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AN ADAPTIVE REUSE AND RESTORATION OF A MAINE BARN

by

Sarah Elizabeth Williams

A Thesis Submitted in Partial Fulfillment  
of the Requirements for a Degree with Honors  
(Civil Engineering)

The Honors College

University of Maine

May 2012

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## **ABSTRACT**

This is a study of a post and beam barn in Orono, Maine that examines the changes necessary to use the barn as an event center. Included is a structural analysis of the current barn structure to determine its adequacy for the new use under current design standards, including IBC 2009. The architectural portion of this study examines the capacity of the building and the egress and restroom facilities requirements for that capacity, as well as the ADA requirements. Provided is a final design that incorporates the architectural aspects and the structural changes necessary to meet modern standards. Structural modifications to the roof and floor framing and an addition for restrooms and kitchen space are recommended.

## **ACKNOWLEDGEMENTS**

I would like to acknowledge the contributions of the following people:

Edwin Nagy, who agreed to be my Thesis Advisor and assisted me with the structural analysis of the barn,

George Markowsky, who allowed me to do a project on his barn, and let me tailor the project to my own interests,

Russell Edgar, who volunteered his time and expertise to determine the species of wood used in the original barn construction,

Greg Frost, who volunteered his time and expertise as an architect to give me guidance on the architectural design for the barn,

Geoffrey Williams, my father, who spent a full day in December measuring the barn with me, and who answered my late night structural design questions,

and Kathy Williams, my mother, who tried to keep me on schedule.

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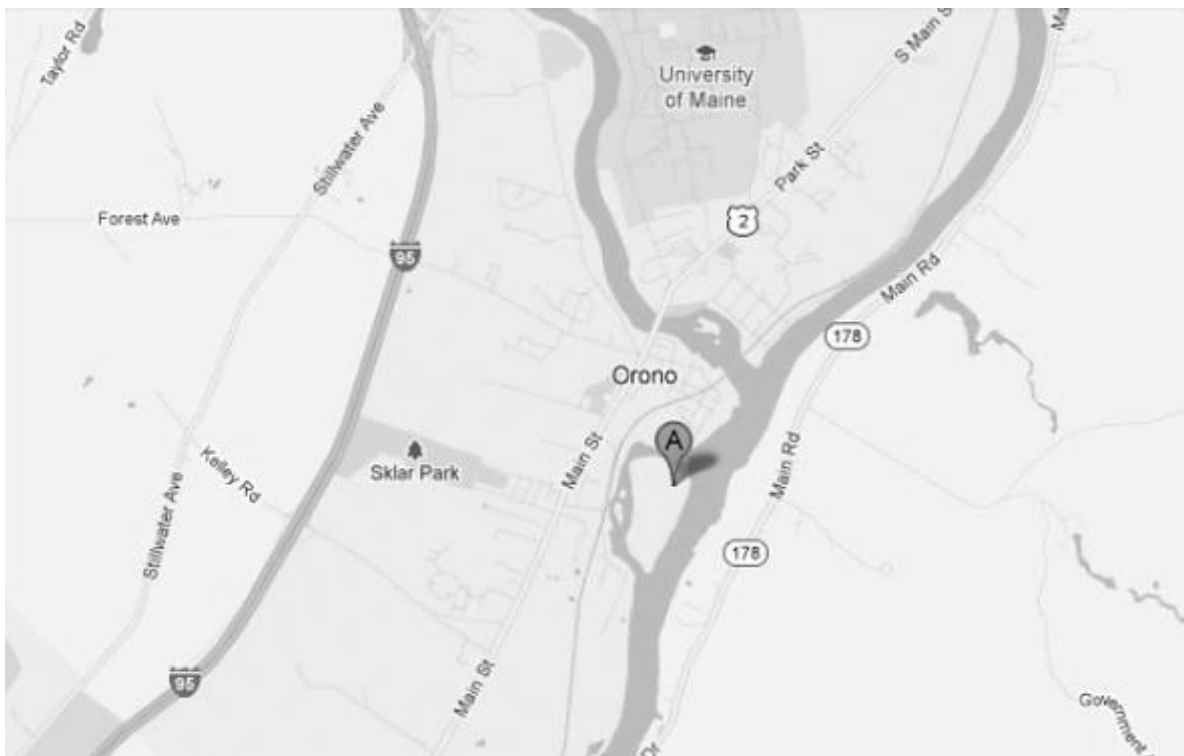


## CHAPTER 1: INTRODUCTION

This chapter provides an overview of my honors thesis project including the background of the project, the owner's requests, and a description of the project.

### BACKGROUND

Ayers Island is an old mill complex located in Orono, Maine. Throughout its lifetime it has been many things including: a saw mill, a pulp mill, and a textile mill (Personal communication, GM, 2011). In June of 1999, Ayers Island LLC and the Town of Orono signed a lease-purchase agreement. Dr. George Markowsky was my contact for Ayers Island LLC which currently owns the property. For location of Ayers Island in relation to Orono, ME, see Figure 1: Location of Ayers Island below.



**Figure 1: Location of Ayers Island**

(Taken from Google Maps)

The mill complex has the main manufacturing building and several outbuildings including a 40 foot by 105 foot timber frame barn. This barn was the focus of my project. See Appendix A: Existing Site Plans for drawings of Ayers Island.

#### OWNERS REQUEST

Dr. Markowsky is interested in using the barn as a small event center: a place to hold meetings, weddings, wedding receptions, concerts, dinners, lectures, and other special events (Millennium Barn, 2002). Dr. Markowsky would like to preserve the acoustics and interior aesthetic of the barn. He is also interested in whether or not the barn can be used year-round (Personal communication, GM, 2011). See Figure 2: Exterior View of Existing Barn below.



**Figure 2: Exterior View of Existing Barn**

## PROJECT DESCRIPTION

This project involved examining how to adapt an existing Maine barn for a new use as an event center. I analyzed the barn structure in accordance with modern building codes. Then I detailed the structural changes necessary to bring the barn up to current building code standards. Also an architectural layout was designed for the existing barn and an addition to provide the necessary spaces for an event center. As a civil engineer I focused on the structural analysis of the barn. However, there are many other disciplines that are required for a full design that I do not have experience in, which I excluded from this project. Below is detailed the scope of the project and the exclusions from the project.

### *Scope of Project*

This project included the following:

- Investigation of the current structural condition of the barn
- Creating field sketches of the existing barn
- Performing a structural analysis of existing barn
- Detailing the necessary structural changes conceptually
- Creating an architectural design including an addition
- Creating drawings of my proposed design.

### *Exclusions from Scope*

This project did not include the following:

- Economic analysis
- Foundation analysis and design for the existing barn

- Structural and foundation design for the addition
- Water and sewer system design
- Electrical design
- Transportation design
- Full site layout and design.

## CHAPTER 2: EXISTING CONDITIONS

This chapter provides a brief history of the barn. It also details the current conditions of the barn as seen during the site visit made on December 27, 2011 by Geoffrey Williams, P.E. and myself. Detailed sketches can be found in Appendix B: Existing Conditions Drawings. The barn at Ayers Island is 3 bays wide by 7 bays long for a total of 40 feet wide by 105 feet long. The 8 frames on the long side were labeled Frame A through Frame H, and the 4 lines of posts were labeled Line 1 through Line 4. See

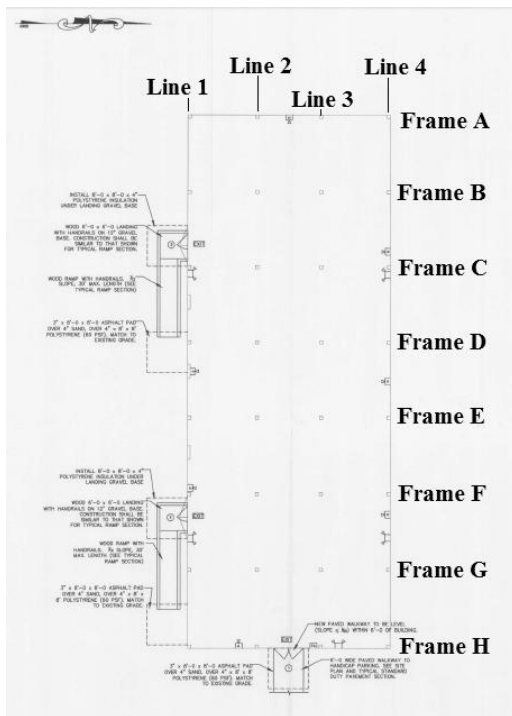
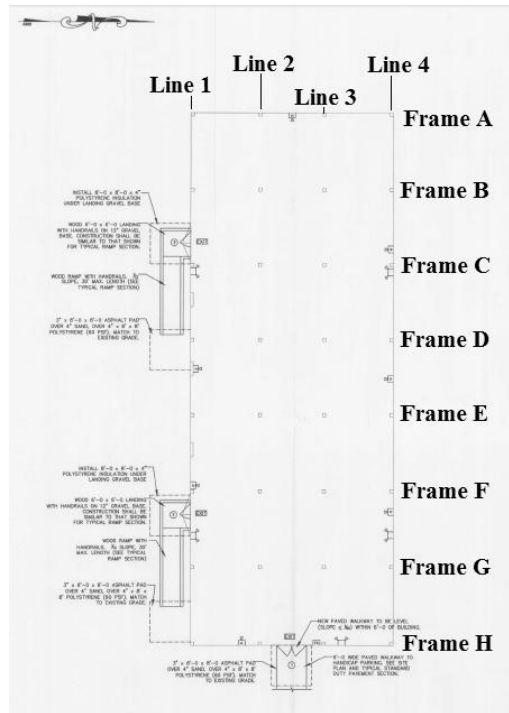


Figure 3: Labeled Frames and Lines below. The corner closest to the Ayers Island entrance is labeled Frame A, Line 1.



**Figure 3: Labeled Frames and Lines**

(Adapted from Barn Building Occupation Plan, James W. Sewall Company, 2005)

#### HISTORY OF THE BARN

The barn on Ayers Island likely dates between the years 1860 and 1907. The Eastland Woolen Mill plan drawn by Industrial Risk Insurers on November 16, 1995, which can be found in Appendix A: Existing Site Plans, dates most of the buildings on Ayers Island from 1907 and later. However, the barn is not dated in this drawing and based on its post and therefore likely pre-dated 1907.

