5.0 PHASE III DATA RECOVERY: DIAMOND POND MILL

5.1 FIELD METHODS

Diamond Pond is an artificial impoundment of Waples Branch, as it flows northward to meet the Broadkill River at the town of Milton, in Sussex County, Delaware. The pond is located on the south side of Route 319, a two-lane road south of the town that extends along the top of the mill dam constructed in the early-nineteenth century to create the pond (Figure 5-1). The roadway is carried over the outlet of Diamond Pond by Bridge 3-806, a reinforced concrete box culvert constructed ca. 1917. The bridge is located at the site of the Diamond Pond mill (7S-C-96)[1], also known as Paynter's sawmill, which operated from as early as 1815 through the end of the nineteenth century. The proposed upgrade of Route 319 and replacement Bridge 3-806 prompted archaeological investigation of the site to determine whether evidence of the mill remained in that location.

Submerged mill-related resources had been tentatively identified by local informants, reportedly downstream, or north of, the bridge culvert. The presence of the resources was confirmed by archaeological survey teams. Investigation of the remains using traditional archaeological methods prior to construction disturbance appeared impractical given the relatively deep, flowing water. Following procedures used in previous bridge replacement work conducted on behalf of DelDOT (e.g., Resnick and Frye 2005; Crane et al. 2003), the archaeological investigation was scheduled as a task within the demolition and construction sequence. The construction contractor removed the existing deck of the bridge as per contract, with an architectural historian on site to record the features underlying the modern road surface as they were exposed. Section 4.3.5 of this report contains a description of the findings. An archaeologist was also on hand to monitor the process and to document any archaeologically significant deposits that might be revealed or disturbed. None were noted.

The contractor erected coffer dams on the upstream and downstream sides of the bridge in order to control water flow and provide a dry environment for construction of the new culvert, deck, and road surface (Figure 5-2, 5-3). A 12-inch pump redirected water from the upstream side of the dam (the north or pond side) over and around the bridge, returning it to the stream below or south of the downstream coffer dam. Several additional, smaller pumps were used to control back flow and seepage within the downstream coffer dam, within which the archaeological work was conducted.

Erecting the coffer dams caused relatively little disturbance south of the bridge. Based on maps of existing conditions, the eastern bank of the stream was minimally disturbed—vegetation remained on the upper slope at the time of the archaeological investigation, indicating that the slope existing prior to construction was undisturbed. The top of the western bank, in contrast, had been lowered several feet. A silt fence was installed along the verge, and the slope to the stream had been cut back 2-3 feet from the original pool line. Water stood 3-4 feet deep immediately downstream from the culvert. Interlocking corrugated metal sheet pilings were driven approximately 20 feet into the ground using a

[1] a complete Delaware CRS form is included in Appendix B.

