Figures

Pictures

Chapter 15. Timber Planking, Puncheons, and Boardwalks

“Timber planking” is a simple structure of wooden sills and planks built low to the ground. It does not have railings or bull rails. It is used to traverse wet, boggy areas in remote and primitive settings. The sills are usually logs cut to the appropriate length and the planking is either hand split or sawn boards. The planking is laid parallel to the path of travel. This structure is commonly used in the boreal forests of Alaska and Canada and in the Pacific Northwest and the northeastern states.

A “puncheon” is a type of rustic log or timber boardwalk that is built close to the ground (< 24 inches above ground) with an individual span of less than 12 feet. It may be used to cross small ephemeral watercourses or wet, boggy areas. It usually consists of mudsills, joists, soil dams, and wooden decking, but does not include a railing. A bull rail may be added in equestrian and accessible designs. “Puncheon” is a French term for timber planking and this term and structure are used by trail professionals primarily in the Pacific Northwest. These are somewhat rustic structures built with logs, split timbers, or milled timbers. Their construction consists of mudsills, joists, soil dams, and decking. The decking is either hand split or milled wood and is laid perpendicular to the path of travel. Because of the rustic and low profile appearance, these structures “fit” the setting of the temperate rain forest very well.

A “boardwalk” has a wider range of uses than a puncheon because it can be elevated above 24 inches and/or have railings. Boardwalks have varying designs that are usually built close to the ground but may exceed 48 inches from the top of the decking to the ground. They are used to span wet, boggy areas but may also be used in areas with chronically standing water or poor soil capability such as sand. They usually consist of sills, piers, joists, soil dams, and decking. Bull rails are used in accessible and equestrian trail designs. Boardwalks may also include posts and railings when higher than 48 inches off the ground. They have a variety of structural ground support or abutment designs.

A “gadbury,” also known as a “plankwalk,” is another trail structure that can be used to span across wet boggy areas. This simple structure is comprised of log sills and stringers/decking. The decking is composed of log stringers sawn in half with the sawn side facing up to serve as the walking surface. These half sawn logs are pinned to the log sills, which are notched to receive the logs. Given the amount of earth-to-wood contact, the logs should be redwood, cedar, or another tree species resistant to rot. Log bull rails can also be added to this structure if needed. This type of structure is usually limited to remote backcountry areas where local materials are the only available option. Given the limited application of this structure, its design and construction is not addressed in this chapter. Refer to the US Forest Service for details on the design and construction of a gadbury.

15.1. Best Management Practices

Installation of timber planking, puncheons, and boardwalk structures in wet areas should occur during the time of year when ephemeral streams and springs are dry or at the lowest flow. Sediment control devices, such as silt fences or straw waddles, are installed down slope of the intended excavation area to prevent sediment from entering the watershed. All excavated material should be exported to a stable location far enough away from the construction site that it cannot re-enter the watercourse. Additional silt fences should be installed between the watercourse and the excavated material if there is any chance of that material migrating back into the watercourse.

Once installation of the structure is complete, all excess excavated soil or any soil trapped in the silt fence or waddles should be hauled away from the influence of the watercourse and used as backfill on trail structures or side cast on appropriate slopes. All sediment retention structures are removed and any disturbed areas are re-vegetated and rehabilitated per Chapter 25, *Trail Removal and Site Restoration*.

15.2. Timber Planking

15.2.1. Applications

Timber planking structures are used when the trail alignment traverses through a wet, boggy area or saturated and chronically wet soil. In northern boreal forests, these conditions are often difficult to avoid. Constructing trail tread through fens or tundra mat with underlying permafrost is nearly impossible and the only practical solution is to build a structure across them.

Timber planking is intended only for pedestrian use. It is not suitable or safe for equestrian use. It is also not intended for mountain bikes, although skilled cyclists may be able to traverse these structures without difficulty. This structure is also not intended for use on accessible trails. Sawn planking is laid with the grain parallel to the direction of travel and the surface can become slippery when wet.

Timber planking structures represent a minimalist approach. They are primarily used in remote settings where primitive conditions are expected by the user. These structures are not suitable for Class 1 or 2 trails. Typically, the materials for these structures are manufactured from trees cleared during the initial stages of trail construction. Timber planking is designed to be low to the ground. When used to traverse fens and tundra mat they usually are no more than 1.5 feet above the ground. (See Photo 15.1.) These structures are not intended to be used in locations where water is flowing because they do not possess the necessary free board (i.e., clearance) and may restrict water flow.

Photo 15.1 - Timber Planking Structure (left) and Curved Planking (right)

15.2.2. Construction

Construction of a timber planking structure begins by laying out, excavating, and leveling the foundations for the log or sawn timber sills. Where soil conditions allow, the earthen foundations for the sills should be level front to back and side to side. The sill foundations should also be level to each other to avoid uneven loading of the structure. In fens with tussocks or in dense tundra mat, precise leveling and squaring of the sills may not be possible. Excavation may also need to be kept to a minimum to reduce disturbance to vegetation and permafrost. The builder needs to make the sills as level and square as the site conditions allow.

The sills should be comprised of the most rot-resistant tree species available, such as redwood or cedar. The bark and sapwood should be removed from the sill logs to reduce rot and increase their lifespan. The diameter and length of the sills will be determined by the strength of the underlying soil and the intended width of the planking. The sill will also need sufficient height to provide an air gap between the wooden planks and the surrounding soil. The maximum distance between two sills should not exceed 8 feet. (See Figure 15.1.) The leveling and squaring of the sills should be performed following the process used in puncheon construction discussed below.

The top of the sills should also be level to provide a flat surface that the planks can fully rest upon. If power tools are permissible, a portable saw mill, chainsaw, or a chainsaw with a power plane attachment can be used to perform this task. If they are not allowed, then a beveled hatchet, adze, draw knife, slick, or wood chisel can be used to level the tops of the sills. Prior to anchoring the sills they should be pre-drilled with two 9/16-inch diameter pilot holes on either end of the log. A 5/8-inch piece of rebar is then driven through each hole to pin the sill log to the ground. The length of the rebar should be sufficient to have it penetrate through the sill and into the ground a minimum of 30 inches. (See Figure 15.1.) If the underlying soil is subject to severe freeze-thaw or frost-heave conditions then do not pin the sills. Pinning will not allow the timber planking structure to freely move with the undulating ground.

Once the sills are anchored, the planking is installed. These planks should be a minimum of 4 x 12 inches in dimension and have a maximum free span of 8 feet. They should also be constructed of rot resistant wood, such as redwood or cedar. If constructed of native materials they will either be rough sawn (using a portable saw mill) or hand split using splitting wedges. The planking can be installed either as a single plank or two planks side by side. If an individual timber plank structure is being constructed, the plank should be installed so that the ends are flush with the outside edge of the starting and ending sills. With a multiple timber plank structure, the ends of the first planks are placed flush with the outside edge of the beginning sill and approximately halfway on (or center of) the next or second sill. The next set of planks will butt against the first planks and rest halfway on the second sill and halfway on the third sill. (See Figure 15.1.)

The planks should be fastened to the sills by drilling a 5/16-inch pilot hole through the planking and driving in 7-inch galvanized spikes or 7-inch timber lock screws until they are flush with the planking's surface. A punch or drift pin should then be used to recess the heads of the nails a minimum 1/8-inch below the surface of the planking. A minimum of six nails or screws should be used for each piece of planking (three on each end of the planking). The two outside nails are located approximately 1 1/2 inches in from the edge of the planking. (See Figure 15.1.)

Where multiple timber planking sections are constructed, it is important that the planking structure conforms visually to the surrounding setting. Long, straight sections of planking on a trail that is curving around the hillslope will look out of place and contrast to the natural setting. In these settings, the timber planking structure should be laid out and constructed to curve with the terrain. To achieve the desired curve, the ends of the planking must be cut at an angle. The angle will vary depending on the amount of curve desired. Once the planks have been cut, the sills are set to match the angle of the end cuts on the planking. (See Figure 15.2.)

15.3. Puncheons

15.3.1. Applications

Puncheons are used when the trail alignment traverses through saturated or chronically wet soil. Normally these locations would be avoided during the layout and design process. However, sometimes landform limitations may require traversing through this type of ground, especially in marshes, boreal forests, temperate rain forests, or low wetlands associated with stream or river valleys. They may also be required when the trail alignment unknowingly intercepts a sub-surface ground water flow or when a small ephemeral watercourse needs to be crossed and there is no suitable wet crossing location. In the Pacific Northwest they are also used to span over exposed tree roots that are associated with the redwood, fir, spruce, and hemlock trees.

Puncheons are designed to be low to the ground. When used to traverse saturated and wet soil or tree roots, they are no more than 2 feet above the ground. (See Photo 15.2 and Figure 15.3.) These structures are not intended to be used where water is flowing across a low flat area without a defined channel because they do not possess the necessary free board and may disrupt the flow. They should not be used in applications where railings are required (i.e., decking elevations of 48 inches or higher above the channel).

Photo 15.2 - Puncheon

Puncheons are a very good design solution for providing an accessible trail surface when native soils are too weak to meet the firmness and stability standards and site conditions prohibit the use of trail hardening, turnpikes, or causeways. They also can be used to bridge over obstacles such as roots and rocks that are in excess of accessibility standards. (See Chapter 8, *Accessible Trail Design*.)

Puncheons can be used by horses but due to a horse's sensitivity to vibrations, noise, and confinement, puncheons are not ideal for equestrian trails and should be used sparingly. The span of a puncheon on an equestrian trail should also be kept minimal since the more time a horse is on a puncheon the more likely it is to become spooked.

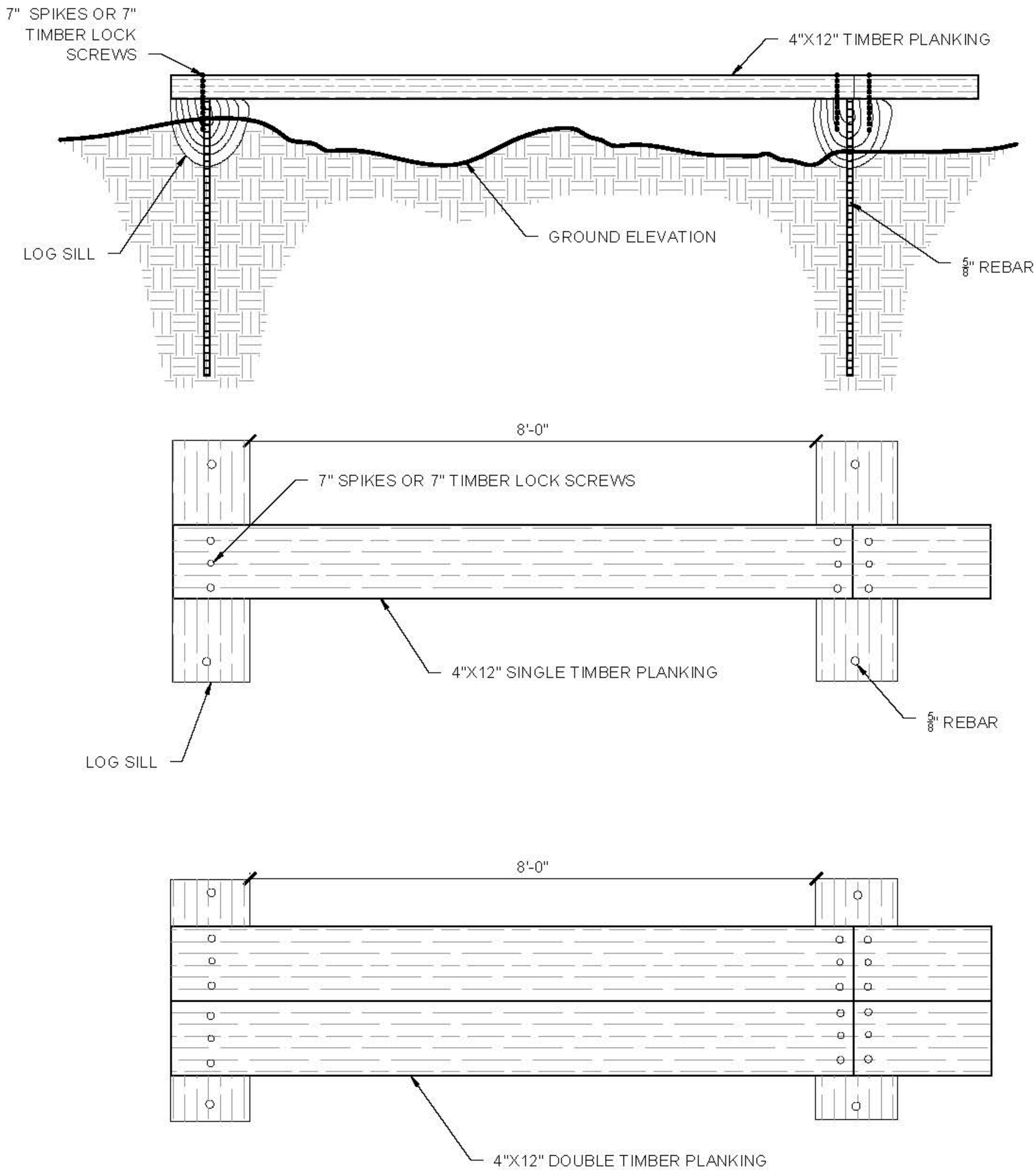

Figure 15.1 - Timber Planking

TIMBER PLANKING

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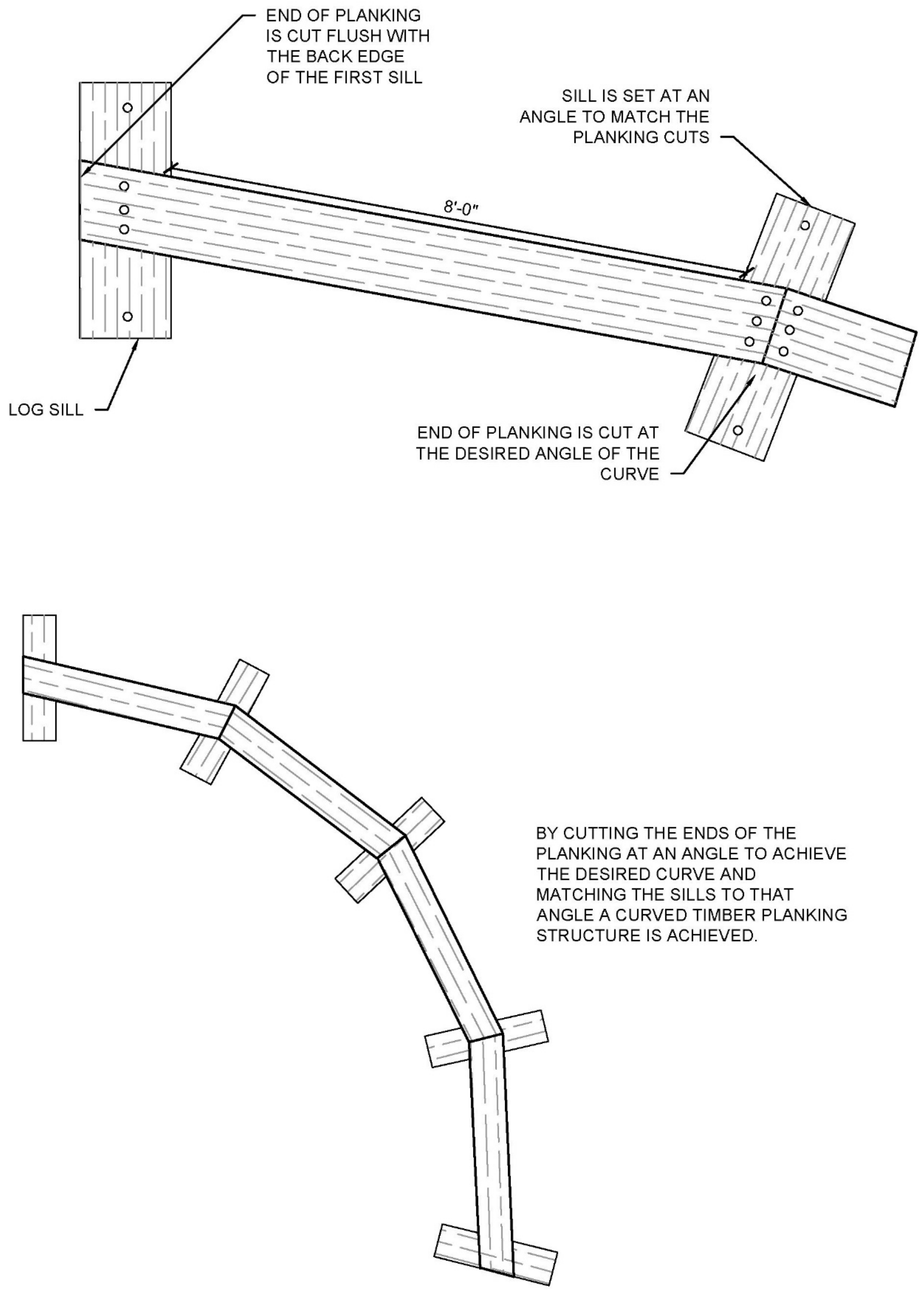

Figure 15.2 - Curved Timber Planking

CURVED TIMBER PLANKING

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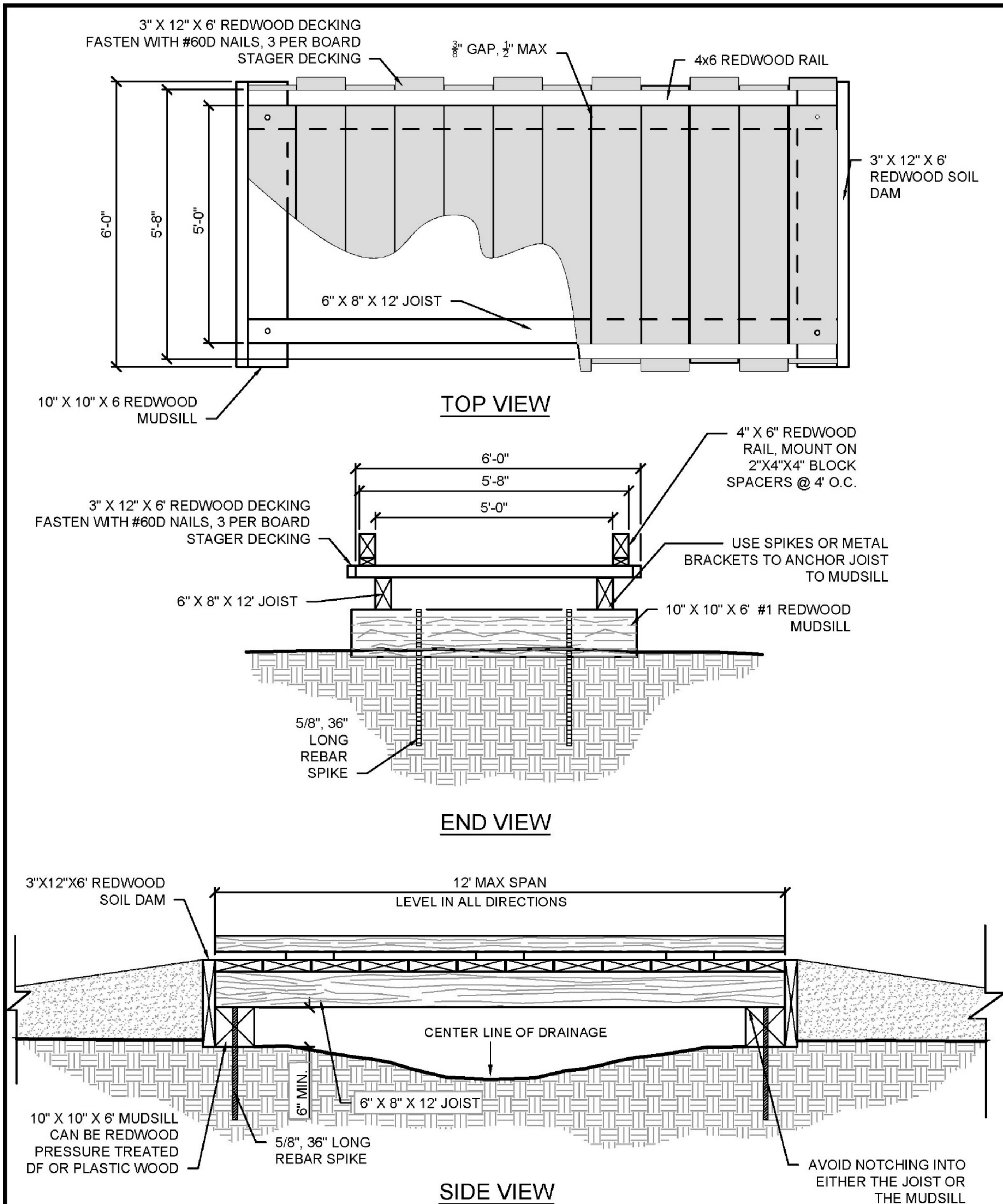

Figure 15.3 - Puncheon Structures

PUNCHEON STRUCTURES

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15.3.2. Construction

Construction of a puncheon begins by laying out, excavating, and leveling the mudsill foundation. For the purposes of this exercise, this leveling process will be performed with an Abney hand level or clinometer, McLeod, and a tape measure. The use of builder levels, stadia rods, and batter boards is discussed later in this chapter under the "Concrete Pier Block Construction" section and in Chapter 16, *Trail Bridges*. The simple but effective layout method described here is a common practice when constructing less complex trail structures in the field.

Use the trail work log and flag line to locate the starting and ending location of the puncheon and its general alignment on the ground. Drive a 5/8-inch x 3- to 5-foot metal form stake into the ground at the starting and ending points of the structure's length. These two stakes also represent the centerline of the puncheon's width. (See Figure 15.4.)

Once the starting and ending points have been identified, the approximate footprint of the puncheon must be determined. The footprint can be determined by using two 6-foot pieces of 2- x 4-inch lumber (ledger boards) and placing them on the ground to represent the puncheon's mudsills. These ledger boards are used instead of the 6-foot length of 10- x 10-inch mudsills because they are light and easy to move around. They are laid on the ground just inside of the two pieces of rebar marking the starting and ending points of the puncheon. They are placed so they are the same distance apart as the intended length of the puncheon structure, as measured from the back of one board to the back of the other board. The ledger boards are adjusted until the prescribed length is achieved by measuring across (perpendicular) from both ends of the two boards. After the ledger boards are the correct distance apart, drive two 12-inch spikes into the ground in front of the ledger boards, approximately 1 foot from each end. These spikes will help maintain the correct distance between the two ledger boards. (See Figure 15.4.)

Next, the two boards are squared to each other by measuring diagonally from the back corner of one board to the other. This measurement is taken from all four corners. (See Figure 15.5.) If the cross measurements are identical then the two boards are square to each other. If they are not identical, then the boards are out of square and must be adjusted by carefully sliding one of the boards in a parallel direction that lengthens the short diagonal measurement and shortens the long diagonal measurement. (See Figure 15.5.) When performing this adjustment, it is important to keep the board against the 12-inch spikes to maintain the prescribed distance between the boards.

It is also important to make these adjustments incrementally. If the two cross measurements are 4 inches off, lengthen the short measurement by moving it 2 inches in a parallel direction. This adjustment will effectively lengthen the short diagonal measurement and shorten the long diagonal measurement and is why the board must be moved only half the distance needed. After each adjustment, re-measure both the diagonal distances and separation between boards. (See Figure

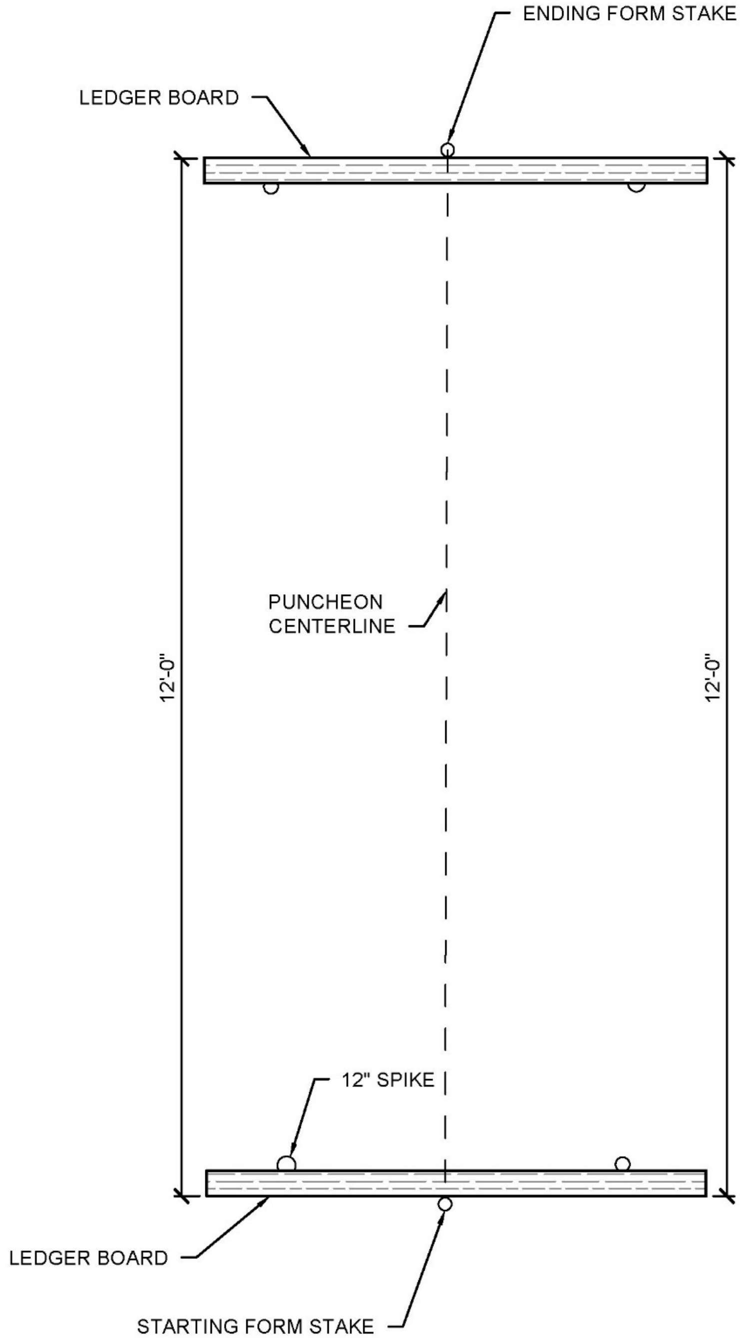
15.5.) It may take several small adjustments until the two boards are the prescribed distance apart and square to each other.

Once the boards are square, drive a 5/8-inch x 3- to 5-foot form stake at the far outside corner of each board. (See Figure 15.6.) Once the stakes are installed, remove the ledger boards and 12-inch spikes. These six stakes represent the outer footprint of the mudsill foundation.

Sometimes the ground may be so uneven or irregular that boards cannot be used for this layout exercise. If that is the case, replace the boards with six form stakes (three stakes per side): one each at the back outside corners of the two boards and one each in the center back. (See Figure 15.7.) This method may take a little longer as the adjustments are more awkward and less precise but the results will be the same.

Once the six form stakes have been installed, visually locate the corner of the puncheon footprint with the highest elevation. Next, locate an area outside of the footprint, equal to or higher than the highest corner of the footprint. This location must be where all four corners of the puncheon footprint can be seen at the same time. It is where the elevations should be sighted using a McLeod, Abney hand level, or clinometer and a tape measure.

First, clear a flat spot on the ground with the McLeod down to mineral soil. It should be large enough so the blade of the McLeod can rest fully on the cleared and leveled area. Next, set the McLeod blade down on the leveled area. The McLeod has now become the equivalent of a tripod. Note, to improve this method, the round end of the McLeod handle can be cut flat with a hand saw to obtain a level surface to sight from. Take the Abney hand level and set the percent and degree gauges to zero. This instrument now becomes the auto level and can be sighted to obtain a level, horizontal elevation. Note, a clinometer can also be used for the same purpose by adjusting the clinometer until it is resting level on top of the McLeod handle. Next, have a co-worker go to the form stake at the perceived lowest corner of the footprint. Have the co-worker take a steel locking tape measure and hold it plumb with the end of the tape measure flush against the ground and against the form stake. The tape measure is the stadia rod. The tape needs to be facing the McLeod so it can be read by the person looking through the Abney hand level or clinometer. To ensure that the tape measure is reasonably plumb, the person holding the tape can hold a torpedo level next to it and adjust the tape as required.



1. LOCATE THE STARTING AND ENDING LOCATIONS FOR THE PUNCHEON AND DRIVE IN FORM STAKES MARKING THE CENTER OF THOSE LOCATIONS.

2. PLACE BACK OF LEDGER BOARD AGAINST THE FORM STAKE.

3. ONCE THE LEDGER BOARDS ARE LAID DOWN MEASURE THE DISTANCE FROM THE BACK OUTSIDE EDGE OF ONE LEDGER BOARD TO THE BACK OUTSIDE EDGE OF THE OTHER. REPEAT THIS MEASUREMENT ON THE OPPOSITE SIDE OF THE LEDGER BOARDS. THE DISTANCE SHOULD BE 12 FEET.

4. ONCE THE LEDGER BOARDS ARE THE CORRECT DISTANCE APART DRIVE IN 12" SPIKES IN FRONT OF THE LEDGER BOARDS APPROXIMATELY 1' FROM THE ENDS OF THE BOARDS.

Figure 15.4 - Puncheon Ledger Board Layout

PUNCHEON LEDGER BOARD LAYOUT

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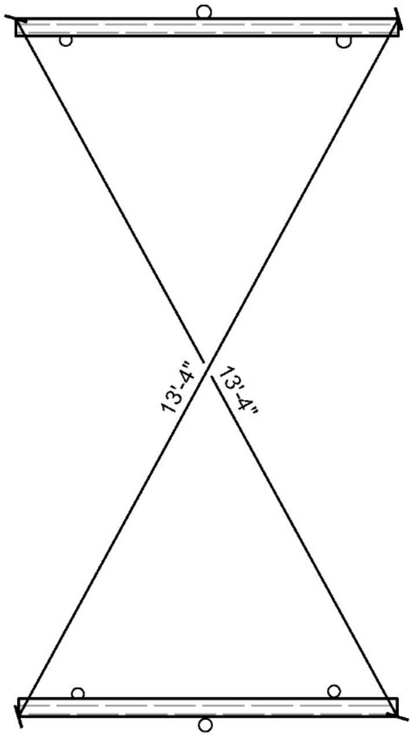
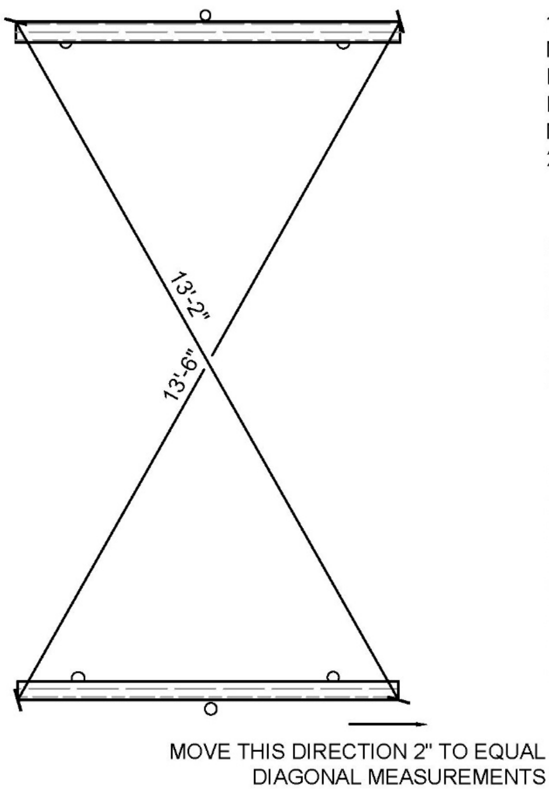


1. MEASURE DIAGONALLY FROM THE OUTSIDE CORNER OF ONE LEDGER BOARD TO THE OUTSIDE CORNER OF THE OTHER. IF THE MEASUREMENTS ARE THE SAME THEN THE TWO LEDGER BOARDS ARE SQUARE TO EACH OTHER.



1. IF THE TWO MEASUREMENTS ARE NOT THE SAME SUBTRACT THE SHORT MEASUREMENT FROM THE LONG MEASUREMENT AND DIVIDE THAT NUMBER IN HALF. (13'6" - 13'2" = 4" / 2 = 2")

2. TO SQUARE THE LEDGER BOARDS SLIDE ONE OF THE BOARDS LATERALLY ALONG THE SPIKES TOWARDS THE SHORT MEASUREMENT SIDE 2". RE-MEASURE AND ADJUST AS NECESSARY

3. MOVING LATERALLY HALF OF THE DISTANCE BETWEEN THE TWO MEASUREMENTS SHORTENS THE LONG MEASUREMENT AND LENGTHENS THE SHORT MEASUREMENT. MOVING THE LEDGER BOARD ALONG THE SPIKES MAINTAINS THE CORRECT DISTANCE APART.

Figure 15.5 - Squaring the Ledger Board

SQUARING THE LEDGER BOARD

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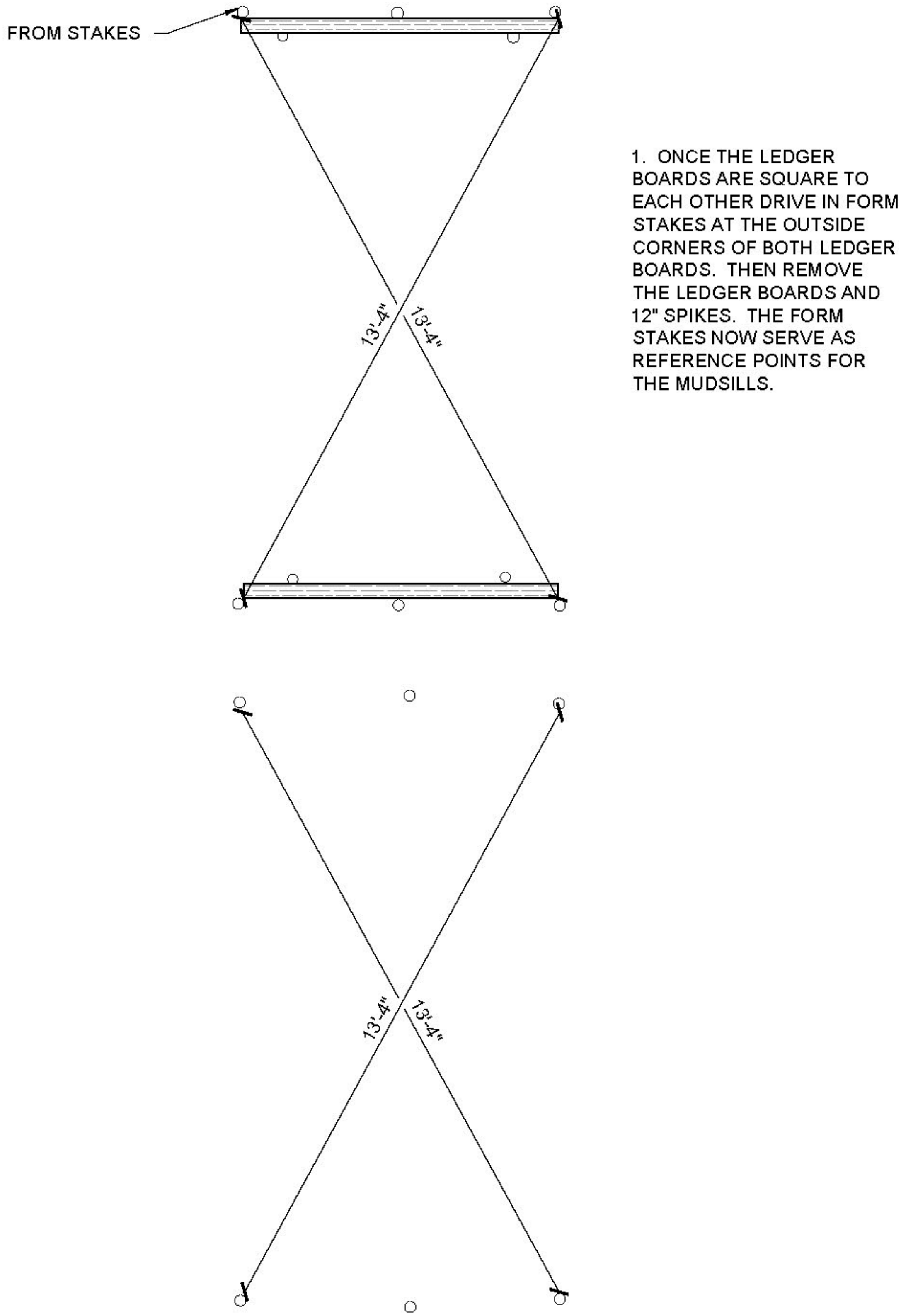

Figure 15.6 - Replacing the Ledger Board with Form Stakes

REPLACING THE LEDGER BOARD WITH FORM STAKES

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1. MEASURE 3' ON BOTH SIDES OF THE BEGINNING AND ENDING STAKES AND DRIVE IN FORMING STAKES AT THESE LOCATIONS.

2. MEASURE LINEARLY BETWEEN EACH FORM STAKE. ADJUST STAKES UNTIL THEY ARE 12' APART.

3. MEASURE DIAGONALLY BETWEEN EACH OUTSIDE FORM STAKE. ADJUST STAKES LATERALLY UNTIL THEY ARE EQUAL DISTANCES APART.

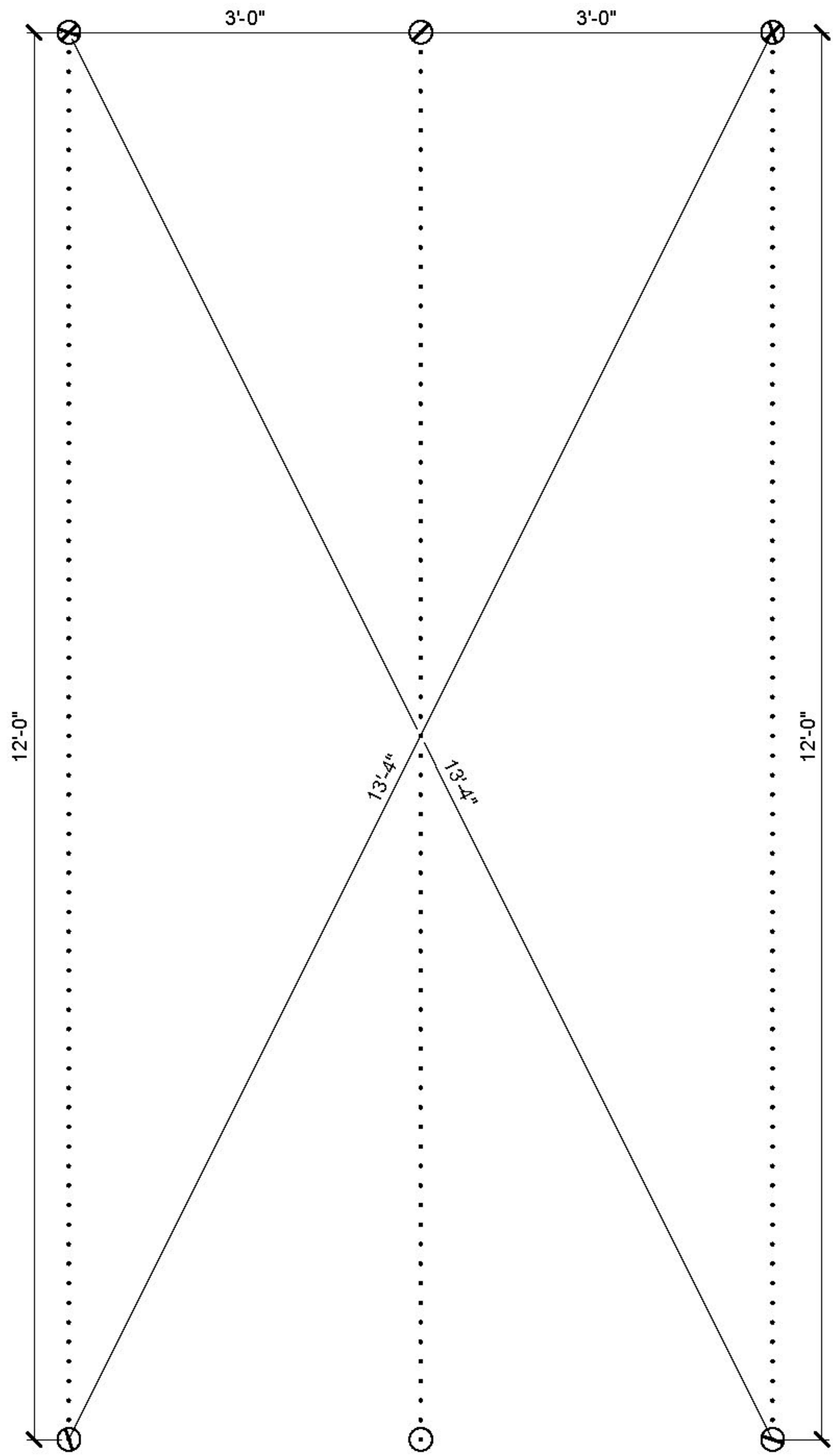

Figure 15.7 - Laying Out Mudsills with Form Stakes

LAYING OUT MUDSILLS WITH FORM STAKES

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Next, place the Abney hand level or clinometer on top of the McLeod handle and sight through the instrument looking at the tape measure. Adjust how the hand level or clinometer is sitting on the end of the McLeod handle until the interior bubble shows that the instrument is level. Then, have the person holding the tape slide his or her finger down the tape measure until they intersect where the horizontal line of the hand level or clinometer crosses the tape. Check to ensure that the tape is plumb and the hand level is level. If the numbers on the tape measure can't be read, have a co-worker read them.