**The Ayers Island barn is a New England style barn, which is characterized by the door in the gable end. The New England style barn replaced the English style barn, which has the door in one of the side walls, as the most popular type of barn in New England by 1860 (Hubka, 1984, p. 52). The New England style barn is often three bays wide, as is the Ayers Island barn (Hubka, 1984, p.55). New England style barns that were built after 1840 often use 8 inch by 8 inch sawn members for the major structural members, which is the case on Ayers Island (Hubka, 1984, p.56). The barn on Ayers Island has framing for windows over the main doors and a cellar**

which was typical of New England style barns built after 1850 (Hubka, 1984, p. 58). From this information it is reasonable to date the barn on Ayers Island between 1860 and 1907. See

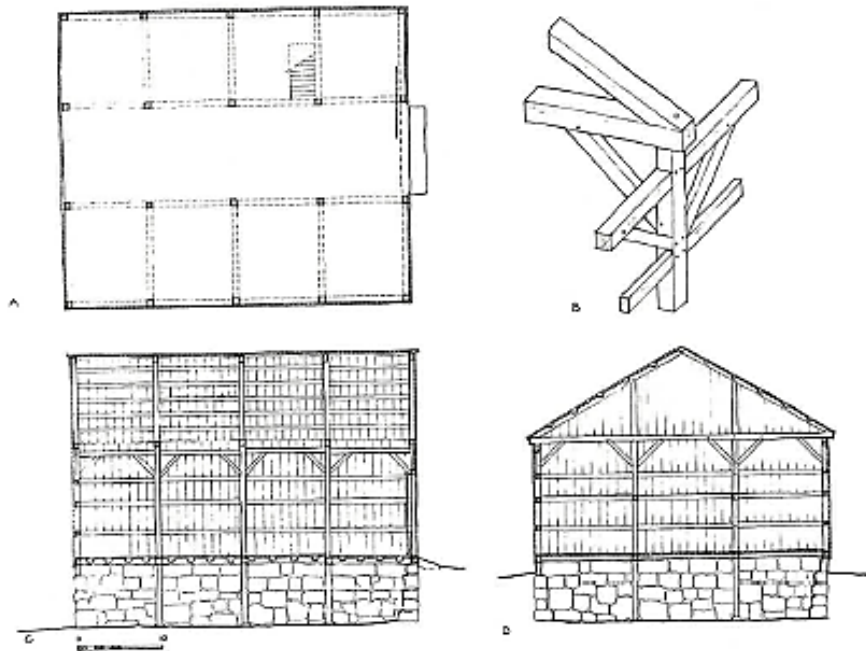


Fig. 45. A New England barn: A, plan; B, framing detail at plate; C, longitudinal section; D, transverse section. Sawyer-Black Farm, Sweden, Maine.

Figure 4: New England style barn, below for a drawing of a typical New England style barn.

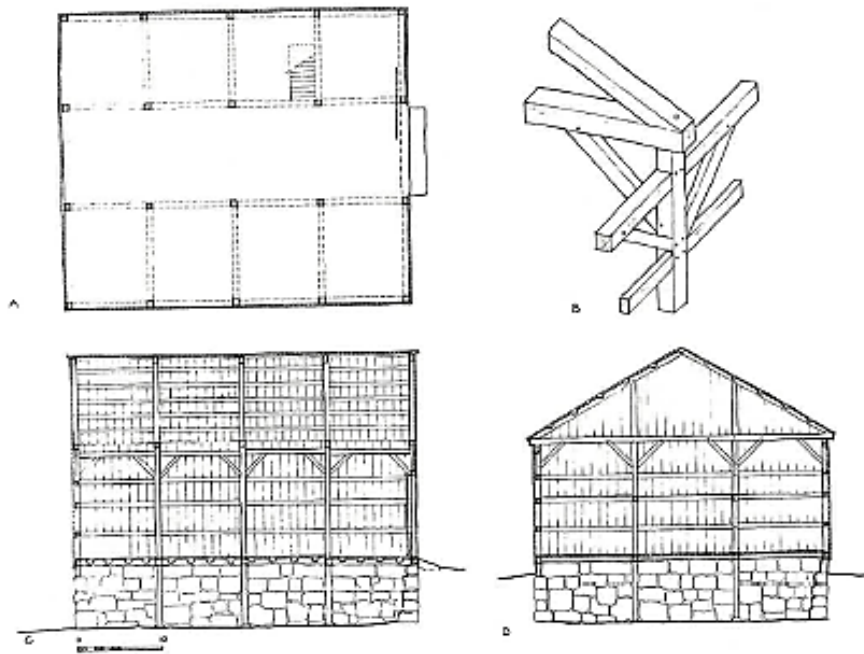


Fig. 45. A New England barn: A, plan; B, framing detail at plate; C, longitudinal section; D, transverse section. Sawyer-Black Farm, Sweden, Maine.

#### Figure 4: New England style barn

(Hubka, 1984, Fig. 45, p.57)

The barn appears to have been added onto. There are two types of frames in the barn, interior and exterior. Frame E, which is near the center of the barn, is an exterior frame. This supports the conclusion that the barn has been added onto. Frame E was the old end wall for a three bay by four bay barn. There is framing for the center door. There is also evidence of framing for a side door and for the minor wind girts. A close examination of the exterior posts in Frame E shows that the old exterior boarding is still attached. From these observations it can be concluded that the Barn on Ayers Island was added onto at some point. Based on the fact that the framing of the three added bays is very similar to the original four bays, it is reasonable to assume that the additional bays were added



relatively soon after the construction of the original barn (Personal communication, G.W., 2011).

There is also evidence that there used to be a line of 6 inch by 8 inch beams 7 feet 10 inches off the floor on Line 2. This was likely framing for a hay loft between Line 1 and Line 2. These beams have since been removed (Personal communication, G.W., 2011).

The barn on Ayers Island uses the typical 8 inch by 8 inch framing members. The 9 on 12 pitch of the roof is also common (Personal communication G.W., 2012). The angled purlin posts, described below, were not the most common choice, but I did find several examples of barns with angled purlin posts in my research. The barn on Ayers Island does have a unique piece of framing. I could not locate anything similar to the eave beam, which will be described below, in my research.

## EXTERIOR

The exterior of the barn includes board sheathing and faux brick siding. The board sheathing consists of two layers of  $\frac{3}{4}$  inch sawn lumber. Unless noted as nominal all member sizes in this report are actual measured sizes. These two layers of boarding help create a weather tight building by overlapping the seams. The boarding is nailed into the wall framing which will be discussed in Interior Framing below. The faux brick siding is nailed onto the exterior layer of sheathing.

### *Issues Noted*

The faux brick siding has peeled off the side of the barn in many places. The boarding remains in good shape over most of the barn. There were only a few places where there

was evidence of rot. See Figure 5: Current Exterior of the Barn below, for an image of the peeling faux brick siding.



**Figure 5: Current Exterior of the Barn**

#### ROOF FRAMING

**The barn on Ayers Island has a roof with a 9 on 12 pitch. The roofing includes: shingles, a layer of 1 inch boarding, 3 inch by 6 inch rafters at 27 inches on center, 5 ½ inch by 7 inch purlins and 8 inch by 8 inch eave beams. The boarding runs parallel to the ridge of the roof and is nailed to the rafters. The rafters are 27 feet long and run from the ridge line to the eave beam. The purlins run parallel to the ridge line and support the rafters at approximately the middle of their span. The eave beam is supported by an 8 inch by 8 inch cross beam, which is discussed below**

**in Interior Framing. See**

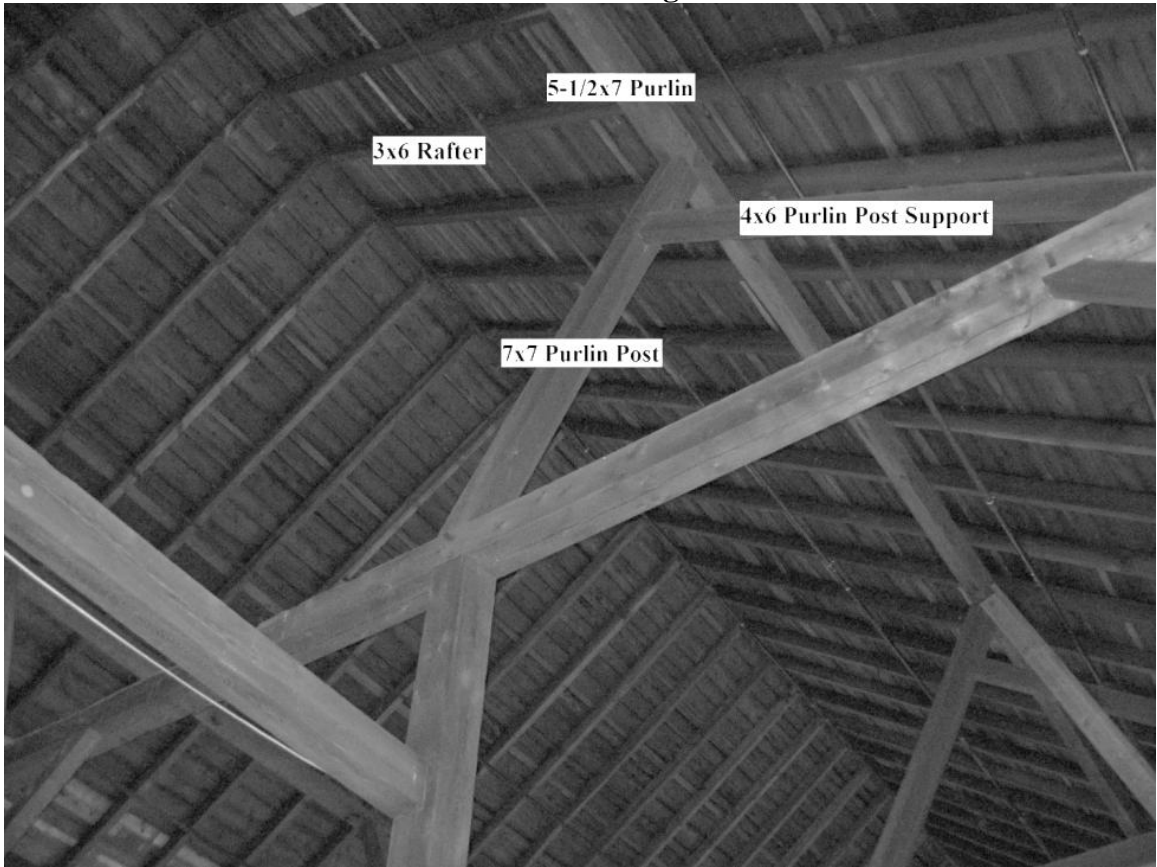
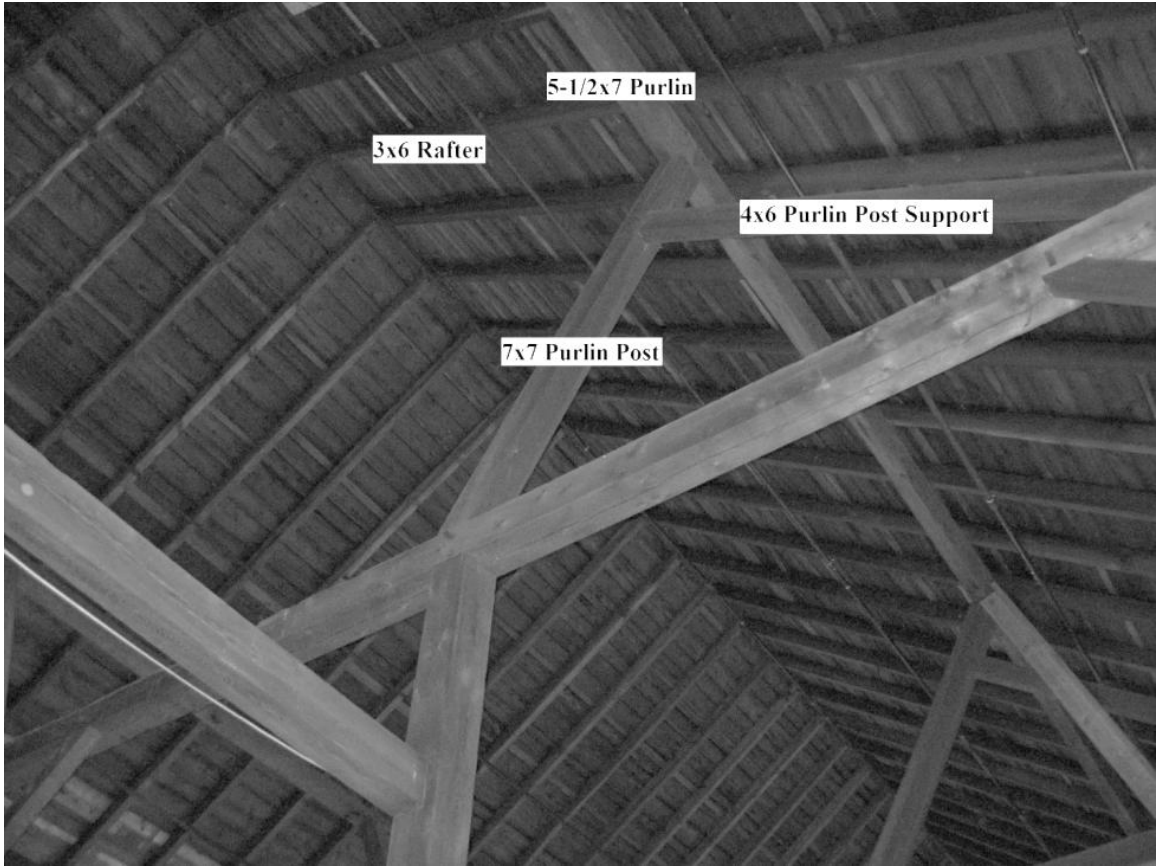