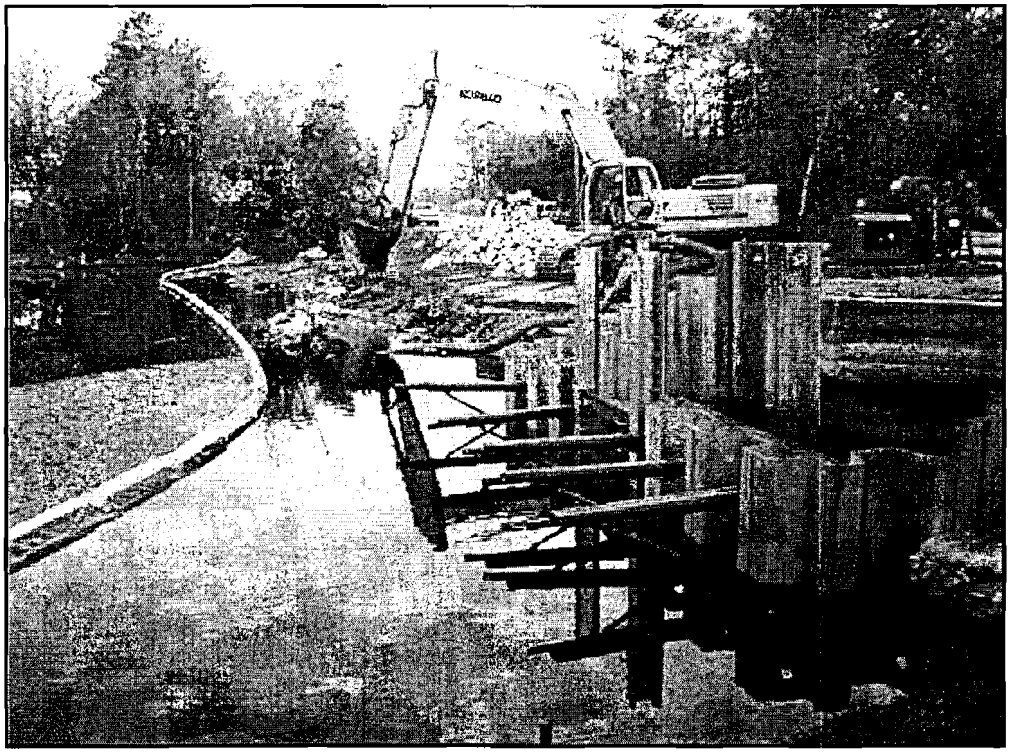


Figure 5-2. Cofferdam on the Upstream (millpond) Side of the Bridge.

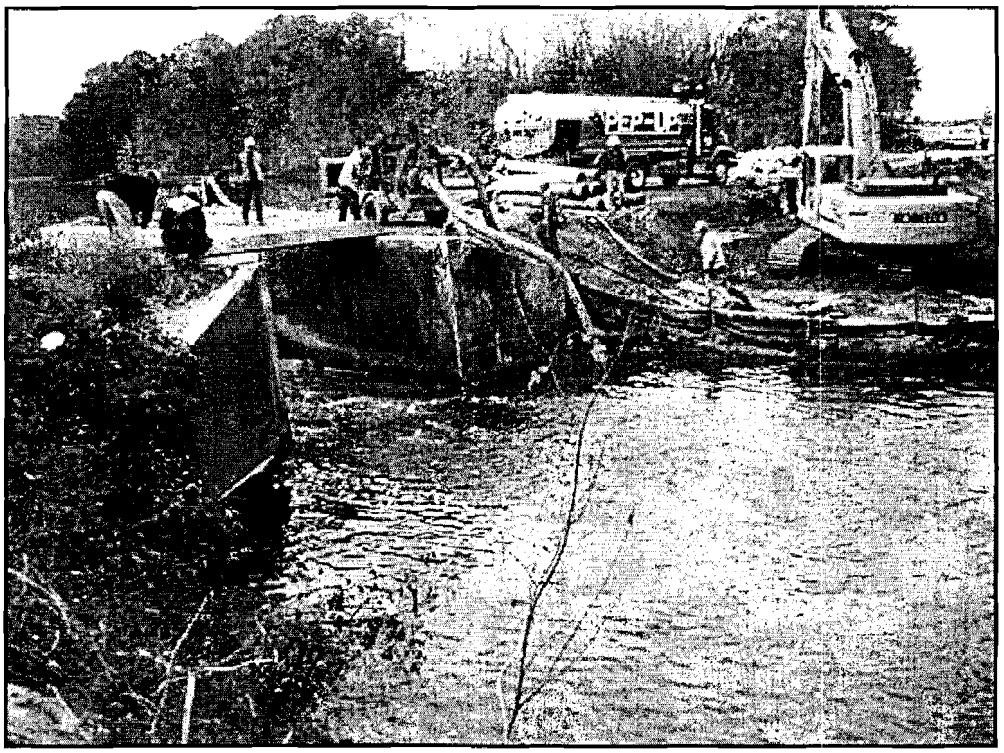


Figure 5-3. Pumps on the Downstream Side of the Bridge.