Once the correct elevation on the tape measure is identified, write it down. Drawing a simple sketch of the puncheon mudsill layout area is also a good way of keeping track of and recording these elevations. Next, take an elevation measurement approximately 1 foot in front of the form stake just sighted. This measurement is necessary to identify the ground elevation for the entire area where the mudsill will eventually be installed. After recording the elevation, repeat this process for the remaining two form stakes, then perform this process on the opposite mudsill site. (See Figure 15.8.)

Once completed, there will be twelve elevations: one at each corner of the two mudsill footprints and four intermediate elevations at the form stakes between the corners. (See Figure 15.9.) If the ground is level at all twelve of these elevations, the number on the tape measure at each location is the same. If they are not the same, the lowest number on the tape measure represents the highest ground and the highest number on the tape measure represents the lowest ground. (See Figure 15.9.) Level the foundation for the mudsills to the lowest elevation (i.e., highest number) so the entire foundation is in mineral soil with no fill. If a foundation in mineral soil is not possible due to significant excavation requirements or other site conditions, such as rock outcrops or large roots, then a retaining wall may be required to contain the fill needed to level the foundation. (See Chapter 13, *Retaining Structures*.)

The foundations for the mudsills are then excavated so both foundations are level to each other. The earthen foundations for the mudsills should be level front to back and side to side. While excavating, elevation shots with a clinometer or Abney hand level should be taken to ensure that over-excavation does not happen. If over-excavation occurs, use well-compacted, crushed aggregate to elevate the foundation. The stakes should be kept in place if possible as they serve as a reference for the foundation footprint and for placing the mudsills once the foundations are level.

Once the foundations are level to each other, the mudsills can be set on the ground, against and in front of the three form stakes marking the perimeter of the foundation. At this time the mudsills should be very close to being the proper distance apart and square to each other. Use the distance and squaring exercise previously performed and adjust the mudsills until this is accomplished. (See Figures 15.5 and 15.6.) The finished elevations of the mudsills can also be checked by using the Abney hand level, McLeod, and tape measure. The elevation shots are taken off the top of the mudsills at each end and in the center. The mudsills should be level to each other to avoid uneven loading of the structure. In addition, the ground between the mudsills' foundations should be leveled as necessary to ensure that, once attached to the mudsills, the joists will have a minimum 6-inch air gap.

The mudsills should be a minimum of 6 feet long, 10- x 10-inch con heart redwood, cedar, or pressure treated Douglas fir. If the native soil is weak and unconsolidated, the length of the mudsills may need to be increased to 8 feet. Note, if 8-foot mudsills are required, 8-foot ledger boards are needed. The mudsills are anchored to the native soil by drilling a 9/16-inch hole approximately 6 inches from each end of the mudsill. These holes should be drilled prior to laying the mudsill on the ground so the auger bit does not come into contact with the soil. The holes are centered on the mudsill. Then a 5/8-inch x 3-foot piece of rebar is driven through the holes and into the ground so that the top of the rebar is flush with the top of the mudsill. (See Figure 15.10.)

Once the mudsills are placed, the joists are installed. There should be a minimum of two 6- x 8-inch select structural Douglas fir joists attached to the top of the mudsills. The milled stringer chart in Chapter 16, *Trail Bridges,* has been engineered for select structural Douglas fir. When using redwood or cedar, the joist size needs to be sufficient to meet the 100 pounds per square foot live load requirement. The joists should be squared to the mudsills, centered, and spaced so the two outside joists are 48 inches apart (outside to outside) for a puncheon without bull rails. The joist spacing should be 60 inches if bull rails are installed. The maximum free span of these joists should be 12 feet. If a longer free span is used, the dimensions of the joists must be increased according to the milled stringer chart in Chapter 16, *Trail Bridges*. To layout the joists, measure the length of the mudsill and divide that number in half. Then measure that distance from one end of the mudsill and scribe a line from top to bottom across the mudsill. This line is the center of the mudsill. From that line measure 24 inches toward the end of the mudsill in both directions; then scribe lines from top to bottom across the mudsill at those locations. These two lines represent the outside edges of the joists. Note, if bull rails are to be installed, measure 30 inches in both directions to scribe the top to bottom lines. The joists should be fixed to the mudsills by pre-drilling the joist with a 3/8-inch diameter pilot hole and driving a 12-inch galvanized spike through the joist and into the mudsill. (See Figure 15.11.)

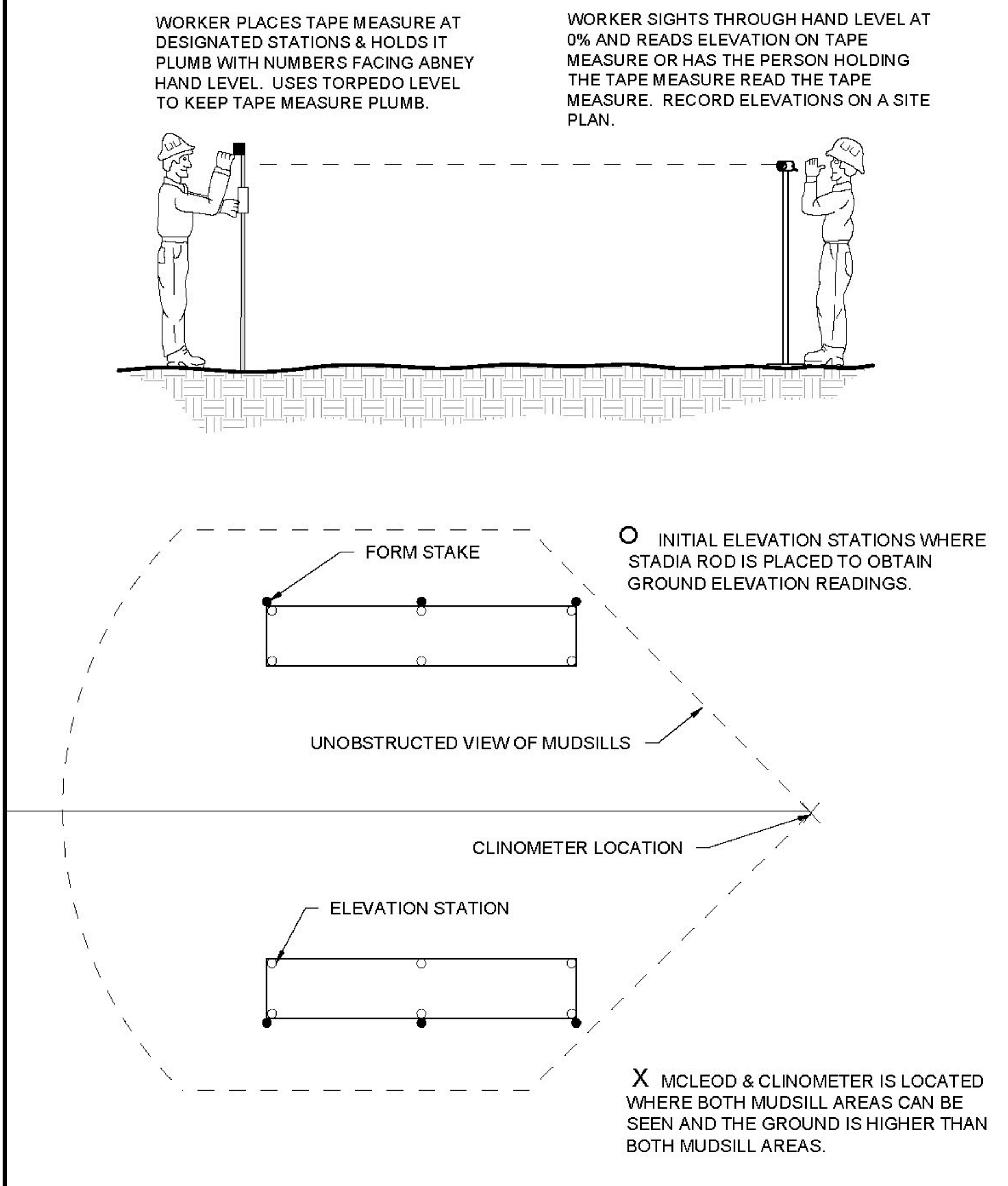

Figure 15.8 - Puncheon Mudsill Elevations with Clinometer or Abney

PUNCHEON MUDSILL ELEVATIONS WITH CLINOMETER OR ABNEY

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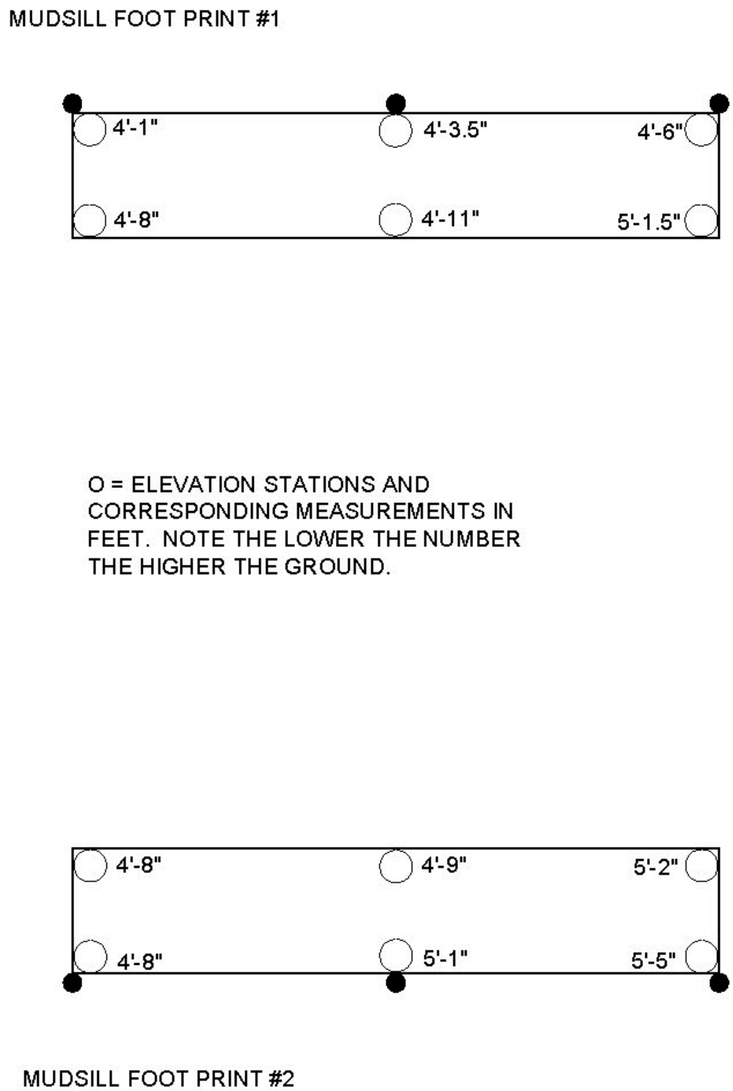

Figure 15.9 - Puncheon Mudsill Elevations Site Plan

PUNCHEON MUDSILL ELEVATIONS SITE PLAN

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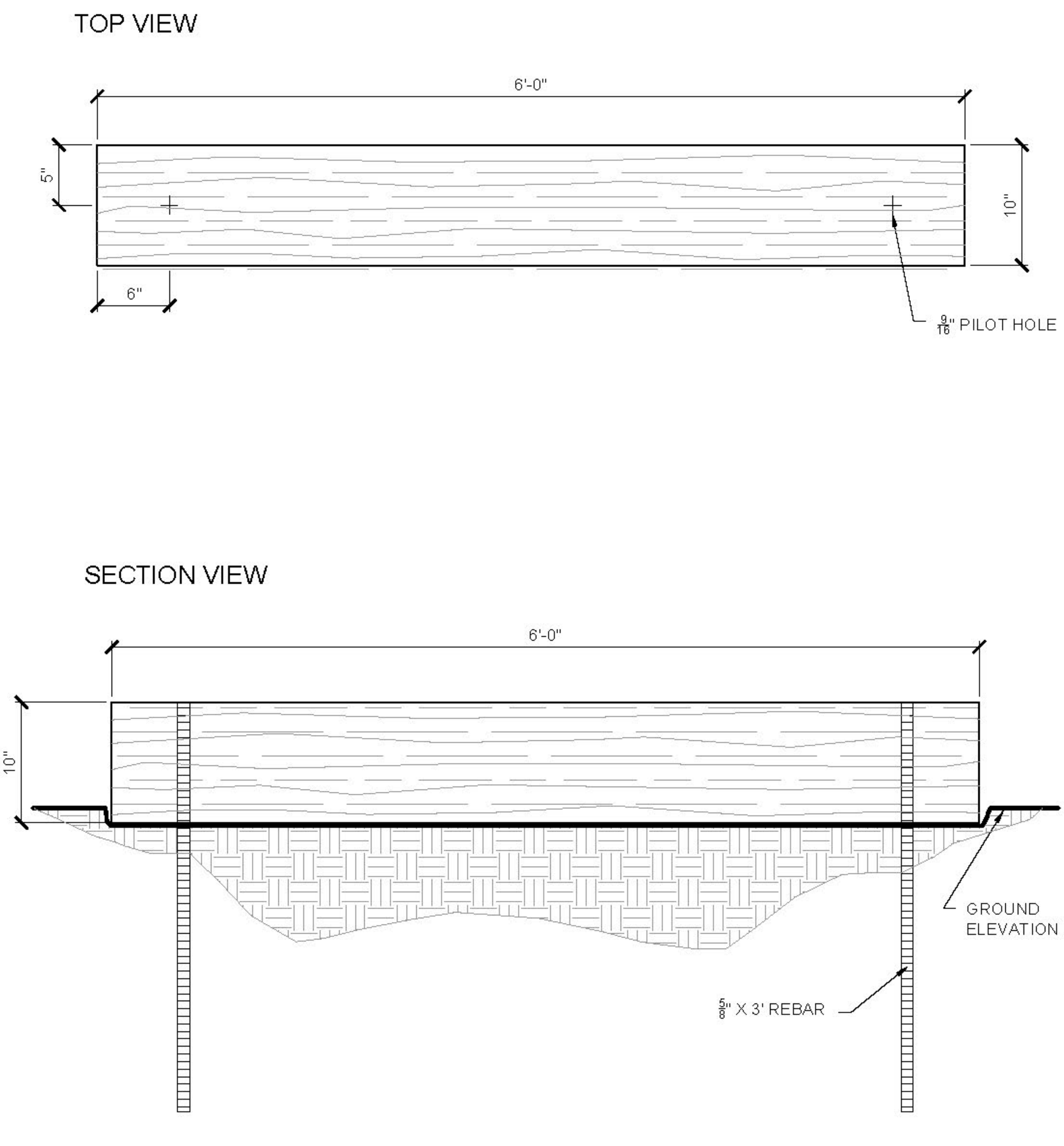

Figure 15.10 - Puncheon Mudsill Anchoring

PUNCHEON MUDSILL ANCHORING

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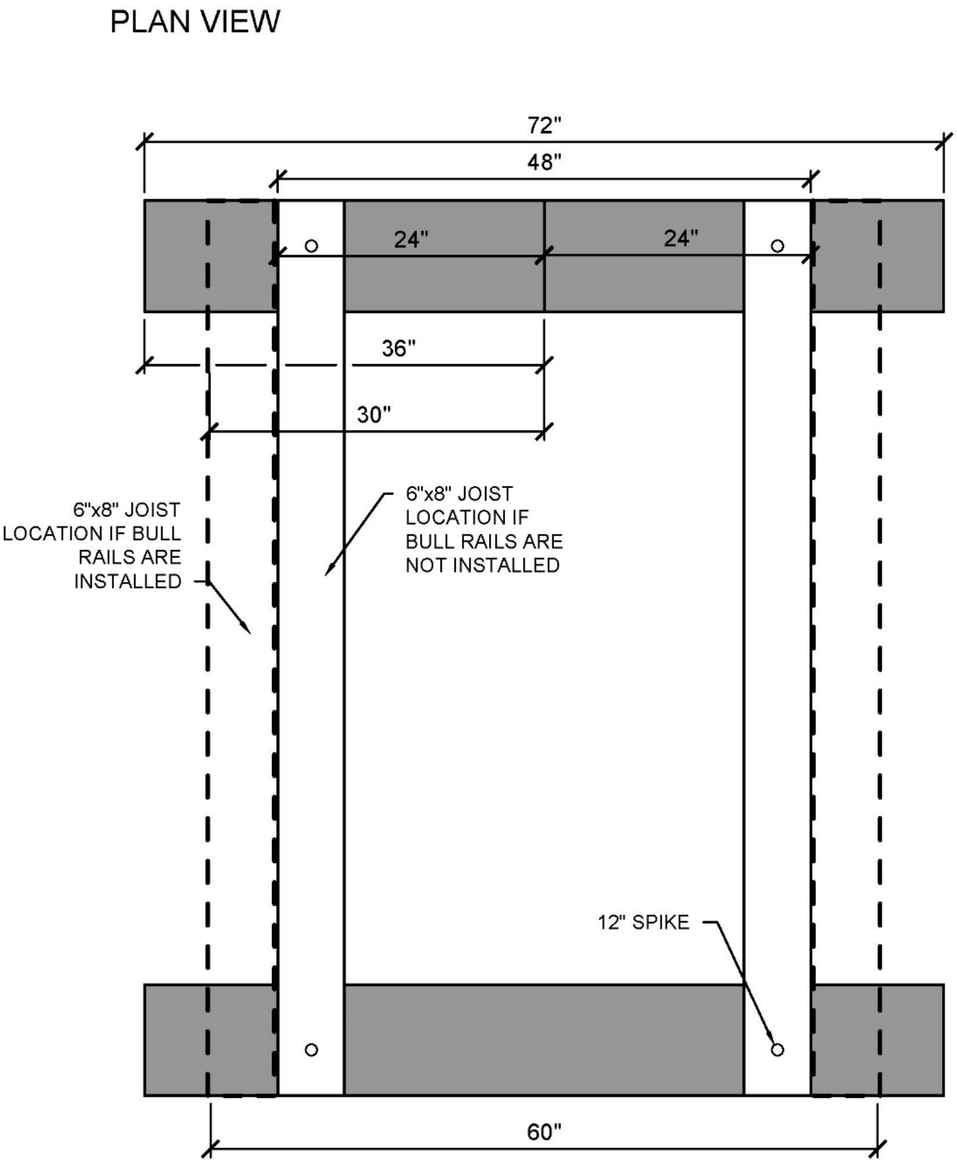

1. MEASURE THE LENGTH OF THE MUD SILL (72") AND DIVIDE THAT NUMBER IN HALF (36"). MEASURE 36" FROM THE END OF THE SILL TOWARDS THE CENTER OF THE SILL AND SCRIBE A LINE FROM TOP TO BOTTOM ACROSS THE SILL. THIS IS THE CENTER LINE OF THE SILL. THEN MEASURE 24" OUT IN BOTH DIRECTIONS FROM THIS LINE AND SCRIBE LINES FROM TOP TO BOTTOM ALONG THE SILL. THESE LINES REPRESENT THE OUTSIDE EDGE OF THE JOISTS. USE 30" FOR THIS MEASUREMENT IF BULL RAILS ARE TO BE INSTALLED.

2. CUT JOISTS TO DESIGNED LENGTH (12') AND LAY THEM ON THE MUD SILLS SO THE OUTSIDE EDGES OF THE JOISTS LINE UP WITH THE LINES SCRIBED ON THE SILLS. THE ENDS OF THE JOISTS SHOULD BE FLUSH WITH THE OUTSIDE EDGE OF THE MUD SILLS. ANCHOR THE JOISTS TO THE MUD SILLS BY DRILLING 3/8 " DIAMETER PILOT HOLES AND DRIVING 12" SPIKES THROUGH THE JOISTS AND INTO THE MUD SILLS.

Figure 15.11 - Installing Puncheon Joist

INSTALLING PUNCHEON JOIST

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Once the joists are pinned, the decking can be installed. The decking material should be 3 inches thick and a minimum of 60 inches long if there are no bull rails and 72 inches long if there are bull rails. The decking should be installed to overhang the outside of the stringers by a minimum of 5 to 7 inches and be perpendicular to the stringers. This overhang is necessary to cover the exposed sides of the joists for aesthetic purposes. When laying the decking down, a rough or irregular edge to the decking can be achieved by altering the overhang length of every other piece of decking. For example, one end of the decking overhangs the joist by 5 inches and the other end overhangs the joist by 7 inches. The next decking laid down will have reverse overhanging lengths. Holding a tape measure between the outside of the joist and the end of the decking is an easy way to achieve this stagger. This staggering technique is performed to reduce the uniform appearance of the structure and have it blend in with the natural environment. Unless the climate is cool and moist most of the year, a space of 1/4 to 3/8 inches should be left between the decking boards to allow for swelling and shrinking of the decking boards. In a very hot and dry desert climate, board shrinkage can be substantial. In these conditions, the decking should be installed without a gap, otherwise the gap may become too wide, especially by accessible trail standards. (See Figure 15.12.)

Note, when installing decking it is important that the boards are laid with the crowned side up. The crown of a decking board is the natural curvature of a board caused by the tree's growth rings. To see the crown of a 3- x 12-inch decking board, look down the flat side of the board and observe if the surface is convex (crowned) or concave (cupped). By installing the decking board with the crowned side up, the outside edges of the board will rest flush on the joist and not lift or curl once fastened to the joist. If it is installed with the cupped side up, the outside edges of the board will continue to warp upward and pull the fasteners loose, causing the board to become a tripping hazard.

Using the center of the joist as a guide, a chalk line can be snapped across the top of the decking to provide a reference for nailing. The decking should be fastened to the joist by drilling a 7/32-inch pilot hole through the decking and into the stringer. The depth of the pilot hole should leave at least 1 1/2 to 2 inches of un-drilled wood in the joist to firmly grasp the fastener. When using long decking screws (5 to 6 inches), it may be necessary to drill the holes deeper because screws this long shear easily. When the decking wood is hard and dry it may also be necessary to lubricate the nails or screws to install them. Liquid hand cleaner (in a can) works well for this purpose and is easy to use.

With 3-inch decking, drive in 60D galvanized nails until they are flush with the decking surface. A punch or drift pin should then be used to recess the head of the nails a minimum 1/8-inch below the surface of the decking. Stainless steel deck screws 6 inches long can also be used to fasten the decking to the joist. If the decking used is 6 inches wide or less, then two fasteners are used per board. These fasteners should be placed approximately 1 1/2 inches from the edge of the boards to keep the boards from curling or cupping. If the boards are wider than 6 inches, then three fasteners per board are used; two approximately 1 1/2 inches from the edge of the board and one in the center. (See Figure 15.12.)

If hand split decking is used then an adze should be used to level the decking. If power tools can be used, then a chainsaw with a power plane attachment can be used to quickly level the decking's surface. Prior to leveling the decking, make sure the nail heads are well below the depth of wood that needs to be removed. Leveling should be sufficient so there are no vertical rises in the decking's surface in excess of 1/4 inch.

Once the decking is down and secured, the soil dams are installed. The soil dams are attached to each end of the puncheon to provide separation between the puncheon structure and the surrounding soil. They should be con heart redwood, cedar, or pressure treated Douglas fir. The soil dams should be a minimum dimension of 3 inches thick and the same length as the mudsills. The number of boards will be dictated by the overall height of the puncheon. The soil dam should span from the bottom of the mudsill to the top of the decking. It is fastened to the ends of the joist and the mudsill. Pilot holes should be pre-drilled to facilitate nailing the soil dam to the joist and mudsill.

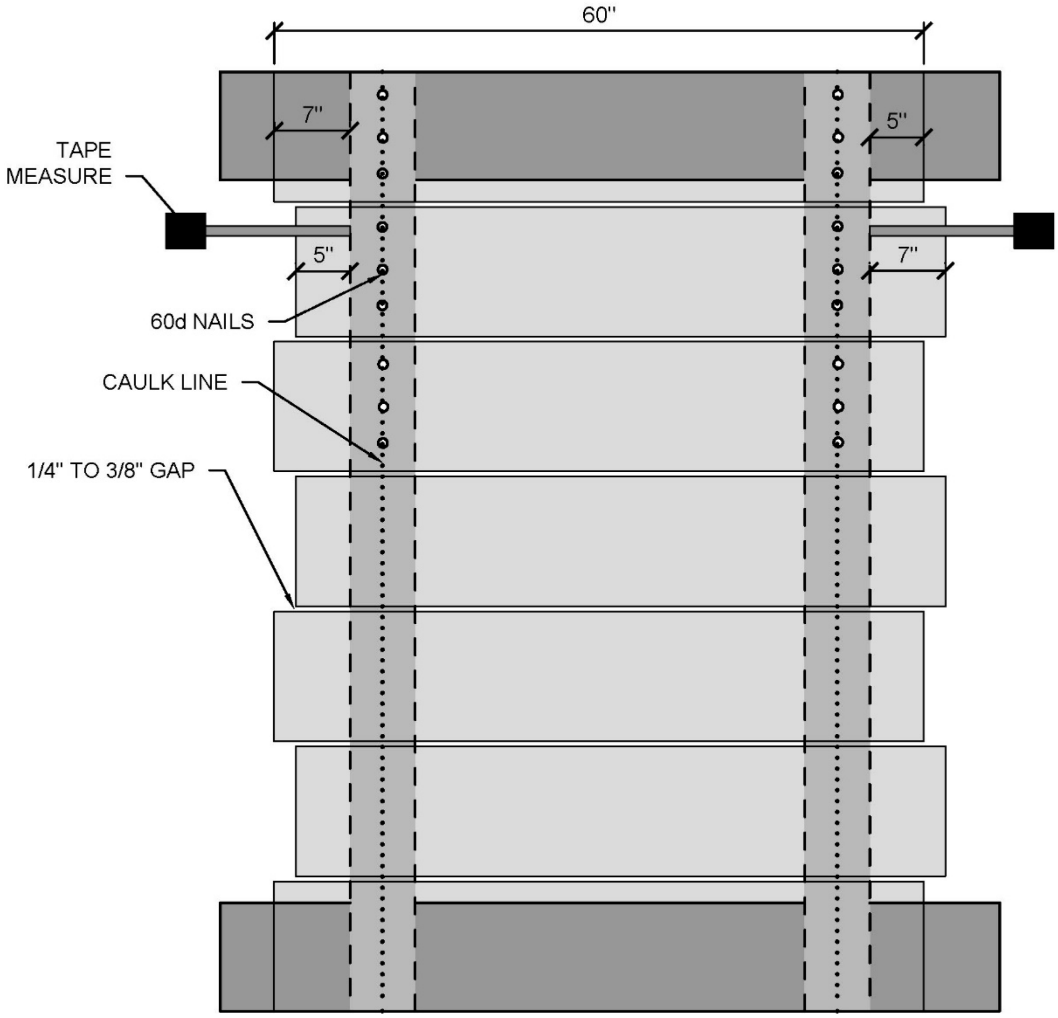
To determine the fastening pattern, measure the on-center width between the two outside joists and dividing that measurement in half. (See Figure 15.13.) Next, find the center of the soil dam board by measuring the length and dividing that number in half. Then measure from the end of the soil dam board toward its center using this distance. At that location, scribe the center of the board across its full width. Then measure out from that line the distance previously determined to be half the on-center distance between the joists. Perform this measurement on both sides of the soil dam board center line and scribe those lines across the full width of the boards. These lines represent the center of the joists where the pilot holes will be drilled. If there are three joists then the center line of the soil dam board represents the center of the middle joist. Use a drill and a twist drill bit to drill the pilot holes along these scribed lines on the soil dam board. For 12-inch wide boards, drill three holes as described below. To avoid anchoring the soil dam into the decking board, measure down from the top of the board approximately 4 1/2 inches for the top pilot hole. Then measure 1 1/2 inches up from the bottom edge of the board for the bottom pilot. Then measure half the distance between these two holes to locate the middle pilot hole. For soil dam boards less than 12 inches wide, use two pilot holes, each approximately 1 1/2 inches in from the top and bottom of the board. (See Figure 15.13.)

From the previous layout of the joists, the mudsill should already have a center line mark. Transcribe that line to the front of the mudsill so it can be seen when looking at the end of the puncheon. This line represents the centers of the puncheon and the soil dam boards. A pre-drilled soil dam board is then placed against the end of the puncheon so that the top of the board is flush with the top of the decking board.

The line on the center of the soil dam board should line up with the line scribed on the center of the mudsill. While holding the soil dam board in place, use nails to fasten it to the ends of the joist and/or mudsill. Galvanized 60d nails are used to fasten the soil dam boards. Once the topsoil dam board is installed, the second soil dam is installed following the same process. Depending on the overall height of the puncheon, the second 12-inch soil dam board may need to be ripped to fit in the remaining space or the soil in front of the mudsill can be excavated to provide the space to accommodate a 12 inch wide board. (See Figure 15.13.)

If the decking board on the end of the puncheon has the same overhang on both sides of the joist, an alternative method of lining up the soil dam is to measure the length of the end decking board. Divide that distance in half and use that measurement to locate the center of the decking board. Scribe a line on the top outside edge of this decking board. This line represents the center of the puncheon and the soil dam boards. A pre-drilled soil dam board is then placed against the end of the puncheon so that the top of the board is flush with the top of the decking board. The line on the center of the soil dam board should line up with the line scribed on the center of the decking board. While holding the soil dam board in place, use nails or screws to fasten it to the ends of the joist and/or mudsill. Note, if the decking has been installed with an alternating stagger to the overhang, then the center line mark on the decking must be moved toward the short overhang side the distance of the stagger to achieve the true center of the puncheon.

Once the soil dams are installed, the area between the soil dams and the existing trail tread should be filled with the prescribed tread material and compacted in maximum 3-inch lifts. The finished trail grade should be flush with the top of the decking.



1. LAY A 60" LONG DECKING BOARD ACROSS JOIST SO THE OUTSIDE EDGE OF THE DECKING IS FLUSH WITH THE END OF THE JOIST. USE A TAPE MEASURE TO MEASURE FROM THE OUTSIDE OF THE JOIST TO THE END OF THE DECKING. MEASURE 5" ON ONE SIDE AND 7" ON THE OTHER. REVERSE THESE OVERHANGS ON THE NEXT DECKING BOARD TO PROVIDE A STAGGERED AND IRREGULAR EDGE TO THE DECKING. PROVIDE A 1/4" TO 3/8" GAP BETWEEN DECKING BOARDS.

2. ONCE ALL THE DECKING BOARDS ARE DOWN, LOCATE THE CENTER OF EACH JOIST AND SNAP A CAULK LINE OVER THE TOP OF THE DECKING BOARDS TO MARK THE CENTER OF THE JOIST. THEN ANCHOR THE DECKING TO THE JOIST BY DRIVING THREE 60d GALVANIZED NAILS OR THREE 5 1/2" DECKING SCREWS (ONE IN THE CENTER AND ONE 1 1/2" IN FROM THE EDGE OF THE DECKING BOARD. USE A PUNCH TO SET THE HEAD OF THE NAILS 1/8" BELOW THE SURFACE OF THE DECKING.

Figure 15.12 - Installing Puncheon Decking

INSTALLING PUNCHEON DECKING

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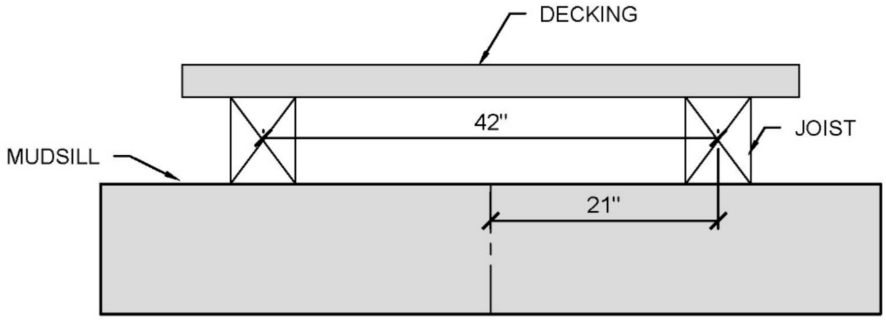
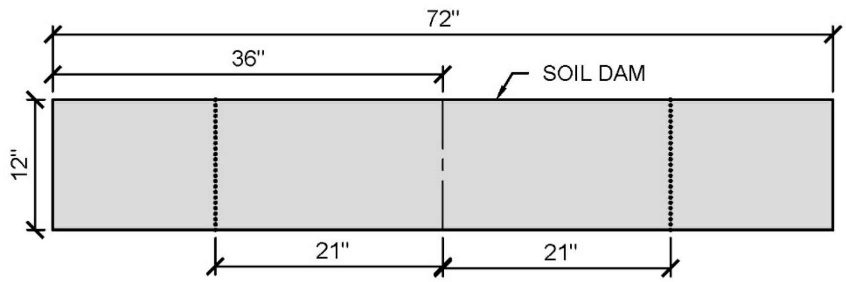
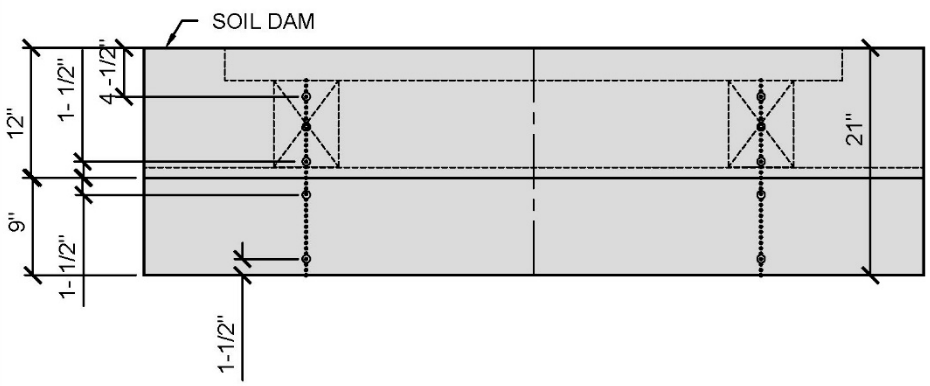


1. MEASURE THE DISTANCE BETWEEN THE CENTERS OF THE JOISTS (42''). THEN DIVIDE THAT MEASUREMENT IN HALF (21''). TRANSCRIBE THE MUDSILL CENTER LINE TO THE FRONT OF THE MUD SILL.



2. MEASURE THE LENGTH OF THE SOIL DAM (SHOULD BE THE SAME AS THE MUDSILL 72''). DIVIDE THAT MEASUREMENT IN HALF (36''). THEN MEASURE FROM THE END OF THE SOIL DAM TOWARDS THE CENTER THAT DISTANCE (36''). SCRIBE A VERTICAL LINE ACROSS THE SOIL DAM AT THAT DISTANCE. THIS IS THE CENTER OF THE SOIL DAM.



3. MEASURE OUTWARDS FROM THE SOIL DAM CENTER LINE HALF THE DISTANCE BETWEEN THE CENTER OF THE JOISTS (21''). SCRIBE VERTICAL LINES ACROSS THE SOIL DAM AT THAT DISTANCE. THESE LINES REPRESENT THE CENTERS OF THE JOISTS.

4. MEASURE FROM THE TOP OF THE DECKING TO THE BOTTOM OF THE MUDSILL (21''). SUBTRACT 12'' FROM 21'' TO DETERMINE THE WIDTH OF THE REMAINING SOIL DAM BOARD. RIP A 12'' WIDE SOIL DAM BOARD TO 9''. LAY THE 9'' WIDE BOARD AGAINST THE 12'' WIDE BOARD AND TRANSPOSE THE JOIST CENTER LINE LINES.

5. MEASURE DOWN FROM THE JOIST CENTER LINE SCRIBES FROM THE TOP OF THE 12'' SOIL DAM BOARD 4 1/2'' AND MARK THAT LOCATION. MEASURE UP FROM THE BOTTOM OF THE 12'' SOIL DAM BOARD 1 1/2'' AND MARK THAT LOCATION. THEN MARK THE LOCATION HALF WAY BETWEEN THOSE TWO MARKS. MEASURE DOWN FROM THE TOP OF THE 9'' SOIL DAM BOARD 1 1/2'' AND MARK THAT LOCATION. MEASURE UP FROM THE BOTTOM OF THE 9'' SOIL DAM BOARD 1 1/2'' AND MARK THAT LOCATION. DRILL PILOT HOLES AT THESE MARKS. INSERT NAILS INTO PILOT HOLES. ALIGN THE CENTER LINE ON THE 12'' WIDE SOIL DAM WITH THE CENTER LINE ON THE MUDSILL AND HOLD THE TOP OF SOIL DAM FLUSH WITH THE TOP OF THE DECKING BOARD. SECURE SOIL DAM TO MUDSILL & JOIST WITH 60d NAILS . HOLD 9'' WIDE SOIL DAM UP AGAINST THE 12'' WIDE SOIL DAM AND ALIGN THE CENTER LINES ON EACH BOARD. SECURE WITH 60d NAILS .

Figure 15.13 - Installing Soil Dam

INSTALLING SOIL DAM

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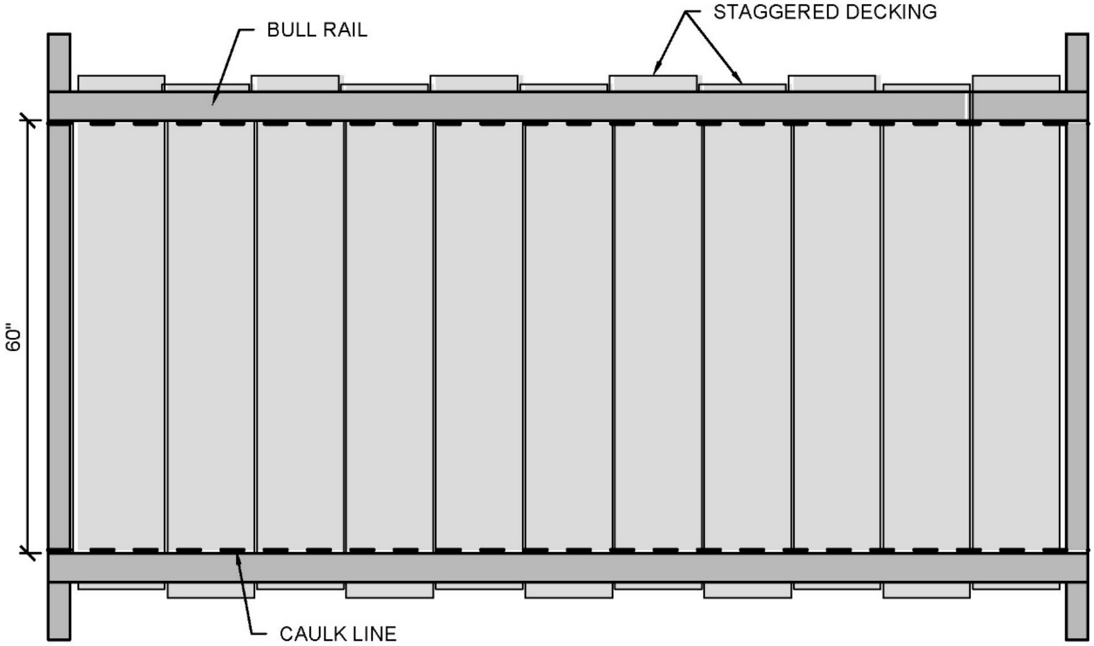
If the puncheon is for an accessible trail, bull rails can be attached to the outside edge of the decking to provide edge protection. Bull rails can also be used on equestrian trails. (See the "Equestrian Puncheons" section.) To provide a 5-foot wide deck between the bull rails, the puncheon joists must be spaced 60 inches apart (outside to outside measurement), instead of the standard 48 inches. Once the decking is installed, snap a string line across the top of the decking boards. The string line should be aligned with the outside edge of the joists. The bull rail will be attached to the decking on the outside of this caulk line. (See Figure 15.14.) The bull rail should be redwood, cedar, pressure treated Douglas fir, or plastic wood. The bull rail is attached to the decking by placing 2- x 4-inch wooden or plastic lumber blocks between the bull rail and decking. These blocks are required to elevate the bull rail off of the decking to allow water to drain and reduce the buildup of organic material that will increase rot. These blocks should be inset from the ends of the bull rail by approximately 2 inches and have a maximum spacing of 48 inches. The bull rail should be a minimum of 4 x 4 inches with 4 x 6 inches preferred. Once the blocks have been properly spaced and the bull rails laid on top of them, clamp the bull rail to the decking to keep the blocks and bull rails fixed until they can be anchored. The bull rails and blocking are attached to the decking by drilling a 3/8-inch hole through the rail, bock, and decking, and fastening all three together with 3/8- x 12-inch galvanized carriage bolts. (See Figure 15.14.) This design should provide a minimum decking width of 60 inches between the bull rails and a minimum 2-inch gap between the decking and the bull rails.