Figure 6: Current Roof Framing below for a labeled image of the roof framing.



**Figure 6: Current Roof Framing**

**The eave beam is an unusual piece of framing because it does not fall over the exterior wall line but is 18 inches out from the exterior wall. In most post and beam construction the rafters land on the exterior wall and a faux rafter or rafter tail is added for the overhang. In the Ayers Island barn the overhang is created by the**

eave beam. See

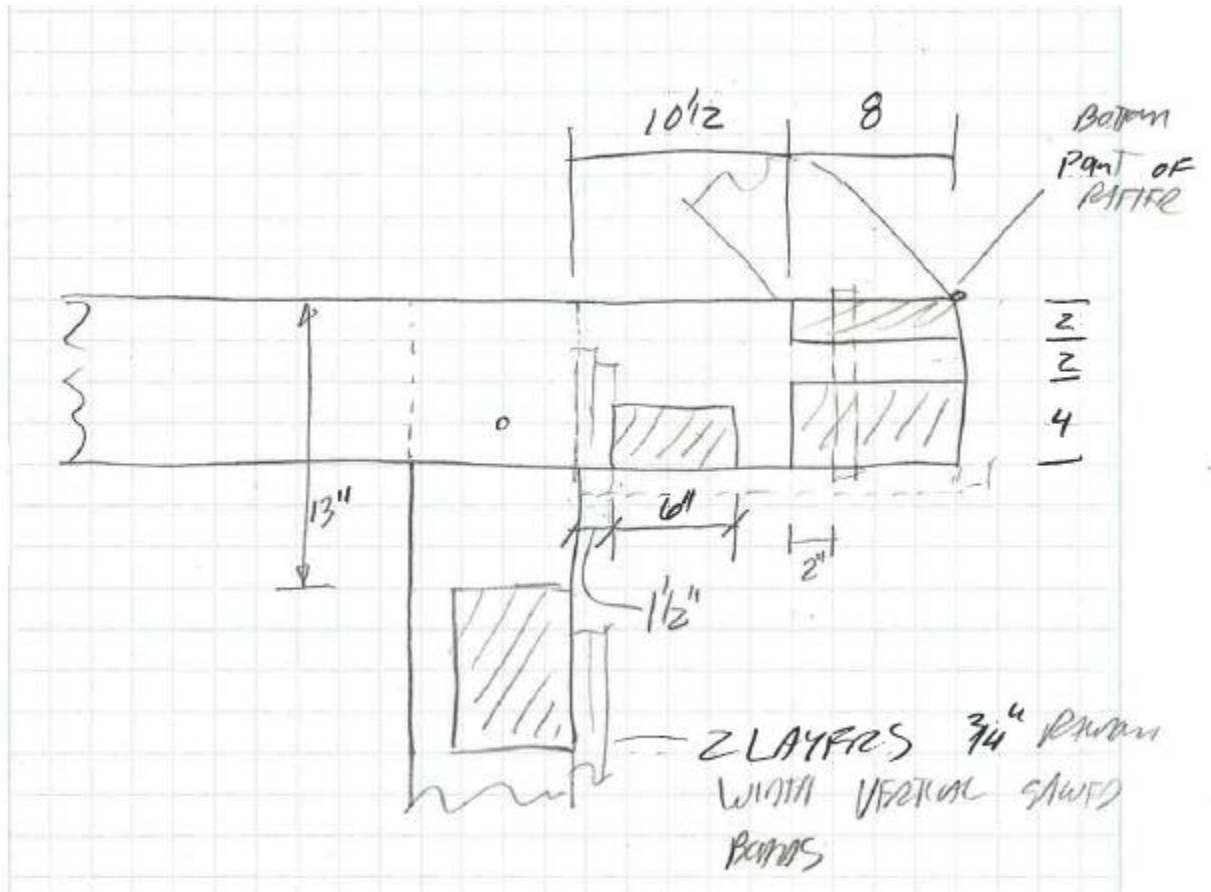
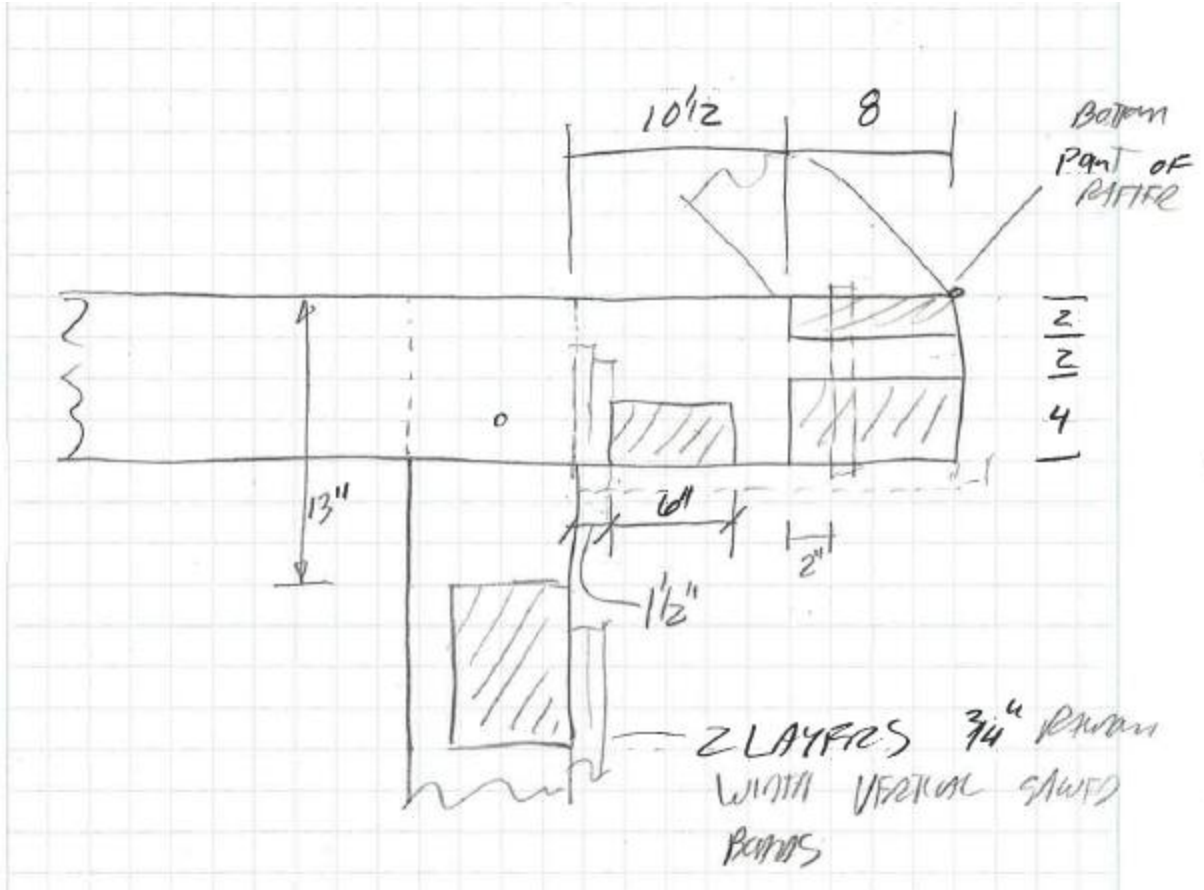


Figure 7: Eave Beam Detail below for a drawing of the eave beam.



**Figure 7: Eave Beam Detail**

*Issues Noted*

**One of the purlins, between Line 1 and Line 2, is supported by two T-beams at Frame C and another two T-beams at Frame D. The T-beams are additional structural members that are used to carry the force from the purlin down to the floor and foundation. They were added by Dr. Markowsky because the purlin post, discussed in Interior Framing below, has split and can no longer carry the purlin**