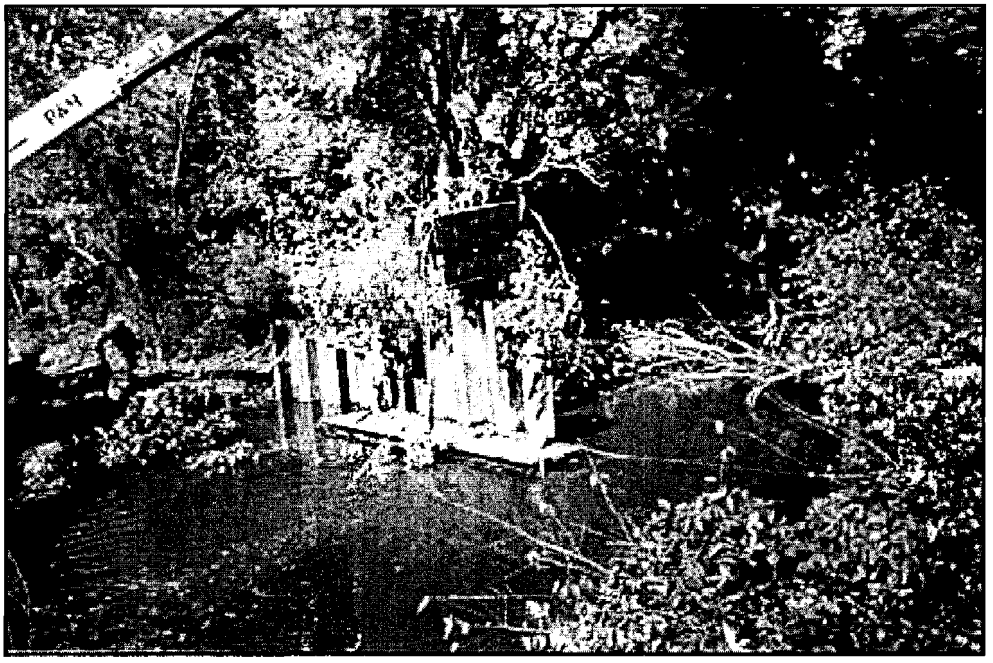


Figure 5-4. Installing Sheet Pilings for the Downstream Section of the Coffer Dam.

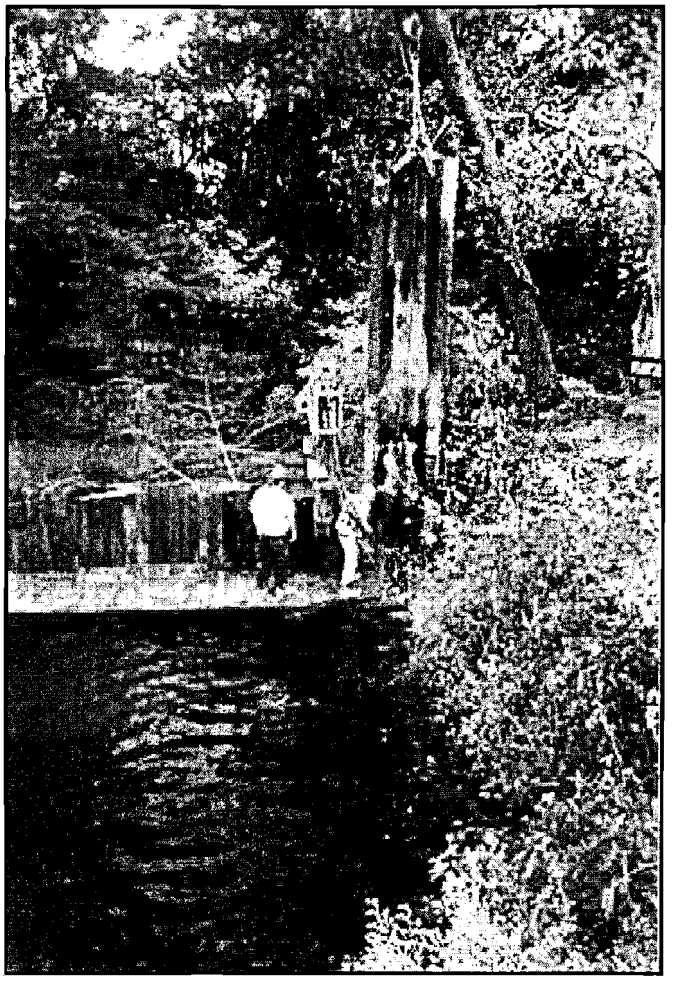


Figure 5-5. Driving Sheet Pilings for the Downstream Section of the Coffer Dam.

crane and vibrator to create the coffer dams (Figures 5-4, 5-5). An archaeologist was on site to monitor the process and document potential disturbances to the historical remains.

