Freestanding and Attached Signs	0.85
Open Signs and Single-Plane Open Frames	0.85
Trussed Towers	
Triangular, square, or rectangular	0.85
All other cross sections	0.95

[a]Directionality factor $K_d = 0.95$ shall be permitted for round or octagonal structures with nonaxisymmetric structural systems.

Table 7 (ASCE 7-16 Table 26.6-1)

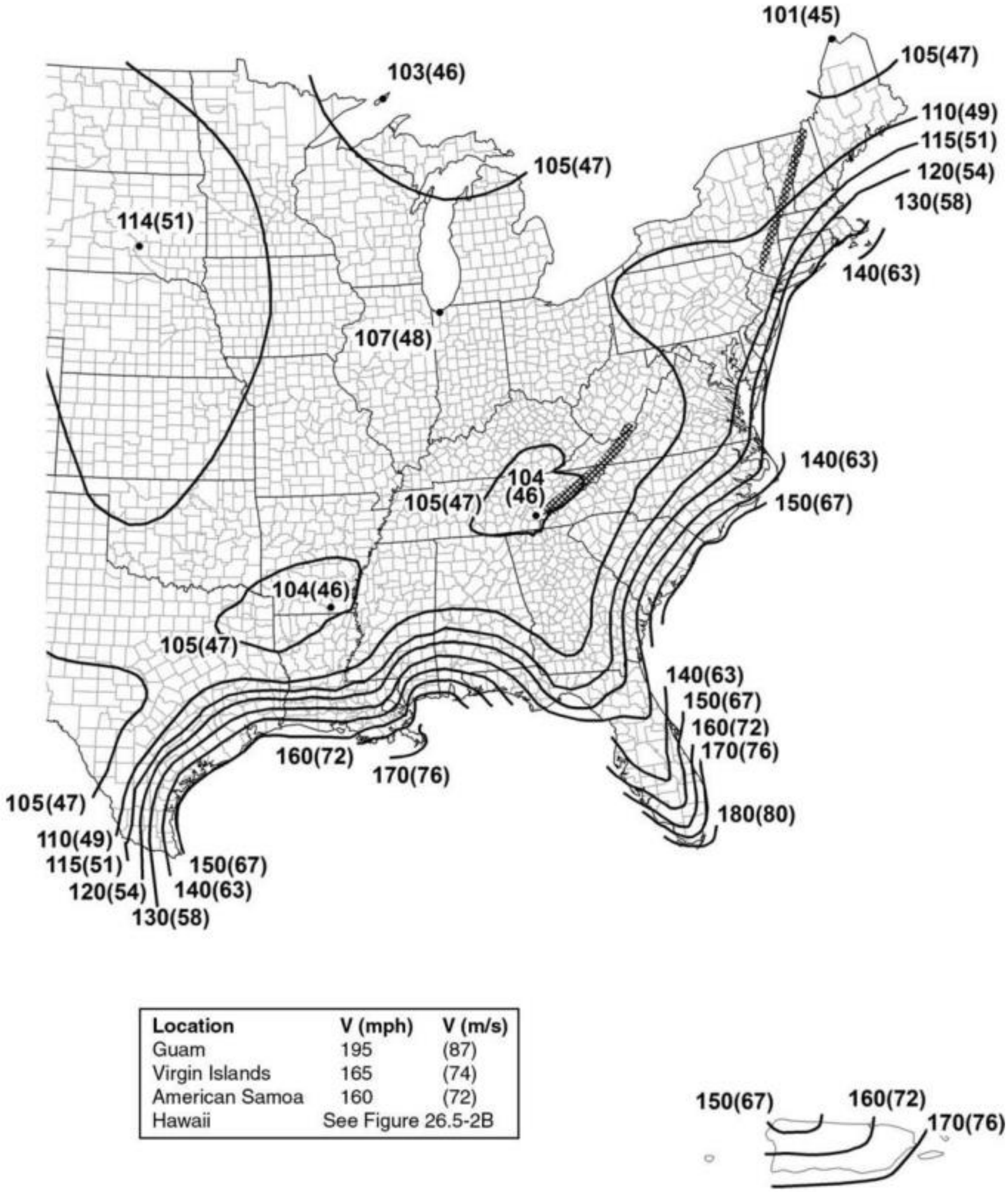
Table 26.9-1 Ground Elevation Factor, K_e