(Personal communication, GM, 2011). See

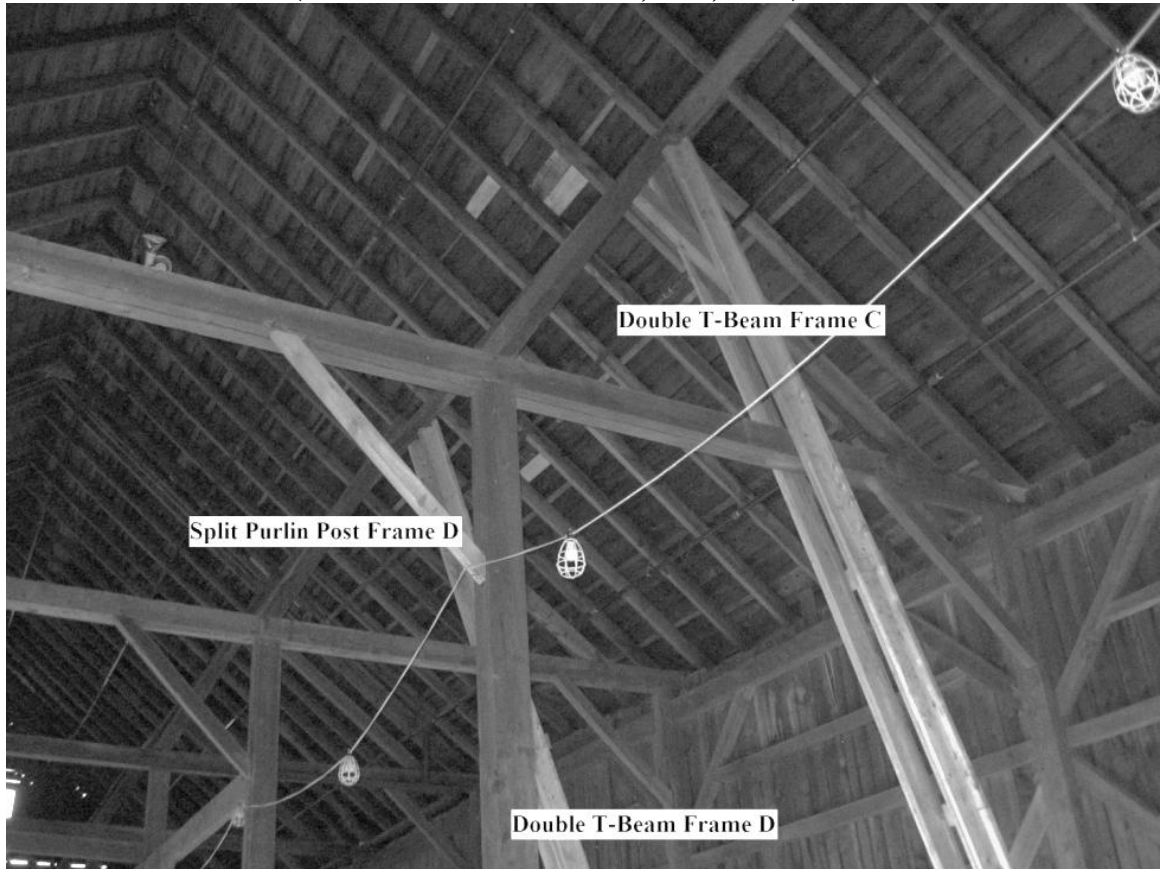
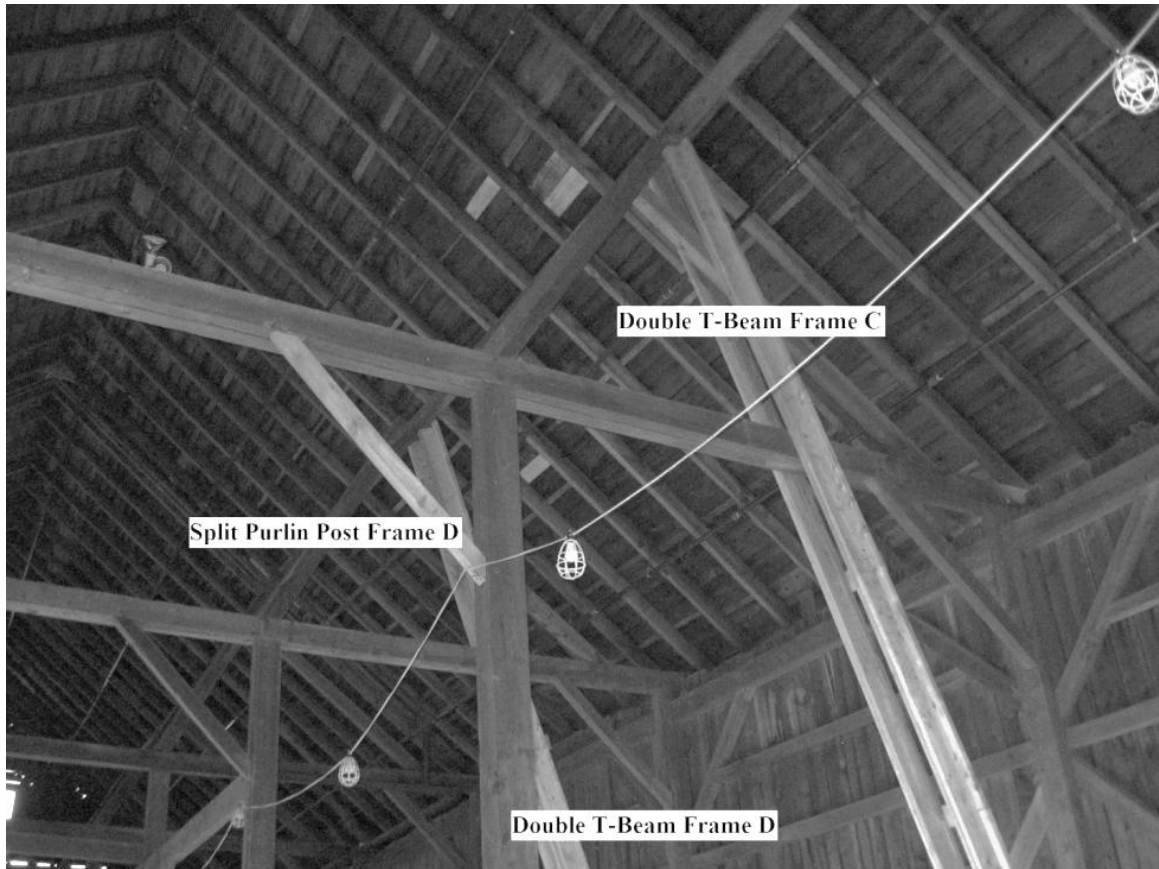


Figure 8: T-beams Supporting Purlin at Frame C and Frame D below.

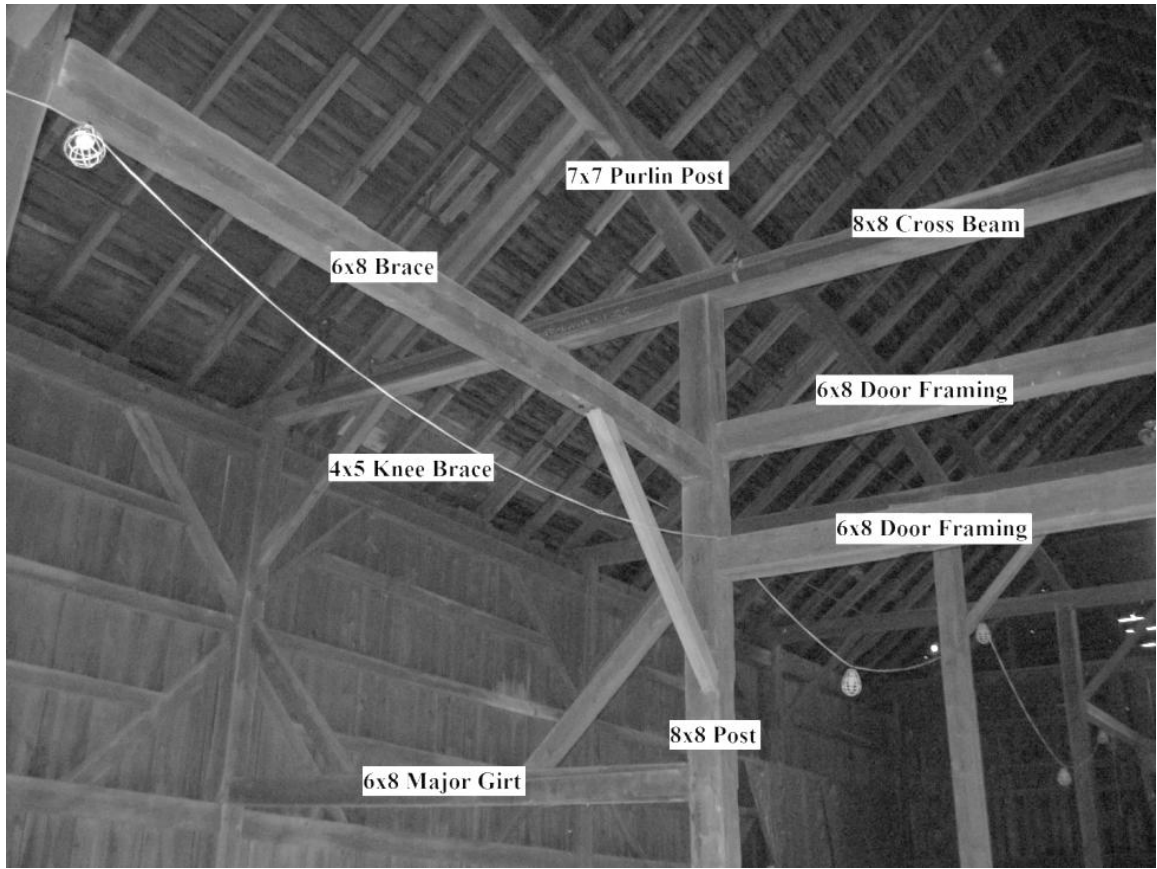


**Figure 8: T-beams Supporting Purlin at Frame C and Frame D**

#### INTERIOR FRAMING

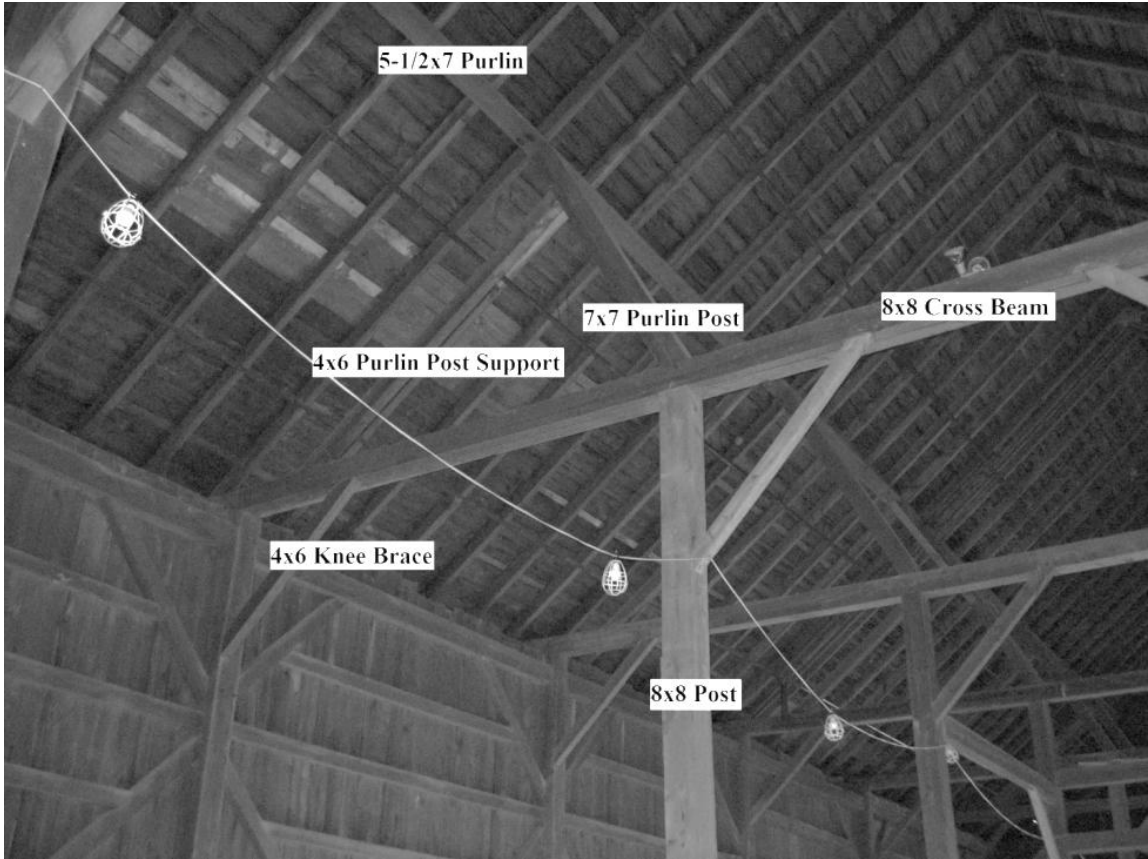
The interior framing includes two typical frames, an end frame and an interior frame. There are also two types of line framing, exterior and interior. A labeled exterior frame can be seen in Figure 9: Exterior Frame, below. The exterior frame includes: four 8 inch by 8 inch posts, a 8 inch by 8 inch cross beam, two 7 inch by 7 inch purlin posts, two 4 inch by 6 inch purlin post supports, two 6 inch by 8 inch beams framing the row of windows over the door, two 6 inch by 8 inch major girts, 4 inch by 5 inch minor girts, and eight 4 inch by 5 inch knee braces. Frames A, E and H are exterior frames.