With the water pumped out of the downstream coffer dam area, timbers related to the saw mill were exposed (Figure 5-6). Hand excavation and cleaning of the features were required to allow documentation of the features (Figures 5-7, 5-8). Documentation consisted of mapping the general layout of the features relative to datum points established around the site area; detailed drawing and photo-documentation of each exposed timber (Figures 5-9, 5-10); and eventually the removal of the timbers along with a sample of posts and wooden sheet pilings associated with the mill structure. Excavation and removing the timbers and posts was carried out with the aid of a mini-excavator (Figure 5-11). Trenches were cut through portions of the site following removal of the timbers to determine whether additional structural elements lay buried beneath the present stream bed. Finally, excavation was conducted along the exposed west bank of the stream to determine whether associated structures might be present in that area. All of these excavations were conducted with the aid of the mini-excavator. Note that in contrast to the survey portion of the project, reported earlier in the text, field measurements related to documentation of the mill were recorded in feet and inches, since those would have been the original units of measurement in which the mill had been designed and constructed.

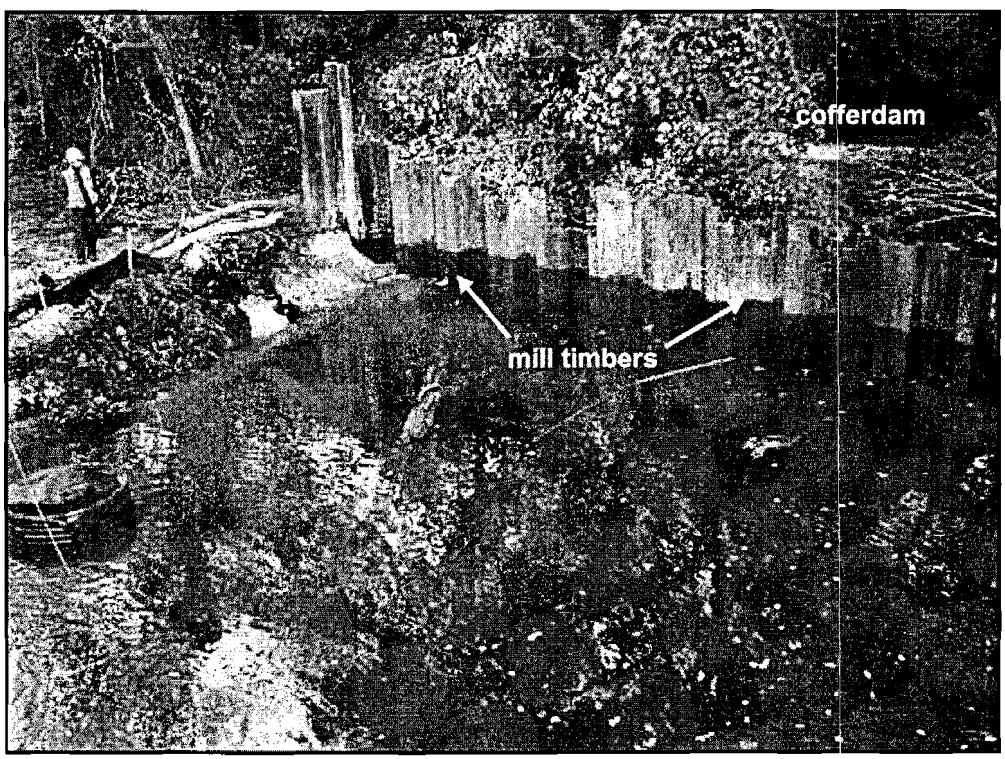


Figure 5-6. Cofferdam on the Downstream Side of the Bridge Showing Exposed Mill Timbers As Water is Pumped Out.