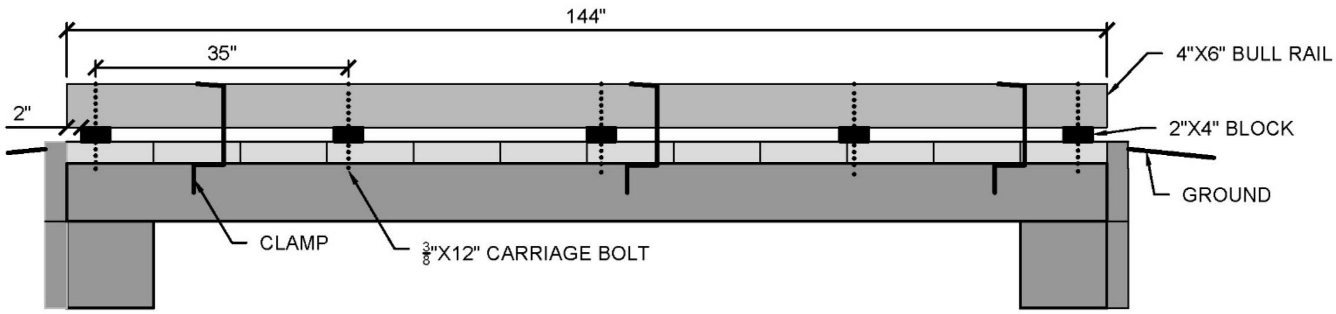
In locations where the ground is wet or has weak soil over a wide area, multiple puncheons can be spliced together to span greater distances. Each section should have a maximum 12-foot span. Note, spans longer than 12 feet require joists that are sized according to the milled stringer chart in Chapter 16, *Trail Bridges*. The mudsills are installed in the same fashion as previously described, but the joists sharing a common mudsill rest half way onto the mudsill. (See Figure 15.15.) The joists from the adjoining 12 foot section butt against the previously installed joists so that they share the same mudsill. Each joist rests on a 5 inch wide portion of the mudsill.

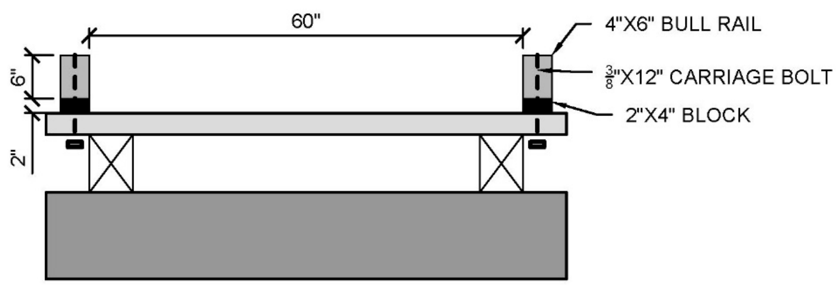
15.3.3. Curved Puncheons

Where multiple puncheons are constructed it is important that they conform visually to the surrounding setting. Long, straight sections of puncheons on a trail that is curving around the hillslope will look out of place and in contrast to the natural setting. In these settings the puncheons should be laid out and constructed to curve with the terrain. There are two basic methods for obtaining this curve: installing the mudsills parallel or flared to each other. (See Figures 15.16 and 15.17.)



1. INSTALL JOISTS WITH A 60" OUTSIDE TO OUTSIDE WIDTH APART. SNAP A CAULK LINE ACROSS THE DECKING ALONG THE OUTSIDE EDGES OF THE JOISTS. INSTALL BLOCKS AND BULL RAILS ALONG THE OUTSIDE EDGES OF THE CAULK LINE.





2. SPACE THE BLOCKS SO THEY ARE 2" IN FROM THE ENDS OF THE BULL RAILS AND NOT MORE THAN 48" APART. CLAMP THE BULL RAILS AND BLOCKS TO THE DECKING.

3. DRILL 3/8" DIAMETER HOLES THROUGH THE BULL RAILS, BLOCKS AND DECKING. FASTEN THE BULL RAILS AND BLOCKS TO THE DECKING WITH 3/8" X 12" CARRIAGE BOLTS.

Figure 15.14 - Installing Bull Rails

INSTALLING BULL RAILS

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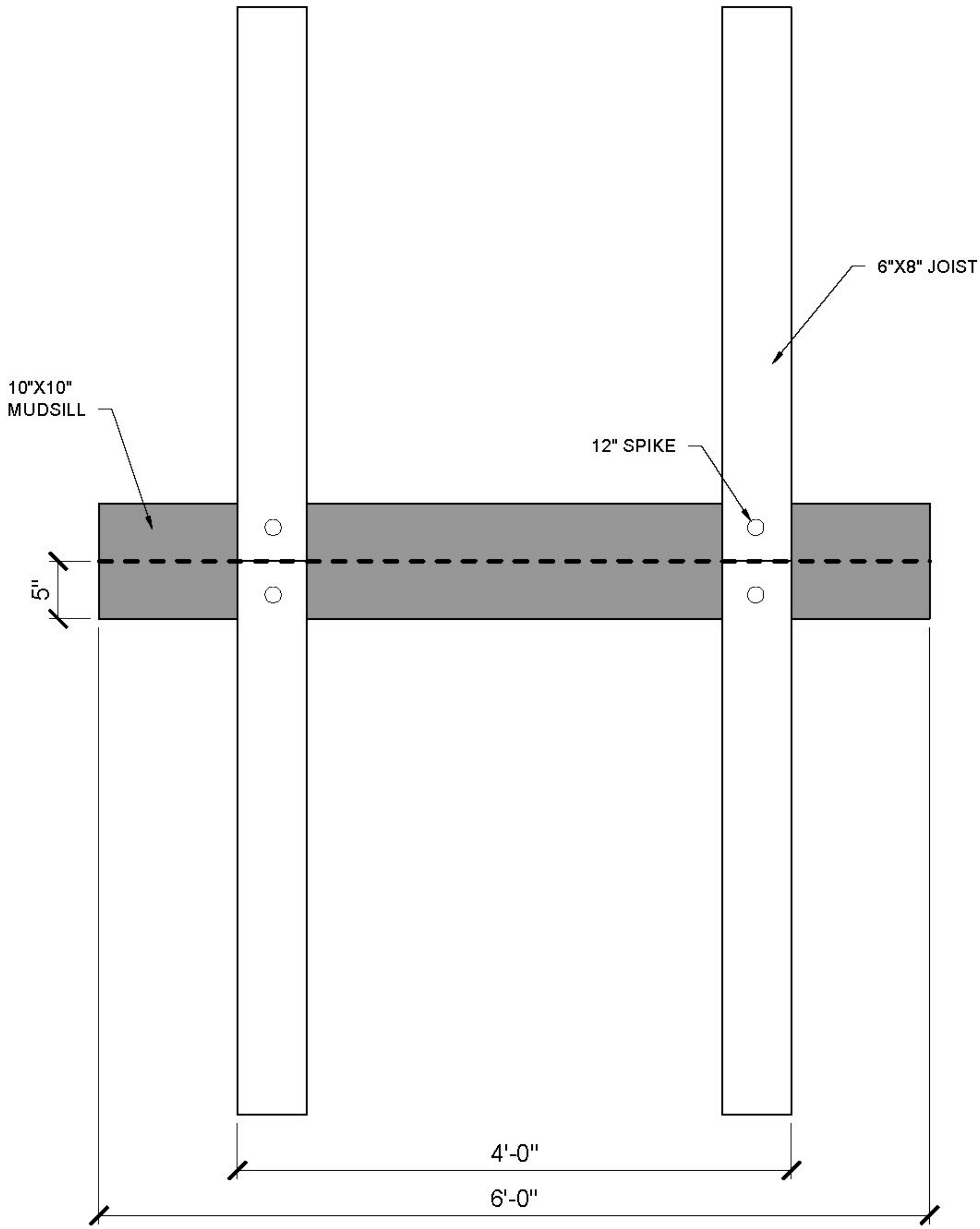

Figure 15.15 - Installing Multiple Puncheon Sections

INSTALLING MULTIPLE PUNCHEON SECTIONS

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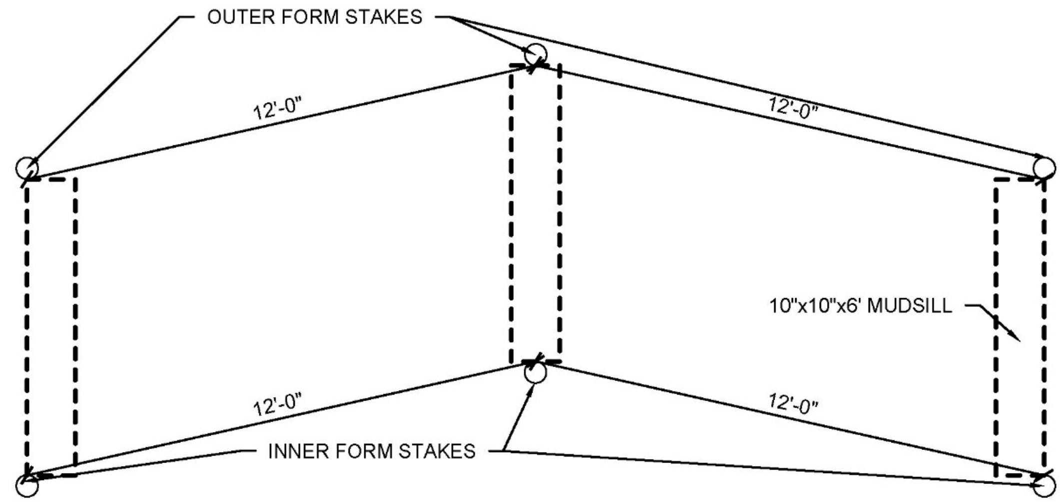
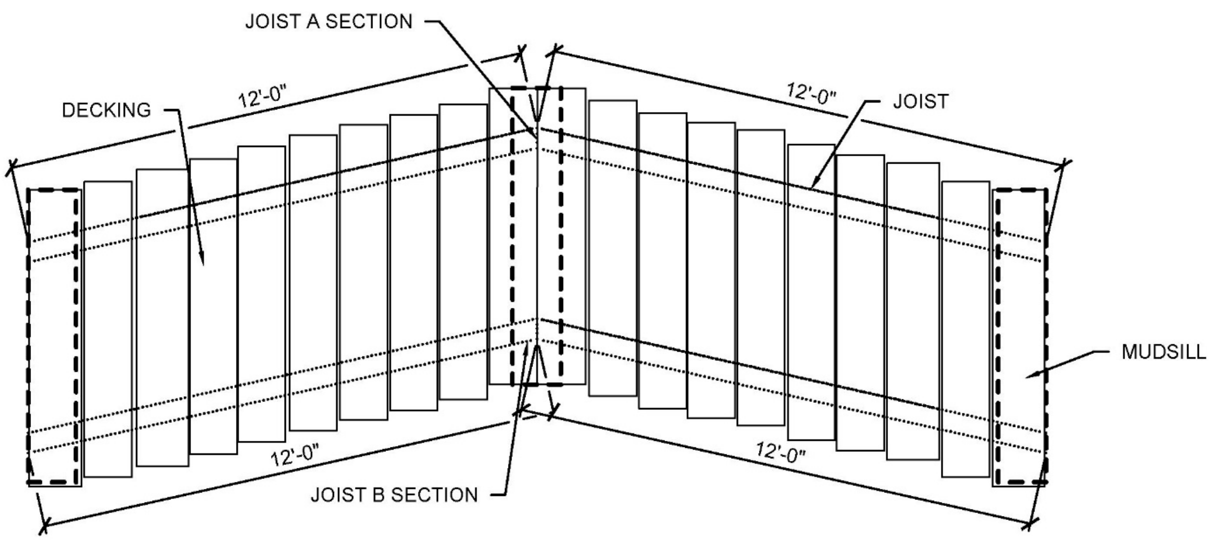
CURVED BOARDWALK WITH MUDSILLS PARALLEL TO EACH OTHER



SET OUTER ROW OF FORM STAKES IN GROUND TO APPROXIMATE THE DESIRED CURVE. SPACE THE STAKES 12' APART AT THE DESIRED ANGLE. SET THE INNER ROW OF STAKES PARALLEL TO THE OUTER ROW 6' BELOW AND 12' APART. INSTALL THE MUDSILLS IN BETWEEN THE FIRST AND SECOND ROW OF STAKES.



MEASURE THE LENGTH OF BOTH OF THE JOIST SECTIONS ON THE OUTSIDE OF THE CURVE
JOIST A SECTION 12' + 12' = 24'
JOIST B SECTION 12' + 12' = 24'
BECAUSE THE MUDSILLS ARE PARALLEL TO EACH OTHER THE TWO JOIST SECTIONS HAVE THE SAME MEASUREMENT. THE DECKING DOES NOT REQUIRE A TAPERED CUT. THE OVERHANG ON THE DECKING IS INSTALLED SO IT IS EQUAL ON BOTH JOIST SECTIONS. THIS OVERHANG PATTERN WILL REFLECT THE CURVE OF THE BOARDWALK JOIST. IF A CURVE WITH A TIGHTER RADIUS IS DESIRED THE DECKING OVERHANG CAN BE UNEQUAL TO ACHIEVE A TIGHTER RADIUS. USING LONGER DECKING BOARDS WILL ALSO PROVIDE MORE OVERHANG AND LATITUDE TO TIGHTEN THE RADIUS. NOTE, THE OVERHANG FOR THE DECKING BOARDS SHOULD NOT EXCEED 12".

Figure 15.16 - Installing Multiple Puncheon Sections with Curve (Parallel)

INSTALLING MULTIPLE PUNCHEON SECTIONS WITH CURVE (PARALLEL)

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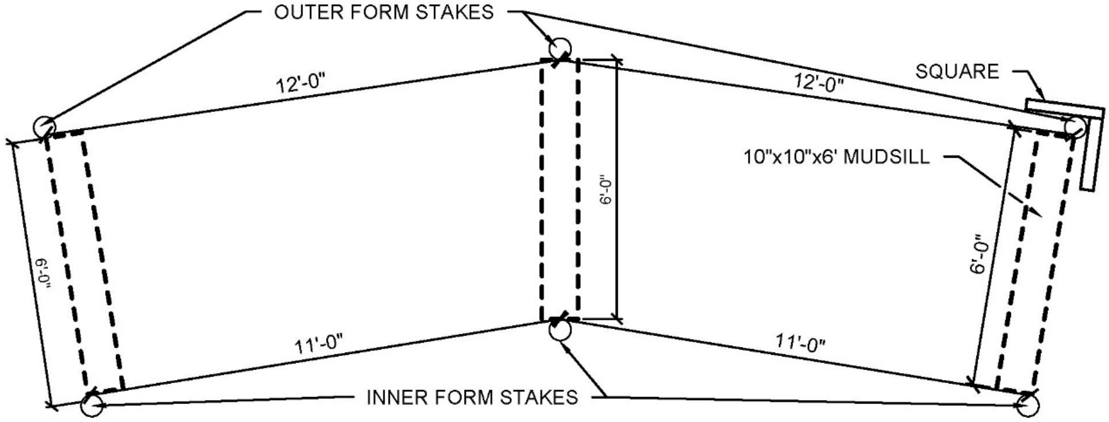
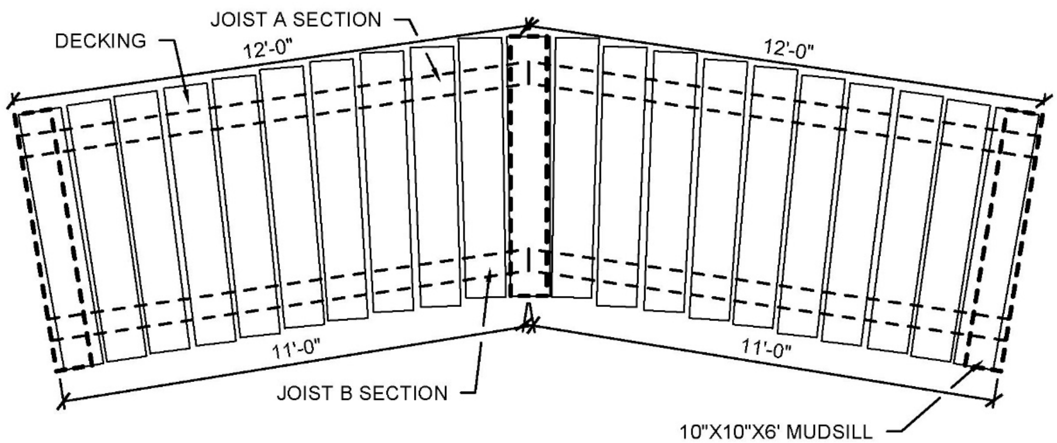
NOT TO SCALE



SET OUTER ROW OF FORM STAKES IN GROUND TO APPROXIMATE THE DESIRED CURVE. SPACE THE STAKES 12' APART AT THE DESIRED ANGLE. SET THE CENTER STAKE OF THE INNER ROW OF STAKES 6' BELOW THE CENTER STAKE OF THE OUTER ROW. SET THE STAKES ON EITHER SIDE OF THE INNER ROW CENTER STAKE 6' FROM THE OUTER ROW STAKES (MEASURED AT A RIGHT ANGLE).



MEASURE THE LENGTH OF BOTH JOIST SECTIONS ON THE OUTSIDE OF THE CURVE
JOIST A SECTION 12' + 12' = 24'
JOIST B SECTION 11' + 11' = 22'
BECAUSE THE MUDSILLS ARE FLARED TO EACH OTHER THE TWO JOIST SECTIONS HAVE DIFFERENT MEASUREMENTS. DIVIDE SECTION B BY SECTION A TO DETERMINE ITS PERCENTAGE OF SECTION A, THEN SUBTRACT THAT PERCENTAGE FROM 100% (22'/24'=92%)(100%-92%=8%)
SECTION B IS 8% SHORTER THAN SECTION A. ASSUME THE DECKING IS 12" WIDE, MULTIPLY THE WIDTH OF THE DECKING TIMES 8% .08x12=.96" NOTE, CONVERT .96 TO THE NEAREST FRACTION OF AN INCH=15/16" TO DETERMINE THE FULL TAPER. DIVIDE 15/16" IN TWO TO OBTAIN THE HALF TAPER TO BE MEASURED FROM BOTH SIDES OF THE DECKING BOARD 15/16/2=15/32"

Figure 15.17 - Installing Multiple Puncheon Sections with Curve (Flared)

INSTALLING MULTIPLE PUNCHEON SECTIONS WITH CURVE (FLARED)

CALIFORNIA STATE PARKS

NOT TO SCALE

15.3.3.1. Parallel Mudsills

When installing a puncheon with a curve, the initial layout can be facilitated by driving form stakes into the ground to approximate the desired curve of the structure. The form stakes identify the locations of the mudsills. For each mudsill location there are two form stakes: one that identifies the outside of the curve and one that identifies the inside of the curve. The outside form stakes are driven in first. These stakes are a maximum 12 feet apart, which is the maximum span of the 6- x 8-inch joists. When installing mudsills that are parallel to each other, the inside form stakes are driven in so they are parallel to each other and the distance between the stakes is identical. (See Figure 15.16.) The outside and inside stakes should be 6 feet apart, which is the length of the mudsills. Using the form stakes as a guide, the ground around the stakes can be cleared, elevations for each mudsill can be identified, and the pads for the mudsills can be leveled to each other. Once the mudsills are installed, measure the distance of both the outside and inside of the curved joist sections. If the mudsills are parallel to each other, the distance will be the same. (See Figure 15.16.) Because the inside and outside measurements of the curved mudsills are identical, the decking does not have to be tapered to approximate the curve. When the decking is installed, the curve of the structure is achieved by adjusting the overhang of the decking. To increase the acuteness of the radius, the decking will have more overhang on the outside joist than on the inside joist. (See Figure 15.16.) If additional curvature is desired, the joists can be installed closer together or longer decking boards can be used. The overhang of the decking should not exceed 12 inches. With this method, the curve of the puncheon is limited.

15.3.3.2. Flared Mudsills

If a more acute radius is required (e.g. the puncheon needs more curvature), the flared mudsill method should be used. The layout process is similar to the parallel method except the inside form stakes are set at an oblique angle (tapered inward) to the outside stakes. (See Figure 15.17.) Once the outside form stakes are set at the desired curve, a string line is tied to them. A framing square is then used to set a second string line at a right angle to the first line. Measure 6 feet down the second string line and set the inside form stake at that location. Follow this process to set the rest of the inside form stakes. (See Figure 15.17.) Due to the flaring of the mudsills, the inside length of the curved puncheon will be shorter than the outside length. To compensate for the difference, the decking will need to be tapered (narrower at the bottom or inside of the curve). To determine the taper of the decking boards, measure the distance between the outsides of the joist sections and between the insides of the joist sections. (See Figure 15.17.) In the example in Figure 15.17, the outside section is 24 feet and the inside section is 22 feet. In this case, divide the inside measurement (22 feet) by the outside measurement (24 feet) to obtain the percentage difference between the two (22 ft. ÷ 24 ft. = 92%). Thus, the inside joist section is 8% shorter than outside joist section (i.e., 100% - 92% =

8%). Assuming the decking is 12 inches wide, multiply the width of the decking (12 inches) by 8% to obtain the taper of each decking board (.08 x 12 in. = 0.96 in.). Convert 0.96 to the nearest 1/16th of an inch by multiplying it by 16/16 (e.g., 0.96 x 16/16 inch = 15/16 inch). Since the taper of the decking boards will be applied to both sides of each board, divide the total taper (15/16 inches) by two to obtain the taper applied to each side of the board (e.g.,15/16 in.÷ 2 = 15/32 in.). (See Figure 15.18.) On one end of the decking board, measure 15/32 inches inward from both sides of the board and scribe a line. Scribe lines from these two marks to the outside edge on the opposite end of the board. Once both lines are scribed, rip the board along those two lines to achieve the correct decking taper. The remaining board width (11 1/16 inches) will match the inside taper of the curved boardwalk.

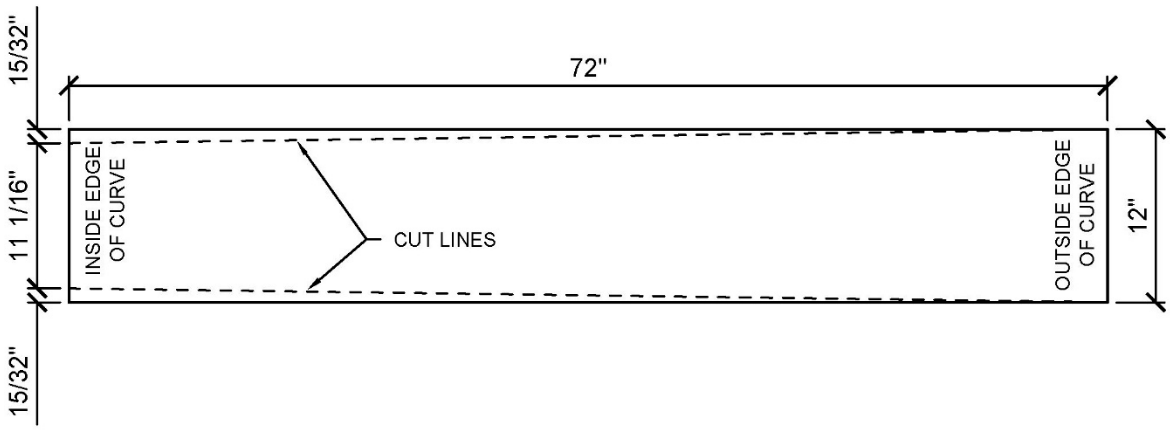
Perform this process on all the decking boards and then install them as previously discussed. If bull rails are required, install them in short sections with angled butt joints so that they can contour with the decking. (See Figure 15.18.)

15.3.4. Equestrian Puncheons

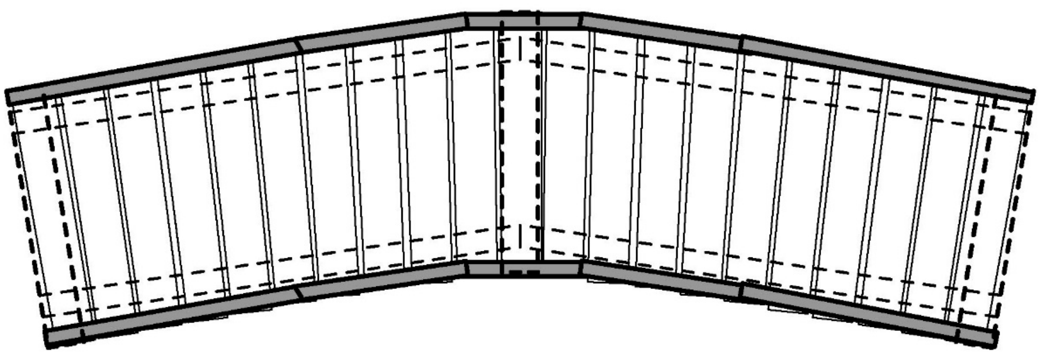
While the basic structural design is the same for hiking and equestrian puncheons, there are some design modifications to accommodate horses. The joists must be a minimum of three 6- x 8-inch pressure treated Douglas fir to reduce the deflection (bounce) in the joists as a horse crosses the puncheon. The milled stringer chart in Chapter 16, *Trail Bridges*, has been engineered for select structural Douglas fir. When using redwood or cedar, the joist size needs to be sufficient to meet the 100 pounds per square foot live load requirement. This requirement provides a stable tread surface and reduces the horse's apprehension when crossing over these structures. The decking should have a minimum thickness of 4 inches, a minimum length of 72 inches, and a minimum space between bull rails of 60 inches. Note, with 4-inch thick decking, 7-inch galvanized spikes should be used to nail it down. The bull rails should be a minimum of 4 x 8 inches. Horses require large bull rails, not because of their size but their poor vision. (See Chapter 7, *Equestrian Trails*.) Bull rails should be installed in the same manner as those on a pedestrian puncheon except the carriage bolts should be longer to accommodate the 8-inch bull rail and 4-inch decking. (See Figure 15.19.) The approaches to both ends of the bridge should be level, if possible. A ramp should be constructed for the approach if the trail grade is below the grade of the puncheon tread. (See Chapter 13, *Retaining Structures*.) If a step or a series of steps is needed, it should be designed as per the specifications in Chapter 17, *Trail Steps*.

TAPERING DECK BOARDS

ON ONE END OF THE DECKING BOARD MEASURE 15/32" INWARD FROM THE SIDE OF THE BOARD (ON BOTH SIDES OF THE BOARD). SCRIBE A LINE FROM THAT MARK TO THE OUTSIDE EDGE ON THE OPPOSITE END OF THE BOARD. ONCE BOTH LINES ARE SCRIBED, RIP THE BOARD ALONG THOSE LINES TO ACHIEVE THE CORRECT DECKING TAPER. THE REMAINING 11 1/16" BOARD WIDTH WILL MATCH THE INSIDE TAPER OF THE CURVED BOARDWALK. CONVERSLY THE OUTSIDE EDGE OF THE DECKING WILL RELECT THE DESIRED CURVE OF THE PUNCHEON. IF A CURVE WITH A TIGHTER RADIUS IS DESIRED THE DECKING OVERHANG CAN BE UNEQUAL (THE LENGTH OF DECKING EXTENDING BEYOND THE OUTSIDE JOIST IS GREATER THAN THE LENGTH OF THE DECKING EXTENDING BEYOND THE INSIDE JOIST) TO ACHIEVE A TIGHTER RADIUS. A TIGHTER RADIUS CAN ALSO BE ACHIEVED BY SETTING THE JOISTS 36" APART TO OBTAIN MORE DECKING. USING LONGER DECKING BOARDS WILL ALSO PROVIDE MORE OVERHANG AND THE ABILITY TO TIGHTEN THE RADIUS. NOTE, THE OVERHANG FOR THE DECKING BOARDS SHOULD NOT EXCEED 12".



INSTALLING BULL RAILS



THE BULL RAILS ARE INSTALLED IN SHORT SEGMENTS AND BUTTED TOGETHER. THEY ARE CUT AT ANGLES THAT ARE SIMILAR TO THE CURVE OF THE STRUCTURE.

Figure 15.18 – Curved Puncheon (Tapered Decking and Bull Rails)

CURVED PUNCHEON (TAPERED DECKING AND BULL RAILS)

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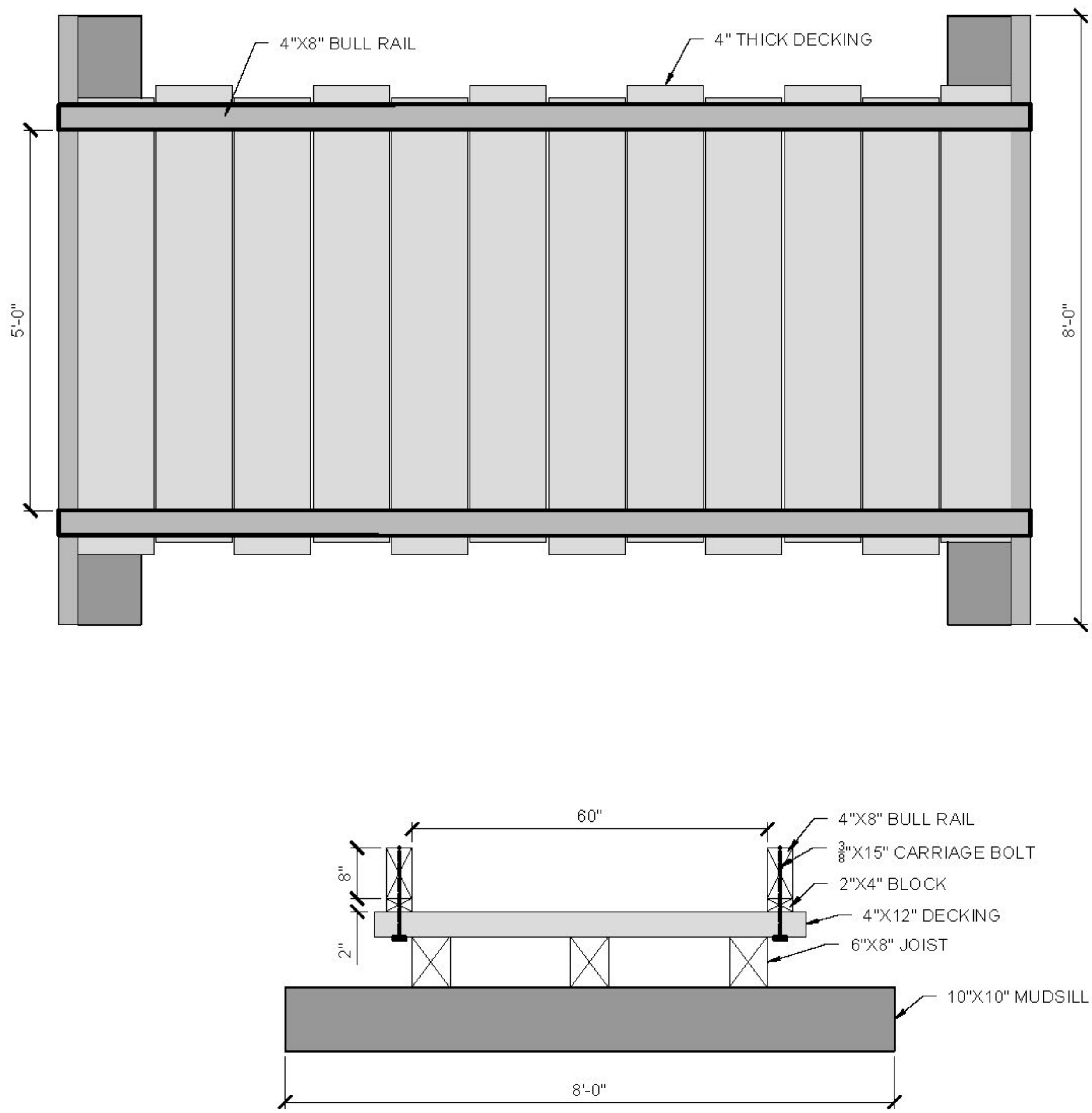

Figure 15.19 - Equestrian Puncheon

EQUESTRIAN PUNCHEON

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15.4. Boardwalks

15.4.1. Applications

Boardwalks are used in applications similar to puncheons, including locations where the parent soil is too weak and unstable to support the intended user traffic. They are commonly used to traverse sand dunes or low, poorly drained areas with saturated soil. Boardwalks are sometimes used to span over shallow standing water such as marshes. They are also used to span over sensitive areas, such as riparian plant communities or locations where tree roots are exposed and require protection. They also can be used to prevent soil compaction, which can harm vegetation adjacent to the trail. In addition, boardwalks can be used to prevent or mitigate damage to sensitive cultural and natural resources, such as shell middens or hydrothermal areas. Given the high cost of these structures, boardwalks are used mostly on Class I trails. (See Photo 15.3.)

Photo 15.3 - Boardwalks

Boardwalks can be designed to be low or relatively high off the ground. When used to traverse sandy soil, saturated and wet soil, or tree roots, they usually are no more than 24 inches above the ground. When used to cross ephemeral watercourses or ponding water, they can be more than 24 inches from the decking to the lowest point in the watercourse. They also can be used in applications where railings are required (e.g., decking 48 inches or greater above the channel). These structures are not intended to be used where water is flowing since they do not possess the necessary free board and may restrict water flow. They are, however, an effective structure for spanning across ponding water where high flows and associated debris do not occur.

Boardwalks are a very good design solution for providing an accessible trail surface where native soil is too weak to meet firmness and stability standards, and site conditions prohibit the use of trail hardening, turnpikes, or causeways. They also can be used to bridge over obstacles such as roots and rocks that are in excess of accessibility standards.

Boardwalks are primarily used on pedestrian and accessible trails but they are also appropriate on mountain bike trails. Due to their high elevation off the ground and a less robust design, most boardwalk structures are not suitable for equestrian use.

There are numerous boardwalk designs that can be used on trails. The basic differences between these designs regard the foundations and the types of materials used to construct the boardwalk's superstructure. The foundations discussed in this handbook are wood and plastic wood mudsills, concrete pier blocks, diamond piers, and helical piers. The superstructure materials discussed are wood, fiberglass, metal, wood composites, and plastic lumber. Each of these alternatives are discussed below.

15.4.2. Materials

Some of the drawbacks to boardwalks are their relatively short life span and high maintenance and replacement costs. One way of mitigating the short life span is to construct them using materials comprised of fiberglass and plastic. As previously discussed, plastic mudsills can be used to provide the foundation. Fiberglass joists can be substituted for wooden joists and structural plastic lumber can be substituted for wooden decking, soil dams, and bull rails.

There are vendors that sell pre-manufactured boardwalks. These boardwalks have fiberglass joists and offer a variety of materials for the decking and bull rails. These boardwalks are usually shipped as a package that can be assembled in the field, but they also can ship a fully assembled structure up to 50 feet in length. Some manufacturers allow fiberglass joists and attachment hardware to be ordered separately. Then the mudsills, decking, soil dams, and bull rails can be purchased independently.

The advantage of pre-manufactured boardwalks is that some of the components are lighter in weight, they are easy to assemble, and they are rot-resistant. If kept out of direct sunlight, they will have significantly longer life spans than wooden structures. The disadvantage of these structures is that they will warp and break down if exposed to direct sunlight. They also are not very aesthetically pleasing and may not be appropriate in some trail systems.

15.5. Boardwalk Foundations

15.5.1. Wooden Mudsills

Wooden mudsills are perhaps the simplest foundation used in constructing boardwalks. The advantage of this foundation is that it is relatively simple to install, can be made of on-site native materials, and can distribute the weight of the boardwalk over a wide area (depending on the surface area of the mudsill). The disadvantage is that it eventually rots and loses structural integrity. Even rot-resistant wood, such as redwood and cedar, will last only 15 to 30 years depending on the site conditions. Pressure treated wood generally will not last as long and as redwood and cedar and has the added problem of leaching wood preserving solvents into the surrounding soil. Even with the limited life span, wooden mudsills are a viable and effective option, especially when using an unskilled labor force or when the mudsills can be generated on-site.

15.5.2. Plastic Lumber Mudsills

Another option for mudsills is to use plastic lumber. Plastic lumber, even structurally reinforced plastic lumber, has less structural strength than traditional wood, metal, or fiberglass. It has limited use as joists, headers, or railings, but can be an effective foundation when fully supported by the ground and the load is bearing straight down on the mudsill. Recycled plastic lumber can be purchased in a variety of dimensions and colors. Installation is identical to the wooden mudsills. Plastic lumber is more brittle than wood but it can be cut or drilled through similarly to wood. However, the hardness, impurities in the plastic, and build-up of plastic residue on cutting edges will dull saw blades, saw chains, and drill bits faster than wood. Traditional woodworking hand tools, such as beveled axes, slicks, drawknives, and wood chisels, are not effective in shaping this material. Power tools, such as chainsaws, gas and electric powered drills, and electric powered circular saws, are the most effective in working with this material.

Plastic wood in large dimensions costs three to four times as much as conventional wooden products. This material is also subject to warping if not stored on a flat surface, fully supported on the bottom, confined or bound with metal bands, and be out of direct sunlight. This material is also heavier than wood, which can be a factor when packing it long distances.

The lifespan of plastic lumber is still somewhat of an unknown given that it has been around for a relatively short period of time. Considering its rot-resistant properties, it should be expected to last many decades. The anticipated lifespan may more than offset the additional cost for this material. If purchased in dark colors such as brown or black it can also be relatively unobtrusive, especially if all or most of the mudsill is hidden under the boardwalk.

The color and texture of plastic wood, the need to use power tools, and its increased weight make the use of plastic mudsills more appropriate on Class I trails. Its increased lifespan, especially when combined with some of the non-native building materials discussed below, makes plastic lumber mudsills a viable option to traditional materials.

15.5.3. Construction

The installation of wooden and plastic mudsills and their associated joists, decking, soil dams, and bull rails was previously discussed under puncheons. These same construction methods apply to boardwalks using mudsill foundations.

15.5.4. Concrete Pier Blocks

15.5.4.1. Applications

Concrete pier blocks have been used for the foundation of boardwalks for many years. They provide a simple yet durable, long-lasting foundation. Concrete pier blocks are most often used with post and pier designs. Unlike the other foundations discussed in this chapter, concrete pier blocks are not meant to be used where the underlying soil is saturated or unconsolidated. They lack the load-bearing surface area to support the boardwalk superstructure in weak soil. However, due to their smaller surface area (approximately 1 square foot), they are very effective as a foundation where the boardwalk is used to span over roots or rock outcrops. If the ground is firm and stable, concrete pier blocks can be placed directly onto the ground once they have been flattened and leveled. They also can be set onto a simple concrete footing where the use of concrete is appropriate. Resting on a concrete pad or footing increases the load capacity of the piers and helps retain their position.

15.5.4.2. Construction

Prior to installing the pier blocks, the boardwalk foundation should be laid out. Layout involves setting up center line stakes, batter boards, and string lines to establish the location of each concrete pier; squaring the locations of the pier blocks to each other; and identifying the finished elevations of the posts to be set on top of the concrete pier blocks.

The first step in laying out concrete pier blocks for a boardwalk structure is to identify the total length, width, and height of the desired structure. The length and height will be determined by site specific needs. The width will be determined by the trail classification and user group standards.