Ground Elevation above Sea Level		Ground Elevation Factor
ft	m	K_e
<0	<0	See note 2
0	0	1.00
1,000	305	0.96
2,000	610	0.93
3,000	914	0.90
4,000	1,219	0.86
5,000	1,524	0.83
6,000	1,829	0.80
>6,000	>1,829	See note 2

Notes

1. The conservative approximation $K_e = 1.00$ is permitted in all cases.
2. The factor K_e shall be determined from the above table using interpolation or from the following formula for all elevations:
   $K_e = e^{-0.0000362 z_g}$ (z_g = ground elevation above sea level in ft).
   $K_e = e^{-0.000119 z_g}$ (z_g = ground elevation above sea level in m).
3. K_e is permitted to be take as 1.00 in all cases.

Table 8 (ASCE 7-16 Table 26.9-1)

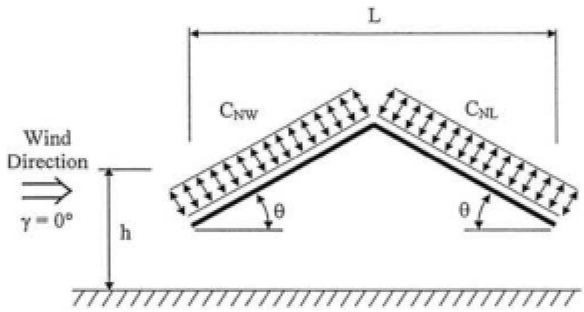


Location	V (mph)	V (m/s)
Guam	195	(87)
Virgin Islands	165	(74)
American Samoa	160	(72)
Hawaii	See Figure 26.5-2B	

FIGURE 26.5-1B (*Continued*). **Basic Wind Speeds for Risk Category II Buildings and Other Structures**

Figure 33 (ASCE 7-16 Figure 26.5-1B)

Diagram



Notation

L = Horizontal dimension of roof, measured in the along-wind direction, ft (m).
h = Mean roof height, ft (m).
γ = Direction of wind, degrees.
θ = Angle of plane of roof from horizontal, degrees.

Net Pressure Coefficient, C_N

		Wind Direction, $\gamma = 0°, 180°$			
		Clear Wind Flow		Obstructed Wind Flow	
Roof Angle, θ	Load Case	C_{NW}	C_{NL}	C_{NW}	C_{NL}
7.5°	A	1.1	−0.3	−1.6	−1.0
	B	0.2	−1.2	−0.9	−1.7
15°	A	1.1	−0.4	−1.2	−1.0
	B	0.1	−1.1	−0.6	−1.6
22.5°	A	1.1	0.1	−1.2	−1.2
	B	−0.1	−0.8	−0.8	−1.7
30°	A	1.3	0.3	−0.7	−0.7
	B	−0.1	−0.9	−0.2	−1.1
37.5°	A	1.3	0.6	−0.6	−0.6
	B	−0.2	−0.6	−0.3	−0.9
45°	A	1.1	0.9	−0.5	−0.5
	B	−0.3	−0.5	−0.3	−0.7

Notes

1. C_{NW} and C_{NL} denote net pressures (contributions from top and bottom surfaces) for windward and leeward half of roof surfaces, respectively.
2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to 50%. Obstructed wind flow denotes objects below roof inhibiting wind flow (>50% blockage).
3. For values of θ between 7.5° and 45°, linear interpolation is permitted. For values of θ less than 7.5°, use monoslope roof load coefficients.
4. Plus and minus signs signify pressures acting toward and away from the top roof surface, respectively.
5. All load cases shown for each roof angle shall be investigated.