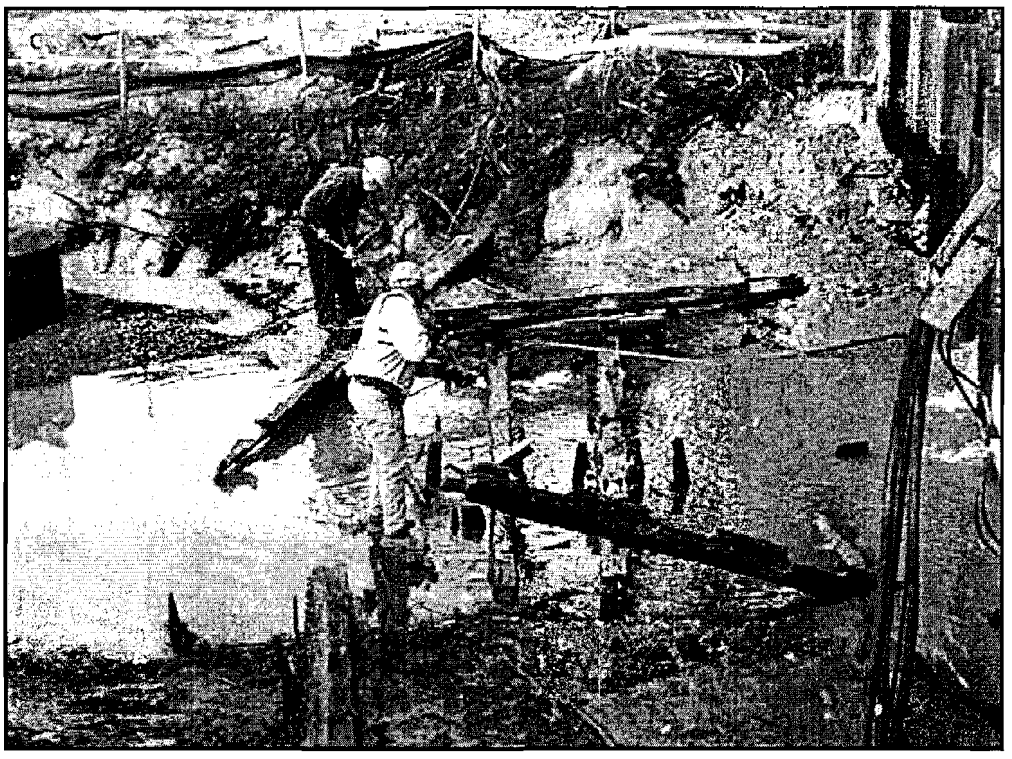


Figure 5-7. Mill Timbers Being Washed and Cleaned.

Figure 5-8. Cleaning the Mill Timbers.