**Figure 9: Exterior Frame**

A labeled interior frame can be seen in Figure 10: Interior Frame, below. The interior frame includes: four 8 inch by 8 inch posts, a 8 inch by 8 inch cross beam, two 7 inch by 7 inch purlin posts, two 4 inch by 6 inch purlin post supports, and four 4 inch by 5 inch knee braces. Frames B, C, D, and F are interior frames.



**Figure 10: Interior Frame**

Lines 1 and 4 are exterior wall lines. A labeled exterior wall line can be seen in

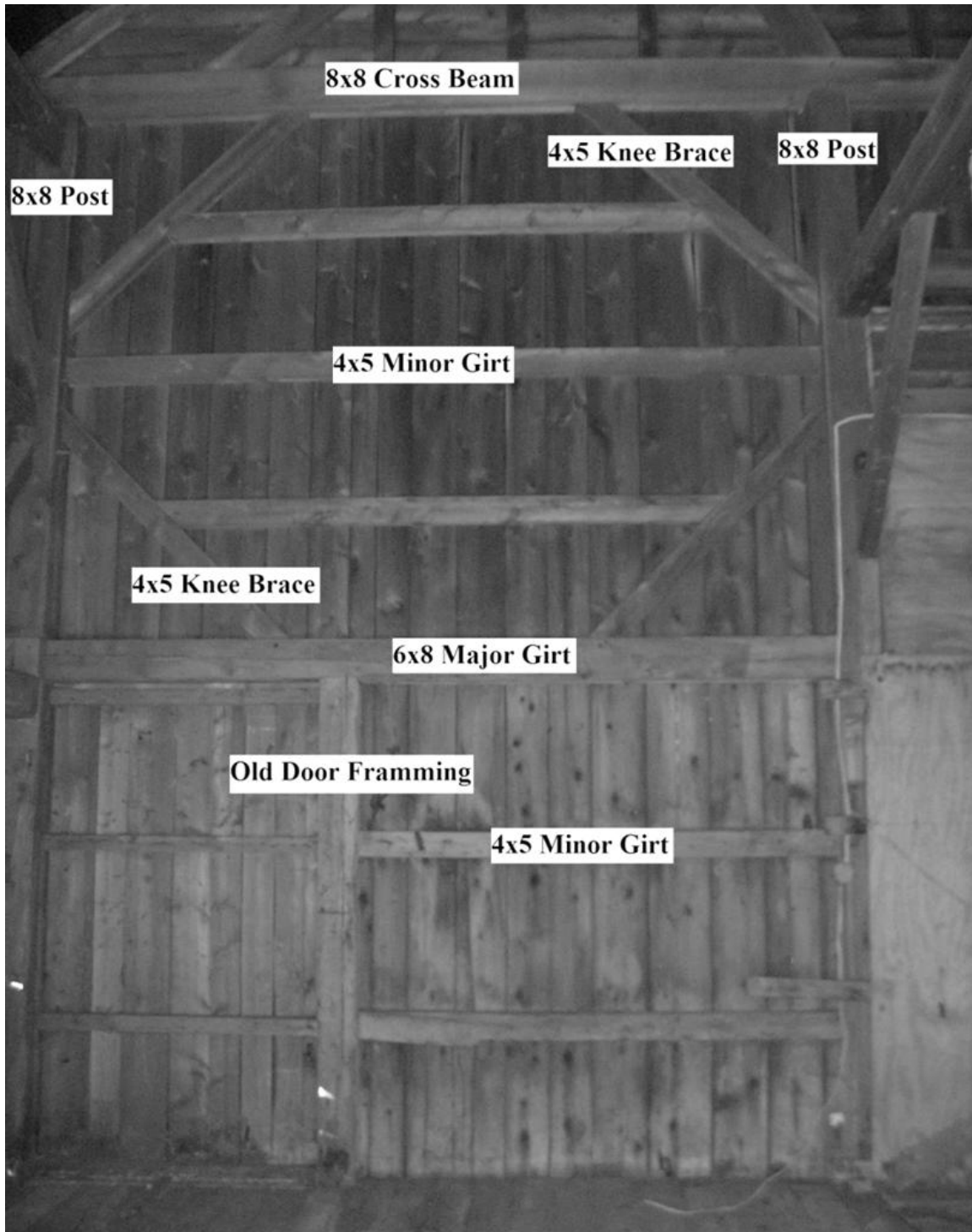
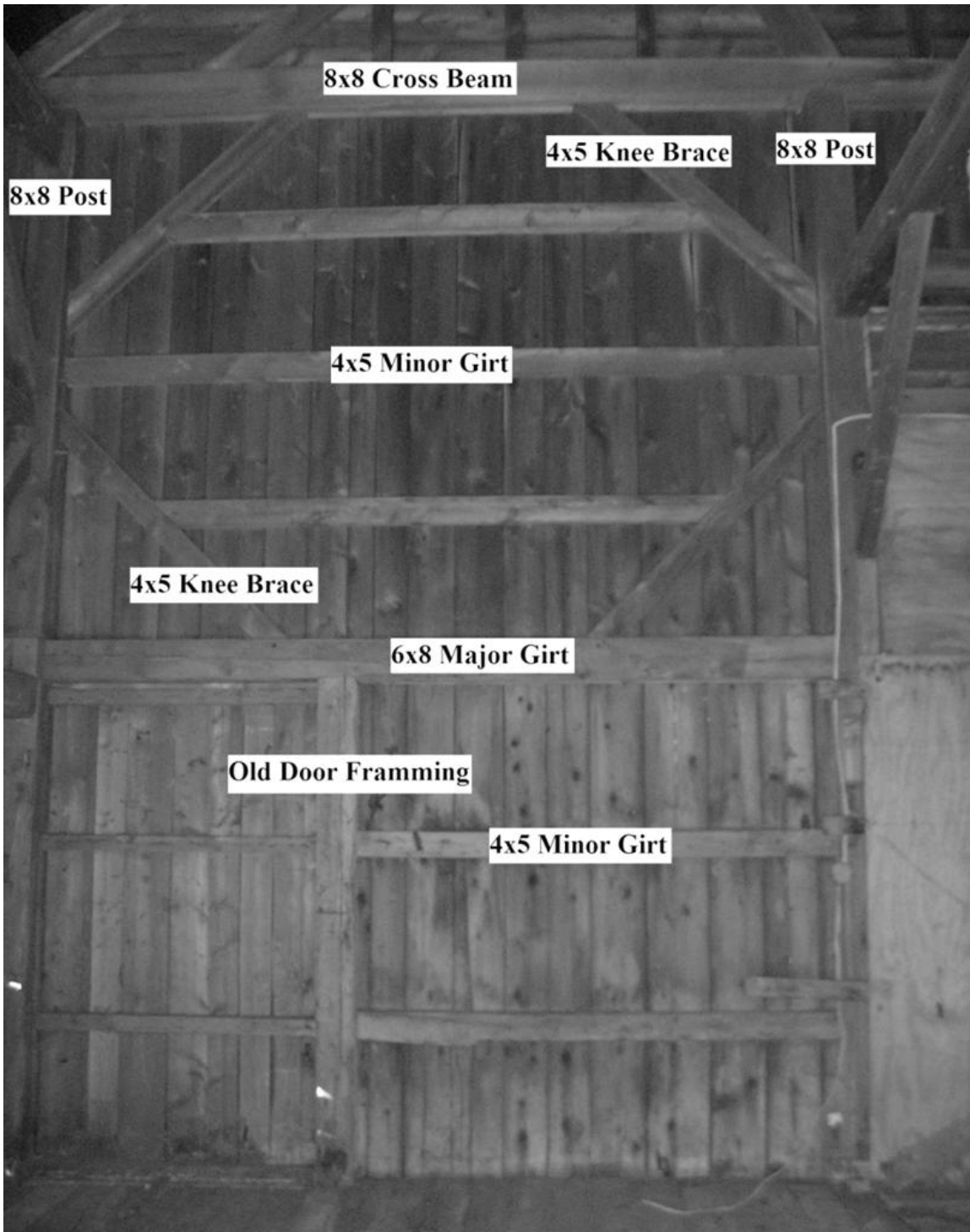
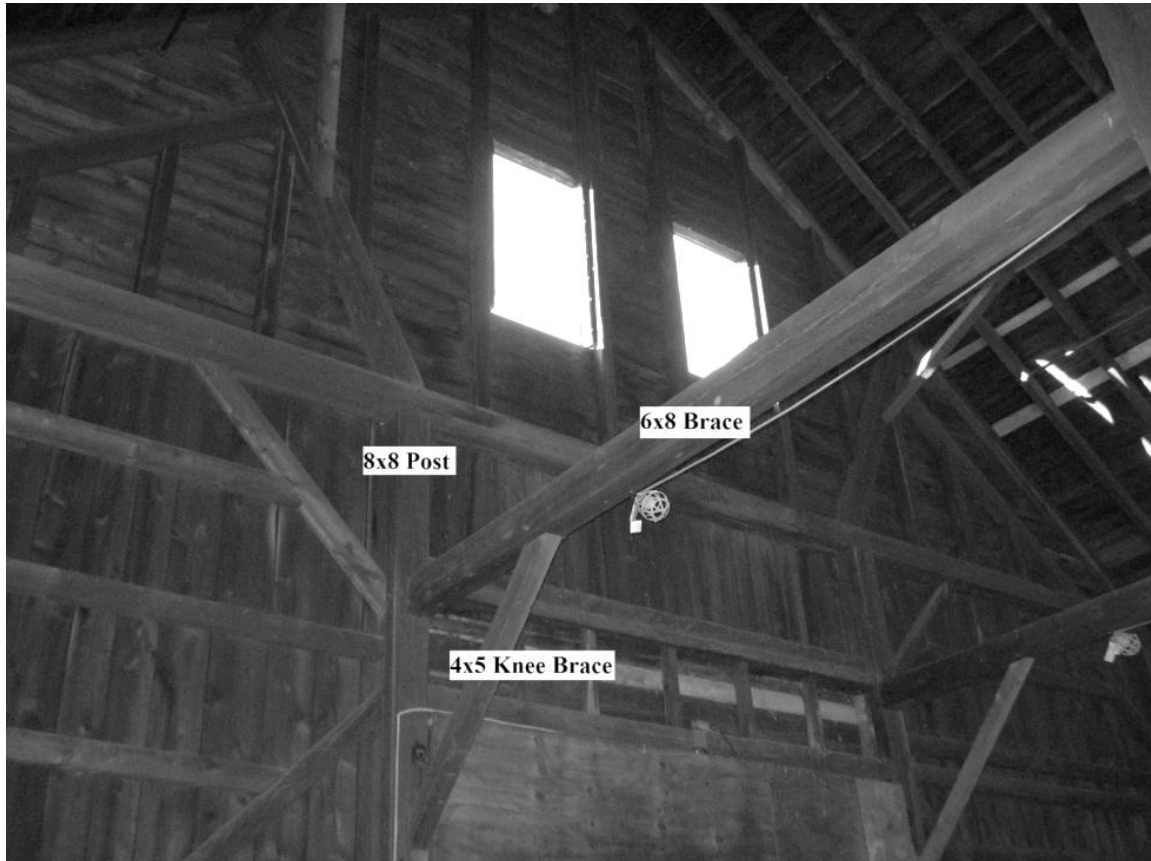