FIGURE 27.3-5 Main Wind Force Resisting System, Part 1 ($0.25 \leq h/L \leq 1.0$): Net Pressure Coefficient, C_N, for Open Buildings with Pitched Free Roofs, $\theta \leq 45°$, $\gamma = 0°, 180°$

Figure 34 (ASCE Figure 27.3-5)

p (psf)		
case A	27.67	19.16
case B	-2.13	-19.16

Table 9 (Wind Load, p, from Equation 5)

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		ASD only	ASD and LRFD											LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	-	-	-	2.54	0.85	λ
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	2.70	0.80	λ
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	C_i	-	-	-	-	2.88	0.75	λ
$F_c' = F_c$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	C_P	-	-	2.40	0.90	λ
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_b	1.67	0.90	-
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	1.76	0.85	-

Table 10 (NDS for Wood Construction Manual Table 4.3.1)

Table 4B Reference Design Values for Visually Graded Southern Pine Dimension Lumber (2" - 4" thick)[1,2,3,4,5]

(Tabulated design values are for normal load duration and dry service conditions, unless specified otherwise. See NDS 4.3 for a comprehensive description of design value adjustment factors.)

USE WITH TABLE 4B ADJUSTMENT FACTORS

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)							Specific Gravity[4]	Grading Rules Agency
		Bending	Tension parallel to grain	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of Elasticity			
		F_b	F_t	F_v	$F_{c\perp}$	F_c	E	E_{min}	G	
SOUTHERN PINE										
Dense Select Structural	2" - 4" wide	2,700	1,900	175	660	2,050	1,900,000	690,000	0.55	
Select Structural		2,350	1,650	175	565	1,900	1,800,000	660,000		
Non-Dense Select Structural		2,050	1,450	175	480	1,800	1,600,000	580,000		
No.1 Dense		1,650	1,100	175	660	1,750	1,800,000	660,000		
No.1		1,500	1,000	175	565	1,650	1,600,000	580,000		
No.1 Non-Dense		1,300	875	175	480	1,550	1,400,000	510,000		
No.2 Dense		1,200	750	175	660	1,500	1,600,000	580,000		
No.2		1,100	675	175	565	1,450	1,400,000	510,000		
No.2 Non-Dense		1,050	600	175	480	1,450	1,300,000	470,000		
No.3 and Stud		650	400	175	565	850	1,300,000	470,000		
Construction	4" wide	875	500	175	565	1,600	1,400,000	510,000	0.55	
Standard		475	275	175	565	1,300	1,200,000	440,000		
Utility		225	125	175	565	850	1,200,000	440,000		
Dense Select Structural	5" - 6" wide	2,400	1,650	175	660	1,900	1,900,000	690,000	0.55	
Select Structural		2,100	1,450	175	565	1,800	1,800,000	660,000		
Non-Dense Select Structural		1,850	1,300	175	480	1,700	1,600,000	580,000		
No.1 Dense		1,500	1,000	175	660	1,650	1,800,000	660,000		
No.1		1,350	875	175	565	1,550	1,600,000	580,000		
No.1 Non-Dense		1,200	775	175	480	1,450	1,400,000	510,000		
No.2 Dense		1,050	650	175	660	1,450	1,600,000	580,000		
No.2		1,000	600	175	565	1,400	1,400,000	510,000		
No.2 Non-Dense		950	525	175	480	1,350	1,300,000	470,000		
No.3 and Stud		575	350	175	565	800	1,300,000	470,000		
Dense Select Structural	8" wide	2,200	1,550	175	660	1,850	1,900,000	690,000	0.55	
Select Structural		1,950	1,350	175	565	1,700	1,800,000	660,000		
Non-Dense Select Structural		1,700	1,200	175	480	1,650	1,600,000	580,000		
No.1 Dense		1,350	900	175	660	1,600	1,800,000	660,000		SPIB
No.1		1,250	800	175	565	1,500	1,600,000	580,000		
No.1 Non-Dense		1,100	700	175	480	1,400	1,400,000	510,000		
No.2 Dense		975	600	175	660	1,400	1,600,000	580,000		
No.2		925	550	175	565	1,350	1,400,000	510,000		
No.2 Non-Dense		875	500	175	480	1,300	1,300,000	470,000		
No.3 and Stud		525	325	175	565	775	1,300,000	470,000		
Dense Select Structural	10" wide	1,950	1,300	175	660	1,800	1,900,000	690,000	0.55	
Select Structural		1,700	1,150	175	565	1,650	1,800,000	660,000		
Non-Dense Select Structural		1,500	1,050	175	480	1,600	1,600,000	580,000		
No.1 Dense		1,200	800	175	660	1,550	1,800,000	660,000		
No.1		1,050	700	175	565	1,450	1,600,000	580,000		
No.1 Non-Dense		950	625	175	480	1,400	1,400,000	510,000		
No.2 Dense		850	525	175	660	1,350	1,600,000	580,000		
No.2		800	475	175	565	1,300	1,400,000	510,000		
No.2 Non-Dense		750	425	175	480	1,250	1,300,000	470,000		
No.3 and Stud		475	275	175	565	750	1,300,000	470,000		
Dense Select Structural	12" wide	1,800	1,250	175	660	1,750	1,900,000	690,000	0.55	
Select Structural		1,600	1,100	175	565	1,650	1,800,000	660,000		
Non-Dense Select Structural		1,400	975	175	480	1,550	1,600,000	580,000		
No.1 Dense		1,100	750	175	660	1,500	1,800,000	660,000		
No.1		1,000	650	175	565	1,400	1,600,000	580,000		
No.1 Non-Dense		900	575	175	480	1,350	1,400,000	510,000		
No.2 Dense		800	500	175	660	1,300	1,600,000	580,000		
No.2		750	450	175	565	1,250	1,400,000	510,000		
No.2 Non-Dense		700	400	175	480	1,250	1,300,000	470,000		
No.3 and Stud		450	250	175	565	725	1,300,000	470,000		