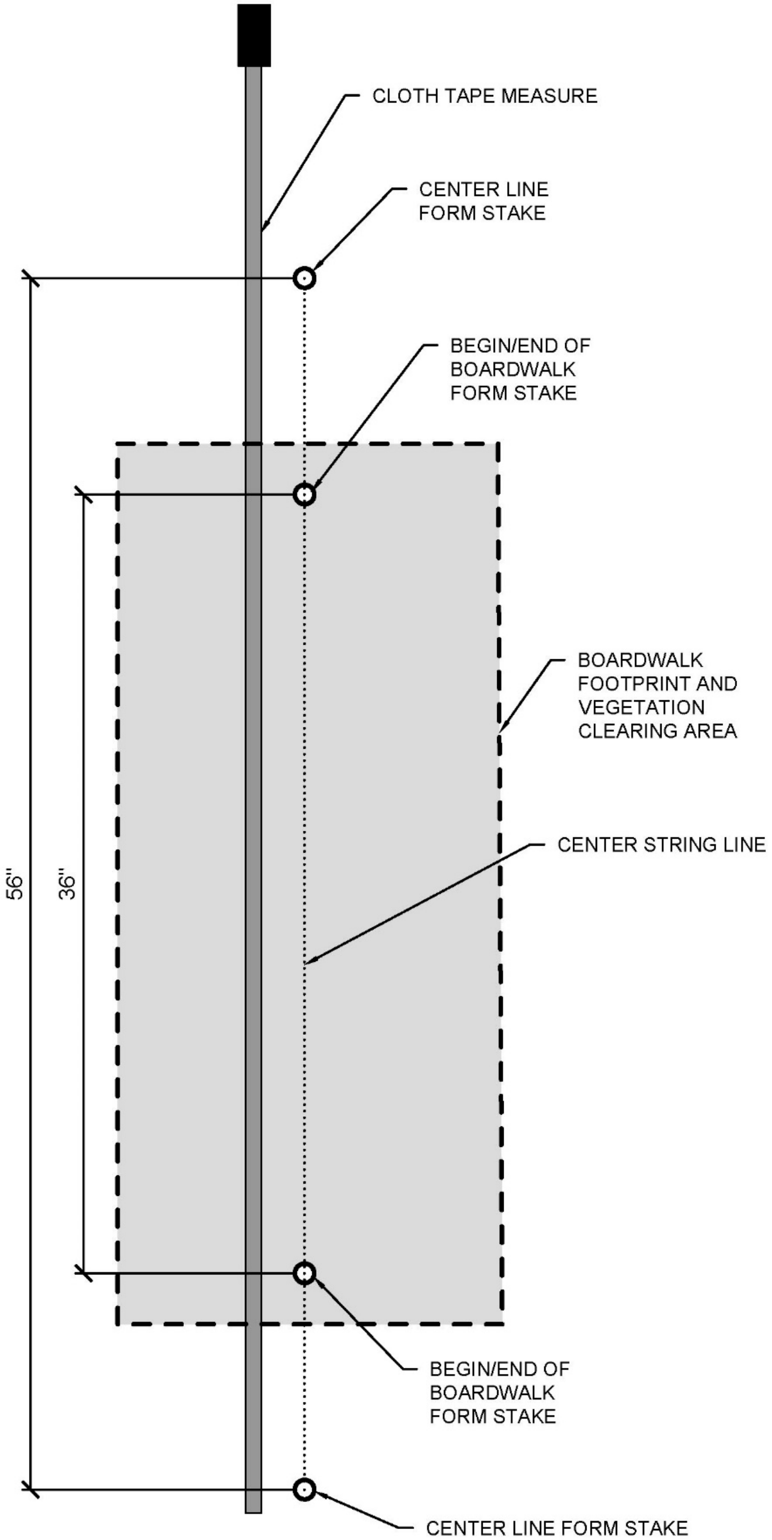
A. Establishing the Boardwalk Center Line and Footprint

Once the size of the structure is determined, use the Trail Log, design specifications, and associated flag line to locate the starting and ending locations of the boardwalk and its general alignment on the ground. Lay a cloth or steel tape measure on the ground along the center line of the intended structure so that it extends a minimum of 10 feet beyond both ends of the boardwalk. The additional 10 feet is required to keep the centerline form stakes out of the boardwalk footprint and construction area. Drive two 5/8-inch x 5-foot metal form stakes into the ground at these two locations. Longer stakes may be required if the ground has substantial elevation differences. Next, tie builder’s string to one of the stakes, stretch it to the other stake, and tie it off so that the string is taut. Note, vegetation that interferes with the string may need to be removed. The metal form stakes have holes running through the center of them. The string line is run through these holes, wrapped around the stake three or four times, and tied off with two half-hitches. A 12-inch pipe wrench can be used to turn the stake if the holes don’t line up with the direction of the boardwalk. The stakes and builder's string should be high enough off of the ground so that the string freely clears the ground along its entire length. (See Figure 15.20.)

Locate the starting point of the boardwalk along this string line and drive a form stake into the ground next to the string line. Then use a cloth or metal tape to measure along the center string line to the end point of the boardwalk. This measurement is the total length of the boardwalk. Drive in another form stake next to the string line at this location. The distance between these two stakes is the total length of the boardwalk. Establish the approximate footprint of the structure by flagging an area 1 foot longer on each end and 1 foot wider on each side of the intended boardwalk. (See Figure 15.20.) Untie the center line string to get it out of the way and remove any vegetation that interferes with the layout and construction of the boardwalk.

Locate the highest elevation within the boardwalk footprint by using a clinometer. Sight on the reference point of the person working with you to see which location within the footprint is the highest. Use an Abney hand level or a clinometer on top of a McCloud handle, and sight on a tape measure held vertically by the other person as previously discussed. (See Figure 15.8.)

Once the highest elevation within the footprint is established, visually locate an area equal to or higher and outside of the footprint where all of the footprint can be seen at the same time. This location is where the auto level is set-up. A thorough explanation of setting-up and using an auto level and stadia rod is described in Appendix J.



1. IDENTIFY THE BOARDWALK LOCATION AND ALIGNMENT. LAY A CLOTH TAPE MEASURE ON THE GROUND TO IDENTIFY THE BOARDWALK ALIGNMENT AND THE STARTING AND ENDING POINTS.

2. MEASURE 10' BEYOND THE STARTING AND ENDING POINTS AND DRIVE 5' LONG FORM STAKES INTO THE GROUND. TIE BUILDERS STRING TO ONE OF THE FORM STAKES, PULL IT TAUT AND TIE IT TO THE OTHER STAKE TO CREATE THE CENTER STRING LINE.

3. LOCATE THE STARTING POINT OF THE BOARDWALK AND DRIVE IN A FORM STAKE NEXT TO THE CENTER STRING LINE. MEASURE THE DESIGNED LENGTH OF THE BOARDWALK DOWN THE CENTER STRING LINE AND DRIVE IN A FORM STAKE AT THAT LOCATION.

4. USING THE DESIGNED WIDTH OF THE BOARDWALK ESTABLISH THE APPROXIMATE FOOTPRINT OF THE STRUCTURE BY FLAGGING AN AREA ONE FOOT LONGER ON EACH END AND ONE FOOT WIDER ON EACH SIDE OF THE INTENDED BOARDWALK STRUCTURE. UNTIE THE CENTERLINE STRING TO GET IT OUT OF THE WAY AND TRIM OR REMOVE ANY VEGETATION THAT WILL INTERFERE WITH THE LAYOUT AND CONSTRUCTION OF THE BOARDWALK WITHIN THIS AREA.

Figure 15.20 - Boardwalk Center Line Layout

BOARDWALK CENTER LINE LAYOUT

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B. Laying Out the Boardwalk Batter Boards

Using the auto level and stadia rod, verify the highest ground within the boardwalk footprint. The auto level will provide accurate horizontal elevation readings, which will be used to establish the finished horizontal elevations of the batter boards. Rather than taking elevation readings following a systematic grid, take elevation readings where the ground is visually higher. The objective is to identify the highest point of ground, not to develop an elevation profile. Remember, the lowest recorded number on the stadia rod represents the highest ground. The purpose of identifying the highest ground is to ensure the batter board elevations are high enough off of the ground to allow for the combined height of the pier block and the post. If this height is not accounted for, the finished batter board height may be only a few inches above the highest elevation within the boardwalk footprint, which could result in having to excavate substantial quantities of earth within the boardwalk footprint to create enough space for the pier block and post. For the sake of this exercise, the highest elevation recorded was 45 inches. Once that elevation is determined, record it for future reference. Note, a stadia rod in feet and inches is preferable to a standard engineering rod, which is in tenths and hundredths of a foot. Since all trail structure drawings and the standard tape measures used in trail construction are in feet and inches using a stadia rod with the same scale is more practical for trail workers. A thorough explanation of how to read a stadia rod is described in Appendix J.

Next, the finished height of the batter board must be determined. Usually this height represents the top of the post that will sit on top of a pier block. This elevation can be determined by first identifying the desired deck height of the boardwalk, and then subtracting the height of the boardwalk members above the post. For example, if the desired boardwalk height is 36 inches above the highest ground of the boardwalk footprint, then the combined height of the decking (1 1/2 inches), joist (7 1/2 inches), and header (7 1/2 inches) should be subtracted from 36 inches (1 1/2 in. + 7 1/2 in. + 7 1/2 in. = 16 1/2 in.). Thus, 19 1/2 inches is available for the post and pier block (36 in. – 16 1/2 in. = 19 1/2 in.). Subtract 19 1/2 inches from the 45 inch stadia rod reading and the horizontal reference elevation for the top of the batter boards will be 25 1/2 inches (45 in. – 19 1/2 in. = 25 1/2 in).

Once the horizontal height of the batter boards has been established, the center string line can be adjusted to that elevation. Hold the stadia rod against one of the center line form stakes and raise or lower the stadia rod until the 2 feet 1 1/2 inch mark on the rod is level with the auto level. Raise the stadia rod 2 inches and tie the builder’s sting through the hole nearest the bottom of the stadia rod. This measure sets the string line elevation about 2 inches high. Then, while holding the stadia rod against the form stake at the elevation of 2 feet 1 1/2 inches, drive the form stake down until the string line is level with the 2 feet 1 1/2 inches mark on the stadia rod. Repeat this process on the other center line form stake, ensuring that the center string line remains taut. (See Figure 15.21.)

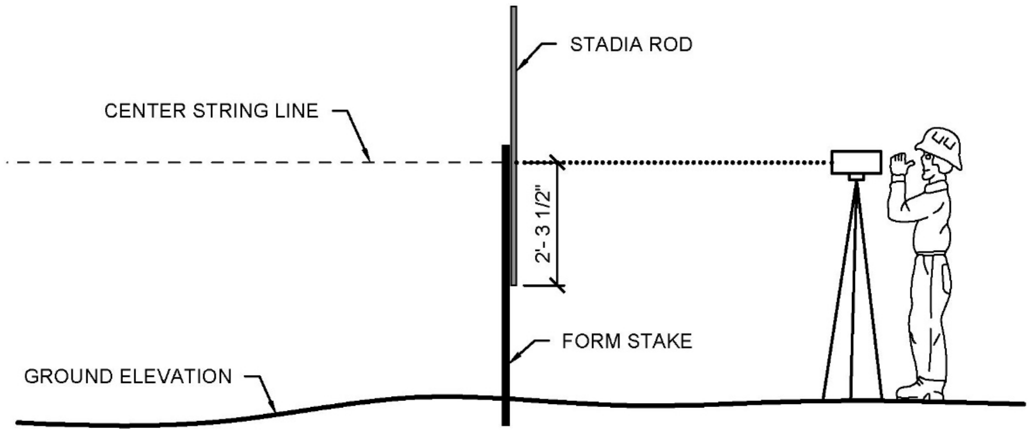
C. Installing the End Batter Boards

To install the end batter boards that extend beyond the footprint of the boardwalk in this example, measure from the center line stake approximately 3 1/2 feet laterally. Using 3 1/2 feet produces a batter board width greater than the footprint, which is necessary to have room for all the string lines on top of the batter board. This measurement should be taken from the inside of the center line form stake at a 90 degree angle to the center line string. Have another person hold a framing square inside the intersection of the tape measure and the center string. The body of the square should be laid so it is parallel to the center string line and just resting against it. Adjust the tape measure until it is parallel to the tongue of the square and just resting against it. At the 3 1/2-foot measurement, drive in a metal form stake. Try to keep the stakes plumb when driving them into the ground. Drive them in until they are firmly anchored into the ground. If necessary, use a 12-inch pipe wrench to turn the form stakes until the holes are parallel to the center string line. (See Figure 15.22.)

Next, install another form stake on the opposite side of the center line following the same process. Once completed, this process should result in the form stakes being approximately 7 feet apart and at a right angle to the center line. Repeat this process at the other end of the center line. Longer form stakes may be required if the ground elevations are substantially different.

For the purposes of this layout exercise, the batter board is an 8 foot section of 1- x 6-inch board. Soft wood, such as pine, redwood, or cedar, is preferred to facilitate driving nails or drilling holes into the board. When installing the batter board, two people are required to hold the board against the two form stakes so that it is level and the top of the board is approximately 1/4-inch above the center string line. The 8-foot long batter board should also extend beyond each form stake by approximately 6 inches. Use a battery powered drill and a 3/16-inch bit to drill a pilot hole through the batter board. Use one of the holes in the form stakes as a guide so that the pilot holes and form stake holes line up. Attach the batter board to the form stake by driving a 16d duplex nail through the batter board and form stake hole. Once driven through, bend the duplex nail over the form stake to secure the batter board.

Attaching the batter board to the form stake can also be accomplished by using a machine screw or bolt with a nut. This method produces less disturbance to the form stake and batter board. Use the auto level and stadia rod to re-check the elevation of the batter board. Then drive the form stakes down evenly until the top of the batter board is at the prescribed 2-foot 1 1/2 inch-horizontal elevation. (See Figure 15.22.) Providing the additional 1/4 inch of height in the first measurement means the final elevation can be adjusted by driving the form stakes down further. Once the batter boards are set at the correct horizontal elevation, place the stadia rod on top of the batter board to verify that both ends are level to each other. Record that elevation on the site plan.



TIE THE CENTER STRING LINE 2" HIGHER ON THE FORM STAKE THAN THE 2'- 1 1/2" HORIZONTAL ELEVATION. HOLDING THE STADIA ROD AGAINST THE FORM STAKE DRIVE THE STAKE DOWN UNTIL THE CENTER STRING LINE ELEVATION IS AT THE 2' - 1 1/2" HORIZONTAL ELEVATION.

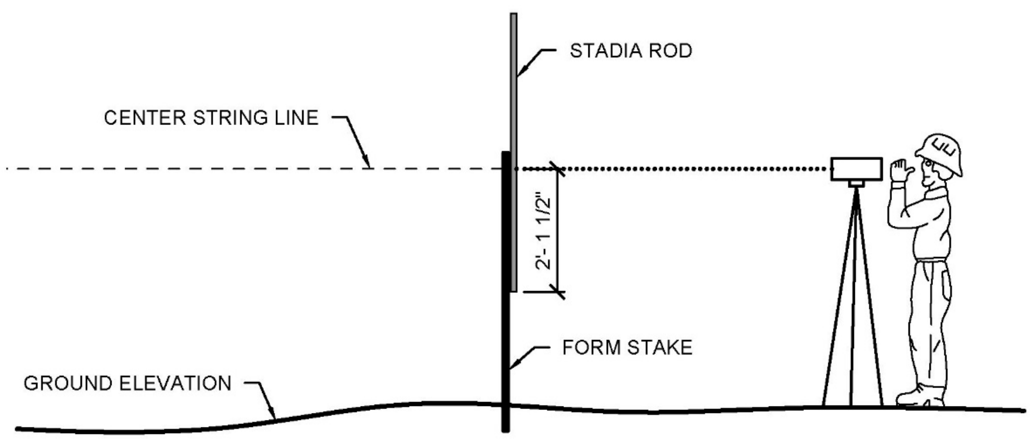


Figure 15.21 - Setting String Line to Batter Board Elevation

SETTING STRING LINE TO BATTER BOARD ELEVATION

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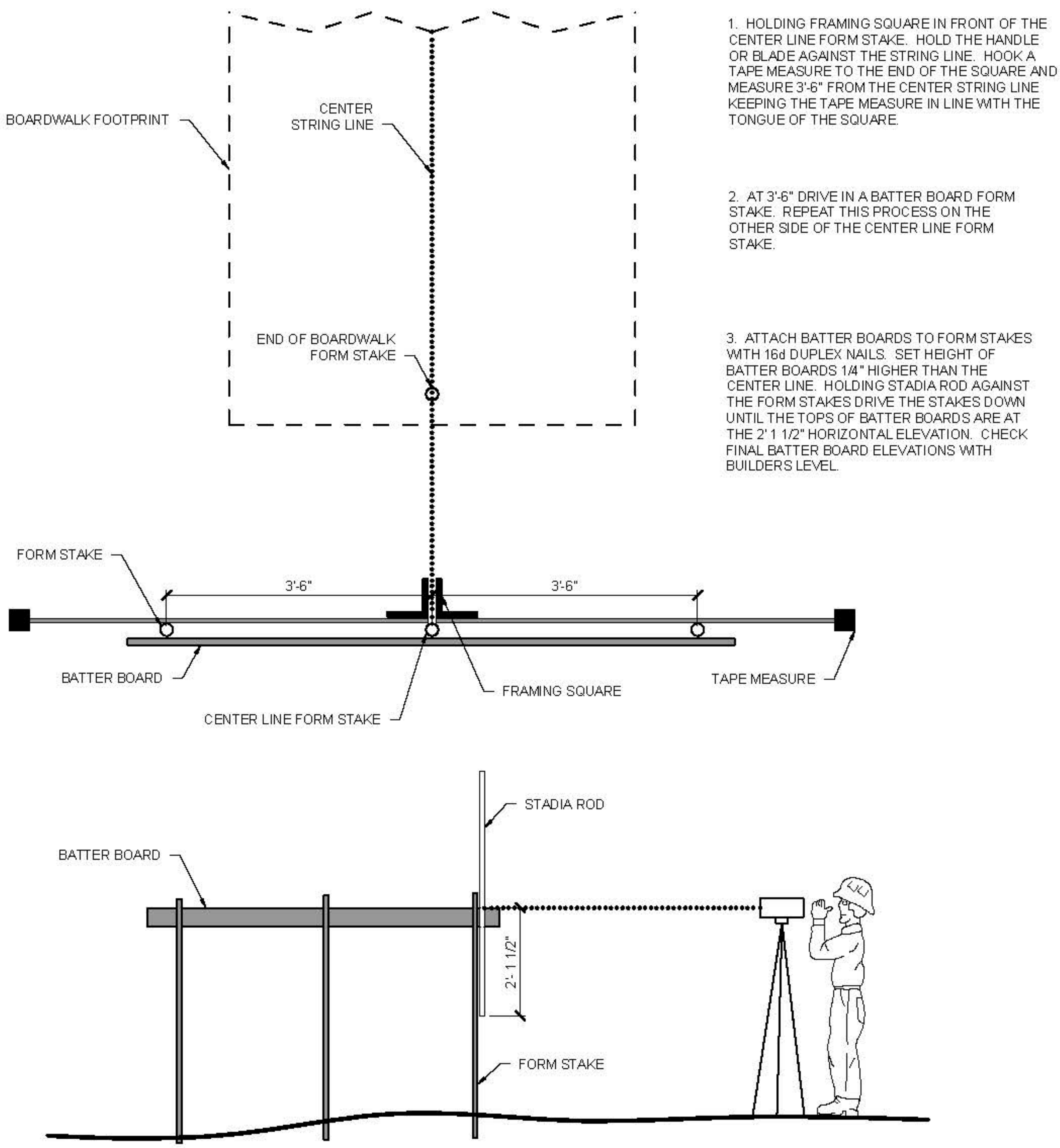

Figure 15.22 - Boardwalk End Batter Board Layout

BOARDWALK END BATTER BOARD LAYOUT

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At the other end of the center string line, install the end batter board following the same process. Once the batter board is installed, set the stadia rod on top of it and sight the horizontal elevation at each end of the batter board. These elevations should be the same as those recorded on the first batter board.

Once the end batter boards are installed, the center of the batter board must be identified by measuring the length of the batter board, dividing it in half, and measuring that distance from one end of the batter board toward the center of the board and scribing a line across the top of the board. This line represents the center of the end batter board. The batter boards on each end of the boardwalk are now centered to the intended alignment of the boardwalk and are approximately square, level, and at the desired finished elevation of the pier post. The center string line can now be removed.

D. Squaring the End Batter Boards

Next, the end batter boards must be squared by measuring out from the center line on the batter board an equal distance in both directions. This distance can be arbitrary, but to be efficient it should be the prescribed distance between the concrete pier blocks. The layout of the pier blocks is determined by the designed width of the boardwalk and the dimensions of the joists. (See Figure 15.23.) Using Figure 15.23 as an example, if the designed width of the boardwalk is 60 inches inside the bull rails, then the overall width of the decking will be 72 inches. To keep the base of the concrete pier blocks from projecting beyond the outside edge of the decking, the centers of the pier blocks must be located within the outside edge of the decking by 8 3/4 inches. This layout will result in spacing (on center) between the pier blocks of 54 1/2 inches. (See Figure 15.23.)

Based on these layout criteria, the initial pier block string lines would be installed so they are 27 1/4 inches (54 1/2 inches ÷ 2 = 27 1/4 inches) on either side of the center of the end batter board. Measure from the batter board center line 27 1/4 inches in both directions and scribe two additional lines. These two lines represent the center of the pier blocks and joists. (See Figure 15.23.) Perform this layout on both batter boards.

Once the pier block center string lines have been scribed on the batter boards they must be squared to each other. First, measure the distance between the two batter boards from the pier block center line scribes. (See Figure 15.24.) These two measurements should be the same distance if the previous batter board layout and installation was performed correctly. If not, then the batter boards will need to be adjusted until they are equal distance apart. Once the batter boards are equal distance apart, measure diagonally from the pier block center line scribe on one batter board to the pier block center line scribe on the other. (See Figure 15.24.) If the two measurements are the same then the batter boards are square to each other. If they are not the same, subtract the short measurement from the long measurement and divide that number in half. To square the batter boards, move both of the pier block center line scribes laterally the distance just calculated. This movement is toward the short measurement side and is performed only on one of the two batter boards. Once completed, re-measure and if the measurements are still not equal repeat the squaring process until they are. (See Figure 15.24.) After the two batter boards are squared, remark the end batter board center line by measuring inward 27 1/4 inches from one of the two center pier block marks and scribing a line across the top of the batter board.

E. Installing the End Batter Board String Lines

The string lines used to layout the concrete pier blocks are installed next. Drive 8d duplex nails into the top of each batter board through the four scribed lines. Next tie string lines to the duplex nails on one batter board and stretch those to the duplex nails on the other batter board. Make sure the lines are taut, then, tie them off. Once completed, there are two batter board string lines installed that represent the center of the pier block rows that run the length of the boardwalk. (See Figure 15.25.)

F. Installing the Side Batter Boards

The next step is to determine the number and layout of pier blocks required. The number of pier blocks is determined by the dimensions of the joists and the total span of the boardwalk. If two 6- x 8-inch joists are used, then the maximum span cannot exceed 12 feet, which is the maximum span for a 6- x 8-inch structural DF joist at 100 pounds per square foot live load. Note, if larger dimensioned joists are used, the span between the pier blocks can be increased. (See milled stringer charts in Chapter 16, *Trail Bridges.*) If the boardwalk structure is designed to be 36 feet long, then there will be three 12 foot segments (36 ft. ÷ 12 ft. = 3). Since each segment will have two joists, there will be two rows of pier blocks with four pier blocks in each row for a total of eight pier blocks. For the outside of the 3 1/2- x 5 1/2-inch post to be flush with the end of the boardwalk, the center of the end pier blocks must be moved inward 1 3/4 inches. (See Figure 15.26.) This measurement is based on the concrete pier block having a 12-inch wide base and an 8-inch wide top. Keep in mind that the dimensions of concrete pier blocks vary, so always measure the pier blocks before determining the layout. Based on this information, the on-center layout for the pier blocks will be 11 feet 10 1/4 inches, 12 feet, and 11 feet 10 1/4 inches. When measured from the end batter board (which is 10 feet from the end of the boardwalk), the measurements will be 10 feet 1 3/4 inches, 22 feet, 34 feet, and 45 feet 10 3/4 inches. (See Figure 15.26.)

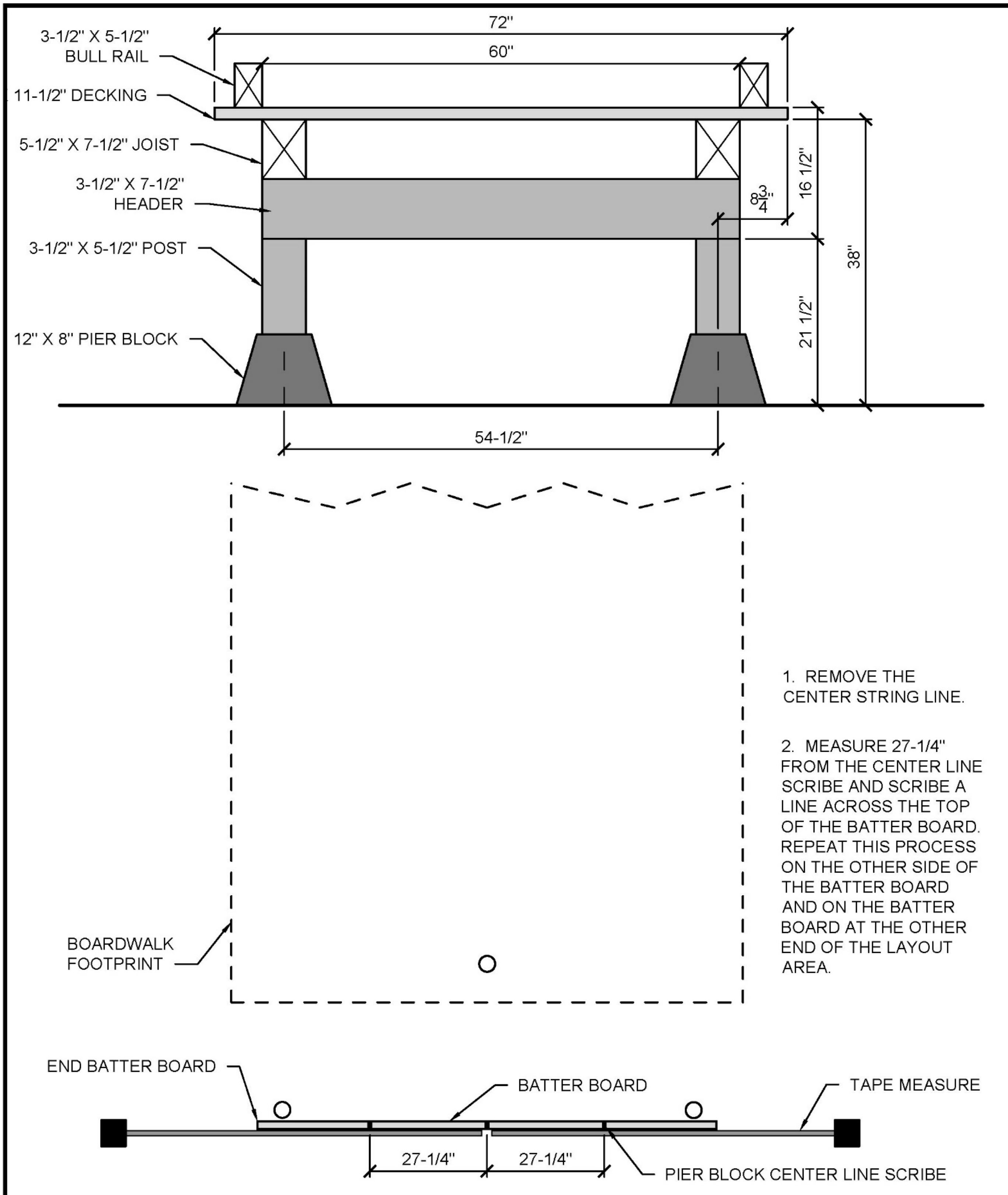

Figure 15.23 - Pier Block String Line Layout

PIER BLOCK STRING LINE LAYOUT

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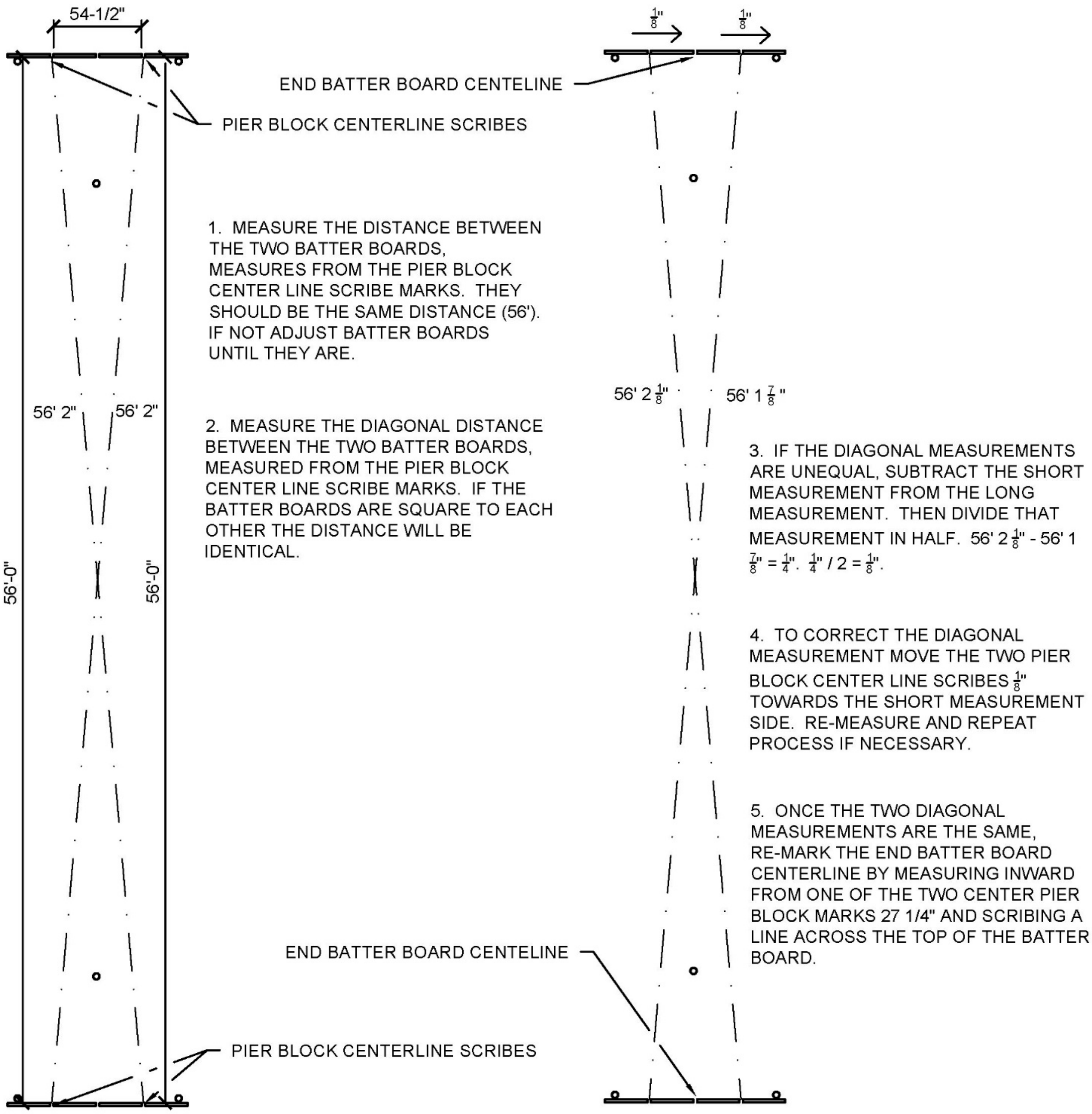

Figure 15.24 - Squaring the End of Batter Boards

SQUARING THE END OF BATTER BOARDS

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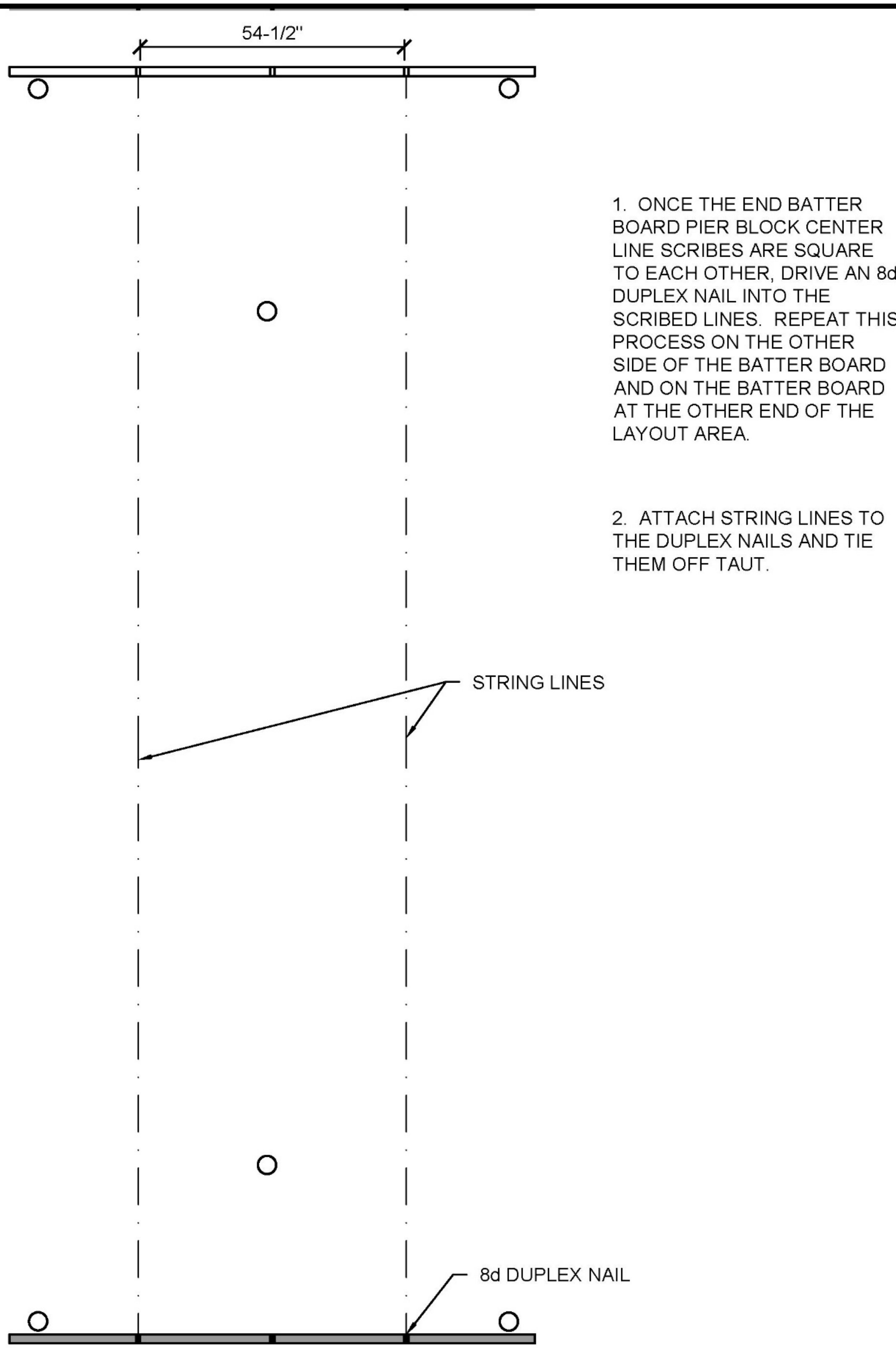

Figure 15.25 - Installing Pier Block Centerlines

INSTALLING PIER BLOCK CENTERLINES

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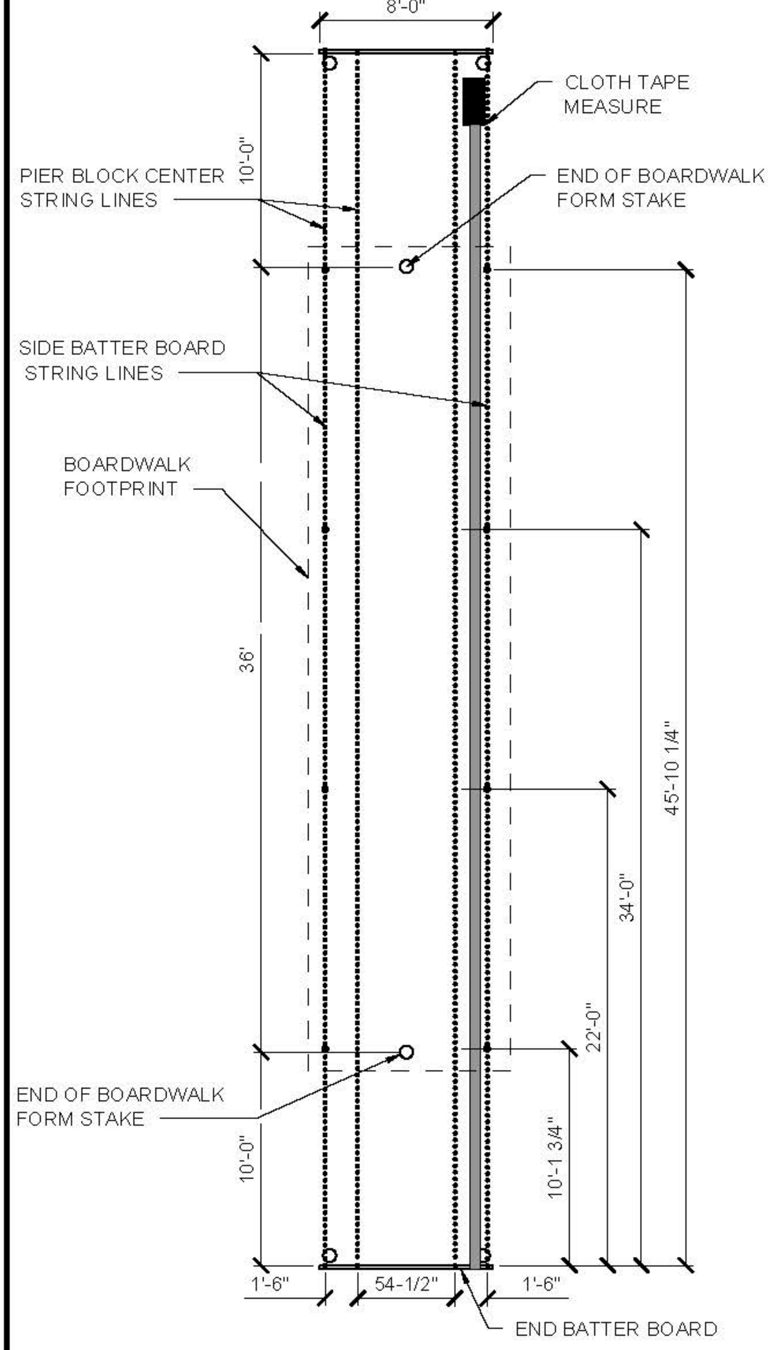

1. MEASURE FROM THE TOP OF THE END BATTER BOARDS 1'-6" INCHES OUTWARD FROM THE DUPLEX NAILS IDENTIFYING THE CENTER OF THE PIER BLOCKS. SCRIBE LINES ACROSS THE BATTER BOARDS AT THESE LOCATIONS. DRIVE 8D DUPLEX NAILS INTO THE TOP OF THE BATTER BOARDS THROUGH THE FOUR SCRIBED LINES. NEXT TIE STRING LINES TO THE DUPLEX NAILS ON ONE OF THE END BATTER BOARDS AND STRETCH THOSE TO THE DUPLEX NAILS ON THE OTHER END OF THE BATTER BOARD. MAKE SURE THE LINES ARE TAUT, AND THEN TIE THEM OFF.

2. TO IDENTIFY THE LOCATION OF THE SIDE BATTER BOARDS FIRST IDENTIFY THE APPROXIMATE CENTERS OF THE PIER BLOCKS. MEASURE FROM THE END BATTER BOARD DOWN THE SIDE BATTER BOARD STRING LINE 10' 1 3/4" AND SCRIBE A LINE ON THE STRING. THE END OF THE BOARDWALK IS AT 10' BUT THE CENTER OF THE PIER BLOCK IS SET IN 1 3/4" SO THE OUTSIDE OF THE POST WILL BE EVEN WITH THE END OF THE BOARDWALK. THEN, MEASURE 22 FEET, 34 FEET, AND 45 FEET 10 1/4 INCHES AND MARK THE STRING LINE AT EACH OF THESE LOCATIONS TO IDENTIFY THE REMAINING PIER BLOCK CENTERS IN THE ROW. THE PIER BLOCKS ON THE OTHER END OF THE BOARDWALK ARE ALSO SET IN 1 3/4".

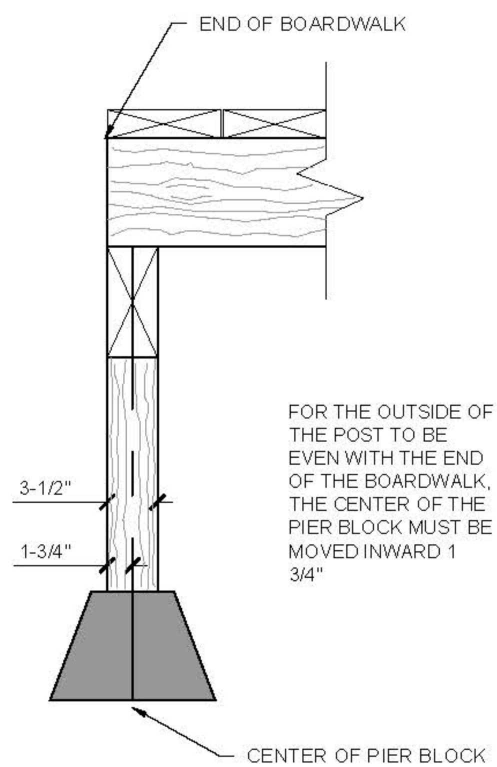

Figure 15.26 - Side Batter Board Layout

SIDE BATTER BOARD LAYOUT

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Once the pier block layout is determined, the side batter boards for the perpendicular string lines are installed. These string lines are used to accurately locate the final placement of the pier blocks. Once installed there will be string lines that represent the center of the pier blocks along the length of the boardwalk and perpendicular string lines that represent the center of the pier blocks at the prescribed distance between the pier blocks. Where these two lines cross over each other is the center of each pier block. To layout the side batter boards, measure from the top of the end batter boards 1 foot 6 inches outward from the duplex nails identifying the center of the pier blocks. Scribe lines across the batter boards at these locations. Drive 8d duplex nails into the tops of the batter boards through the four scribed lines. Next, tie string lines to the duplex nails on one of the end batter boards and stretch those to the duplex nails on the other end batter board. Make sure the lines are taut and then tie them off. To identify the approximate location of the side batter boards, measure from the end batter board 10 feet 1 3/4 inches to locate the center of the first pier block and mark the string line with a felt-tipped marker to designate the location. Then, measure 22 feet, 34 feet, and 45 feet 10 1/4 inches and mark the string line at each of these locations to identify the remaining pier block center lines. Repeat this process on the other side batter board string line.