Figure 11: Exterior Wall Framing below. The exterior wall lines include two 6 inch by 8 inch major girts and 4 inch by 5 inch minor girts which run between the exterior posts in each frame. There are also knee braces that connect the major girts and the exterior posts.



**Figure 11: Exterior Wall Framing**

The interior line framing consists of 6 inch by 8 inch braces and knee braces connecting the exterior frames to the interior frame adjacent to them. A labeled interior line can be seen in Figure 12: Interior Line Framing below.



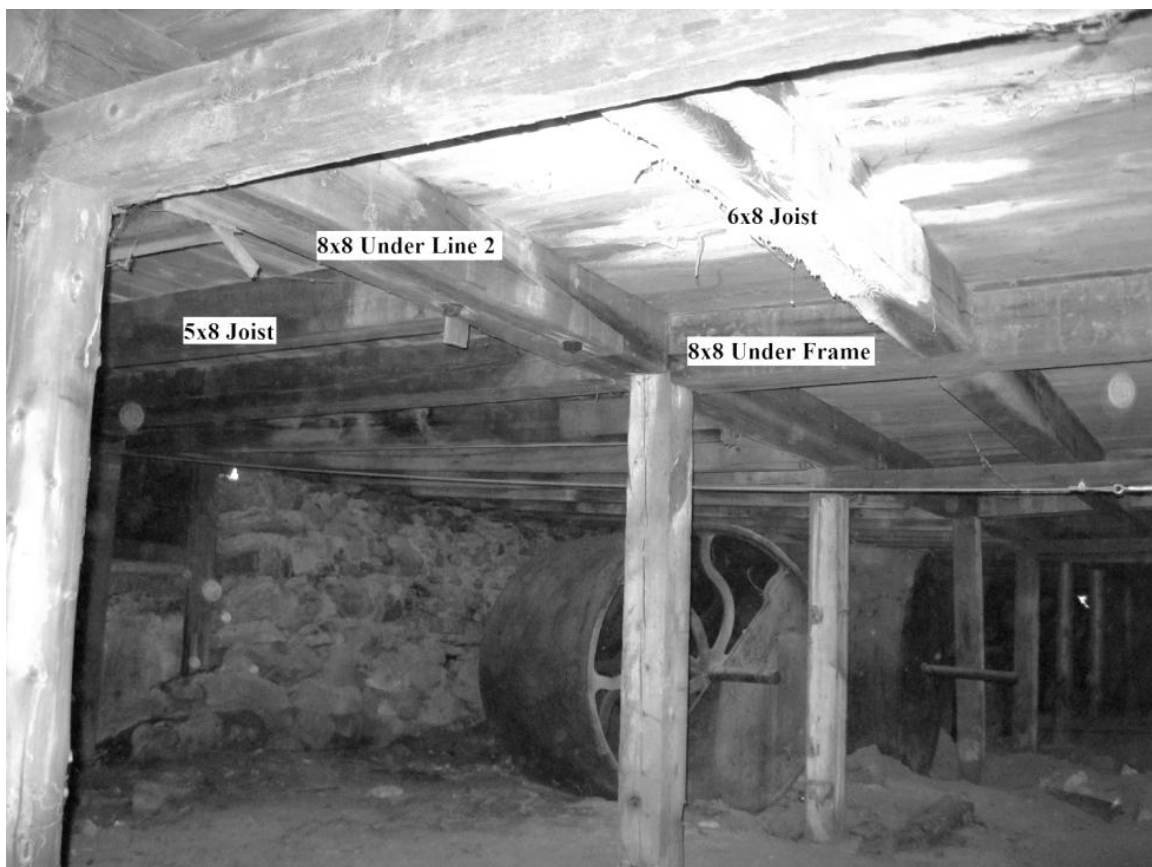
**Figure 12: Interior Line Framing**

*Issues Noted*

Pieces of the interior framing have been removed, including the line of 6 inch by 8 inch beams along Line 2. Several of the interior columns have been repaired after the lower sections were removed (Personal communication, G.M., 2011). Some of the original 4 inch by 5 inch knee braces have been removed and replaced with nominal 4 by 4 knee braces. Also one of the purlin posts in Frame D has split, as discussed above.

## FLOOR FRAMING

The floor framing includes: 3 inch thick floor random width boards, 8 inch by 8 inch sill plates around the exterior, 8 inch by 8 inch beams under the frame lines, 8 inch by 8 inch beams under the interior lines, 5 inch by 8 inch joists at 3 feet on center between Line 1 and Line 2 and between Line 3 and Line 4, and 6 inch by 8 inch joists at 38 inches on center that run between the frame lines. See Figure 13: Floor Framing below, for a labeled drawing of the floor framing.



**Figure 13: Floor Framing**

*Issues Noted*

There are several issues with the current floor framing. The 8 inch by 8 inch beam that runs under Frame E has split in the center. Also, many of the 5 inch by 8 inch joists and the 6 inch by 8 inch joists are split where they frame into the beams. See Figure 14:

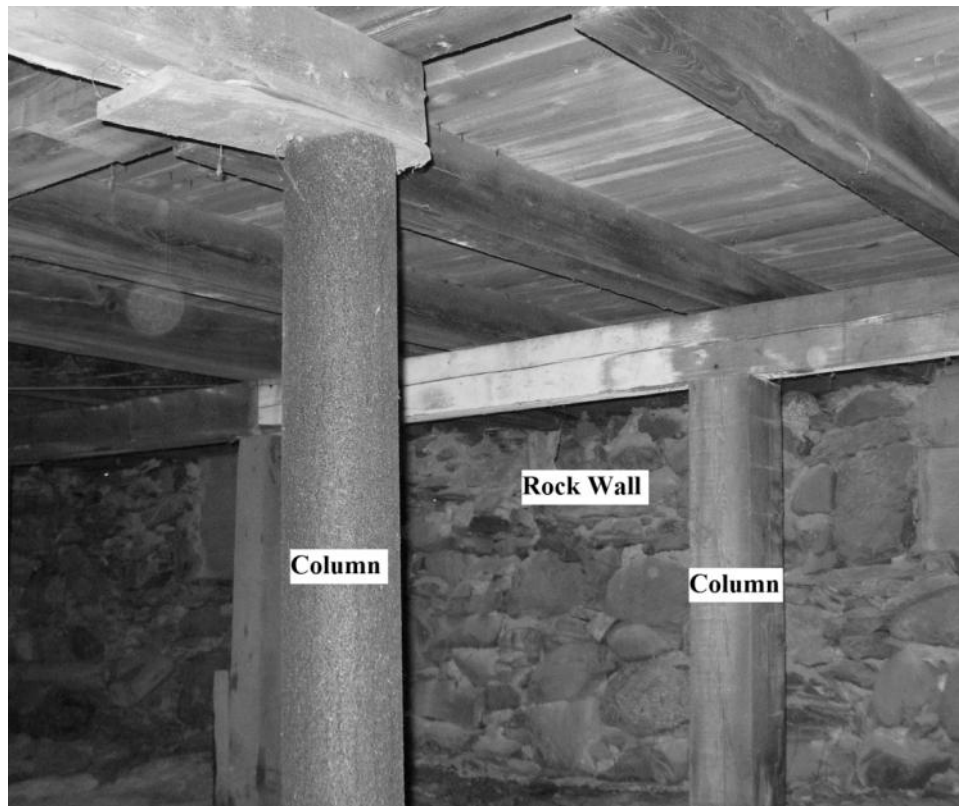
Issues with Floor Framing below.



**Figure 14: Issues with Floor Framing**

## FOUNDATION

The foundation of the barn on Ayers Island includes an exterior rock wall and columns under the interior posts that land on 2 foot by 2 foot concrete footings. See Figure 15: Foundation below for a labeled image.



**Figure 15: Foundation**

### *Issues Noted*

The columns under the interior posts are a mismatched collection of steel and wood shapes. Most of the concrete footings have become buried under the dirt floor of the cellar. Analysis of the foundation was excluded from the scope of this project.



## **CHAPTER 3: STRUCTURAL ANALYSIS**

This chapter will detail the structural analysis process and results.

### **ALLOWABLE STRESS DESIGN**

For the structural analysis Allowable Stress Design (ASD) was used. In ASD the largest forces the member will likely feel are calculated and then compared to a statistically allowable capacity. The allowable capacity is calculated in accordance with National Design Standards for Wood (NDS 2005). The calculated force must be less than the allowable capacity. The National Design Standards for Wood (NDS 2005) provides the statistically allowable values for different species and sizes of wood under different conditions.

### **ASSUMPTIONS**

The structural analysis was performed using several assumptions. The missing or damaged pieces of the structure were assumed to be in place and in good repair. The existing shingle roof was replaced with a metal roof because of the reduction a metal roof would make in the snow load discussed below.

The barn was assumed to be square and plumb meaning that all members are straight in the vertical and horizontal directions and the corners are perfect 90 degree angles. This assumption was made because of the time and equipment required to measure how far off the barn was, and it also simplified the design. From a visual inspection it is clear that the barn has undergone some differential settlement or vertical displacement and some differential horizontal displacement. However, without exact displacements and a full

structural analysis with a model including these displacements the effect of the displacements cannot be known.