Table 11 (NDS Supplement Table 4B)

Table 4D (Cont.) Reference Design Values for Visually Graded Timbers (5" x 5" and larger)[1,3]

(Tabulated design values are for normal load duration and dry service conditions, unless specified otherwise. See NDS 4.3 for a comprehensive description of design value adjustment factors.)

USE WITH TABLE 4D ADJUSTMENT FACTORS

Species and commercial Grade	Size classification	Design values in pounds per square inch (psi): Bending F_b	Tension parallel to grain F_t	Shear parallel to grain F_v	Compression perpendicular to grain $F_{c\perp}$	Compression parallel to grain F_c	Modulus of Elasticity E	Modulus of Elasticity E_{min}	Specific Gravity[4] G	Grading Rules Agency
RED MAPLE										
Select Structural	Beams and Stringers	1,500	875	195	615	900	1,500,000	550,000	0.58	NELMA
No.1		1,250	625	195	615	750	1,500,000	550,000		
No.2		800	400	195	615	475	1,200,000	440,000		
Select Structural	Posts and Timbers	1,400	925	195	615	950	1,500,000	550,000		
No.1		1,150	750	195	615	825	1,500,000	550,000		
No.2		650	425	195	615	375	1,200,000	440,000		
RED OAK										
Select Structural	Beams and Stringers	1,350	800	155	820	825	1,200,000	440,000	0.67	NELMA
No.1		1,150	550	155	820	700	1,200,000	440,000		
No.2		725	375	155	820	450	1,000,000	370,000		
Select Structural	Posts and Timbers	1,250	850	155	820	875	1,200,000	440,000		
No.1		1,000	675	155	820	775	1,200,000	440,000		
No.2		575	400	155	820	350	1,000,000	370,000		
RED PINE										
Select Structural	Beams and Stringers	1,050	625	130	440	725	1,100,000	400,000	0.44	NLGA
No.1		875	450	130	440	600	1,100,000	400,000		
No.2		575	300	130	440	375	900,000	330,000		
Select Structural	Posts and Timbers	1,000	675	130	440	775	1,100,000	400,000		
No.1		800	550	130	440	675	1,100,000	400,000		
No.2		475	325	130	440	475	900,000	330,000		
REDWOOD										
Clear Structural	5"x5" and Larger	1,850	1,250	145	650	1,650	1,300,000	470,000	0.44	RIS
Select Structural		1,400	950	145	650	1,200	1,300,000	470,000	0.44	
Select Structural Open Grain		1,100	750	145	420	900	1,000,000	370,000	0.37	
No. 1		1,200	800	145	650	1,050	1,300,000	470,000	0.44	
No. 1 Open Grain		950	650	145	420	800	1,000,000	370,000	0.37	
No. 2		1,000	525	145	650	900	1,100,000	400,000	0.44	
No. 2 Open Grain		750	400	145	420	650	900,000	330,000	0.37	
SITKA SPRUCE										
Select Structural	Beams and Stringers	1,200	675	140	435	825	1,300,000	470,000	0.43	WCLIB
No.1		1,000	500	140	435	675	1,300,000	470,000		
No.2		650	325	140	435	450	1,000,000	370,000		
Select Structural	Posts and Timbers	1,150	750	140	435	875	1,300,000	470,000		