Once the centers of the pier blocks are marked, install four side batter boards with sufficient length to accommodate the perpendicular center line strings. When installing the form stakes, make sure they are not in line with the locations of the perpendicular string lines. Install the form stakes and batter boards so the tops of the boards are directly in line and centered under the batter board string lines. The batter boards should be slightly higher (1/4 inch) than the string line. Then use the auto level and stadia rod to shoot the elevations of the end batter boards and the side batter boards. Drive the form stakes down until the side batter board elevations match the end batter board elevations. (See Figure 15.27)

In this example, the batter boards need to be approximately 14 feet long. The felt-tipped marks on the side batter board string lines are only used to help locate the placement and length of the side batter boards. They cannot be used as the final reference for the side batter board string lines since these sting lines are subject to stretching. The distance from the end batter boards to the felt-tipped marks will vary depending on the weight of the string line, its tautness, the amount of time the string line has been in place, and the ambient moisture level.

G. Installing the Side Batter Board String Lines

To locate the side batter board perpendicular string lines, measure from the top of the end batter board down the tops of the side batter boards 10 feet 1 3/4 inches to the location of the first pier block center line and scribe a perpendicular line across the top of the side batter board. Repeat this measurement and marking process at 22 feet, 34 feet, and 45 feet 10 1/4 inches to locate the centers of the rest of the pier blocks in this row. Repeat this process across the tops of the side batter boards on the opposite side. At each scribed line on the tops of the side batter boards, drive in 8d duplex nails. Tie string lines to the duplex nails on one side, pull them taut, then tie them off to the duplex nails on the opposite side batter board. Then re-measure the distance of each side batter board string line from the end batter board. This measurement should be made at both ends of the side batter board string line. They should be the correct and identical distance from the end batter board. If they are not equal, adjust the 8d duplex nails on the side batter boards until they are. (See Figures 15.27 and 15.28.)

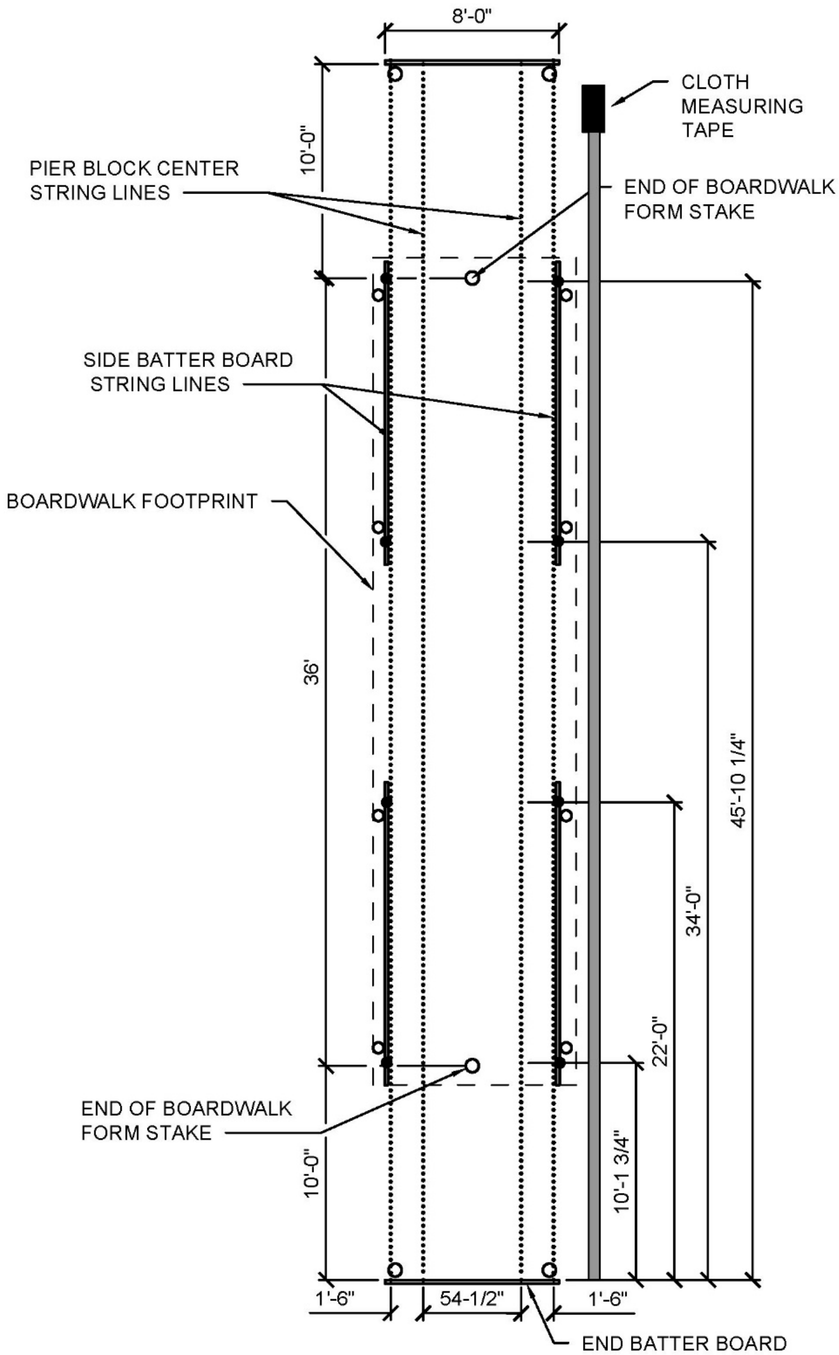
The center of each pier block is where the pier block center string line and side batter board string line intersect. A plumb bob hung from this intersection is used to center the pier block.

H. Laying Out Pier Blocks Without Side Batter Boards

Sometimes ground conditions make it impossible to install side batter boards. In this case a different but less precise method can be employed. Once the end batter boards and pier block center string lines have been installed, measure from one end batter board the prescribed distance along the center string line to the center of the first set of pier blocks and hang a plumb bob next to the center line. Hold the plumb bob so that it just touches the ground. At the tip of the plumb bob, drive in a 40d nail with a piece of flagging attached to it to represent the center of the pier block. Repeat this process on the other pier block center line. Once complete, measure the prescribed distance to the location of the next set of pier blocks and repeat the process. Continue until all the pier block locations have been identified. (See Figure 15.29.)

I. Evaluating Pier Block Elevations and Excavations

The next step in constructing the boardwalk is to measure the height from each string line intersection to the ground. This height is the distance from the base of the pier block to the top of the post. (See Figure 15.30.) The post will be the structural member that goes between the pier block and the header (cross member that supports the joist). This measurement is necessary to ensure that there is adequate space between the ground and the string line to install a standard 8-inch high concrete pier block and post. The length of the post should be a minimum of 6 inches so that it has adequate structural strength and will not split when fastened to the pier block and header. If less than 6 inches of post is available, the height can be adjusted by digging deeper into the footing for the pier block. Another option is to not use a post and set the header directly on top of the pier block, if there is an adequate air gap between the header and the surrounding soil and vegetation. On a site drawing, record the pier locations, the distance from the string line to the ground, and the locations of additional excavations.



1. ONCE THE LOCATIONS OF PIER BLOCK CENTERS ARE MARKED, INSTALL FOUR SIDE BATTER BOARDS WITH SUFFICIENT LENGTH TO ACCOMMODATE THE PERPENDICULAR CENTER LINE STRINGS. INSTALL THE FORM STAKES AND BATTER BOARDS SO THE TOPS OF THE BOARDS ARE DIRECTLY IN LINE AND UNDER THE SIDE BATTER BOARD STRING LINES. THE BATTER BOARDS SHOULD BE SLIGHTLY HIGHER (1/4") THAN THE STRING LINES.

2. DRIVE THE FORM STAKES DOWN WHILE USING THE AUTO LEVEL AND STADIA ROD TO SHOOT THE ELEVATIONS OF THE END BATTER BOARDS AND THE SIDE BATTER BOARDS. ADJUST THE SIDE BATTER BOARD ELEVATIONS TO MATCH THE END BATTER BOARD ELEVATIONS IF NECESSARY.

3. MEASURE FROM THE TOP OF THE END BATTER BOARD DOWN THE TOP OF THE SIDE BATTER BOARD 10' 1 3/4" TO THE LOCATION OF THE FIRST PIER BLOCK CENTER LINE AND SCRIBE A PERPENDICULAR LINE ACROSS THE TOP OF THE SIDE BATTER BOARD. REPEAT THIS MEASUREMENT AND MARKING PROCESS AT 22', 34', AND 45' 10 1/4" TO LOCATE THE CENTERS OF THE REST OF THE PIER BLOCKS IN THIS ROW. REPEAT THIS PROCESS ACROSS THE TOP OF THE SIDE BATTER BOARDS ON THE OPPOSITE SIDE.

Figure 15.27 - Side Batter Board Installation

SIDE BATTER BOARD INSTALLATION

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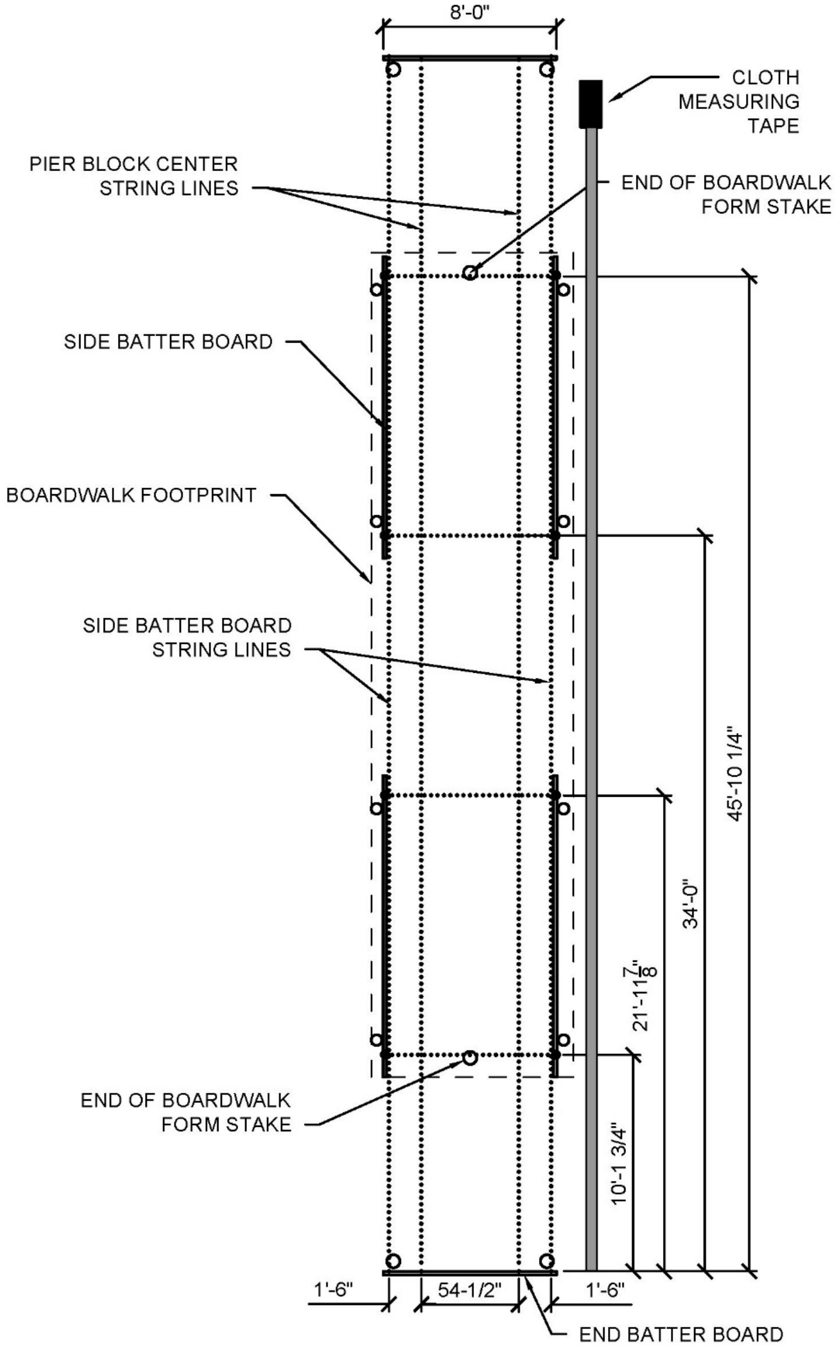
NOT TO SCALE



1. AT EACH SCRIBED LINE ON THE TOPS OF THE SIDE BATTER BOARDS, DRIVE IN 8D DUPLEX NAILS. TIE STRING LINES TO THE DUPLEX NAILS ON ONE SIDE, PULL THEM TAUT THEN TIE THEM OFF TO THE DUPLEX NAILS ON THE OPPOSITE SIDE BATTER BOARD. RE- MEASURE THE DISTANCE OF THE SIDE BATTER BOARD STRING LINES FROM THE END BATTER BOARDS. THEY SHOULD BE THE CORRECT AND IDENTICAL DISTANCE. IF NOT, ADJUST THE 8D DUPLEX NAILS ON THE SIDE BATTER BOARDS UNTIL THEY ARE.

2. THE CENTER OF EACH PIER BLOCK IS WHERE THE PIER BLOCK CENTER STRING LINE AND SIDE BATTER BOARD STRING LINE INTERSECT. A PLUMB BOB HUNG FROM THIS INTERSECTION IS USED TO CENTER THE PIER BLOCK.

Figure 15.28 - Side Batter Board String Line Installation

SIDE BATTER BOARD STRING LINE INSTALLATION

CALIFORNIA STATE PARKS

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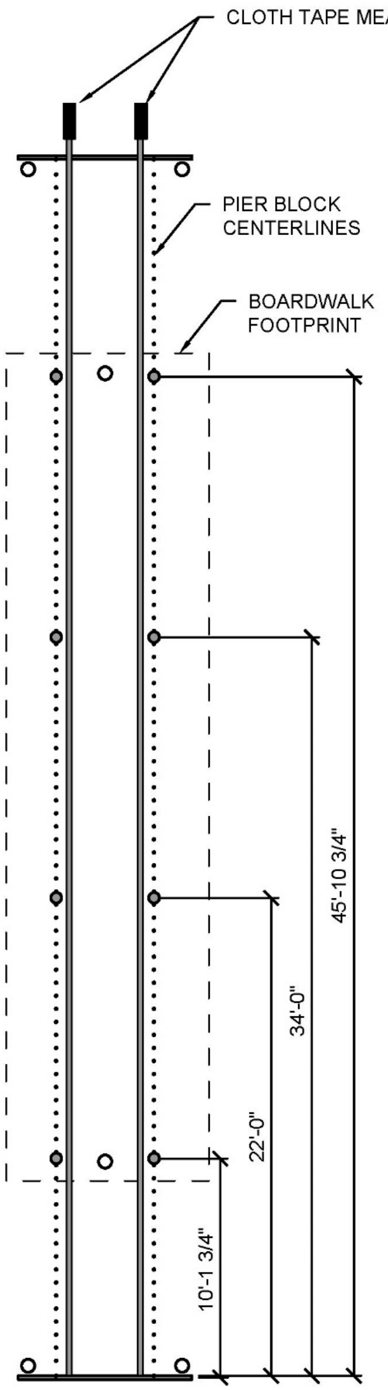

1. MEASURE FROM THE END BATTER BOARD DOWN THE TWO PIER BLOCK CENTER LINE STRINGS. MEASURE THE PRESCRIBED DISTANCE FOR THE CENTERS OF THE FIRST SET OF PIER BLOCKS (10' 1 $\frac{3}{4}$"). AT THAT LOCATION, HANG A PLUMB BOB NEXT TO THE CENTER LINE. HOLD THE PLUMB BOB SO THAT IT JUST TOUCHES THE GROUND.

2. AT THE TIP OF THE PLUMB BOB, DRIVE IN THE 40d NAIL WITH A PIECE OF FLAGGING ATTACHED TO IT. THIS NAIL REPRESENTS THE CENTER OF THE PIER BLOCK. REPEAT THIS PROCESS ON THE OTHER PIER BLOCK CENTER LINE. ONCE COMPLETE, MEASURE THE PRESCRIBED DISTANCE TO THE LOCATION OF THE NEXT SET OF PIERS AND REPEAT THE PROCESS. CONTINUE UNTIL ALL THE PIER BLOCK LOCATIONS HAVE BEEN IDENTIFIED.

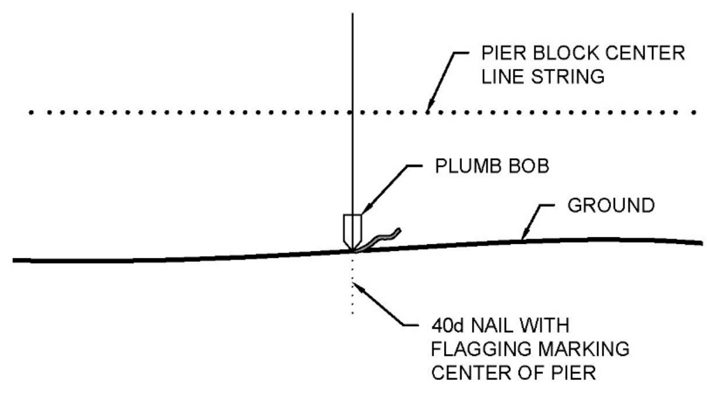

Figure 15.29 - Laying Out Piers without Side Batter Boards

LAYING OUT PIERS WITHOUT SIDE BATTER BOARDS

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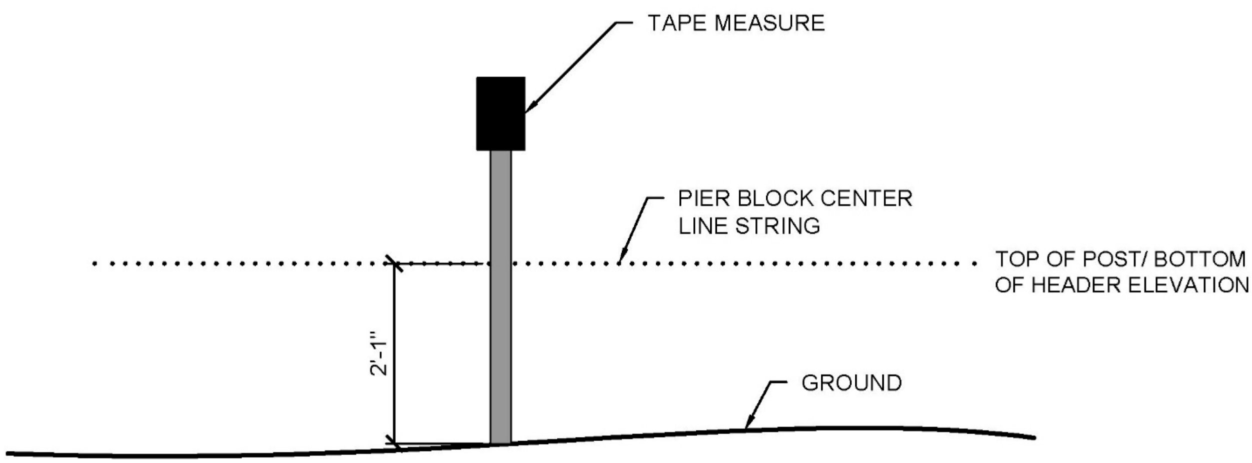

Figure 15.30 - Determining the Combined Height of the Pier Block and Post

DETERMINING THE COMBINED HEIGHT OF THE PIER BLOCK & POST

CALIFORNIA STATE PARKS

NOT TO SCALE

Then, at each of these measurement locations, use a plumb bob to locate where the center of the pier block is located on the ground. Drive a 40d nail into the ground at that location to represent the center of the pier block excavation. (See Figure 15.30.) Once the locations of the pier blocks have been marked, small footings for the pier blocks can be excavated. Because the string lines are attached to duplex nails on the batter boards, they can be quickly untied and set aside while work is occurring on the boardwalk structure. With the string lines out of the way, the crew can work unencumbered on the structure yet they can quickly reestablish the string lines for layout reference when needed. Remove the nails marking the location of the piers once the excavation of each pier begins. Replace the string lines and re-check the pier's position with a plumb bob as necessary.

During excavation of the footings, it is important to achieve four things: (1) the footing for the pier blocks must be excavated into mineral soil and that soil must be firm and stable; (2) the footing must be centered as per the string layout; (3) the footing must be level; (4) the footing must be dug to a depth where the minimum length of the post between the pier block and the header will be 6 inches or where the header will rest on the pier block.

If site conditions allow once the footing is excavated, concrete can be poured into the footing. The pier block is set on top of the concrete before it sets up. Concrete can provide a firm, stable, and level surface to stabilize the pier block. If concrete is used, the thickness of the concrete must also be factored into the layout calculations. In some cases, concrete footings are not necessary or may be prohibited due to environmental conditions.

15.5.5. Diamond Piers

15.5.5.1. Applications

Diamond piers are similar to pier blocks except the pre-cast concrete pier is anchored into the soil by four steel pins. Diamond piers are constructed of pre-cast, air-entrained concrete and come in two sizes: DP50 and DP75. The DP50 model will suffice for most trail construction applications. The DP75 model is used when the parent soil is weak or when the trail structure must support greater than normal weight. The pins are schedule 40 steel pipe, which should be either galvanized steel or stainless steel to resist oxidation and corrosion. The DP50 diamond piers use 1-inch diameter pipe and the DP75 diamond piers use 1 1/4-inch diamenter pipe.

The advantage of diamond piers is that they can be applied in soil that would be too weak to support standard concrete pier block construction methods. (See Photo 15.4.) Soil that is sandy or has a high amount of clay, silt, or water is often encountered in trail construction. The key to the diamond pier's performance in these soil conditions is the four pins that are driven through the pier and into the ground. These pins provide a larger support base for the pier so that the weight of the boardwalk is supported by a much larger area than just the footprint of the pier. (See Figure 15.31.)

Photo 15.4 - Diamond Pier Boardwalk

The length of the pins and the size of the diamond piers are determined by the relative strength of the soil. Weak soil may require long pieces of pipe or the DP75 pier to increase the bearing capacity of the pier system. Therefore, it is important to provide the diamond pier manufacturer with some basic information on the soil type the boardwalk will be constructed upon. It's important to identify the soil type within the typical pin depth, which ranges from 2 to 5 feet below ground. Soil samples should be taken at every location where there are indications of a change in soil type within the footprint of the boardwalk. The soil sample needs to be evaluated by a qualified person, such as soil scientist or a geotechnical engineer. The evaluation does not require laboratory testing or expensive coring equipment. Most local geotechnical engineers can make the evaluation with a single field visit or from regional soil surveys or previous soil studies. For the manufacturer to determine load capacity, an engineer must provide them with a general description of the soil, along with its angle of internal friction ("phi angle"), cohesive strength (if applicable), unit weight (i.e., weight of the soil), and issues regarding the local water table or water flowing near the piers. It is also helpful to know the local frost depth, because some jurisdictions require that the pins extend below the frost line.

Diamond piers cannot be used in rocky ground or ground with large, closely knit roots. These sub-surface features will prevent the pins from being driven into the ground. Diamond piers are also not meant to be used in loose, unconsolidated or wet, saturated soil where the pins will not be able to obtain a solid anchor. They are also not intended to be used in regions where extensive frost heave occurs.

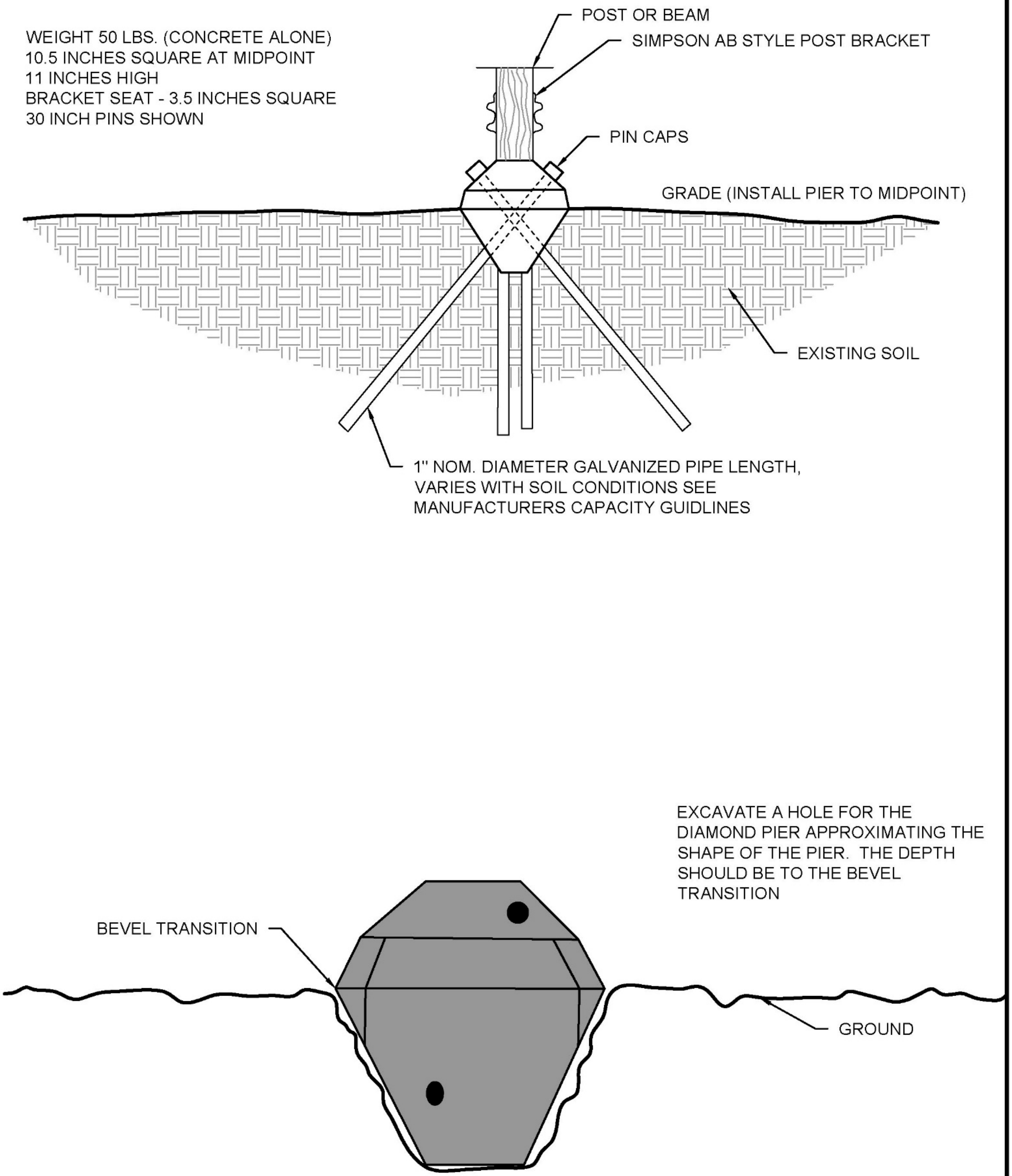

Figure 15.31 - Diamond Pier DP-50 Model

DIAMOND PIER DP-50 MODEL

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NOT TO SCALE

15.5.5.2. Construction

The layout method for diamond piers is the same as that previously discussed for pier blocks. To install diamond piers, the required number of pre-cast concrete diamond piers and the corresponding number of pins and pin caps are needed. The necessary hand tools and equipment include a shovel, a hydraulic-, phuenamatic-, or gas-powered driving hammer with driving head, a sledge hammer, a post driver, a torpedo level, and a reciprocating or cut off saw with a steel cutting blade or a pipe cutter.

Using a plumb bob and the string lines, locate the center of where each diamond pier will be installed. Mark that location with a 40d nail and a piece of colored flagging. Remove the string lines and use a shovel to dig a hole slightly larger than the conical base of the pier to allow for adjustment. (See Figure 15.31.) On sloping terrain, dig the hole deeper on the uphill side so that the pier sits level. Repeat this process for all the piers.

Reset the string lines and use the plumb bob to center the piers. Use excess soil to fill in any voids around the piers and compact the soil to secure the piers. Depending on the composition of the native soil, imported aggregate may be required to firmly hold the piers in position. Remove the string lines and slide opposing pins through the driving cavities in the pier. Be sure to support the opposing pins in the center of the cavity and set them a foot or two into the soil with a sledge hammer or sliding post driver. (See Photo 15.5.) Then, drive each pin alternately several inches at a time with a roto hammer or sledge hammer, periodically checking for plumb and centering. Do not drive a pin all the way down at once because it can cause the pier to be pulled to one side. Continue to rotate around the pier, driving the pins in increments, until the pier is firmly secure in its intended position, level and ready for final driving. Avoid hitting the pier with the automatic hammer as it may fracture.

Photo 15.5 - Driving in a Diamond Pier Pin

If a pin meets substantial resistance in the soil before it has been driven its full length, it may be left in this partially driven position and cut off with a reciprocating saw (i.e., saws-all) or pipe cutter. However, only after the pin will not drive more than an inch during a full 60 seconds of uninterrupted automatic hammering and attempts to drive the pin with single sudden 10-pound sledge hammer blows have been made. If, after a reasonable period, attempts to re-drive the pin using both methods above have been made, the protruding portion of the pin may be cut off. If necessary, the ends of the pins may be sharpened to improve driving in difficult material. Sharpen by performing a double miter cut to create a symetrical point. An assymetrical point will cause the pin to pull off line.

If an obstruction is close enough to the surface or within the soil frost zone, it may be dug up and removed. Once removed, re-compact the soil, re-set the pier, and re-drive the pin. The pier may also be turned or relocated, within the footprint of the design to avoid underground obstacles. A pin may be removed by turning it with a pipe wrench and corkscrewing it upward.

Do not attempt to drive a pin all the way down with just the roto hammer. Also, drive the pins inline with the pier holes and do not allow the weight of the roto hammer to force the pin against the side of the hole and the base of the pier. The piers are concrete and may crack if subjected to continuous blows with the pin in this orientation. Cracked piers must be replaced.

Finish driving the pins with the sledge hammer, leaving 3/4 inch protruding from the top of the cavity and being careful not to damage the pier or upper ends of the pins. Inspect the pins to ensure that they are not bent, broken, or too short by looking down through the core of the pins once dead loads have been applied. Once the pins are in place and the pier is level and plumb, cover the exposed ends of the pins with caps and seal them against the concrete with a 50-year, siliconized adhesive caulk or equivalent. Ensure that the surface of the concrete is dry before applying the caulk. Repeat this procedure for all piers.

Next, the posts are fastened to the piers. This process is discussed below under pier and post installation.

15.5.6. Helical Piers

15.5.6.1. Applications

A pier system that can be used in weak or saturated soil is a helical pier. This pier system is comprised of a screw anchor lead section, screw anchor extension (pier), and beam seat bracket. It may also include a helical pier cross brace, which is attached to the ledger, if required. (See Figure 15.32.) The size, length, and spacing of the piers are dependent on the relative strength of the soil, the weight of the structure, and the loading requirement of the structure. Generally, weak soil will require a large diameter helical plate (“helix”) or more helices. Using a larger diameter helix or additional helices provides more surface area and spreads the weight of the structure over a larger area. Long screw anchor extensions may be necessary to reach firm soil. Large diameter screw anchor extensions may also be required to withstand the torque necessary to screw in the large diameter helices or provide the support and loading requirement of a large structure. It is important that all of the steel in this system be hot-dipped galvanized steel to reduce oxidation and corrosion.

Helical piers are perhaps the best foundation for boardwalks on chronically saturated soil. When installed properly, they minimize disturbance to natural resources and provide a solid structural foundation where most foundation systems cannot. Using this pier system requires extensive soil testing, which is usually performed by a geotechnical firm that takes core samples for laboratory analysis. Some manufacturers of these systems will not sell helical piers without a proper soil analysis.

In addition, some manufacturers will not sell their product to an unlicensed installer or may require that the trail crew completes an installation course. If the organization has the engineering support and requisite skills, helical piers may be purchased and installed by staff.

Given these restraints, some trail organizations may be reluctant to use this structure unless they have a real need for it. Although it may be more expensive, putting out a design-build contract for a helical pier system might be the most practical solution.

This pier system cannot be used in soil that is rocky or that has bed rock or large root intrusions. These subsurface conditions can either bind up or break the torque shear pins prematurely. If torque shear pins are not used, the extension shaft may shear off. This system is intended for loose, unconsolidated soil or soil comprised of silt, sand, or loam. The soil profile needs to be deep enough for the helical pier to be securely anchored.

15.5.6.2. Construction

The layout method for helical piers is the same as those previously discussed for pier blocks. However, extra care may need to be taken if the layout is performed in a marshy environment. Water depth, vegetation, and soft soil will require longer batter board stakes and a method for the trail crew to traverse the marsh without sinking into the boggy soil or harming sensitive plants and animals. It is ideal if the batter boards for the string lines can be set-up outside of the marshy area.

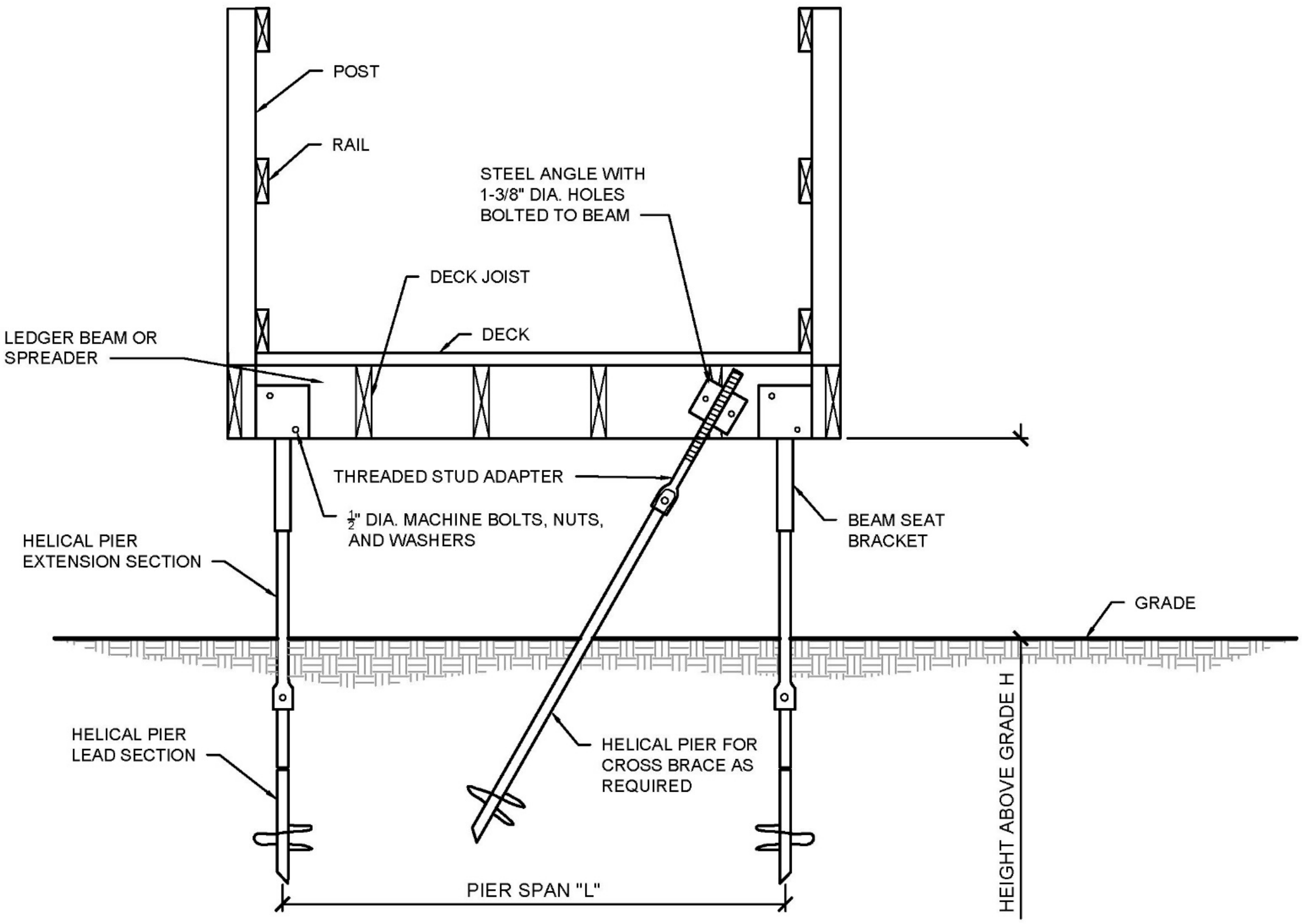

Figure 15.32 - Helical Pier

HELICAL PIER

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NOT TO SCALE

Most of the helical piers used in trail applications can be screwed into the ground with a two person, gas-powered hole auger. If site conditions permit, a hole auger can be attached to light equipment such as a mini-excavator or skid steer. The key to installing this type of pier is to get it started at the correct location per the layout, keep it plumb as it is screwed in, and finish the installation at the correct torque setting.

Torque resistance is measured by the shearing of a pre-determined number of shear pins or by reading the torque being applied using a mechanical torque indicator. An extension shaft is added to the screw anchor lead section until the proper torque is achieved. Coupling the extension shafts is usually facilitated by bolting them together. Once the proper torque setting and finished elevation have been achieved, the adjacent pier is installed. When complete, beam seat brackets are bolted to the extension shafts. (See Figure 15.32.)

If a cross brace helical pier is used to provide additional support, it is screwed into the ground between the two previous piers. This helical pier should be slightly forward of the two previous piers and screwed in at an angle of approximately 35%. (See Figure 15.32.) Once this pier is installed, a threaded stud adapter is bolted to the extension shaft.

Once all the helical piers and beam seat brackets have been installed, the headers are installed. The installation of these structural members is discussed below. However, if a cross brace helical anchor is used, it must be attached to the header, which can be facilitated by attaching a steel angle bracket to the threaded end of the cross brace anchor and fastening that bracket to the header with carriage bolts. (See Figure 15.32.)

15.6. Boardwalk Construction

15.6.1. <u>Post Installation</u>

Posts are installed identically in concrete pier block and diamond pier systems. Installation on concrete pier blocks will be addressed in this section to avoid redundancy. After the concrete pier blocks are installed and the string lines are re-set, another measurement is taken from the string line intersection to the top of the pier block. These measurements determine the height of the posts. (See Figure 15.33.) Cut posts of 4- x 6-inch redwood, cedar, or pressure treated Douglas fir lumber to this length. If permitted, the ends of the posts and the wooden blocks on top of the piers should be painted with a wood preservative to reduce rot. The posts are then secured to the concrete pier blocks by either toe nailing the posts to the wooden blocks seated on top of the pier blocks with 16d galvanized nails or to pier blocks with a manufactured galvanized bracket, such as a Simpson Post Base, embedded into them. The posts should be fastened onto the concrete pier blocks so that they are parallel to the headers that will be placed on top of them. (See Figure 15.34.)