The structural analysis was performed with the assumption that the maximum capacity of the event center would be 300 people. The actual possible capacity of the barn is 600 people, based on a 40 foot by 105 foot building with 7 square feet per person (Personal communication, G.F., 2011). The 300 person maximum occupancy was chosen for several reasons. Assembly spaces with 300 people or less fall under occupancy category II in the building code (IBC, 2009, Section 1604.5). The occupancy category determines how important the structure is and what importance factor should be used in the structural analysis. An occupancy category II building uses an importance factor of 1.0, but the higher occupancy categories have higher importance factors. Another reason that a 300 person maximum occupancy was chosen was because of the number of restroom facilities necessary for the full 600 person occupancy. Also, conversations with Dr. Markowsky determined that 300 people was a reasonable place to cap the occupancy because it was unlikely that more than that would be attending an event (Personal communication, G.M., 2011).

Another assumption made in the structural analysis was that the event center would only be used seasonally. A seasonal use building does not need to meet the insulation requirements of a year-round building (Personal communication, G.F., 2011). Also a heating system that is capable of heating the entire barn is not necessary for a seasonal building. The cost of the project would be reduced by not needing to include heating and insulation. As a seasonal building the event center would not produce revenue during the

late fall to early spring. Depending on the demand for the event center during that time it may make sense for Dr. Markowsky to use the seasonal use building as an intermediate step to a year-round event center.

## LOADS

Loads were determined using the International Building Code 2009 (IBC 2009) and American Society of Civil Engineers 7-05 (ASCE 7-05). IBC 2009 is the building code in Orono, Maine, where the barn is located. IBC 2009 and ASCE 7-05 detail the process for calculating the loads or forces applied to the building as well as how to apply them. There are two general types of loads, gravity loads and lateral loads.

### *Gravity Loads*

Gravity loads are forces that act on the building because of the effects of gravity. For this project the gravity loads considered were: dead load, live load, and snow load. The dead load is the force in the member that results from the self-weight of the member. These forces were calculated using an assumed density of 35 pounds per cubic foot for wood (Personal communication, E.N., 2011). The dead load is applied to each member individually. The live load is determined by the use of the space. For an assembly area with movable seating the required live load is 100 pounds per square foot (IBC, 2009, Table 1607.1). This live load is applied to the floor.

The snow load results from the weight of snow on the roof of the barn. Snow load is calculated in accordance with chapter 7 of ASCE 7-05 (IBC, 2009, Section 1608). The snow load depends on the location of the structure in the country, the pitch of the roof,

the roofing material, the expected temperature of the roof, and the importance factor of the structure. The importance factor is used to reflect the relative importance of different structures. Schools and hospitals have high importance factors, whereas farm buildings and temporary structures have low importance factors. This structural analysis assumes that the occupancy of the event center will be limited to 300 people; therefore, an importance factor of 1.0 was used. The snow load for the Ayers Island barn calculated out to 37 pounds per square foot. Unbalanced snow loading and drift loading was not considered in the analysis.

### *Lateral Loads*

Lateral loads are forces that attempt to push a building over. The most common lateral loads are wind load and seismic load. Seismic load is the force on a building that results from an earthquake. Wind load is the force on a building that results from the wind blowing on that building. From conversations with Edwin Nagy, P.E. and Geoffrey Williams, P.E. it was determined that I could safely assume that the wind load would control over the seismic load (Personal communication, E.N., 2011) (Personal communication, G.W., 2011). This is because a wood building is relatively light when compared to steel or masonry and the seismic load is calculated based on weight. The wind load was calculated using the simplified method from chapter 6 of ASCE 7-05. The wind pressures on the long side of the barn are 9.9 pounds per square foot on the roof and 14.4 pounds per square foot on the wall. On the gable end the wind pressure was 14.4 pounds per square foot (ASCE, 2005, Figure 6-2).

## RESULTS OF WOOD TESTING

A sample of wood from the barn was tested by Mr. Russell Edgar at the Advanced Engineered Wood Composites lab (AEWC) at the University of Maine. Mr. Edgar said, “I’m fairly certain the beam is Eastern Hemlock...this is due to the unique softwood combination of lacking resin canals (as found in pine, spruce, Douglas-fir and larch/tamarack) and having ray tracheid cells

(In the top and bottom row of ray cells...those that grow transversely in a radial direction outward from the center of the tree). There is also a fairly abrupt transition from early wood (lower density part of ring grown in the spring) and late wood (higher density part of ring grown in summer/early fall)” (Personal communication, R.E., 2011). Based on Mr. Edgar’s findings and the fact that old growth timber is stronger than modern timber, it was assumed that all structural members were Select Structural, the highest grade or quality of wood, Eastern Hemlock (Personal communication, E.N., 2011).

## MODEL

The model was created using RISA 2D Educational software. This software allows the user to create a model of a structure including assigning the structural properties of each member. The user then specifies the loads on each member and runs the software. RISA 2D Educational will then calculate the forces and deflections in each member. Using 2D models to analyze a 3D structure created some challenges. I used 2D models in two directions to calculate all of the loads on a particular member. This method may be conservative because the additional stiffness that the framing in the other direction provides was not accounted for.

During the modeling process I chose to use RISA 2D Educational software because I could access it free of charge. However, the educational version does have limitations. It only allows 50 members in each model, so I had to exclude some members. I only considered the major framing members and did not model things like the minor girts. I also had to use several separate models and apply the results of one model on another. To simplify my model I used the centerline of each member as its location.

I checked the accuracy of the model by applying the equations of statics. In the models of the purlin and eave beam I checked that the pound per foot load multiplied by the tributary area of the supports was close to the support reaction that RISA provided. With the frame and line models I made sure that the loads in each direction matched the support reactions in that direction.

#### STRUCTURAL ANALYSIS PROCESS

The structural analysis process involved creating the RISA 2D Educational model, applying the loads to the model, calculating the allowable forces in each member and comparing the allowable forces to the forces generated by the RISA 2D Educational software. I started with the roof framing and ran iterations of the roof framing design until the framing was adequate. Then the results of the final roof framing design were used in the models of the frames and lines. The floor was analyzed separately, because of its simplicity. All design calculations were performed in accordance with NDS 2005. Full design calculations can be found in Appendix C: Structural Analysis Calculations.

## SUMMARY OF RESULTS

The results of the structural analysis showed that several members were inadequate. The floor joists were not adequate to carry the floor loads because of their length. The eave beam was not adequate to carry the load from the rafters because of its connection to the cross beam. The cross beams in Frames A and H were not adequate to carry the wind load because of the current bracing. Finally, the posts were not adequate to carry the wind load when the wind blows on the long side of the building. Therefore, structural changes are necessary to bring the barn up to modern building code standards. Modern building codes include safety factors that this barn was not originally designed for.

## **CHAPTER 4: ARCHITECTURAL DESIGN**

This chapter will detail the architectural design process for this project. The focus of this project was on the structural analysis. This architectural design contains information on the required design considerations and some notes on aesthetics.

I met several times with Gary Frost A.I.A. of G.L. Frost Architecture in Bangor, Maine to discuss Ayers Island. After our discussions Mr. Frost informed me that for a seasonal use event center I would need to consider the Life Safety Code, the Americans with Disabilities Act, and the Maine Plumbing Code. I asked if there were any historic preservation regulations that would apply to the barn on Ayers Island. Mr. Frost informed me that historic preservation guidelines only applied to buildings on the National Register of Historic Places (Personal communication, G.F., 2011). I searched the National Register of Historic Places and Ayers Island was not listed (2011).

Although the historic preservation guidelines are not required they should be considered in a final architectural design. These guidelines provide useful information on how best to merge the new and the old. Also, if Dr. Markowsky wished to have the barn on Ayers Island added to the National Register of Historic Places following the appropriate historic preservation guidelines may be a point in his favor. However, historic preservation guidelines were not formally used in this design.

### **MAINE PLUMBING CODE**

The Maine plumbing code, which is based on the 2009 Uniform Plumbing Code, determined the necessary number of bathroom facilities based on the number of



occupants in a building. After a conversation with Dr. Markowsky, it was decided to limit the occupancy of the event center to 300 people (Personal communication, 2011). From the Uniform Plumbing Code it was determined that there would need to be eight bathroom stalls, water closets, for women, two water closets and two urinals for men, one staff restroom, and two drinking fountains in the event center (2009).

#### LIFE SAFETY CODE

The Life Safety Code was created by the National Fire Protection Association and it lays out rules for egress, fire protection, and signage to reduce the loss of life in an emergency (Cote and Harrington, 2003). The rules that apply to a building depend on the occupancy of that building. When the barn was used for storage the Life Safety Code requirements were minimal, to use the barn as an event center it must meet more stringent requirements.

Chapter 12/13 New and Existing Assembly Occupancies provides the requirements that pertain to this project. The requirements were examined based on the maximum occupancy of 300 people. There should be at least two exits, means of egress, from the building (Cote and Harrington, 2003, Sec. 7.4.1.2). These means of egress should be located remotely from each other so that in case of emergency it would be less likely that both doors will be blocked (Cote and Harrington, 2003, Sec. 7.5). All means of egress should be 36 inches wide (Cote and Harrington, 2003, Sec. 7.3.4). The Life Safety Code also specifies a maximum travel time from any point to an exit. Based on the geometry of the barn and the fact that the barn already has a sprinkler system, I determined that two

exits on opposite ends of the barn would be sufficient (Cote and Harrington, 2003, Sec. 7.6).

These exits could be either marked as emergency exits only or they could be used as part of the normal entrance and exit scheme of the building. These exits could be placed in the end walls where there is old framing for doors. This placement made the most sense due to the fact that the ground around the barn slopes away. The large barn doors in the center aisle on each end would allow for processions through the barn from one side to another and a new main entrance located in the center of the line 1 wall would allow for convenient access to the center of the space.

#### AMERICANS WITH DISABILITIES ACT

The Americans with Disabilities Act (ADA) ensures that buildings are safe and accessible for all people. To use the barn on Ayers Island as an event center, the barn needs to meet ADA Requirements. The floor of the barn is located approximately 2 feet above the ground surface. The entrances require stairs and the main entrance requires a ramp. The stairs should conform to ADA Section 4.9 and the ramp should meet ADA Section 4.8 requirements (2012). The floor surface needs to be planed so that there is less than ¼ inch of difference between adjacent boards (ADA, 2012, Sec.4.5.2). The proposed layout of the barn needs to meet ADA Section 4.3, which deals with providing an accessible route, and ADA Section 4.13, which deals with spacing around doors (2012).

#### AESTHETIC CONSIDERATIONS

I have had several conversations with the owner about the aesthetics of the barn. He specifically requested that the interior of the barn remain as it is, if possible. To achieve this, the structural additions should complement the existing framing. The owner was not

averse to replacing the existing faux brick siding with clapboards or another barn appropriate option. He was also interested in displaying the wall framing with a wall of glass (Personal Communication, G.M., 2011).

## **CHAPTER 5: PROPOSED DESIGN**

This chapter will detail the proposed design for the barn for its new use as an event center. The proposed structural design will provide conceptual changes to correct structural inadequacies in the existing framing. The proposed architectural design will provide a layout that meets the owner's requests and legal requirements.

### **PROPOSED STRUCTURAL DESIGN**

There are several changes necessary to make the existing barn structurally sound according to IBC 2009 loads. The 5 inch by 8 inch floor joists and the 6 inch by 8 inch floor joists are inadequate. Adding center supports to the floor joists will make them adequate. This solution is in line with the current framing of the floor because these supports have already been added in several places.