No.1		925	600	140	435	750	1,300,000	470,000		
No.2		550	350	140	435	525	1,000,000	370,000		
Select Structural	Beams and Stringers	1,200	675	140	435	825	1,300,000	470,000	0.43	WWPA
No.1		1,000	500	140	435	675	1,300,000	470,000		
No.2		650	325	140	435	450	1,100,000	400,000		
Select Structural	Posts and Timbers	1,150	750	140	435	875	1,300,000	470,000		
No.1		925	600	140	435	750	1,300,000	470,000		
No.2		550	350	140	435	525	1,100,000	400,000		
SOUTHERN PINE		(Wet Service Conditons)								
Dense Select Structural	5" x 5" and Larger	1,750	1,200	165	440	1,100	1,600,000	580,000	0.55	SPIB
Select Structural		1,500	1,000	165	375	950	1,500,000	550,000		
No. 1 Dense		1,550	1,050	165	440	975	1,600,000	580,000		
No. 1		1,350	900	165	375	825	1,500,000	550,000		
No. 2 Dense		975	650	165	440	625	1,300,000	470,000		
No. 2		850	550	165	375	525	1,200,000	440,000		
Dense Select Structural 86		2,100	1,400	165	440	1,300	1,600,000	580,000		
Dense Select Structural 72		1,750	1,200	165	440	1,100	1,600,000	580,000		
Dense Select Structural 65		1,600	1,050	165	440	1,000	1,600,000	580,000		

Table 12 (NDS Supplement Table 4D)

Table 4B Adjustment Factors

Size Factor, C_F

Appropriate size adjustment factors have already been incorporated in the tabulated design values for most thicknesses of Southern Pine and Mixed Southern Pine dimension lumber. For dimension lumber 4" thick, 8" and wider (all grades except Dense Structural 86, Dense Structural 72, and Dense Structural 65), tabulated bending design values, F_b, shall be permitted to be multiplied by the size factor, $C_F = 1.1$. For dimension lumber wider than 12" (all grades except Dense Structural 86, Dense Structural 72, and Dense Structural 65), tabulated bending, tension and compression parallel to grain design values for 12" wide lumber shall be multiplied by the size factor, $C_F = 0.9$. When the depth, d, of Dense Structural 86, Dense Structural 72, or Dense Structural 65 dimension lumber exceeds 12", the tabulated bending design value, F_b, shall be multiplied by the following size factor:

$$C_F = (12/d)^{1/9}$$

Repetitive Member Factor, C_r

Bending design values, F_b, for dimension lumber 2" to 4" thick shall be multiplied by the repetitive member factor, $C_r = 1.15$, when such members are used as joists, truss chords, rafters, studs, planks, decking, or similar members which are in contact or spaced not more than 24" on center, are not less than 3 in number and are joined by floor, roof, or other load distributing elements adequate to support the design load.