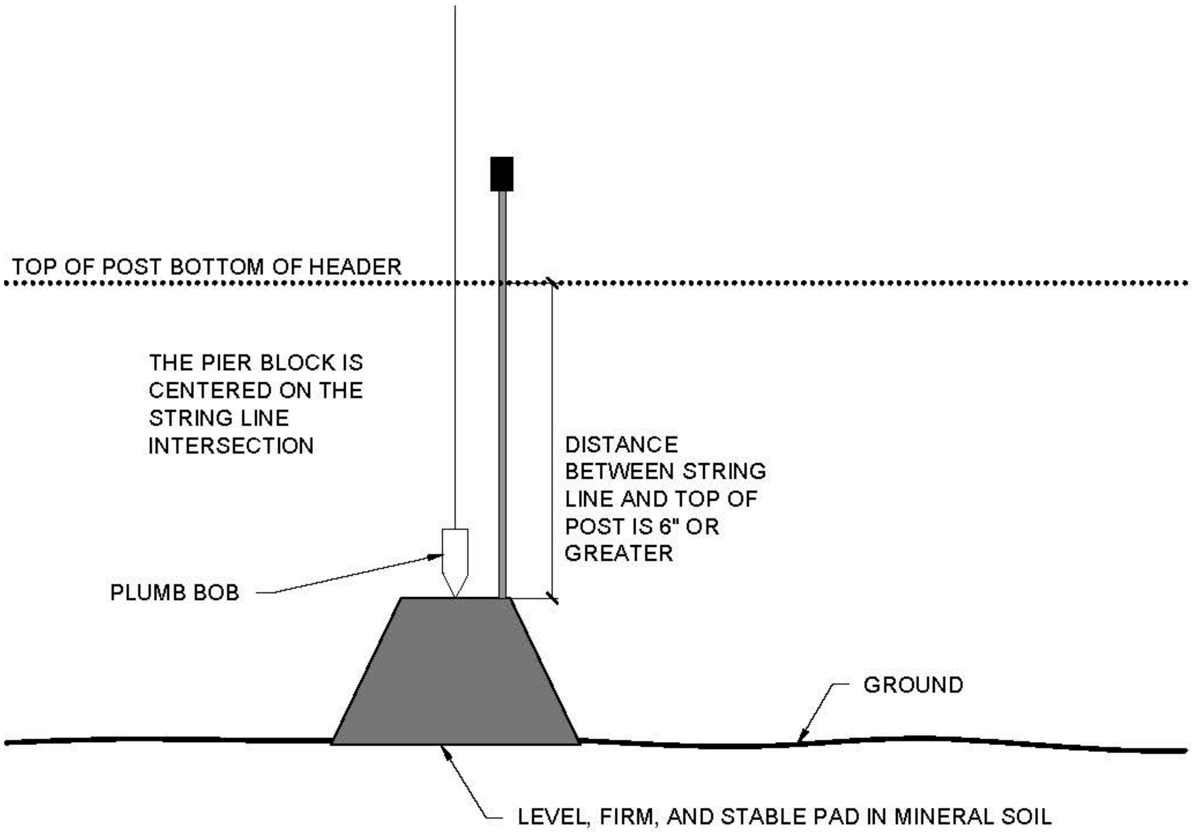

Figure 15.33 - Measuring the Height of the Post or Pier

MEASURING THE HEIGHT OF THE POST OR PIER

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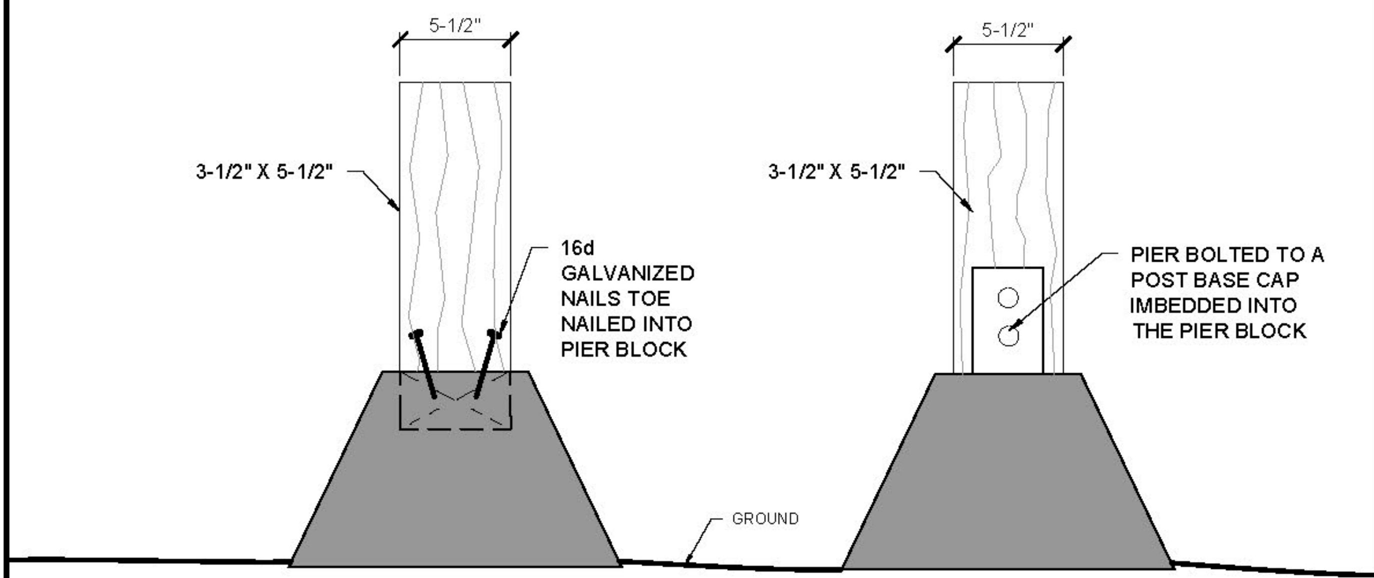
NOT TO SCALE



PIERS CAN BE ATTACHED TO THE PIER BLOCK BY TOE NAILING WITH 16d GALVANIZED NAILS. THEY ALSO CAN BE ATTACHED BY THROUGH BOLTING THEM TO A BASE CAP BRACKET IMBEDDED INTO THE PIER BLOCK.

Figure 15.34 - Pier Installation

PIER INSTALLATION

CALIFORNIA STATE PARKS

NOT TO SCALE

15.6.1. Header Installation

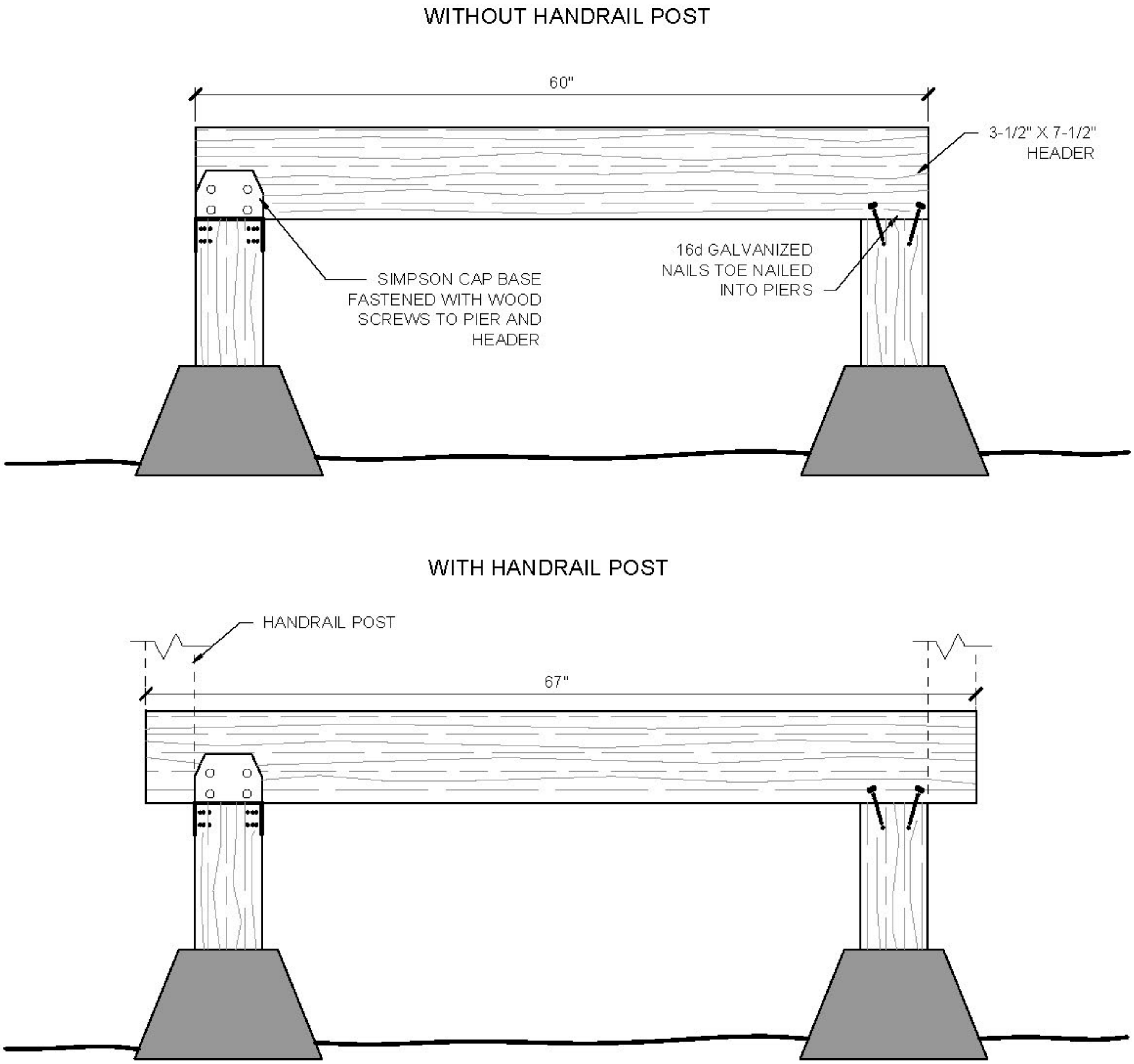
At this point, the tops of all the posts are level to each other. Next, the headers are installed to support the joists. These structural members span across the posts and are perpendicular to the path of travel. The headers should be a minimum of 4- x 8-inch redwood, cedar, or pressure treated Douglas fir. The length of the headers depends on the desired width of the boardwalk. The joists are usually set inside the decking by a minimum of 6 inches to hide the boardwalk substructure and provide a more aesthetically pleasing structure. If the designed tread width is 60 inches (inside the bull rails), the header length is also 60 inches. In this case, the overall width of the boardwalk would be 72 inches, including the 60-inch tread and the 6-inch overhang on each side of the decking. However, if the structure requires railings, the headers should span the entire width of the boardwalk because they will be used to secure the posts needed for the handrails. If permitted, the cut ends of the pressure treated headers should be painted with a wood preservative to reduce rot. The headers are fastened to the posts by either toe nailing with 16d galvanized nails or using a manufactured galvanized bracket such as a Simpson Cap/Base. (See Figure 15.35.)

15.6.2. Joist Installation

Once the headers are fastened, the joists are installed. Pedestrian boardwalks require a minimum of two 6- x 8-inch joists of pressure treated structural grade Douglas fir. If composite lumber or non-structural plastic wood is used for decking, the number of joists should be sufficient so that the space between the joists does not exceed the manufacture’s recommendation. The maximum free span for all these joists should be 12 feet unless appropriately sized joists are used. Refer to the milled stringer table in Chapter 16, *Trail Bridges*.

If two joists are installed on a boardwalk without railings, they are placed so that the outsides of the joists are flush with the ends of the headers. If the boardwalk requires railings, then the joists are installed 3 1/2 inches inside the ends of the headers to allow room for installing the railing posts to the headers. (See Figure 15.36.)

If three joists are installed, the additional joist is placed in the center of the headers by measuring each header to find its center and scribing a pencil line at that location. Next, measure the width of the joist, which will vary depending on whether the board is full dimension or surfaced. Divide the width in half and measure that distance outward from the previously scribed line in the center of each header. Mark those points and scribe lines across the headers. Repeat this process on the other side of the center line. The center joist is then placed inside these two lines. (See Figure 15.37.) The joist should span halfway across the headers, leaving the other half of the headers for the adjoining joist. If permitted, the cut ends of the joist should be painted with a wood preservative to reduce rot.



HEADERS CAN BE ATTACHED TO THE POST BY THE TOE NAILING WITH 16d GALVANIZED NAILS. THEY CAN ALSO BE ATTACHED USING A SIMPSON CAP BASE FASTENED WITH 8d GALVANIZED NAILS .

Figure 15.35 - Header Installation

HEADER INSTALLATION

CALIFORNIA STATE PARKS

NOT TO SCALE

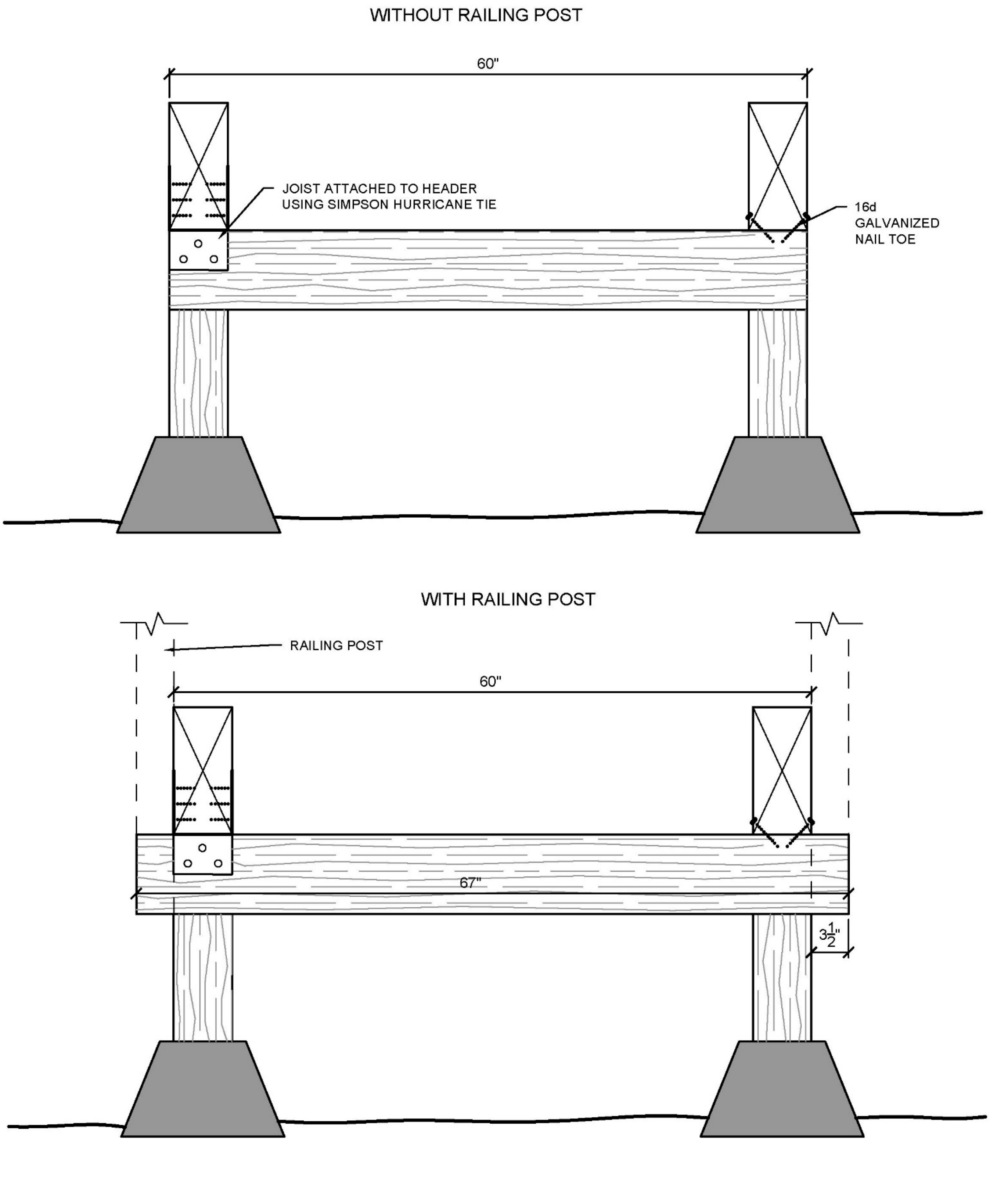


Figure 15.36 - Joist Installation

JOIST INSTALLATION

CALIFORNIA STATE PARKS

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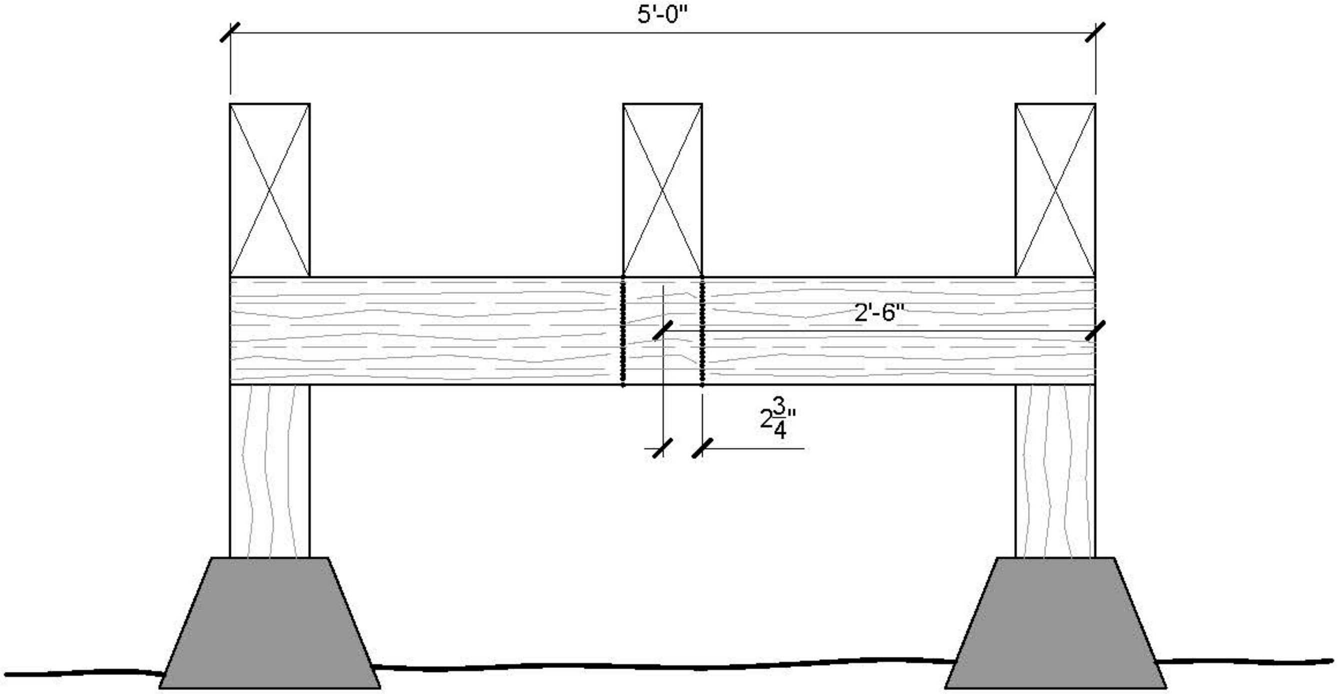

1. MEASURE THE LENGTH OF THE HEADER (60") AND DIVIDE THAT NUMBER IN HALF (30"). THEN MEASURE 30" FROM ONE END OF THE HEADER TOWARDS ITS CENTER. USE A FRAMING SQUARE TO SCRIBE A VERTICAL LINE AT THAT LOCATION. THEN MEASURE 2.75" FROM THE CENTER LINE ON BOTH SIDES OF THE CENTER LINE AND SCRIBE VERTICAL LINES AT THOSE LOCATIONS. INSTALL THE CENTER JOIST BETWEEN THESE TWO LINES. IF THE JOIST IS INSTALLED ON TOP OF THE HEADER THE LAYOUT IS PERFORMED ON TOP OF THE HEADER. IF IT IS INSTALLED ON THE FACE OF THE HEADER THE LAYOUT IS PERFORMED ON THE FACE OF THE HEADER.

Figure 15.37 - Installing Three Joists

INSTALLING THREE JOISTS

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NOT TO SCALE

The joists are fastened to the headers by either toe nailing with 16d galvanized nails or using a manufactured galvanized bracket such as a Simpson Hurricane Tie. (See Figure 15.38.) Joists can also be attached to the headers at the faces of the headers so that the tops of the joists and the headers are at the same elevation when joined. The layout process is the same as the previous layout except it occurs on the faces of the headers instead of on the tops of the headers. The joists are fastened to the headers via a galvanized metal bracket such as a Simpson Double Shear Joist Hanger. (See Figure 15.39.)

15.6.3. Railing Post Installation

If railings are going to be installed (required when the height from the top of the decking to ground level is 48 inches or greater), the posts for those railings are installed next. (See Photo 15.6.) The posts should be 4- x 6-inch redwood or cedar. Pressure treated wood products should never be used where the public will come into direct contact with them (e.g., posts and railings). Prior to installing the railing posts, the number of posts and the layout must be determined. The maximum free span for the railings on boardwalks should be 12 feet. To determine the number of railing posts required, divide the total length of the boardwalk by 12 feet (the maximum distance between posts), then add one additional post to account for the posts required on both ends of the structure. For example, a 36 foot long boardwalk will require four posts per side or eight posts for the entire structure (36 ÷ 12 = 3 + 1 = 4 per side).

Photo 15.6 - Boardwalk Railing

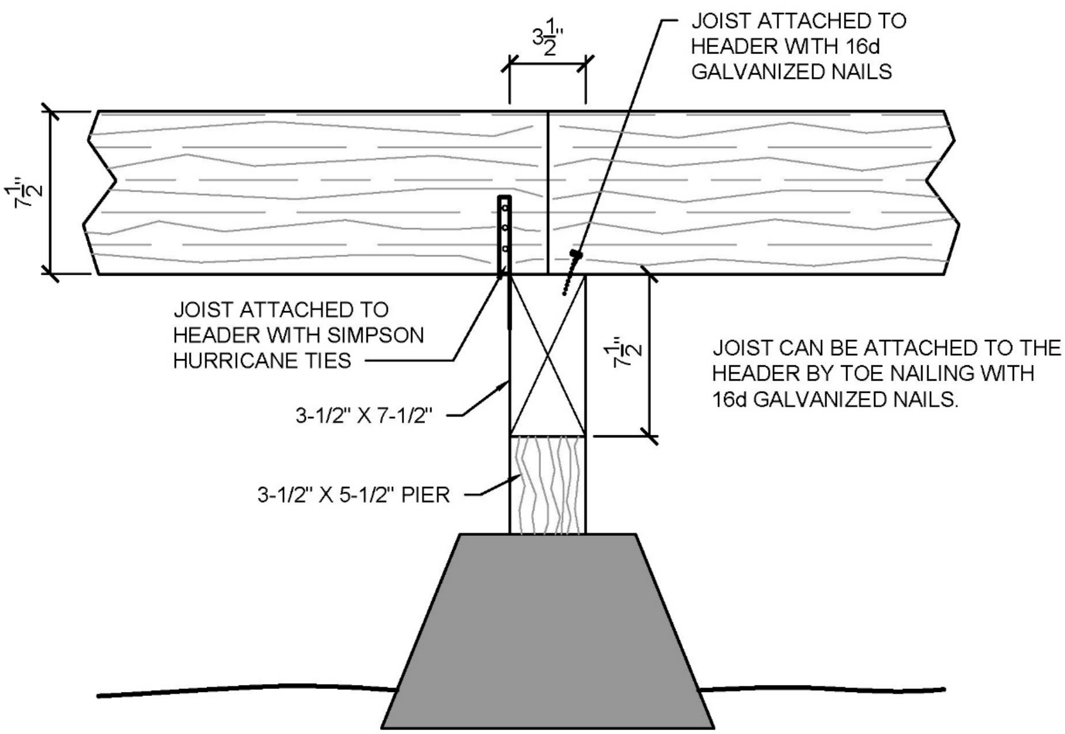
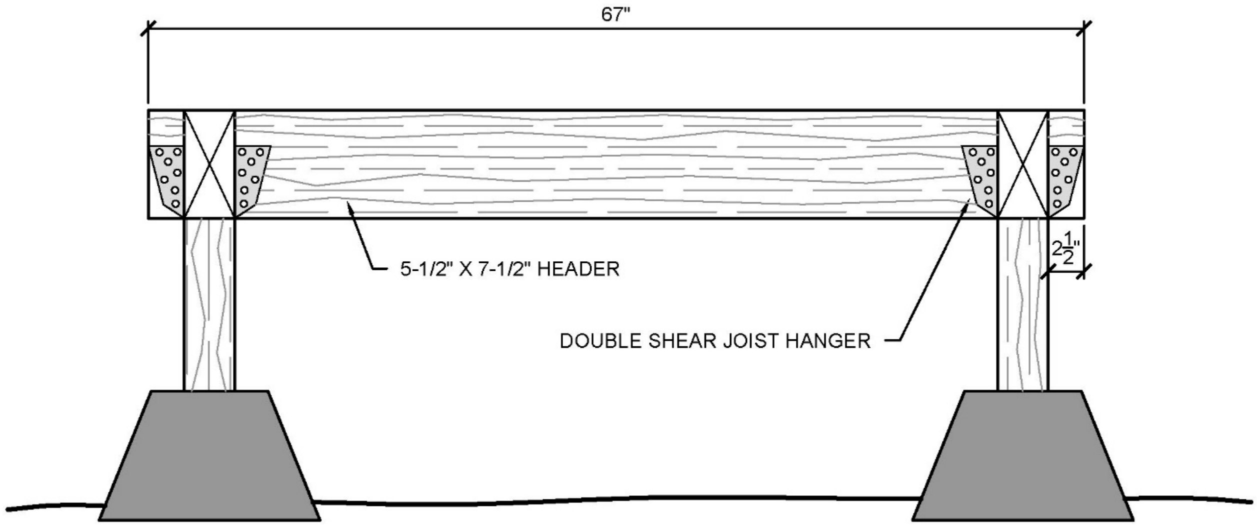


Figure 15.38 - Joist Attachment on Top of Header

JOIST ATTACHMENT ON TOP OF HEADER

CALIFORNIA STATE PARKS

NOT TO SCALE



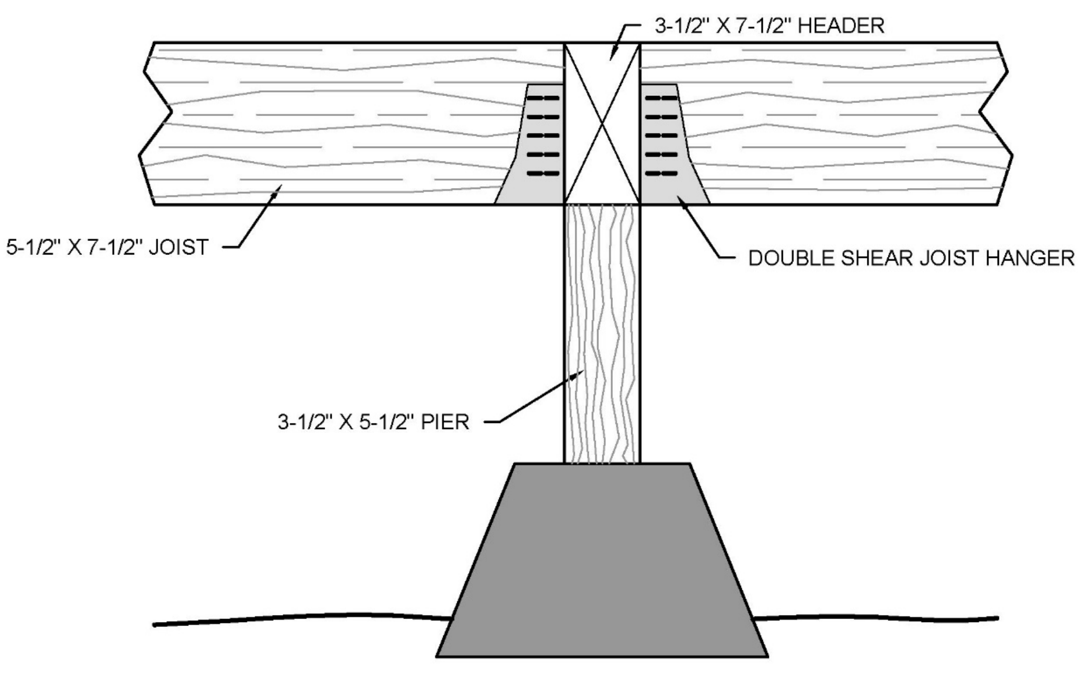


Figure 15.39 - Joist Attachment on Side of Header

JOIST ATTACHMENT ON SIDE OF HEADER

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NOT TO SCALE

Earlier, the concrete pier layout was inset from the ends of the boardwalk by 1 3/4 inches to align the outside edge of the piers, headers, and joists with the ends of the boardwalk. (See the “Concrete Pier Block Construction” section.) Having these structural components flush with the ends of the boardwalk provides nailing surfaces for the soil dams, which are required to separate the boardwalk from the soil in the trail tread. With soil dams attached to the ends of the boardwalk, the railing posts on the ends of the boardwalk must be placed on the insides of the headers to ensure that they do not interfere with the soil dams. With a 12 foot on-center layout for the headers, the posts will also reflect that 12 foot on-center layout except for the last post, which will be shortened by the thickness of the headers. (See Figure 15.40.)

The length of the posts is determined by the designed finished railing height. Pedestrian railings are 42 inches from the top of deck to the top of the railing. At vista points along an accessible trail, railings should not restrict the view between 32 and 51 inches from the top of the deck. However, the railing should be 42 inches high if it is determined to be essential to ensure user safety. In addition, in determining the length of the posts, take into account the height of the joists to which they will attach, the decking height from which they will be measured, and the railing height to which they will be measured as described below.

If surfaced dimensioned lumber (S4S) is used, the headers and joists will each be 7 1/2 inches high, the decking height will be 1 1/2 inches high (for 2 inch decking), and the top railing will be 4 inches high (after the top railing is notched 1 1/2 inches to set on the posts). To determine the necessary post length, add the heights of the header (7 1/2 inches), joists (7 1/2 inches), and decking (1 1/2 inches) to the designed railing height (42 inches for pedestrian), and subtract the height of the railing (4 inches) for a total post length of 54 1/2 inches (7 1/2 in. + 7 1/2 in. + 1 1/2 in. + 42 in. – 4 in. = 54 1/2 in.). (See Figure 15.41.)

Once the post layout has been performed and the posts have been cut to length, they are attached to the headers using a C-clamp, wood hand clamp, bar clamp, or deep throat clamp. After clamping, the posts should be plumbed using a 4-foot carpenter’s level. Once plumb, two 3/8-inch holes are drilled through the posts and the headers approximately 1 1/2 inches in from the tops and bottoms of the headers and offset to prevent splitting either the headers or the posts. The bolt holes in the headers are drilled from the outside of the posts to the inside of the headers, keeping the auger bit level and plumb. Do not push the auger bit all the way through the headers. Finish drilling the holes from the inside of the headers to prevent the wood from splintering on the inside of the headers. The bolt holes in the headers should be painted with a wood preservative to reduce rot. Copper napthenate applied with a bottle brush should suffice. The posts are fastened to the joists by using 3/8- x 10-inch galvanized carriage bolts. (See Figure 15.42.) For additional strength, the posts are attached to the sides of the joists using 3/8- x 10-inch galvanized carriage bolts. (See Figure 15.42.)

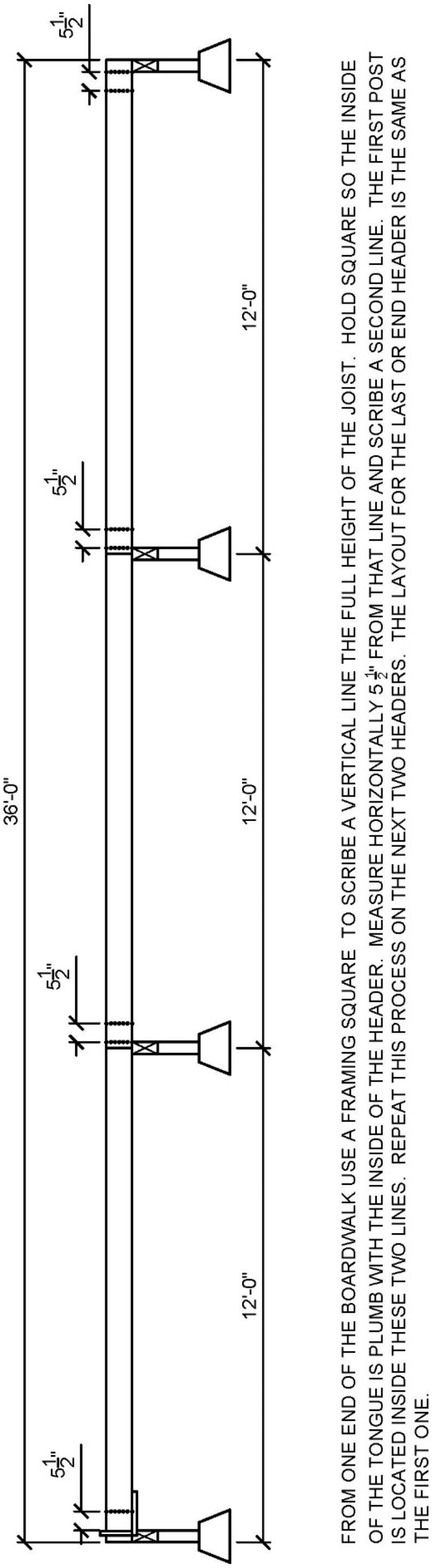

Figure 15.40 - Post Layout

POST LAYOUT

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NOT TO SCALE

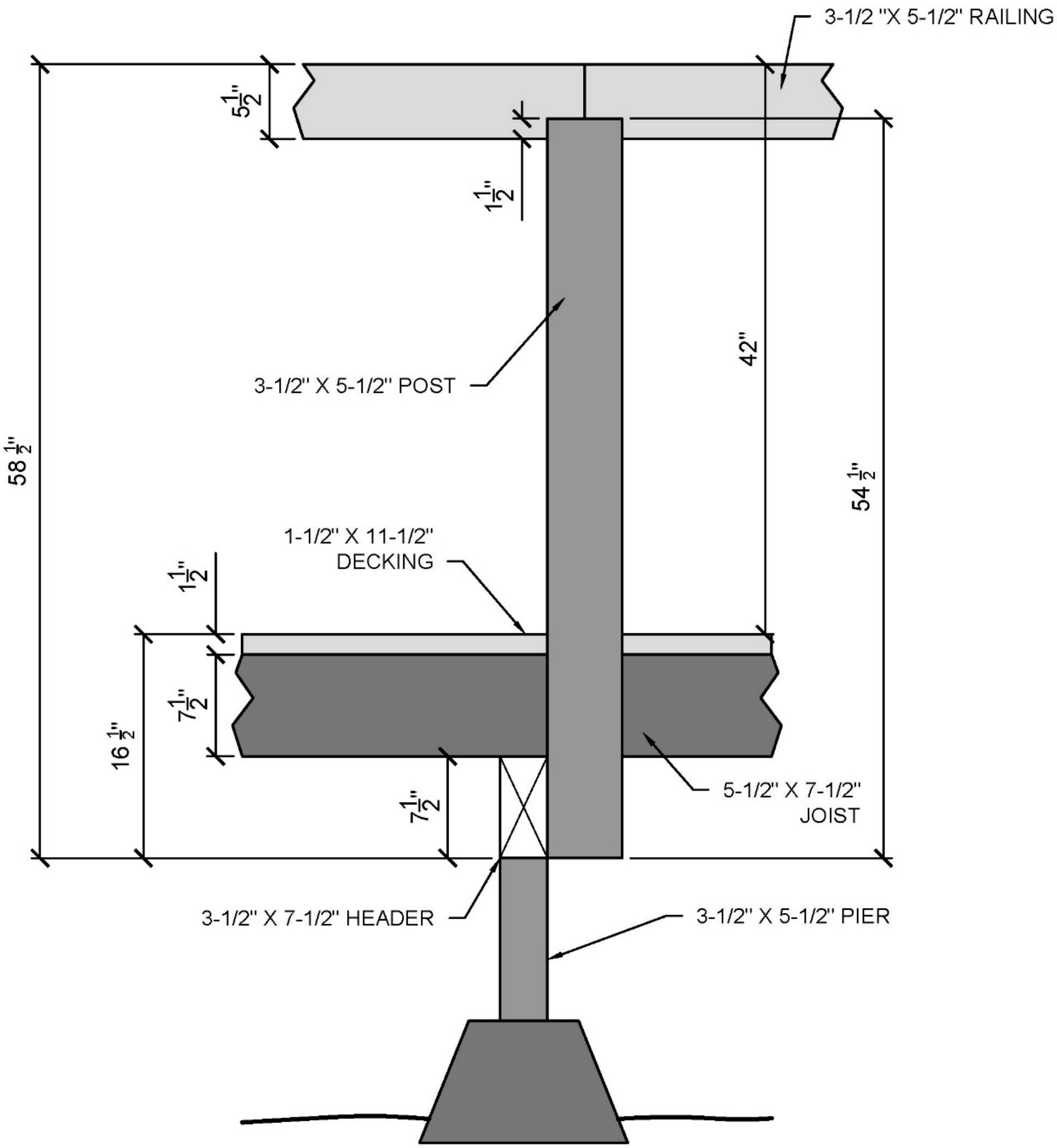


Figure 15.41 - Post Length Determination

POST LENGTH DETERMINATION

CALIFORNIA STATE PARKS

NOT TO SCALE

PLACE POST INSIDE THE TWO SCRIBED LINES ON THE JOIST. BOTTOM OF POST IS FLUSH WITH THE BOTTOM OF THE HEADER. CLAMP THE POST TO THE JOIST. USE CARPENTERS LEVEL TO PLUMB POST. DRILL TWO $\frac{3}{8}$" DIAMETER HOLES THROUGH POST AND HEADER. SECURE POST TO HEADER WITH $\frac{3}{8}$"X12" CARRIAGE BOLTS. DRILL TWO $\frac{3}{8}$" DIAMETER HOLES THROUGH POST AND JOIST. SECURE POST TO JOIST WITH $\frac{3}{8}$"X12" CARRIAGE BOLTS

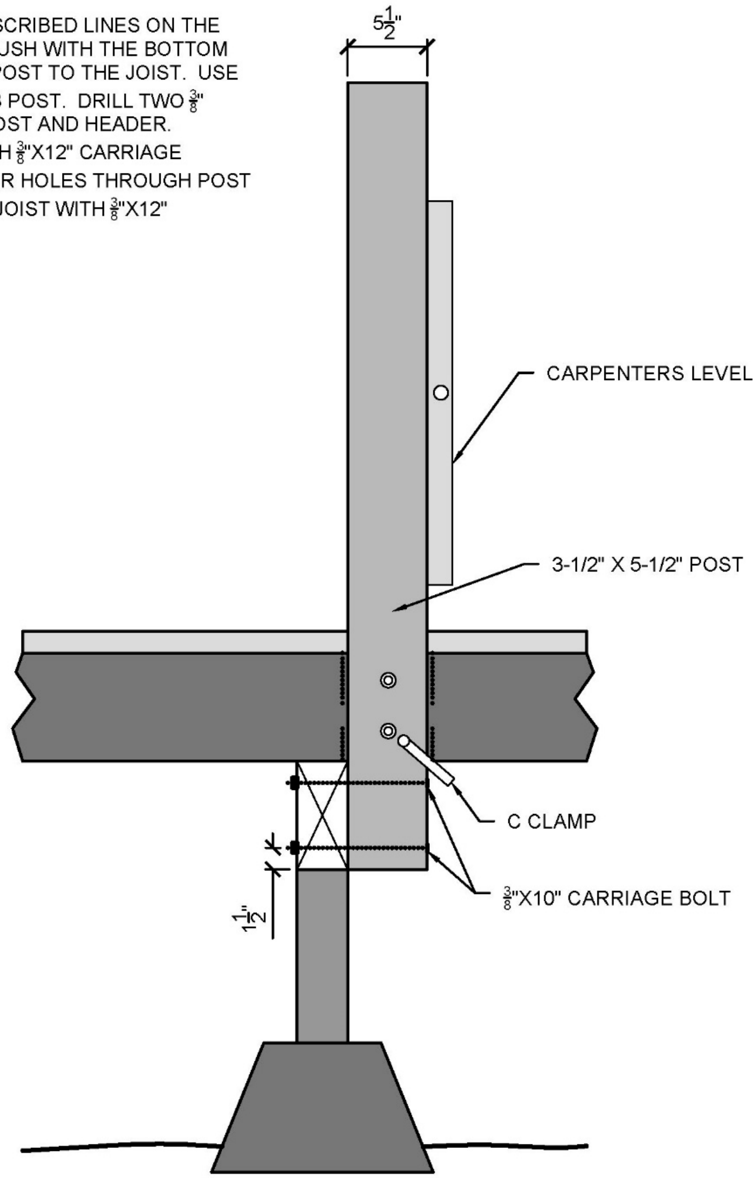


Figure 15.42 - Post Attachment

POST ATTACHMENT

CALIFORNIA STATE PARKS

NOT TO SCALE

15.6.4. Decking

After the posts have been fastened, the decking can be installed. A number of different materials can be used to deck boardwalks. If wood is used, it is usually redwood, cedar, or pressure treated Douglas fir, but some exotic hardwoods have been used. The soft woods come in full dimension (rough sawn) or surfaced (S4S) finishes. Exotic hardwoods come in surfaced (S4S) finishes. Generally in wet climates, rough sawn lumber is preferred due to the better traction this surface provides. In wet, cool climates these materials will last 10 to 15 years. In warm, dry climates they could last 15 to 20 years. The longevity of the hardwoods in this application is unknown due to the short history of use, but it is believed they will outlast the softwoods. Wooden decking generally provides a more aesthetically pleasing appearance. The softwoods, especially with a rough sawn finish, provide better traction.

Wood and plastic composites have become popular decking materials. When these materials were first introduced, they were purported to have a much longer lifespan than conventional wooden decking and be virtually maintenance free. However, issues with fading, warping, mold and mildew growth, and delamination have challenged these claims. These materials do not possess the same structural strength as conventional wood and require additional joists to support the decking boards. The maximum layout for joists with most composite decking is 16 inches on center (check with the manufacture for the appropriate spacing). This material has a wood-like appearance and can be an acceptable choice in the right setting. When used in cool, wet climates, composite decking can leave a very slippery surface. Treatments to provide a slip resistance surface can have a limited lifespan.

Plastic wood decking has been around for several decades. This product has steadily improved over the years and is becoming a viable option for trail builders. Plastic wood comes in structural and non-structural grade lumber. The structural lumber is reinforced with fiberglass or fiber reinforced polymer rods to give it additional strength. The advantage of the structural plastic lumber is that it reduces the number of joists required to support the decking. With 100 pounds per square foot live load, a 2- x 8-inch structural decking board has a maximum span of 27 inches. A 2- x 8-inch non-structural decking board has a maximum span of 19 inches. This material comes in a wide variety of dimensions and colors. It has less aesthetic appeal than wood or composite lumber but is acceptable in the right setting. The life span of this product is still somewhat unknown because it has been in use as a trail building material for only a short period of time. However, if this material is not exposed to direct sunlight, it should last much longer than conventional wooden decking. Plastic lumber expands in warm temperatures and contracts in cold temperatures, which means the boards can warp and twist when the variation in ambient temperature is significant. Climatic conditions should be a factor when considering the use of plastic lumber. When storing plastic lumber, it should be stacked flat, banded tightly, and stored out of the sun. Like composite decking, when used in cool, wet climates, plastic lumber decking can leave a very slippery surface. Some manufacturers offer a roughened surface to improve traction.