To brace the cross beams in Frames A and H so that they can carry the lateral wind load, Lines 2 and 3 should be braced with new nominal 6 inch by 8 inch Eastern Hemlock beams and new 4 inch by 5 inch (Or 4 inch by 4 inch) nominal Eastern Hemlock knee braces. Lines 2 and 3 should be braced between each frame and each brace should have a knee brace connecting it to each column. Currently the end frames (Frame A and Frame H) are only connected by braces to the frames immediately adjacent to them and these braces only have one knee brace.

To solve the issues with the existing eave beams a new steel Hollow Structural Shape, HSS, top plate should be added over the exterior wall posts in Lines 1 and 4. Also, a new steel HSS purlin and purlin post should be added directly over the interior posts in Lines

2 and 3. The new purlin and top plate will take the entire load off of the existing purlins and eave beams. They will place the load directly into the posts, which reduces the load on the cross beam.

Several variations of proposed framing were examined. The arrangement described above was chosen because it fixed the structural issues and improved the load-path. Even though the existing purlin is adequate the new load-path is much better than the load-path in the existing barn. Also, this arrangement of new purlin and top plate is similar to what is more commonly found in barns. The new purlin, purlin posts, and top plate can be made of 8 inch by 8 inch HSS steel which will complement the existing 8 inch by 8 inch framing members.

The posts are not adequate to carry the wind load as the wind blows on the long side of the building. The inadequacy is localized around the point where the knee brace connects to the post. Adding steel plate on the sides of the post around the knee brace will make the posts adequate.

#### PROPOSED ARCHITECTURAL DESIGN

To meet the architectural needs of the new use of the barn as an event center an addition should be added onto the Line 4 side of the barn. This addition should include male, female, and staff bathrooms, a warming kitchen, and a loading and storage area. If the barn is only used seasonally, which this analysis assumes it is, the addition can be supported on posts and the space underneath can be used for storage. The roof of the

addition should be sloped such that a row of clearstory windows can be added in the exterior wall. Dr. Markowsky requested that the entirety of the current barn remain open to be used during events, which is why an addition was added instead of putting the new facilities into the existing building (Personal communication, G.M., 2011).

THE ENTIRE EXISTING BARN CAN BE USED AS ASSEMBLY SPACE, WITH AN OCCUPANCY LIMIT OF 300 PEOPLE. DOORS SHOULD BE ADDED ON EACH END, UTILIZING THE OLD DOOR FRAMING. THE LARGE CENTER AISLE DOORS ON EACH END AND THE LINE OF WINDOWS ABOVE THEM SHOULD BE REPLACED. THE CURRENT WINDOWS IN LINE 1 SHOULD BE REMOVED AND REPLACED WITH SQUARE BARN WINDOWS AND A ROW OF CLEARSTORY WINDOWS, TO MIRROR THOSE ON LINE 4, SHOULD BE ADDED. THE PORTION OF THE EXTERIOR WALL ON LINE 1 BETWEEN FRAME D AND FRAME E SHOULD BE REPLACED WITH A WALL OF GLASS AND A GLASS DOOR TO DISPLAY THE FRAMING. THIS WILL BECOME THE MAIN ENTRANCE TO THE EVENT CENTER AND SHOULD INCLUDE BOTH STAIRS AND A RAMP. A LARGE PATIO COULD BE ADDED ON THE LINE 1 SIDE OF THE BARN TO CREATE A FLOW FROM INDOOR TO OUTDOOR SPACE. FOR DRAWINGS SEE APPENDIX D: PROPOSED DESIGN DRAWINGS

(On attached CD) .

These proposed architectural changes fit with Dr. Markowsky's architectural goals. He wanted to preserve and display the interior framing. This was achieved by choosing to add new members to the framing instead of reframing the entire barn. These new framing members can be 8 inch by 8 inch so that they complement the existing framing. Also the

glass around the entrance and the clearstory windows help display the interior framing.

Dr. Markowsky also indicated that he would like the exterior of the event center to reflect its roots as a barn (Personal communication, G.M., 2011). This is why clapboards or other traditional barn coverings were chosen and the existing windows were replaced with barn windows.

## **CHAPTER 6: ADDITIONAL WORK**

This chapter will detail the additional work necessary for the project to move forward.

### **EXCLUSIONS FROM SCOPE**

Based on experience and time constraints there were several aspects of a complete design that I excluded from the scope of my project. These aspects are important to the feasibility of the project and should be investigated thoroughly.

#### *Economic Analysis*

The question of whether or not the project is economically feasible is often the controlling factor in the decision to proceed with the project. A complete economic analysis would examine the cost of the project as well as the expected increase in profit. Using these values a payback period would be determined which would say how many years it would take for the project to pay for itself.

#### *Foundation Analysis and Design for Existing Barn*

The foundation of the existing barn is a rock wall around the perimeter and posts that land on 2 foot by 2 foot footings on the ground. The capacity and stability of this foundation was not analyzed in this report, however, it is very important. If the foundation is not adequate the barn cannot be used as an event center. An analysis of the existing foundation should be performed by a licensed professional engineer to ensure that it is adequate for the new use of the barn.



### *Structural and Foundation Design for Addition*

This report only provided basic recommendations on the structure and foundation for the addition. Depending on the owner's decisions regarding a seasonal or year-round use building the requirements for the foundation and structure will change. Also, depending on whether the owner decides to use standard residential framing or to continue with the post and beam framing will determine whether a licensed professional engineer's review is required or not.

### *Water and Sewer System Design*

Water and sewer system design was excluded from the project because of lack of experience and time constraints. Ayers Island has been used as a manufacturing center and the main manufacturing building had running water and a sewer system. The barn is connected to the fire suppression system on site, but is not attached to the existing water and sewer systems. These systems can be expensive depending on how extensive the necessary work is. However, they are integral to the functionality of the barn as an event center.

### *Electrical Design*

The electrical design was excluded from this project based on my lack of experience in this area. Currently there is electricity in the barn, but it would need to be rewired to be used as an event center. For safety reasons a licensed electrician should be hired to wire the barn and the addition.

### *Transportation Design*

The designs of the transportation systems to and around Ayers Island are an important aspect of this project that was excluded from the scope. Transportation projects that would be necessary to use the barn as an event center include: an access road design, a parking lot design, and bridge repairs. The current access road around the island would need to be redesigned for the new traffic load and pattern. A new parking lot would need to be designed for the event center. Dr. Markowsky has stated that the existing bridge has been officially closed because it needs repairs (Personal communication, GM, 2012). A one-lane bridge, like the one currently on site, would likely be adequate to carry the volume of traffic the event center would create. However, there may be long delays in one direction when an event ends and a long line of traffic leaves Ayers Island (Personal communication, PG, 2012). To summarize, to use the barn as an event center would require designing a new parking lot and access road, and repairs to the existing bridge.

### *Site Layout and Design*

This project focused only on the barn and did not take into account the rest of Ayers Island. To use the barn effectively as an event center some consideration would need to be given to the rest of the site. This would involve either using the main manufacturing building and other outbuildings in ways that would complement an event center, or hiding the less aesthetically appealing buildings from view.

#### ADDITIONAL WOOD TESTING

I was very fortunate that Mr. Russell Edgar from the Advanced Engineered Wood Composites Lab (AEWC) at the University of Maine generously volunteered his time and expertise to examine a sample of wood from the barn. Without the information he provided the structural analysis of the barn would have been impossible. However, the old growth Eastern Hemlock that the barn is constructed of is likely much stronger than the current values in the National Design Standards for Wood (NDS, 2005). Additional testing could determine how much stronger this old growth Eastern Hemlock is than the current Eastern Hemlock. This could result in a reduction in the structural changes the barn requires. Also, the strength of the mortise and tenon connection depends on the species of wood that the pin is made of, which is currently unknown. Additional testing of the pins could provide a greater understanding of the connection strength.

#### ADDITIONAL STRUCTURAL ANALYSIS

There is unnecessary conservatism in the proposed structural design. To reduce this conservatism an analysis using a 3D model and the actual structural properties of the old growth Eastern Hemlock could be done. The 3D model would eliminate the conservatism that comes from using two 2D models and the actual structural properties of the old growth Eastern Hemlock would eliminate the conservatism that comes from using modern values. Also, an analysis of the mortise and tenon connection using the actual pin properties would reduce the conservatism of the structural analysis.

The proposed design includes a new purlin even though the existing purlin is adequate under the current loading. An alternate design that leaves the existing purlin in place and

solves the issues with the eave beam and its connection to the cross beam could be examined. If Dr. Markowsky is considering using the seasonal event center as an intermediate step to a final year-round facility, the proposed design should be adequate for the year-round facility so that additional structural changes are not necessary later.

#### REVIEW BY A LICENSED PROFESSIONAL ENGINEER

Engineering is a profession rather than an occupation. Similar to other professional careers, such as the medical professions, engineers have licensure requirements. These licensure requirements are in place to protect the safety of the public. They try to ensure that engineers who are licensed to work in a certain discipline are competent in that discipline. Licensed engineers are also required to adhere to a strict code of ethics. This project was done as a student project and should, therefore, not be implemented unless it is reviewed and approved by a licensed professional engineer. Please refer to the University of Maine's student engineering disclaimer at the end of this document.

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## **APPENDICES**

### APPENDIX A: EXISTING SITE PLANS

(On attached CD)

### APPENDIX B: EXISTING CONDITIONS DRAWINGS

(On attached CD)

### APPENDIX C: STRUCTURAL ANALYSIS CALCULATIONS

(On attached CD)

### APPENDIX D: PROPOSED DESIGN DRAWINGS

(On attached CD)

## **STUDENT ENGINEERING DISCLAIMER**

The design and other recommendations that we students are proposing to provide, as described in this proposal, will have been developed by us as students as part of our education in the College of Engineering in order to gain supervised engineering problem-solving experience. Therefore, such information and recommendations, while useful for understanding a particular project's scope and possibilities for implementing solutions, should not be relied upon solely for the purposes of carrying out a project beyond conceptual levels.

Furthermore, such material should not substitute for or replace the services of a design professional practicing in the areas of engineering or architecture, particularly for projects whose direct or indirect impact may affect the safety, health, or welfare of the public.

We students truly look forward to the opportunity to serve with fidelity the public, our future employers, and clients. In providing you with this information, we strive to uphold and enhance the honor, integrity, and dignity of the engineering profession.



## **AUTHOR BIOGRAPHY**

Sarah Elizabeth Williams was born in Lewiston, Maine on April 21, 1990. She was raised in Richmond, Maine and graduated Valedictorian from Richmond High School in 2008.

She is majoring in Civil and Environmental Engineering at the University of Maine.

Sarah has spent three semesters working as a Resident Assistant in Aroostook Hall and Balentine Hall. She is a member of Chi Epsilon. Sarah received the Top Scholar Award and was nominated for an Oak's Award.

Upon graduation on May 5, 2012, Sarah plans to pursue an Advanced Masters in Structural Analysis of Monuments and Historical Constructions. This program is a cooperative effort between Universities in Spain, Italy, Portugal, and the Czech Republic.