Flat Use Factor, C_{fu}

Bending design values adjusted by size factors are based on edgewise use (load applied to narrow face). When dimension lumber is used flatwise (load applied to wide face), the bending design value, F_b, shall also be multiplied by the following flat use factors:

Flat Use Factors, C_{fu}

Width (depth)	Thickness (breadth)	
	2" & 3"	4"
2" & 3"	1.0	—
4"	1.1	1.0
5"	1.1	1.05
6"	1.15	1.05
8"	1.15	1.05
10" & wider	1.2	1.1

Wet Service Factor, C_M

When dimension lumber is used where moisture content will exceed 19% for an extended time period, design values shall be multiplied by the appropriate wet service factors from the following table (for surfaced dry Dense Structural 86, Dense Structural 72, and Dense Structural 65 use tabulated surfaced green design values for wet service conditions without further adjustment):

Wet Service Factors, C_M

F_b	F_t	F_v	$F_{c\perp}$	F_c	E and E_{min}
0.85*	1.0	0.97	0.67	0.8**	0.9

* when $(F_b)(C_F) \leq 1{,}150$ psi, $C_M = 1.0$

** when $(F_c) \leq 750$ psi, $C_M = 1.0$

Figure 35 (NDS Supplement Table 4B Adjustment Factors)

Table 4D Adjustment Factors

Size Factor, C_F

When visually graded timbers are subjected to loads applied to the narrow face, tabulated design values shall be multiplied by the following size factors:

Size Factors, C_F

Depth	F_b	F_t	F_c
d > 12"	$(12/d)^{1/9}$	1.0	1.0
d ≤ 12"	1.0	1.0	1.0

Flat Use Factor, C_{fu}

When members designated as Beams and Stringers* in Table 4D are subjected to loads applied to the wide face, tabulated design values shall be multiplied by the following flat use factors:

Flat Use Factor, C_{fu}

Grade	F_b	E and E_{min}	Other Properties
Select Structural	0.86	1.00	1.00
No.1	0.74	0.90	1.00
No.2	1.00	1.00	1.00

*"Beams and Stringers" are defined in NDS 4.1.3 (also see Table 1B).

Wet Service Factor, C_M

When timbers are used where moisture content will exceed 19% for an extended time period, design values shall be multiplied by the appropriate wet service factors from the following table (for Southern Pine and Mixed Southern Pine, use tabulated design values without further adjustment):

Wet Service Factors, C_M

F_b	F_t	F_v	$F_{c\perp}$	F_c	E and E_{min}
1.00	1.00	1.00	0.67	0.91	1.00

Figure 36 (NDS Supplement Table 4D Adjustment Factors)

Table 2.3.2 Frequently Used Load Duration Factors, C_D[1]

Load Duration	C_D	Typical Design Loads
Permanent	0.9	Dead Load
Ten years	1.0	Occupancy Live Load
Two months	1.15	Snow Load
Seven days	1.25	Construction Load
Ten minutes	1.6	Wind/Earthquake Load
Impact[2]	2.0	Impact Load

1. Load duration factors shall not apply to reference modulus of elasticity, E, reference modulus of elasticity for beam and column stability, E_{min}, nor to reference compression perpendicular to grain design values, $F_{c\perp}$, based on a deformation limit.
2. Load duration factors greater than 1.6 shall not apply to structural members pressure-treated with water-borne preservatives (see Reference 30), or fire retardant chemicals. The impact load duration factor shall not apply to connections.

Table 13 (NDS for Wood Construction Manual Table 2.3.2)

Table 2.3.3	**Temperature Factor, C_t**			
Reference Design Values	**In-Service Moisture Conditions**[1]	**C_t**		
		T≤100°F	**100°F<T≤125°F**	**125°F<T≤150°F**
F_t, E, E_{min}	Wet or Dry	1.0	0.9	0.9
F_b, F_v, F_c, and $F_{c\perp}$	Dry	1.0	0.8	0.7
	Wet	1.0	0.7	0.5

1. Wet and dry service conditions for sawn lumber, structural glued laminated timber, prefabricated wood I-joists, structural composite lumber, wood structural panels and cross-laminated timber are specified in 4.1.4, 5.1.4, 7.1.4, 8.1.4, 9.3.3, and 10.1.5 respectively.