Once the decking material is selected, it is cut to the appropriate length. The decking should extend beyond the outside joists by a minimum of 6 inches. The overhang is necessary to cover the exposed sides of the joists for aesthetic purposes. It also ensures that the decking extends beyond the bull rails, posts, and railings, if they are installed, and prevents trail users from stepping off the ends of the decking when walking next to the bull rails or railings. A layout example for decking without railings and bull rails is as follows. If the measurement from outside to outside of the joists is 48 inches, an additional 12 inches is added to the decking to provide the 6-inch overhang on each side. Thus, the total length of the decking would be 60 inches (48 in. + 6 in. + 6 in. = 60 in.). (See Figure 15.43.)

The decking can be cut at the shop and carried to the job site, or carried to the job site and cut to length there. This decision is often influenced by packing logistics, but faster and more precise cuts are obtained using a radial arm saw or a cut off saw at the shop. If using pressure treated lumber, it is best to order the decking lumber in the required lengths so the ends of the boards are pressure treated. If pressure treated lumber is cut, the wood preservative is compromised. It will not last as long even if the cut ends are painted with a wood preservative.

Next, begin placing the decking on the joists. The decking should be laid perpendicular to the direction of the joists. As each piece of decking is laid down, it is centered on the joists by measuring the length of the overhang on each end. This task is performed by two people more efficiently than one. The overhang should be the same on both ends of the decking board. If it is not, the decking must be adjusted by moving the decking board toward the shorter overhang side. (See Figure 15.43.) Once a decking board is centered on the joists, the next piece of decking is laid down next to it. The same process is followed except a gap is left between the two pieces of decking to allow for future swelling and shrinkage. Normally, a 1/4-inch gap is sufficient, but some materials and climates may require 3/8 inches or more. A wooden wedge, piece of steel, or a 1/4-inch bolt can be placed between the two pieces of decking to maintain a uniform gap. In cool, wet climates where the decking never dries out, no gap between the decking boards is required. In these climates, the gaps will accumulate organics between the boards, which may increase rot in the decking and joists. In a very hot and dry desert climate, board shrinkage can be substantial. In these conditions, decking should be installed without a gap, otherwise the gap may become too wide over time especially by accessible trail standards.

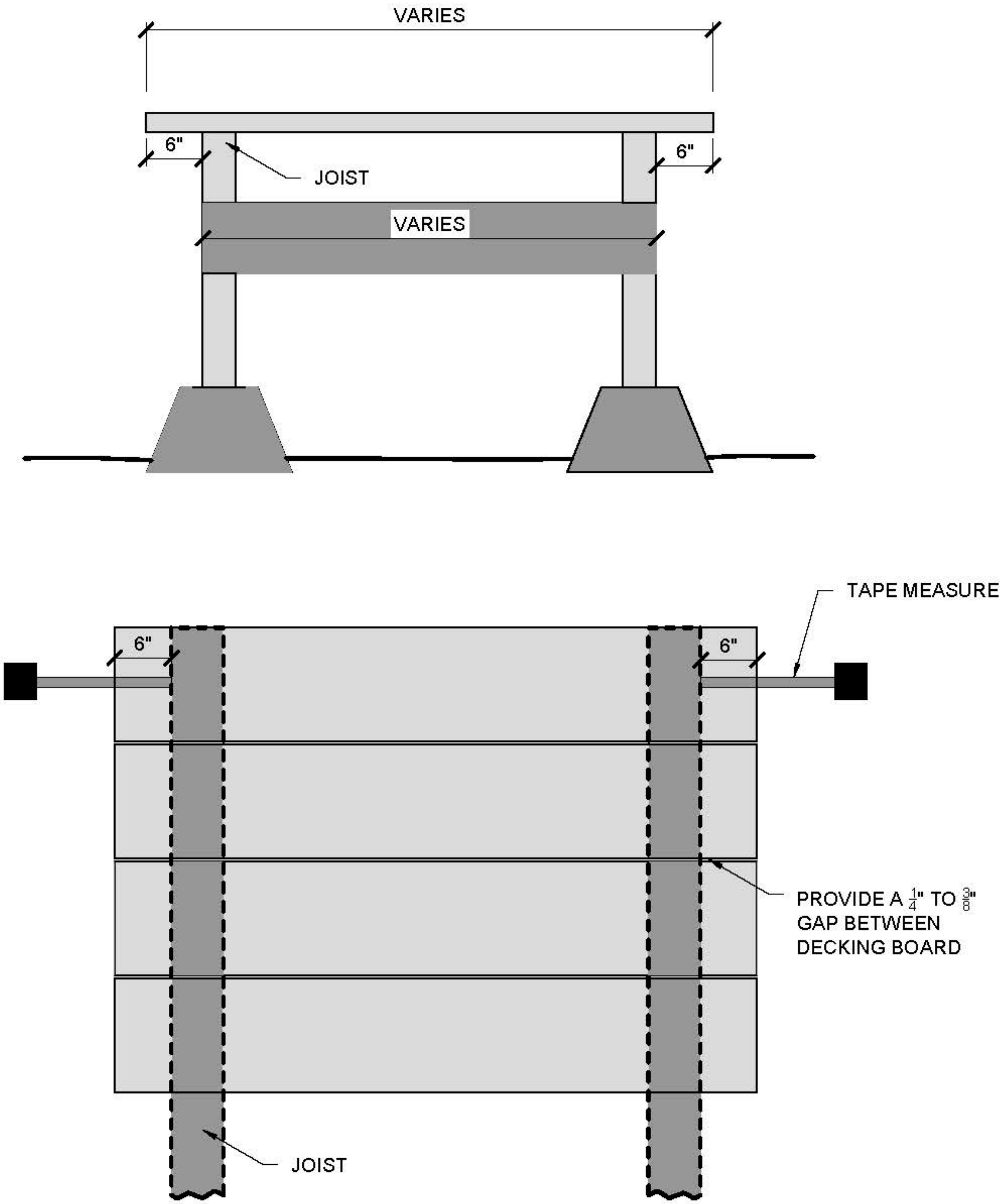


Figure 15.43 - Deck Layout without Stagger

DECK LAYOUT WITHOUT STAGGER

CALIFORNIA STATE PARKS

NOT TO SCALE

A rough or irregular edge to the decking will reduce the uniform appearance of the structure causing it to blend more with the natural environment. This edge can be accomplished by off-setting the overhang of the decking. For example, a decking board with a 7-inch overhang on one side may have a 5-inch overhang on the other side. When the next board is laid down the overhang is reversed to provide the irregular edge. (See Figure 15.44.)

Decking will need to be notched to fit around the posts. Make a simple sketch of the decking and record all the measurements on the sketch. The layout for notching is performed by first measuring the distance between the two posts, from one side of the bridge to the other side, which is 60 inches in this example. (See Figure 16.57). Write down that measurement. Next, measure the distance from the edge of the last piece of decking laid to the post, which is 8 1/4 inches in this example. This measurement should be taken on both ends of the decking since the measurement to each post may not be the same. If this decking board does not extend past the post, no further measurement is required. (See Figure 15.45.)

Once these measurements are taken, lay the next decking board flat on two saw horses or any stable and relatively level surface. Mark an “X” on the side of the decking that will butt up to the previously laid decking. The “X” is necessary to help maintain the correct orientation of the board as it is being laid out, cut, and installed. Find the center of the decking board by measuring the length and dividing it in half. Measure that distance from one end of the decking and scribe a line across the center of the board using a framing square. (See Figure 16.57.) Divide the previously measured distance between the posts (60 inches) in half and measure that distance (i.e., 30 inches) in both directions from the center line and scribe lines using a framing square. These lines represent where the decking will be cut to fit inside the posts. (See Figure 15.45.)

Next, subtract 1/4 inch from the measurements between the last decking laid and the post (e.g., 8 1/4 in. - 1/4 in. = 8 in.) to provide a gap between the last decking board and the one being notched. Note, if a larger gap is required (e.g., 3/8 inches), subtract that measurement. If no gap is required, use the 8 1/4-inch measurement. Then, measure 8 inches from the top edge of the decking board (side with the “X” on it) down the outside edge of the board and scribe a mark at that location. With the use of a framing square, scribe a line from the 8-inch mark to the line marking the inside of the post. If the decking board does not extend beyond the posts then use a pencil to mark the area within the two lines with an “X”. The “X” denotes the portion of the board to be removed from the decking board so it fits around the post. (See Figure 15.45.) After the layout is complete, use a cross cut hand saw to cut along the two lines to remove the wood representing the notch. Repeat this measurement, scribing, and cutting process on the other end of the board.

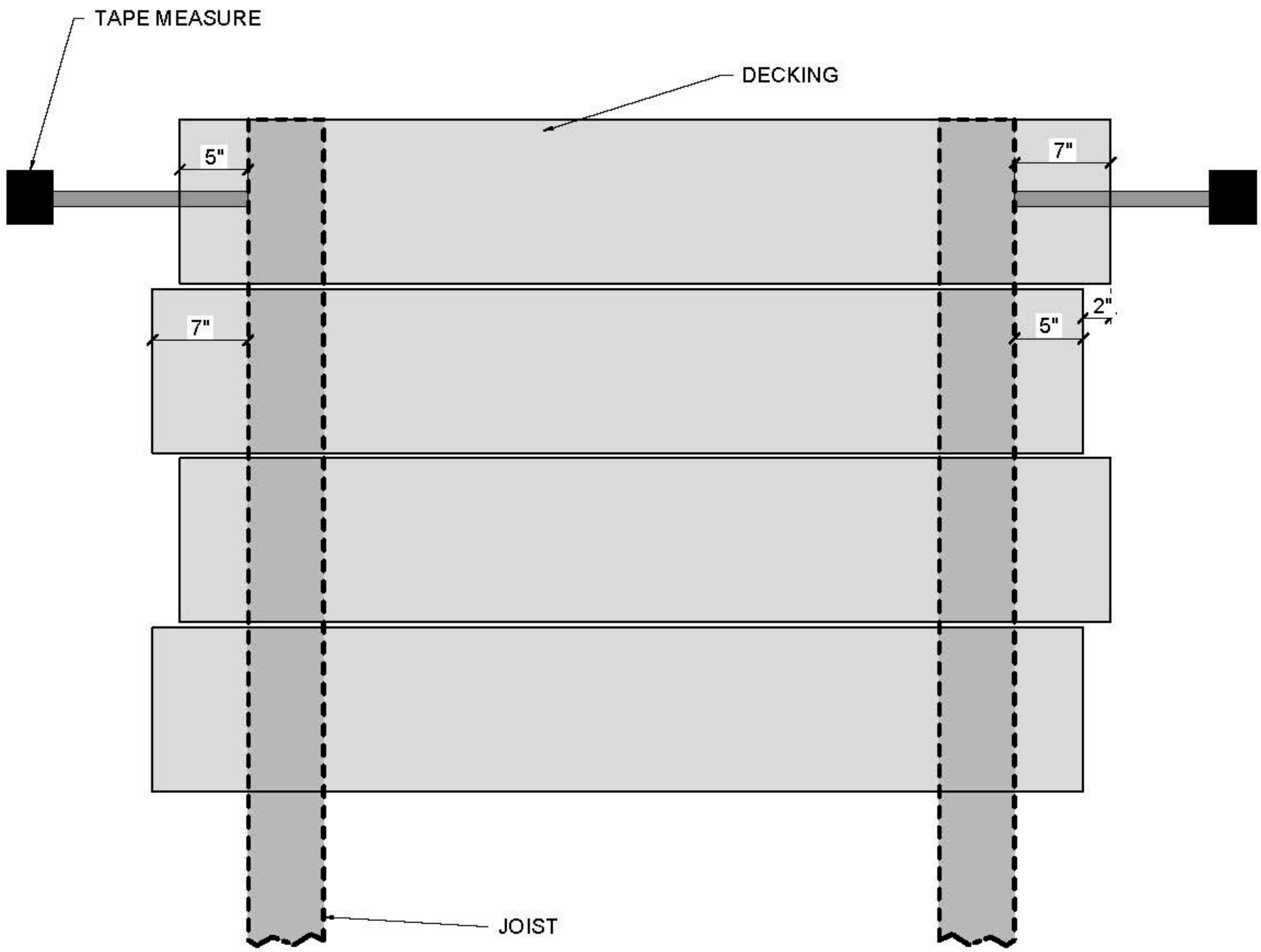
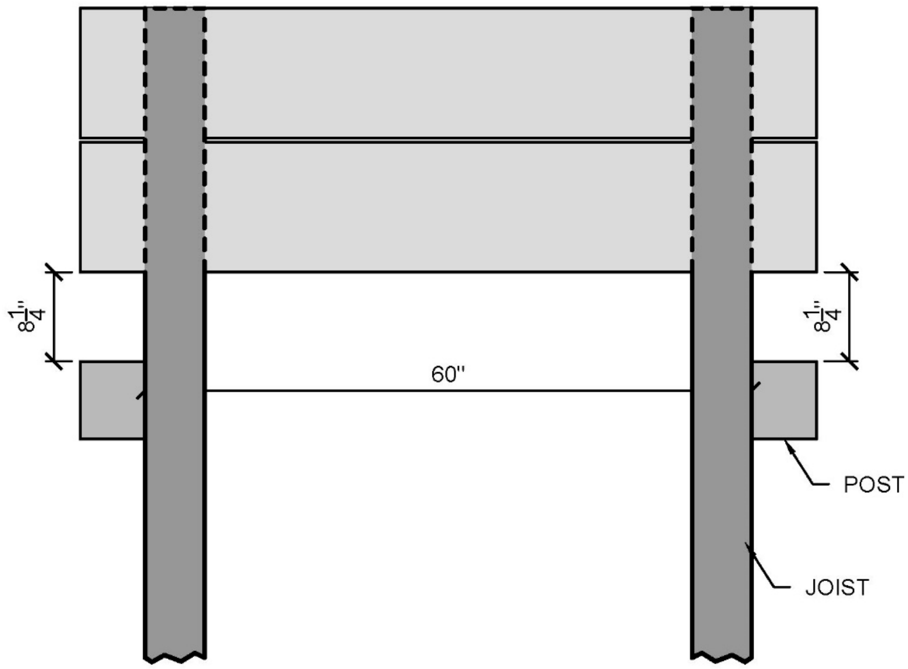


Figure 15.44 – Staggered Decking Layout

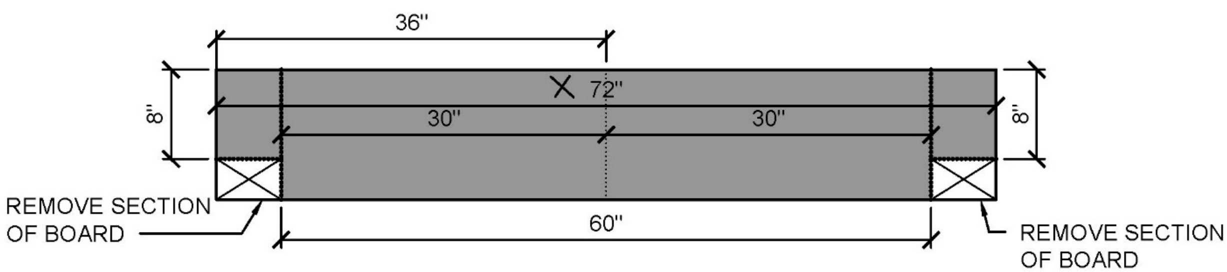
STAGGERED DECKING LAYOUT

CALIFORNIA STATE PARKS

NOT TO SCALE



MEASURE THE DISTANCE BETWEEN THE POSTS (60"). THEN MEASURE FROM THE EDGE OF THE DECKING JUST INSTALLED TO THE INSIDE OF THE POSTS. SUBTRACT $\frac{1}{4}$" FROM THIS MEASUREMENT IF A GAP BETWEEN THE DECKING BOARDS IS REQUIRED. RECORD THESE MEASUREMENTS FOR USE WHEN PERFORMING THE NOTCHING LAYOUT ON THE DECK BOARD.



MARK AN X ON THE SIDE OF THE BOARD THAT WILL BUTT UP AGAINST THE PREVIOUSLY LAID DECKING. MEASURE THE LENGTH OF DECKING (72") AND DIVIDE THAT NUMBER IN HALF (36"). THEN MEASURE IN FROM ONE END OF DECKING 36" AND SCRIBE A CENTER LINE FROM THE TOP OF THE BOARD TO THE BOTTOM. FROM THE CENTER LINE MEASURE OUTWARDS HALF THE DISTANCE BETWEEN THE POST (30") IN BOTH DIRECTIONS AND SCRIBE LINES FROM THE TOP OF THE BOARD TO THE BOTTOM. THESE TWO LINES IDENTIFY THE INSIDE OF THE POSTS. THEN MEASURE FROM THE TOP OF THE BOARD (MARKED WITH AN X) 8" AND SCRIBE PERPENDICULAR LINES FROM THE ENDS OF THE BOARD TO THE LINES MARKING THE INSIDE OF THE POSTS. MARK AN "X" ACROSS THE AREAS ON THE BOTTOM OUTSIDE CORNERS AS THE WOOD INSIDE THOSE LINES WILL BE REMOVED FOR THE NOTCH.

Figure 15.45 – Notching Decking Around Post (Partial Notch)

NOTCHING DECKING AROUND POST (PARTIAL NOTCH)

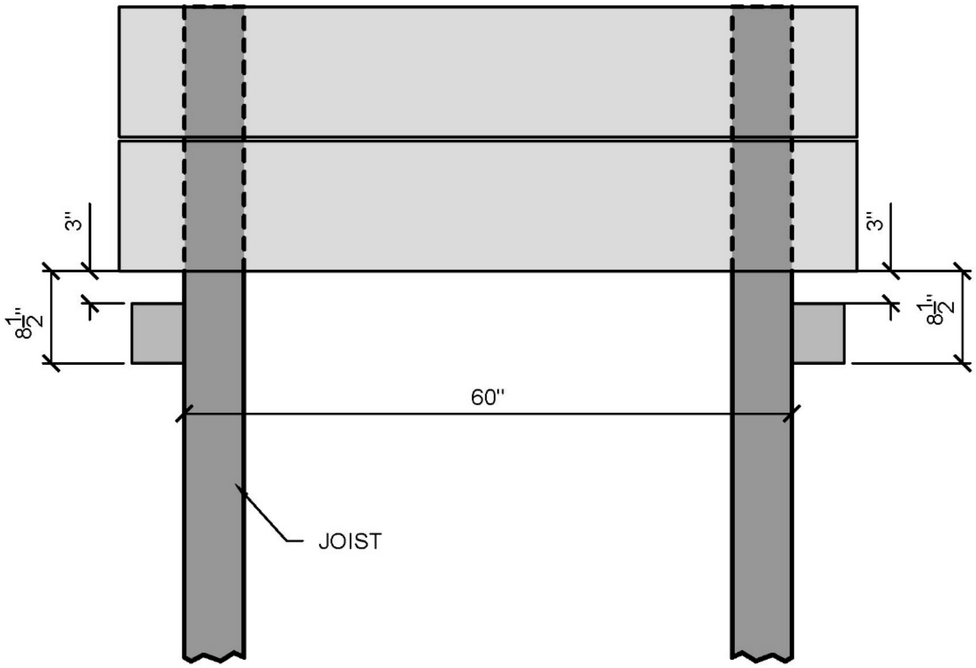
CALIFORNIA STATE PARKS

NOT TO SCALE

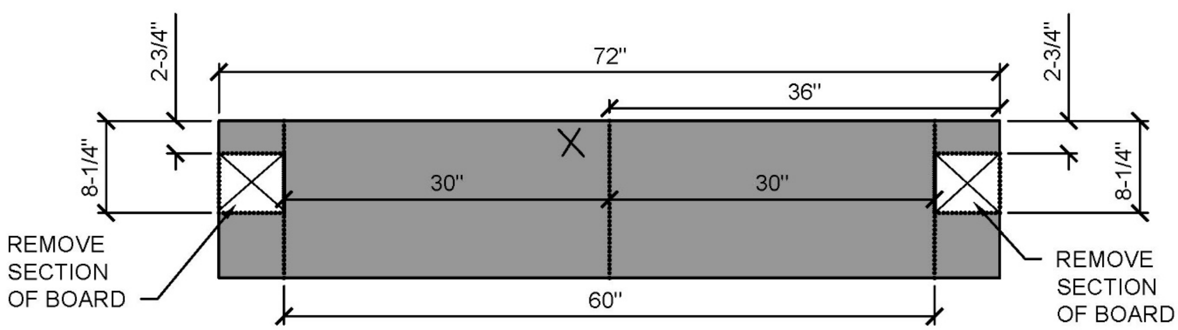
If a full notch is required, perform the measurements for delineating the inside of the post as previously discussed, then measure from the edge of the last decking board to the closest and furthest edges of the post. (See Figure 15.46.) Again, subtract the designed width of the gap between the decking boards (e.g., 1/4 inch) from both of these measurements. Then, measure from the top edge of the decking board (side with the “X” on it) down the outside edge of the board and scribe marks at those two measurements. With the use of a framing square, scribe lines from these two marks to the line marking the inside of the post. Repeat this measurement and scribing process on the other end of the board. Mark the area within the three lines with an “X” for removal. (See Figure 15.46.) Remove this notch by drilling a hole with a 3/4-inch auger drill bit in each inside corner of the notch. A cross cut hand saw can then be used to cut along the two parallel lines and a keyhole saw can be used to cut along the perpendicular line to remove the notch.

When placing the decking, it is important to periodically measure from the end of the boardwalk where the decking installation began to where the last piece of decking was placed. This measurement should be made inside the posts along both sides of the decking. If one measurement is longer than the other, the decking boards on the short side need to be spaced further apart until the two measurements are the same. (See Figure 15.47.) In this manner, the decking is maintained square to the structure and won’t have to be tapered at the end of the boardwalk. Different measurements can result from not maintaining the same gap on each end of the board or not having a square structure prior to installing the decking. It can also occur when using rough sawn boards since their dimensions can vary by as much as 1/16 inch per board. If the structure is not square, the adjustment will have to be made along the full length of the decking, otherwise the last decking board will be wedge-shaped. Installing a wedge-shaped board requires additional work, is visually obtrusive, and demonstrates poor craftsmanship.

Once the decking has the required gaps and is square, secure it to the joists. If the ends of the joists are exposed, hammer a 8d nail into the decking at the ends of the boardwalk and over the center of each joist. Next, attach a chalk line to a nail on one end of the boardwalk and stretch it taut to a nail on the opposite end of the boardwalk. When the chalk line is snapped it will leave a faint line across the top of the decking boards, directly above the center of the joists. If the boardwalk is less than 15 feet, one snap usually suffices. However, with longer spans it will be necessary to hold the chalk line down with one hand and snap it with the other at 10 foot intervals along the boardwalk to obtain a legible chalk line. Repeat this process for each joist.



MEASURE THE DISTANCE BETWEEN THE POSTS (60"). THEN MEASURE FROM THE EDGE OF THE DECKING JUST INSTALLED TO THE INSIDE OF EACH POST. SUBTRACT $\frac{1}{4}$" FROM THIS MEASUREMENT IF A GAP BETWEEN THE DECKING BOARDS IS REQUIRED. THEN MEASURE FROM THE EDGE OF THE DECKING TO THE OUTSIDE OF EACH POST. SUBTRACT $\frac{1}{4}$" FROM THIS MEASUREMENT IF A GAP BETWEEN THE DECKING BOARDS IS REQUIRED. RECORD THESE MEASUREMENTS FOR USE WHEN PERFORMING THE NOTCHING LAYOUT ON THE DECK BOARD.



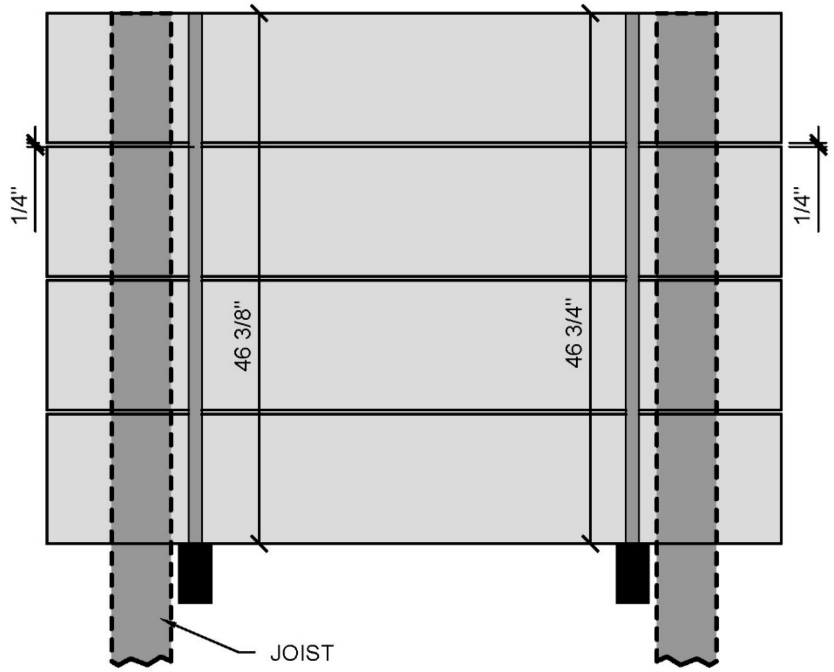
MARK AN X ON THE SIDE OF THE BOARD THAT WILL BUTT UP AGAINST THE PREVIOUSLY LAID DECKING. MEASURE THE LENGTH OF DECKING (72") AND DIVIDE THAT NUMBER IN HALF (36"). THEN MEASURE IN FROM ONE END OF DECKING 36" AND SCRIBE A CENTER LINE FROM THE TOP OF THE BOARD TO THE BOTTOM. FROM THE CENTER LINE MEASURE OUTWARDS HALF THE DISTANCE BETWEEN THE POSTS (30") IN BOTH DIRECTIONS AND SCRIBE A LINES FROM THE TOP OF THE BOARD TO THE BOTTOM. THESE TWO LINES IDENTIFY THE INSIDE OF THE POST. THEN MEASURE FROM THE TOP OF THE BOARD (MARKED WITH AN X) 2-3/4" AND SCRIBE PERPENDICULAR LINES FROM THE END OF THE BOARD TO THE LINES MARKING THE INSIDES OF THE POSTS. THEN MEASURE FROM THE TOP OF THE BOARD 8-1/4" AND SCRIBE PERPENDICULAR LINES FROM THE END OF THE BOARD TO THE LINE MARKING THE INSIDES OF THE POSTS. MARK AN "X" ACROSS THE AREAS OUTLINED BY THESE THREE LINES AS THE WOOD INSIDE THOSE LINES WILL BE REMOVED FOR THE NOTCH.

Figure 15.46 – Notching Decking Around Post (Full Notch)

NOTCHING DECKING AROUND POST (FULL NOTCH)

CALIFORNIA STATE PARKS

NOT TO SCALE



AFTER LAYING DOWN FOUR OR FIVE BOARDS MEASURE THE DISTANCE FROM THE END OF THE BOARDWALK TO THE OUTSIDE EDGE OF THE LAST BOARD LAID ON BOTH SIDES OF THE BOARDWALK. THE MEASUREMENTS SHOULD BE THE SAME. IF NOT, SUBTRACT THE SHORT MEASUREMENT FROM THE LONG MEASUREMENT AND DIVIDE THAT NUMBER BY THE NUMBER OF GAPS BETWEEN THE BOARDS. EXAMPLE: (46 $\frac{3}{4}$" - 46 $\frac{3}{8}$" = $\frac{3}{8}$")($\frac{3}{8}$"/3 GAPS = $\frac{1}{8}$"). THEN INCREASE THE GAPS ON THE SHORT MEASUREMENT SIDE BY $\frac{1}{8}$". THE GAPS WILL BE $\frac{3}{8}$" ON THE SHORT SIDE AND $\frac{1}{4}$" ON THE LONG SIDE. THIS WILL CORRECT THE DECKING BOARD MEASUREMENT.

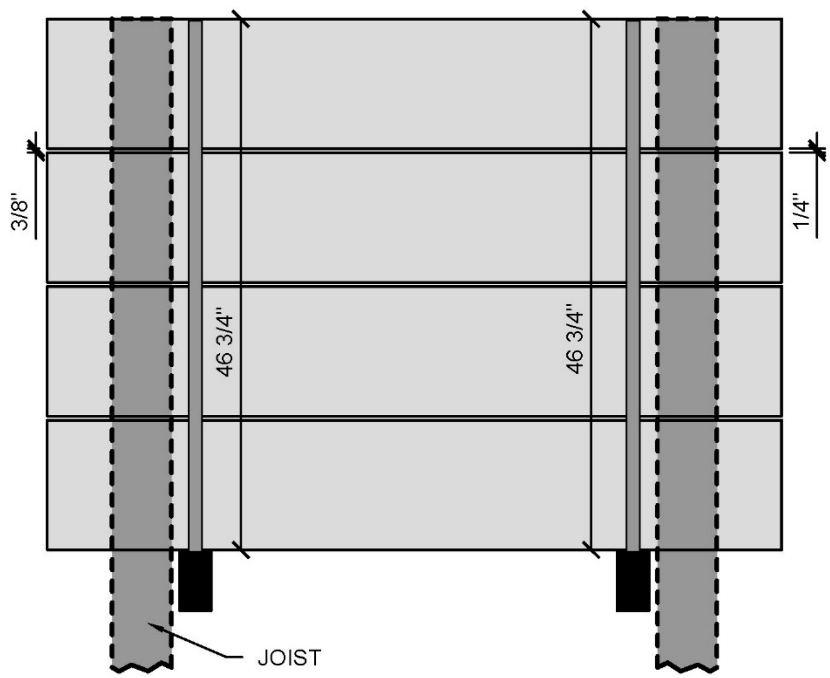


Figure 15.47 – Adjusting Deck Gap to Get it Square

ADJUSTING DECK GAP TO GET IT SQUARE

CALIFORNIA STATE PARKS

NOT TO SCALE

Once the chalk lines are in place, use a drill with a twist bit to drill pilot holes into the decking and joists along the chalk line. Pilot holes will reduce the risk of splitting or splintering the decking boards. If the decking is 6 inches wide or less, two fasteners are used per board, placed approximately 1 1/2 inches from the edge of the boards to keep them from warping. If the boards are wider than 6 inches, three fasteners per board are used; two at approximately 1 1/2 inches from the edge of the board and one in the center. For wooden decking, the pilot holes should be one drill bit size smaller (i.e., 1/32 to 1/16 inch smaller) than the diameter of the fastener. For composite and plastic wood, the bit should be the same diameter as the fasteners because this material is very hard and deck screws would likely shear before passing through. The depth of the pilot holes should leave at least 1 1/2 to 2 inches of un-drilled wood in the joist to firmly grasp the fastener. If using long decking screws (e.g., 5 to 6 inches), it may be necessary to make the holes deeper because screws this long shear easily. When the decking wood is hard and dry, it may also be necessary to lubricate the nails or screws to install them. Liquid hand cleaner (in a can) works well for this purpose and is easy to use. Only decking screws should be used on composite lumber and plastic wood. All fasteners should be stainless steel or galvanized steel for maximum longevity.

If nails are used, they should be driven with a hammer until they are nearly flush with the decking surface. Then, a hand punch and hammer should be used to drive them approximately 1/8 inch below the surface of the decking to prevent hammer marks on the decking and eliminate tripping hazards. Decking screws should also be screwed approximately 1/8 inch below the surface of the deck.

15.6.5. Soil Dam Installation

Once the decking has been fastened down, the soil dams are installed. This task is performed as discussed previously for puncheons. (See Figure 15.13.) If the boardwalk joists are not wooden refer to the soil dam section in Chapter 16, *Trail Bridges.*

15.6.6. Railing Installation

If railings are required, the first railing installed is the top, which is fastened to the tops of the posts previously installed. The finished height of the railing is determined by the user group. The process for determining the correct post height was previous discussed. The railing should be 4- x 6-inch redwood or cedar. Prior to installing the first railing, determine if the railing will terminate at the end of the boardwalk (on the end post) or continue to a post installed in the ground beyond the boardwalk (safety railing that defines the approach to the boardwalk). If the top railing is to terminate on the end post, it should not extend beyond the post more than 12 inches to eliminate potential breakage and provide a more aesthetically pleasing appearance. This information is necessary to determine how the top rail will be notched and secured to the post at the end of the boardwalk.

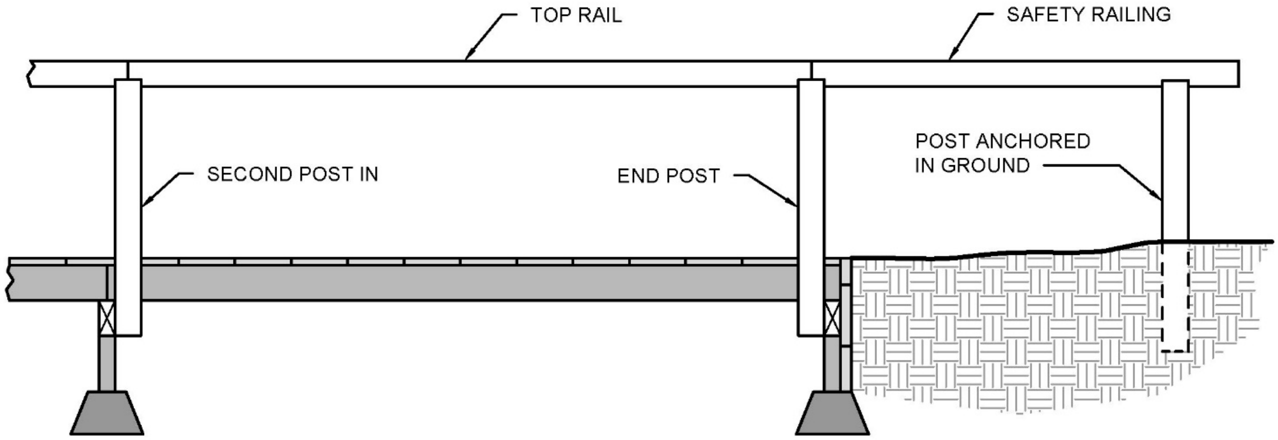
If a safety railing will extend to a post anchored in the ground on the approach to the bridge, the top rail is laid halfway across the top of the end post on the bridge and halfway across the second post in. The safety rail spanning from the end post on the bridge to the post anchored in the ground is laid halfway across the top of the end post on the bridge and spans over the post anchored in the ground (not to extend more than 12 inches beyond the post). If the top rail at the end of the bridge will terminate on the end post on the bridge, it is laid halfway across the second post in and spans over the end post (not to extend more than 12 inches beyond the post). (See Figure 15.48.)

If the railing is too long and extends beyond the center of the second post, it must be cut. While the railing is lying on the post, identify the halfway point on the post and scribe a line on the railing where it intersects the halfway point. Use a carpenter's pencil and a framing square, speed square, or combination square to scribe a line across the railing that identifies where the railing is to be cut. Once that line has been scribed, use the square to scribe a second line down the edge of the railing at a right angle to the first line, resulting in two lines to cut along - one on top of the railing and one on the side of the railing.

Two saw horses should be set up on or near the boardwalk to provide a good surface to perform the cutting and notching. Using a cross cut hand saw, cut the railing to the proper length. Place the railing back on the two posts so that it is half way across both of them.

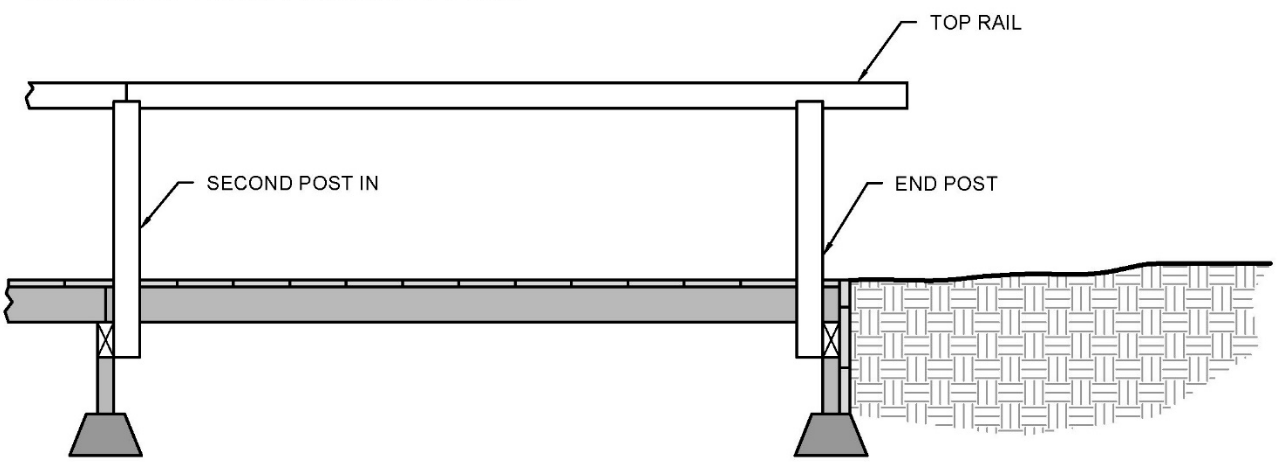
Once the railing is sitting flush and directly over the posts, use a sharpened carpenter's pencil to scribe a line under the railing along the inside of the two posts. This line represents the inside of the railing notch. Turn the railing upside down and lay the tongue (small end) of a framing square so that it is flush with the bottom of the railing. Line the handle (large end) of the square so that it is in line with the line just scribed. Then, use a carpenter's pencil to scribe a line along the tongue of the square toward the end of the railing. Then, scribe a line along the outside of the handle to where it intersects with the line on the bottom of the railing. Perform this task on both sides of the railing. These lines represent the depth of the notch (1 1/2 inches). The tongue of a framing square is 1 1/2 inches wide so it provides the correct depth for the notches. Next, lay the framing square across the end of the railing so that the top of the tongue is flush with the bottom of the railing. The bottom of the tongue should now intersect the two lines just scribed. Scribe this line with a pencil to help maintain a square and plumb cut when notching the railing. (See Figure 15.49.) Perform this task on both ends of the railing.

WITH APPROACHING SAFETY RAIL



THE TOP RAIL ENDS HALFWAY ONTO THE END POST. A SAFETY RAIL BUTTS UP TO THE TOP RAIL AND TERMINATES ON A POST ANCHORED INTO THE GROUND. THE NEXT TOP RAIL BUTTS UP AGAINST THE ADJACENT TOP RAIL AND TERMINATES HALFWAY ONTO THE NEXT POST ON THE BOARDWALK.

WITHOUT APPROACHING SAFETY RAIL



THE TOP RAIL TERMINATES ON THE END POST. IT EXTENDS BEYOND THE END POST SO THE END OF THE RAILING IS EQUAL TO OR LONGER THAN THE BOARDWALK. THE NEXT TOP RAIL BUTTS UP AGAINST THE ADJACENT TOP RAIL AND TERMINATES HALFWAY ONTO THE NEXT POST ON THE BOARDWALK.