Table 14 (NDS for Wood Construction Manual Table 2.3.3)

Table 4.3.8 Incising Factors, C_i

Design Value	C_i
E, E_{min}	0.95
F_b, F_t, F_c, F_v	0.80
$F_{c\perp}$	1.00

Table 15 (NDS for Wood Construction Manual Table 4.3.8)

Table 3.10.4 Bearing Area Factors, C_b

ℓ_b	0.5"	1"	1.5"	2"	3"	4"	6" or more
C_b	1.75	1.38	1.25	1.19	1.13	1.10	1.00

Table 16 (NDS for Wood Construction Manual Table 3.10.4)

Southern Pine No.1 Beam			Fb	Ft	Fv	Fcp	Fc	E	Emin	G
			1350	900	165	375	825	1,500,000	550,000	0.55
			Fb'	Ft'	Fv'	Fcp'	Fc*	E'	E'min	
			781.218	828	147.246	276.375	607.2	1282500	531462.2	
							Fc'			
							476.0773			

Table 17-1 (Beam Design Values)

Cd	Cm(Fb/Ft/	Ct	Cl	Cf	Cfu	Ci(E/Emin	Cr	CT	Cb	Cp	FcE
1.15	0.85	1	1	1	0.74	0.95	1	1.130169	1.1	0.646642	21.02569
	1				0.9	0.8					
	0.97				1	1					
	0.67										
	0.8										
	0.9										

Table 17-2 (Beam Adjustment Factors)

3x5.5 Southern Pine for Rafters			Fb	Ft	Fv	Fcp	Fc	E	Emin	G
			1500	1000	175	565	1650	1,600,000	580,000	0.55
			Fb'	Ft'	Fv'	Fcp'	Fc*	E'	E'min	
			1348.95	920	156.17	378.55	1214.4	1368000	556416.6	
							Fc'			
							936.9692			

Table 18-1 (Rafter Design Values)

Cd	Cm(Fb/Ft/	Ct	Cl	Cf	Cfu	Ci(E/Emin	Cr	CT	Cb	Cp	FcE
1.15	0.85	1	1	1	1	0.95	1.15	1.130169	1	0.646642	21.02569
	1					0.8					
	0.97					1					
	0.67										
	0.8										
	0.9										

Table 18-2 (Rafter Adjustment Factors)

2.5x12 Southern Pine for Joists			Fb	Ft	Fv	Fcp	Fc	E	Emin	G
			1500	1000	175	565	1650	1,600,000	580,000	0.55
			Fb'	Ft'	Fv'	Fcp'	Fc*	E'	E'min	
			1348.95	920	156.17	378.55	1214.4	1368000	556416.6	
							Fc'			
							936.9692			

Table 19-1 (Joist Design Values)

Cd	Cm(Fb/Ft/	Ct	Cl	Cf	Cfu	Ci(E/Emin	Cr	CT	Cb	Cp	FcE
1.15	0.85	1	1	1	1	0.95	1.15	1.130169	1	0.646642	21.02569
	1					0.8					
	0.97					1					
	0.67										
	0.8										
	0.9										

Table 19-2 (Joist Adjustment Factors)

8x8 Soutern Pine Columns			Fb	Ft	Fv	Fcp	Fc	E	Emin	G
			1350	900	165	375	825	1,500,000	550,000	0.55
			Fb'	Ft'	Fv'	Fcp'	Fc*	E'	E'min	
			919.08	828	151.8	251.25	690.69	1425000	590513.6	
							Fc'			
							446.2824			

Table 20-1 (Column Design Values)

Cd	Cm(Fb/Ft/	Ct	Cl	Cf	Cfu	Ci(E/Emin	Cr	CT	Cb	Cp	FcE
1.15	1	1	1	1	0.74	0.95	1	1.130169	1	0.64614	23.36187
	0.67				0.9	0.8					
	0.91				1	1					

Table 20-2 (Column Adjustment Factors)

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		ASD only	ASD and LRFD										LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	-	-	-	2.54	0.85	λ
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	2.70	0.80	λ
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	C_i	-	-	-	-	2.88	0.75	λ
$F_c' = F_c$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	C_P	-	-	2.40	0.90	λ
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_b	1.67	0.90	-
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	1.76	0.85	-

Table 21 (NDS for Wood Construction Table 4.3.1)