Figure 15.48 - End Top Rail Installation

END TOP RAIL INSTALLATION

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NOT TO SCALE

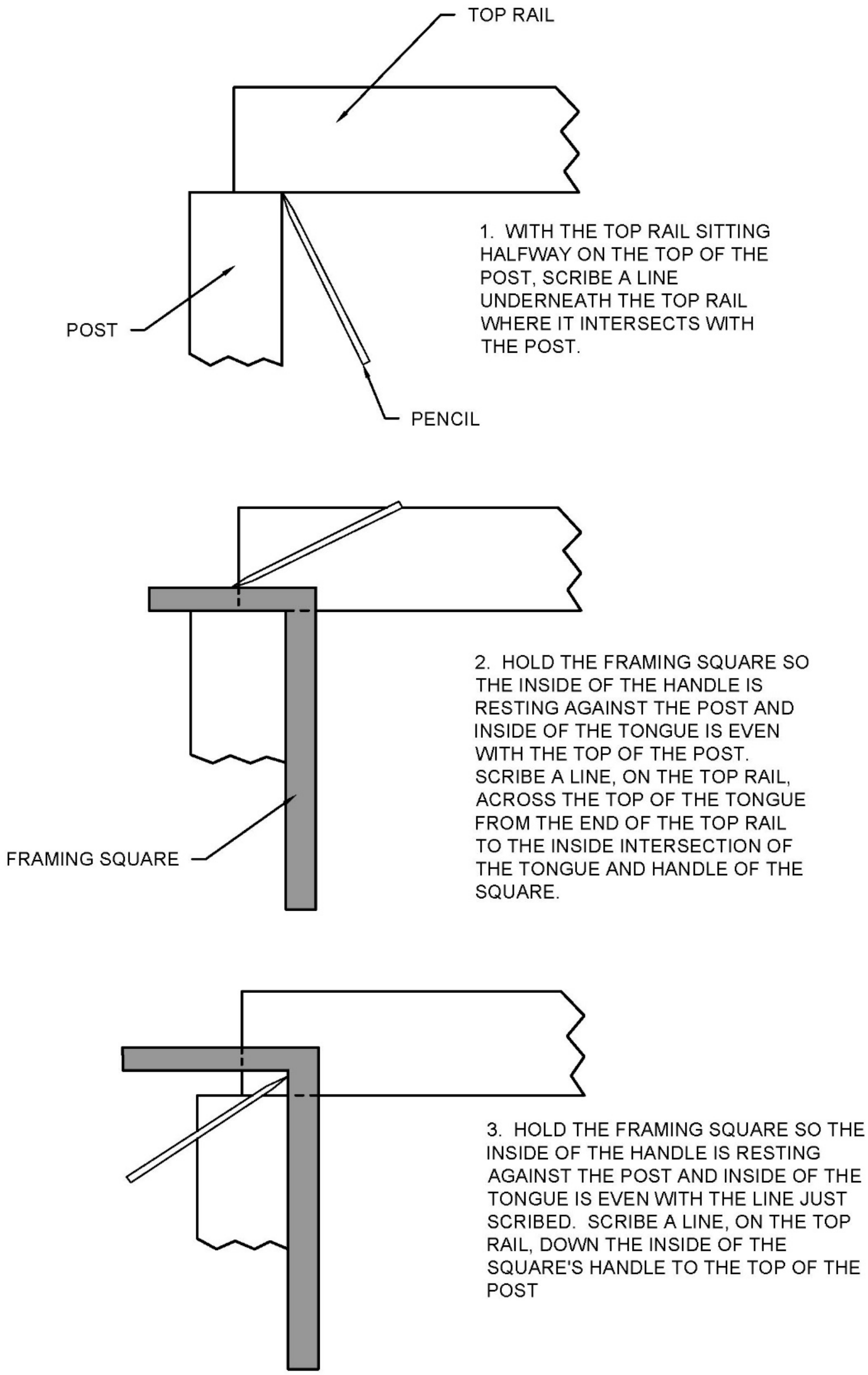

Figure 15.49 - Scribing Top Rail Notches (Partial Notch)

SCRIBING TOP RAIL NOTCHES (PARTIAL NOTCH)

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NOT TO SCALE

Next, lay the railing on the saw horses and cut the first line scribed. Use the line across the bottom of the railing and the two depth lines on the sides to keep the cut plumb and square. Cut just inside these lines so a portion of the pencil line remains. Once this cut is complete, turn the railing on its side and cut along the two lines marking the depth of the notch. Again, keep the saw blade just inside both lines to maintain a plumb cut. Rip the board along these two lines until they intersect. Once these two cuts meet, the wood in the notch can be removed. (See Figure 15.50.) Perform these same cuts on the other end of the railing.

When the notching is complete, set the railing back on top of the posts. If the scribing and cutting were performed properly, the railing should rest flush on top of both posts and the notches along the sides of the railing should be tight to the posts (i.e., within the thickness of a credit card). Do not make the notches too tight because there is a risk of pushing the posts apart and forcing them out of plumb. If, for some reason, the notches do not fit correctly, use a rasp or wood chisel to correct the problem. Remember, wood can always be removed but it can never be put back, so be cautious when making these adjustments.

If the railing is to terminate at the end of the boardwalk, the notching process is altered. Instead of laying the railing halfway across the end post, it is laid so that approximately 1 foot of the railing projects beyond the post. When scribing the bottom of the railing, it is scribed on both sides of the post. The depth notches are performed in the same fashion as previously described except the notch is the full width of the post. The scribe across the end of the railing is not required because the notch is removed approximately 12 inches from the end of the railing. (See Figure 15.51.) The scribing and notching of the railing around the second post is unchanged.

When removing the notch that will accept the end post, perform the cut across the bottom of the railing at both locations scribed, using the lines on the top and sides to keep the cut plumb and square. Use the depth lines to control the depth of the cut. Next, make additional saw cuts between the two notch cuts. These cuts should be approximately 3/8 to 1/2 inches apart and should be as deep as the two outside notch cuts. Again, use the 1 1/2–inch lines marked on both sides of the railing to monitor the depth of the saw cuts. (See Figure 15.52.) Once the saw cuts are complete, a wood chisel or straight claw hammer is used to snap off the thin pieces of wood between the saw cuts. A wood chisel and rasp can then be used to smooth out the bottom of the notch and achieve a uniformly flat and square notch. When complete, place the railing on the two posts. If it fits tightly as described above, it is ready to be fasten to the post. If not, use a wood chisel or rasp to adjust the notch until it fits properly.

The railing is fastened to the posts using galvanized 40d nails. Pilot holes are drilled through the railing and posts to reduce splitting. The twist bit for the pilot hole should be 1/16 inch less than the shank of the fastener. The fasteners are driven in at an angle to provide better attachment to the posts and reduce splitting. (See

Figure 15.53.) The heads of the nails are set flush with a drift punch. Note, because of the steep angle, setting the nails deeper will likely result in splitting the railing.

Once the first railing is secured, the next railing is set on top of the second and third posts in the same fashion. When the railing is set on the second post, it is shoved tightly against the previously installed railing. Depending on the quality of the cuts, there may be small gaps between the ends of these two railings. If so, hold the second railing tightly, and, keeping it firmly against the end of the first railing, set a handsaw flush against the end of the second railing. This portion of the second railing is protruding 1 1/2 inches above the two railings because this railing has not been notched yet. Using the end (face) of the second railing as a guide, saw straight down between the ends of the two railings to remove the wood that was preventing the two ends of the railings from fitting tightly together. Sometimes it may take two or three cuts to accomplish the desired fit.

Once a tight fit is achieved, the second railing is scribed and notched as previously described. If another railing is needed, it will end lying halfway across the third post and the same scribing and notching procedures are applied. If it is the last railing, the end will be scribed and notched in the same fashion as the first railing.

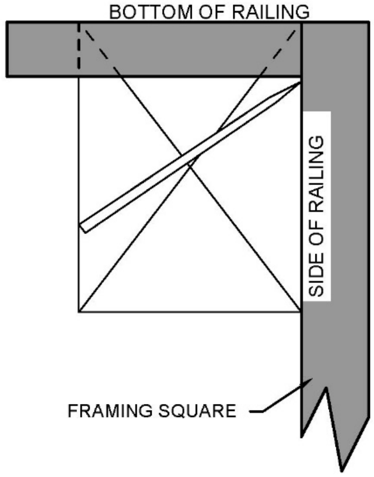
15.6.7. Bull Rails

If required, bull rails are installed after the posts and top railings are assembled as previously described in the section on puncheon construction.

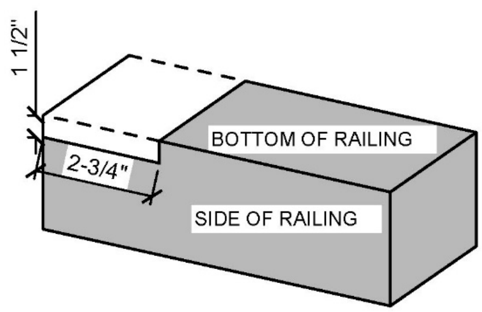
15.6.8. Diagonal Rails

After all the posts, top railings, and bull rails (if required) are installed, the diagonal rails are installed. The diagonal rails provide an additional safety barrier under the top railing and between the posts. Generally, the diagonal rails are installed so they are angled in the same direction, however, any pattern can be applied by the trail designer. For the purposes of this discussion, the diagonal rails will be installed at the same angle and direction. Since they are installed diagonally between the posts, they need to be 1 to 2 feet longer than the top railing, depending on the prescribed finished height.

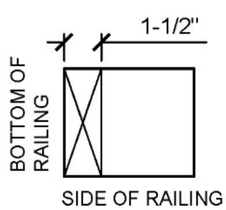
Starting at the end of the boardwalk, the diagonal rail is laid so one end is resting on the decking on the inside of the first post, while the other end is held against the inside of the second post just below the intersection of the top railing. Next, the end of the diagonal rail resting on the decking is placed so the bottom corner is at the intersection of the first post and the decking. The bottom corner of the diagonal rail should be flush against the inside of the post. Then, the upper end of the diagonal rail is held so the top of the diagonal rail is at the intersection of the post and the bottom of the top rail. The inside of the diagonal rail should be flush against the inside of the post and top rail. (See Figure 15.54.)



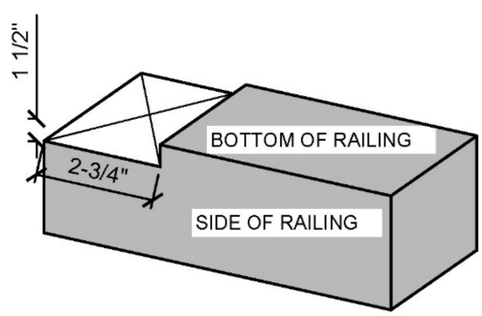
1. WHILE THE RAILING IS UPSIDE DOWN, HOLD THE FRAMING SQUARE ALONG THE END FACE OF THE RAILING SO THE INSIDE OF THE HANDLE IS RESTING AGAINST THE SIDE OF THE RAIL AND THE OUTSIDE OF THE TONGUE IS EVEN WITH THE BOTTOM OF THE RAIL. SCRIBE A LINE DOWN THE INSIDE OF THE SQUARE'S TONGUE TO THE INTERSECTION OF THE SQUARE'S HANDLE.



2. LAY THE RAILING SO THE BOTTOM IS FACING UP. SAW VERTICALLY INSIDE OF SCRIBED LINE DOWN TO HORIZONTAL LINE ($1\frac{1}{2}$"). USE THE LINES ON TOP AND SIDES OF THE RAIL TO KEEP SAW CUTS PLUMB. USE HORIZONTAL LINES ON THE SIDES OF THE RAILING TO CONTROL DEPTH OF CUT.



3. LAY THE RAILING ON ITS SIDE SO THE LINE SCRIBED ON THE END OF THE RAIL IS VERTICAL. SAW VERTICALLY INSIDE OF SCRIBED LINE (X) DOWN TO HORIZONTAL LINE ($2\frac{3}{4}$"). USE THE LINES ON SIDES OF THE RAIL TO KEEP SAW CUTS PLUMB. USE HORIZONTAL LINES ON THE SIDES OF THE RAILING TO CONTROL DEPTH OF CUT.



4. REMOVE PARTIAL NOTCH

Figure 15.50 - Scribing Notch & Cutting Out the Notch (Partial Notch)

SCRIBING NOTCH & CUTTING OUT THE NOTCH (PARTIAL NOTCH)

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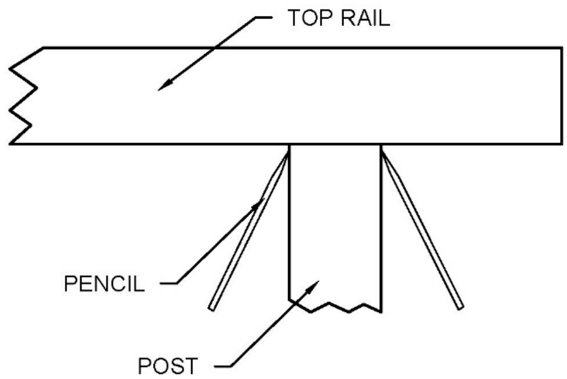
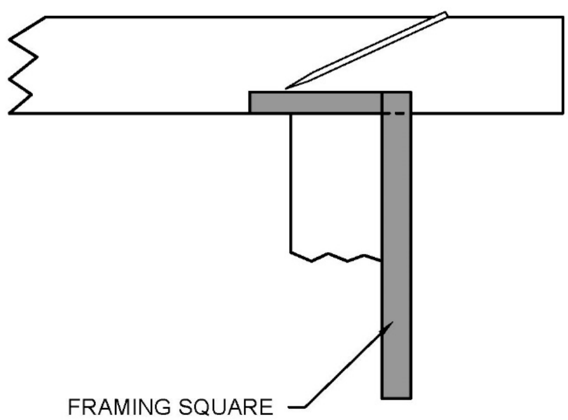
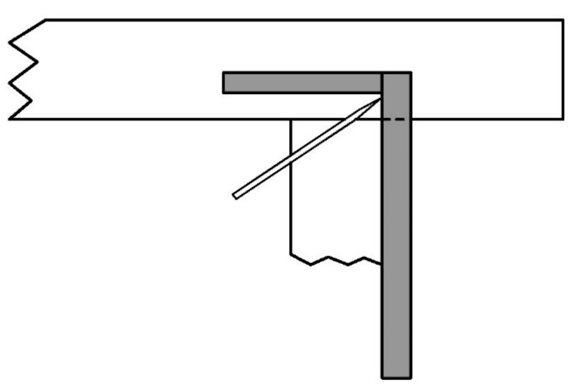
NOT TO SCALE



1. WITH THE TOP RAIL SPANNING APPROXIMATELY 1' PAST THE END POST, SCRIBE TWO LINES UNDERNEATH THE TOP RAIL WHERE IT INTERSECTS WITH THE POST.



2. HOLD THE FRAMING SQUARE SO THE INSIDE OF THE HANDLE IS RESTING AGAINST THE POST AND INSIDE OF THE TONGUE IS EVEN WITH THE TOP OF THE POST. SCRIBE A LINE, ON THE TOP RAIL, ACROSS THE TOP OF THE TONGUE FROM THE INTERSECTION OF THE POST AND RAIL TO THE INSIDE INTERSECTION OF THE TONGUE AND HANDLE OF THE SQUARE.



3. HOLD THE FRAMING SQUARE SO THE INSIDE OF THE HANDLE IS RESTING AGAINST THE POST AND INSIDE OF THE TONGUE IS EVEN WITH THE LINE JUST SCRIBED. SCRIBE A LINE, ON THE TOP RAIL, DOWN THE INSIDE OF THE SQUARE'S HANDLE TO THE INTERSECTION OF THE RAIL AND POST. REPEAT ON THE OTHER SIDE OF THE POST.

Figure 15.51 – Scribing Top Rail Notches (Full Notch)

SCRIBING TOP RAIL NOTCHES (FULL NOTCH)

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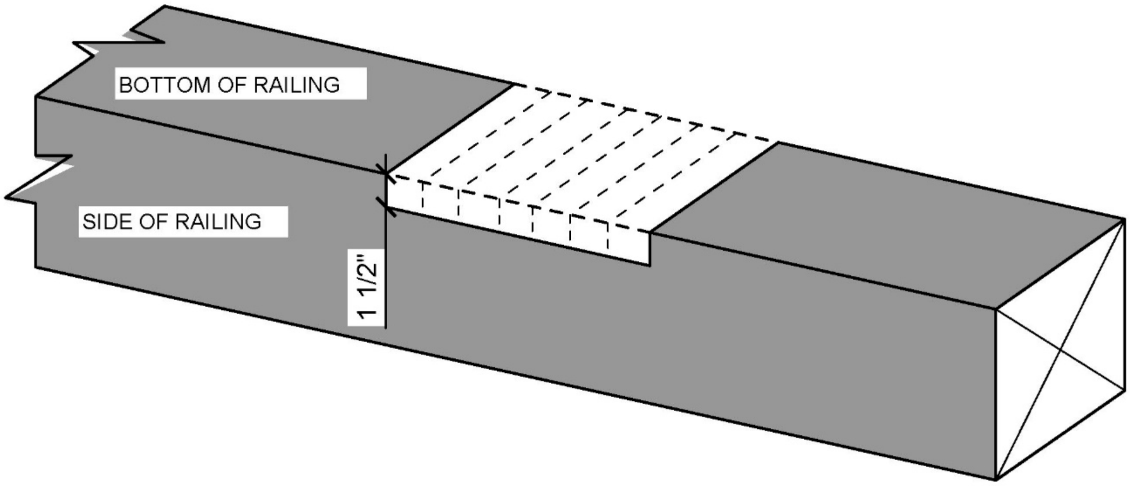
NOT TO SCALE

1. LAY THE RAILING SO THE BOTTOM IS FACING UP. SAW VERTICALLY INSIDE OF SCRIBED LINES DOWN TO HORIZONTAL LINE (1 1/2"). USE THE LINES ON TOP AND SIDES OF THE RAIL TO KEEP SAW CUTS PLUMB. USE HORIZONTAL LINES ON THE SIDES OF THE RAILING TO CONTROL DEPTH OF CUTS. MAKE SAW CUTS APPROXIMATELY 3/8" APART ACROSS THE NOTCH.



2. USE A STRAIGHT CLAW HAMMER OR A WOOD CHISEL TO BREAK OUT THE WOOD BETWEEN THE SAW CUTS. THEN USE A WOOD CHISEL TO CLEAN OUT THE BOTTOM OF THE NOTCH. LEVEL AND SMOOTH THE BOTTOM OF THE NOTCH WITH A WOOD RASP.

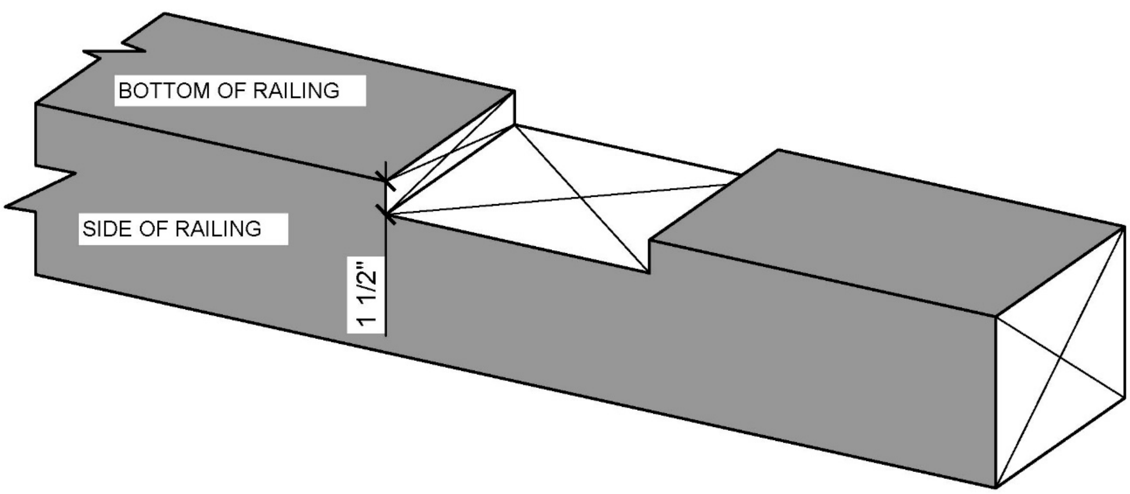


Figure 15.52 – Scribing Notch & Cutting Out the Notch (Full Notch)

SCRIBING NOTCH & CUTTING OUT THE NOTCH (FULL NOTCH)

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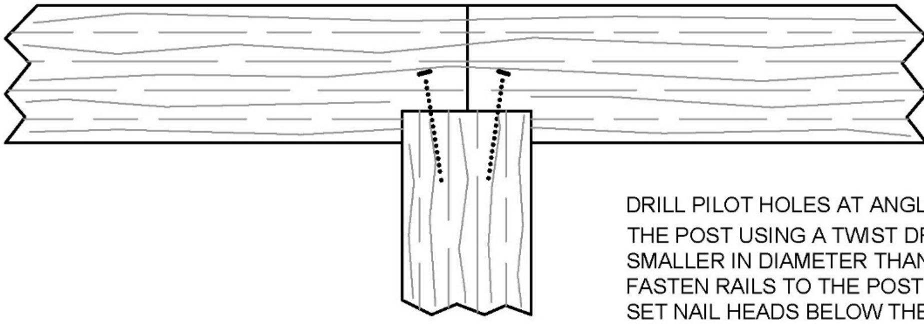
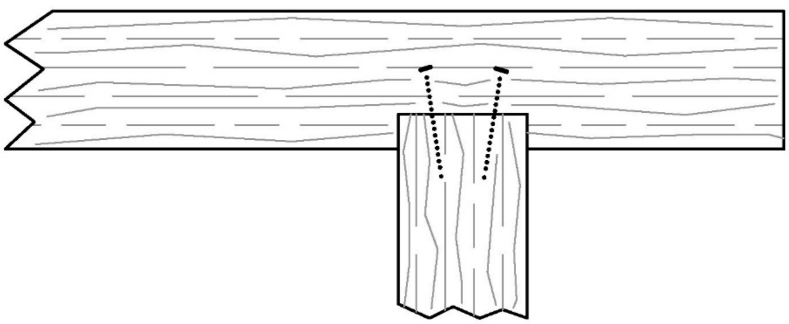
NOT TO SCALE

TOP RAIL BUTTED ON TOP OF POST



DRILL PILOT HOLES AT ANGLE TOWARDS THE CENTER OF THE POST USING A TWIST DRILL BIT APPROXIMATELY $\frac{1}{16}$" SMALLER IN DIAMETER THAN THE FASTENER BEING USED. FASTEN RAILS TO THE POST USING 40d GALVANIZED NAILS. SET NAIL HEADS BELOW THE SURFACE OF THE RAIL USING A PUNCH.

TOP RAIL NOTCHED ON TOP OF POST



DIAGONAL RAIL

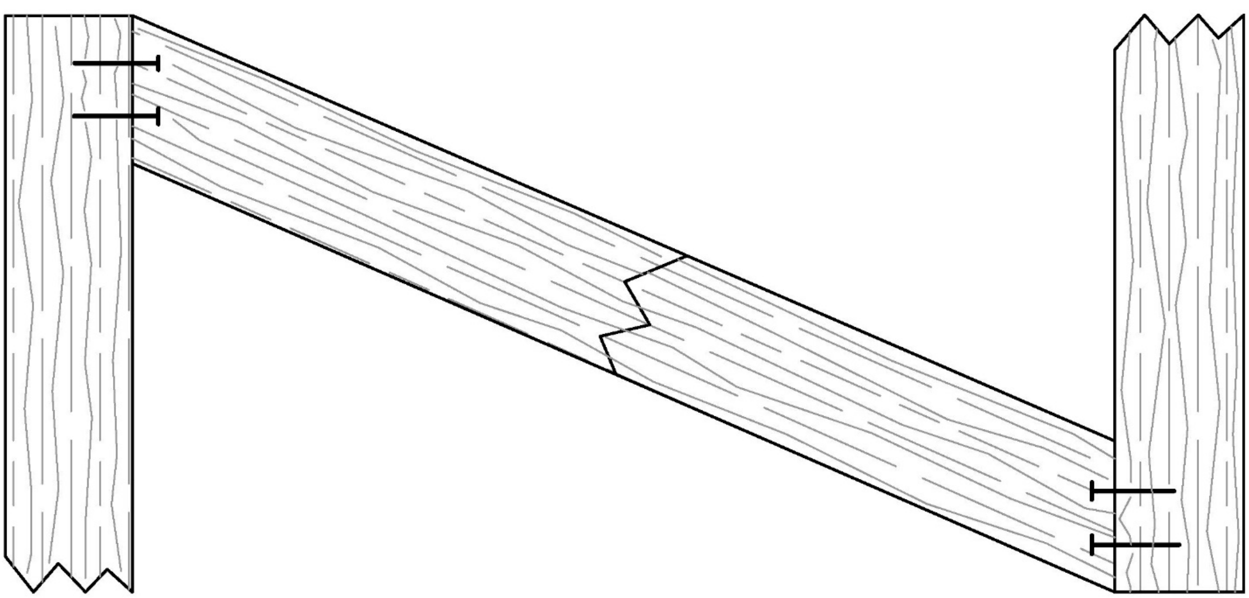


Figure 15.53 – Nailing Patterns for Handrails

NAILING PATTERNS FOR RAILING

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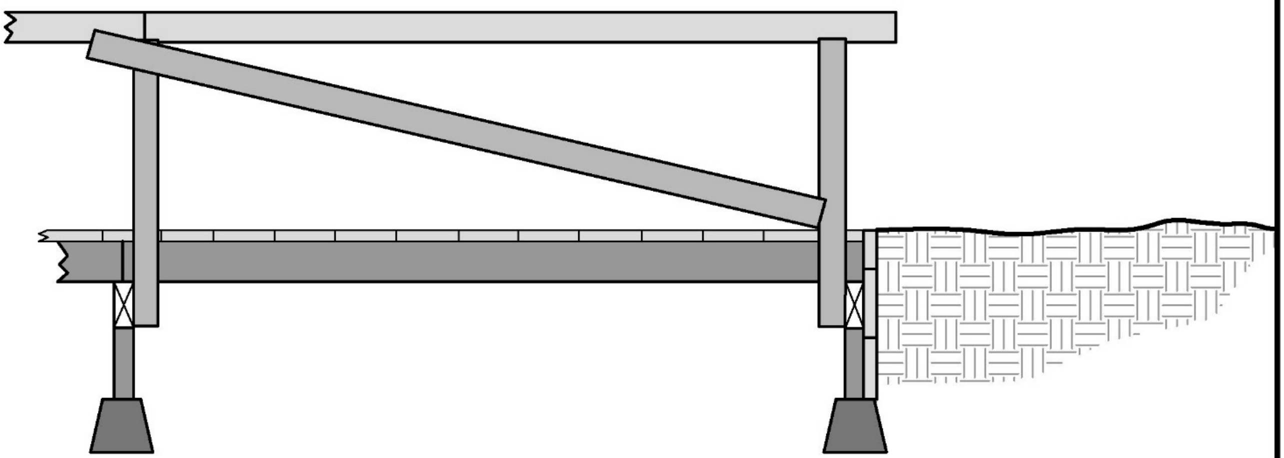
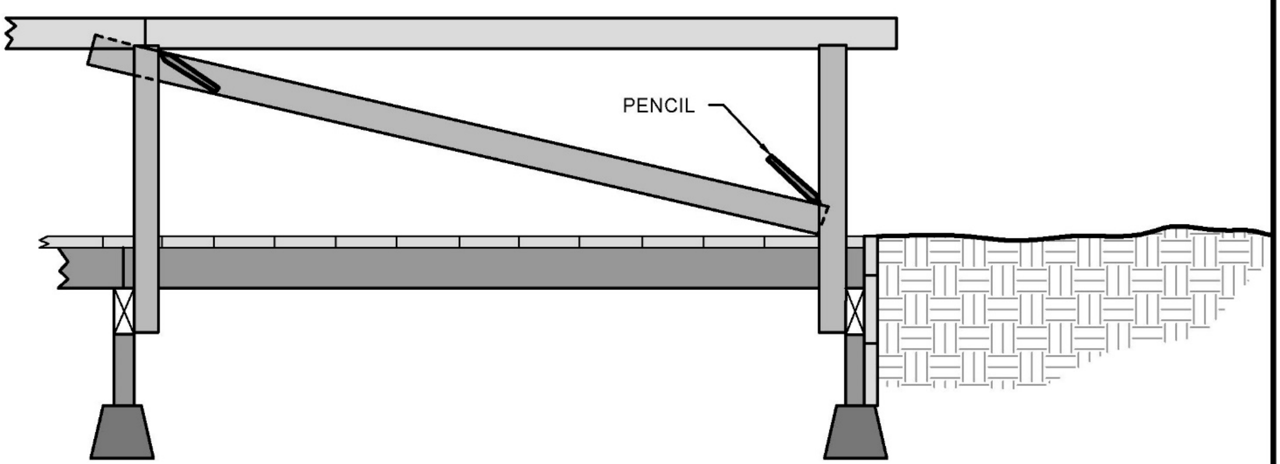
NOT TO SCALE

INSIDE OF RAILING VIEW



1. PLACE THE DIAGONAL RAILING ON THE INSIDE OF THE POST WITH THE BOTTOM EDGE OF THE RAIL RESTING ON THE DECKING. THE BOTTOM CORNER OF THE RAIL SHOULD BE FLUSH WITH THE INTERSECTION OF THE POST AND THE DECKING. THE OTHER END OF THE RAIL SHOULD BE PLACED SO THE TOP OF THE RAIL IS AT THE INTERSECTION OF THE TOP RAIL AND POST.

OUTSIDE OF RAILING VIEW



2. ONCE THE DIAGONAL RAIL IS IN THE PROPER LOCATION USE A CARPENTERS PENCIL TO SCRIBE A LINE ALONG THE OUTSIDE OF THE DIAGONAL RAIL WHERE IT INTERSECTS WITH THE POST.

Figure 15.54 – Diagonal Railing Layout

DIAGONAL RAILING LAYOUT

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NOT TO SCALE

Make sure both ends of the diagonal rail are at the proper intersections. Then, hold the diagonal rail firmly in place and use a carpenter's pencil to scribe a line at both locations where the diagonal rail and post come together. (See Figure 15.54) These two lines are the angles the diagonal rail must be cut to fit inside the two posts. This layout and scribing is best performed by two people – one at each end of the diagonal rail. If working alone, the diagonal rail can be held in place with a wood or C-clamp while the lines are scribed. Note, if bull rails have been installed, the lower end of the diagonal rail is placed where the top of the bull rail and post intersect. (See Figure 15.55.)

After scribing the lines, set the diagonal rail on the saw horses and use a combination or framing square to scribe additional lines at right angles to the ends of the diagonal lines. (See Figure 15.56.) The bottom end of the diagonal rail will require one additional line. This line is across the top of the railing and will serve as a visual guide when performing the diagonal cut. Once the additional line is scribed, lay the rail on its side with the diagonal line facing up and the top line facing you. Use a hand saw to cut along the two pencil lines, leaving a portion of the pencil lines. Watch the top diagonal line, as well as the perpendicular line, when cutting through the rail. If cut along both lines, the cut will be plumb and square.

The top end of the diagonal rail will require a line on the top and bottom to serve as a visual guide when performing the diagonal cut. Once these lines are scribed, lay the rail on its side with the diagonal line facing up and the top line facing you. Use a hand saw to cut outside of the three pencil lines, leaving a portion of the pencil lines. Watch the top diagonal line, as well as the two perpendicular lines when cutting through the rail. If cut along all three lines, the cut will be plumb and square. (See Figure 15.56.)

After cutting both ends, set the rail so it sits just inside of the two posts at the correct angle. Slowly slide both ends of the diagonal rail toward the outside of the post. Note that the railings are intended to fit tightly. If one end is slid in first or gets ahead of the other end, the diagonal rail will bind up between the two posts. If the diagonal rail is too tight, do not force it between the posts because it will drive the two posts apart, making them out of plumb and ruining the notching just performed. If the fit is too tight, remove the rail and look at the cut ends for signs of scuffing or wood compression. Also look at the inside of the two posts for similar marks. Then, use a pencil to outline these "high" areas on the cut ends that are causing the bind. Use a wood rasp to cut down these areas; then re-insert the diagonal rail. If it still is too tight, repeat the process until it fits. Be cautious not to remove too much wood at once because it cannot be replaced and will leave a gap in the railing joint.

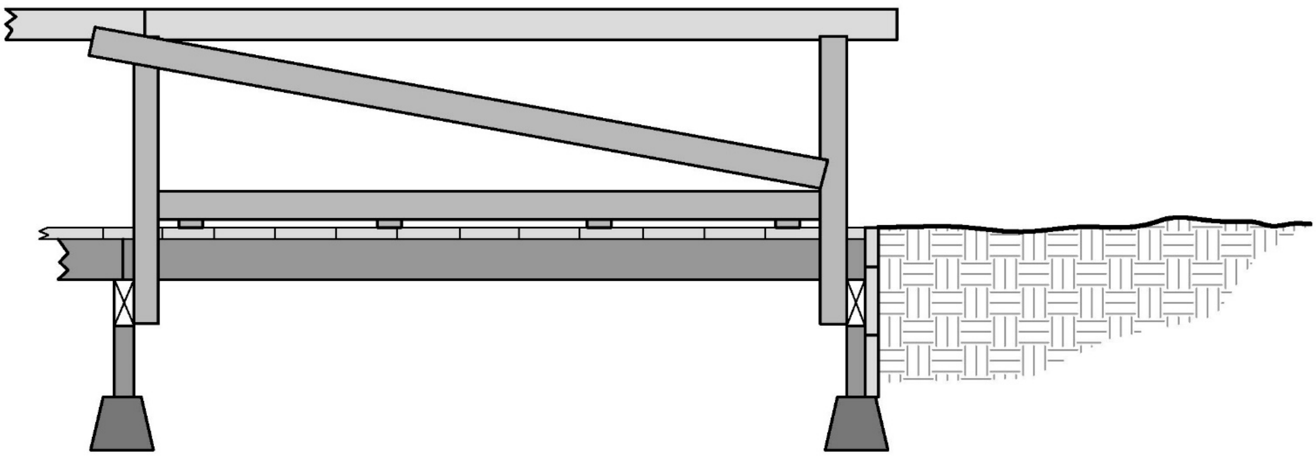
Once the proper fit is achieved, the diagonal rail is fastened in the same fashion as the top rails, with two nails driven in at an angle on both sides of the railing. (See Figure 15.53.) The rest of the diagonal rails are installed in the same fashion as just described.

After all the railings are installed, the posts and railings are sanded to remove splinters and rough areas that might injure trail users. Additional finishing work, such as rounding-off all the corners with a draw knife and rasp, can also be performed to give the structure a more rustic appearance. It is important to note that what trail users most often observe when viewing a boardwalk are the railing and decking. Quality workmanship on these two items will greatly enhance the user's appreciation of the boardwalk.

15.6.9. Project Logistics and Efficiency

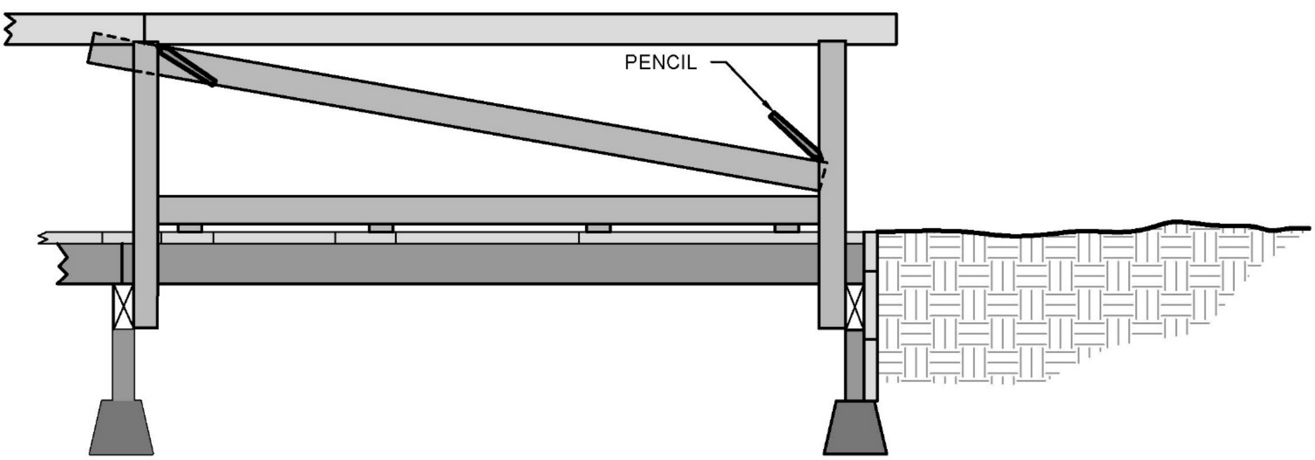
Although the individual tasks of constructing a boardwalk have been discussed in a progressive fashion, two or more of these tasks can occur at the same time. For example, posts can be installed by two trail workers while the decking is installed by two other workers. Once the first set of posts has been installed, the decking can be installed behind the post installers. Depending on the length of the boardwalk and the number of trail workers, several assembly tasks can occur at once, moving from one end of the boardwalk to the other.

INSIDE OF RAILING VIEW



1. PLACE THE DIAGONAL RAILING ON THE INSIDE OF THE POST WITH THE BOTTOM EDGE OF THE RAIL ON TOP OF THE BULL RAIL. THE BOTTOM CORNER OF THE RAIL SHOULD BE FLUSH WITH THE INTERSECTION OF THE POST AND THE BULL RAIL. THE OTHER END OF THE RAIL SHOULD BE PLACED SO THE TOP OF THE RAIL IS AT THE INTERSECTION OF THE TOP RAIL AND POST.

OUTSIDE OF RAILING VIEW



2. ONCE THE DIAGONAL RAIL IS IN THE PROPER LOCATION USE A CARPENTERS PENCIL TO SCRIBE A LINE ALONG THE OUTSIDE OF THE DIAGONAL RAIL WHERE IT INTERSECTS WITH THE POST.

Figure 15.55 - Diagonal Railing Layout with Bull Rail

DIAGONAL RAILING LAYOUT WITH BULL RAIL

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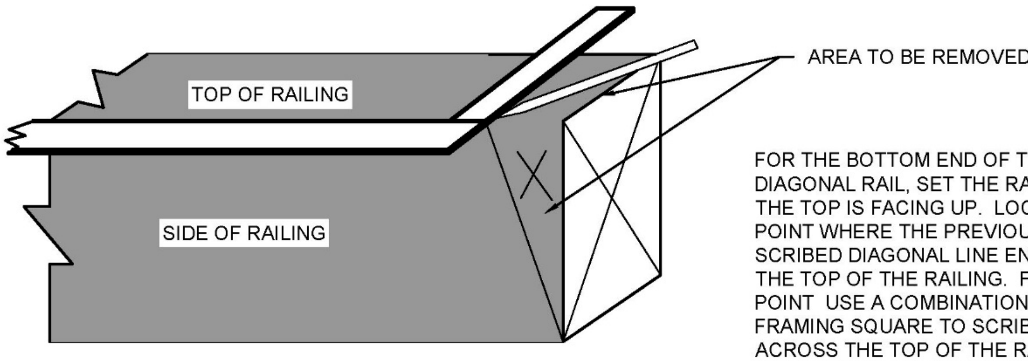
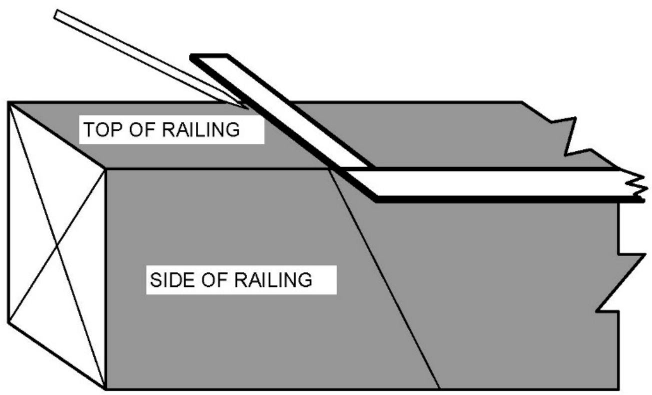
NOT TO SCALE

BOTTOM OF THE DIAGONAL RAIL



FOR THE BOTTOM END OF THE DIAGONAL RAIL, SET THE RAIL SO THE TOP IS FACING UP. LOCATE THE POINT WHERE THE PREVIOUSLY SCRIBED DIAGONAL LINE ENDS AT THE TOP OF THE RAILING. FROM THIS POINT USE A COMBINATION OR FRAMING SQUARE TO SCRIBE A LINE ACROSS THE TOP OF THE RAIL. THEN LAY THE RAIL ON ITS SIDE WITH THE LINE ACROSS THE TOP FACING YOU. USE A HAND SAW TO CUT ALONG THE OUTSIDE OF THE TWO LINES.

TOP OF THE DIAGONAL RAIL



FOR THE TOP END OF THE DIAGONAL RAIL, SET THE RAIL SO THE TOP IS FACING UP. LOCATE THE POINT WHERE THE PREVIOUSLY SCRIBED DIAGONAL LINE ENDS AT THE TOP OF THE RAILING. FROM THIS POINT USE A COMBINATION OR FRAMING SQUARE TO SCRIBE A LINE ACROSS THE TOP OF THE RAIL. FLIP THE RAIL UPSIDE DOWN AND LOCATE THE POINT WHERE THE PREVIOUSLY SCRIBED DIAGONAL LINE ENDS AT THE BOTTOM OF THE RAILING. FROM THIS POINT SCRIBE A THIRD LINE ACROSS THE BOTTOM OF THE RAIL. THEN LAY THE RAIL ON ITS SIDE WITH THE LINE ACROSS THE TOP FACING YOU. USE A HAND SAW TO CUT ALONG THE OUTSIDE OF THE THREE LINES.

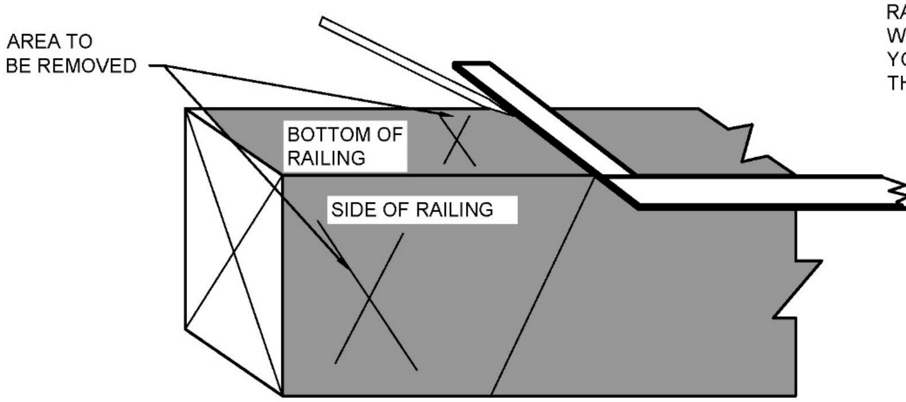


Figure 15.56 - Scribing and Cutting Diagonal Rails

SCRIBING AND CUTTING DIAGONAL RAILS

CALIFORNIA STATE PARKS

NOT TO SCALE