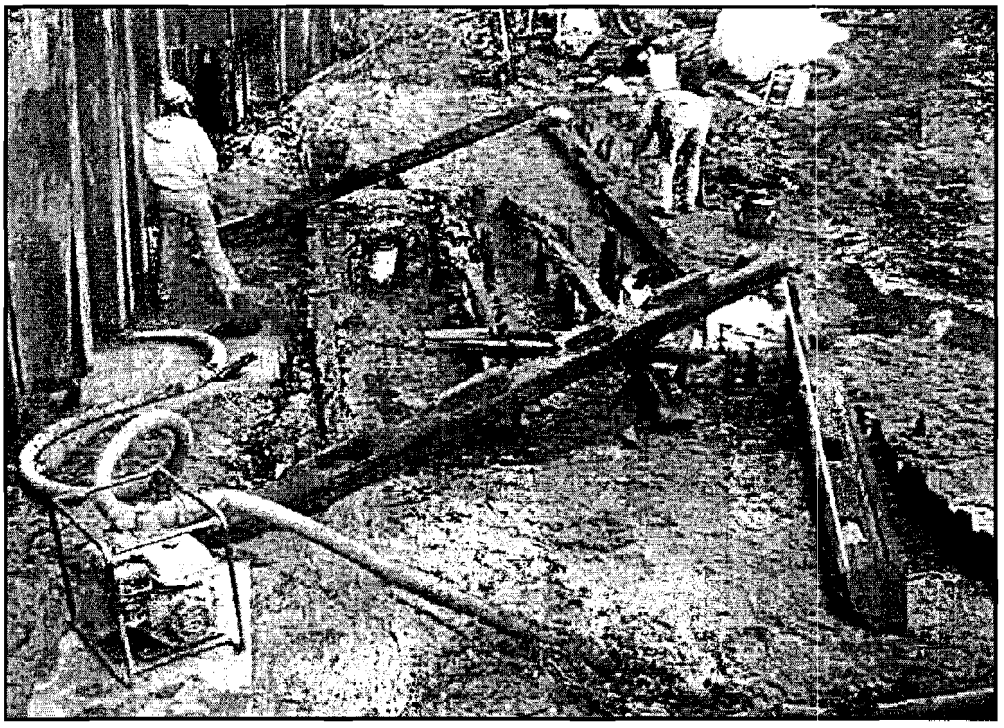


Figure 5-9. Drawing and Mapping the Mill Timbers.

Figure 5-10. Drawing and Mapping the Mill Timbers.

Figure 5-11. Mini-Excavator Helping Remove Posts and Sheet Pilings.

5.2 ARCHAEOLOGICAL FINDINGS

5.2.1 General Conditions

The archaeological remains at the Diamond Pond sawmill (7S-C-96) consisted of wooden structural elements lying in the bed of Waples Branch as it flows northward out of Diamond Pond beneath Bridge 3-806. The remains appeared to be those of the saw mill that stood in this location as early as 1815. The main features of the site consisted of a series of semi-articulated timbers, several disarticulated but related timbers, and associated posts and wooden sheet piles (Figure 5-12). All of the wood was waterlogged and discolored, and most of the pieces were extensively weathered from long-term exposure to running water.

Additional timbers were identified south of the mill structure. These features consisted of cribbing situated beneath the modern concrete culvert and were not part of the nineteenth-century mill.

5.2.2 Structural Features

The main features consisted of a series of large timbers that had originally been joined to form a single rectilinear framework. While none of the timbers remained connected, tenons and mortises were present suggesting the original structural plan. For identification purposes, each timber was numbered as it was mapped and drawn (Figure 5-13). The

timbers are individually described below, with estimates of their original dimensions, where possible, as well as indications as to other timbers with which they may have been associated or articulated. These detailed observations, including accurate information about the locations of mortise and tenon joints, allowed the analytical reconstruction of the framework. In addition, numerous posts and sheet pilings were present in and around the structure. Each of these elements was mapped, and a sample removed and recorded in detail, as described below. Timbers 9 through 12 were associated with cribbing beneath the concrete culvert of the twentieth-century bridge. They are described separately, following descriptions of all of the nineteenth-century mill-related elements.

Note that estimates of the original widths of the timbers were based on identification of unweathered surfaces, where present, or on measurements of the distances between nail heads. The latter estimate was based on the assumption that the nails secured sheet pilings to the original face of the timber, and that the nails have maintained their original positions. The thicknesses of the planks were factored into the calculation (Figure 5-14).

Timber 1

Measured Dimensions:	Length:	16 feet 9 inches
	Width:	6.5 inches
	Thickness:	5.5 inches
Estimated Dimensions:	Length:	17 feet
	Width:	10 inches
	Thickness:	10 inches

Wood Species: white oak

Description: Timber 1 was the northernmost of three cross members that were visible at the base of the mill structure. The timber lay across the watercourse, approximately perpendicular to the axis of the stream (Figure 5-15). Tenons were present at both ends, each measuring approximately 6 inches long, 7 inches wide, and 2 inches thick. The tenons were oriented vertically, and no evidence of peg holes was noted. The wood was deteriorated, but the original dimensions of the timber were estimated from the positions of nails along its northern face, as well as from the width of the tenons, which appeared to be relatively unweathered.

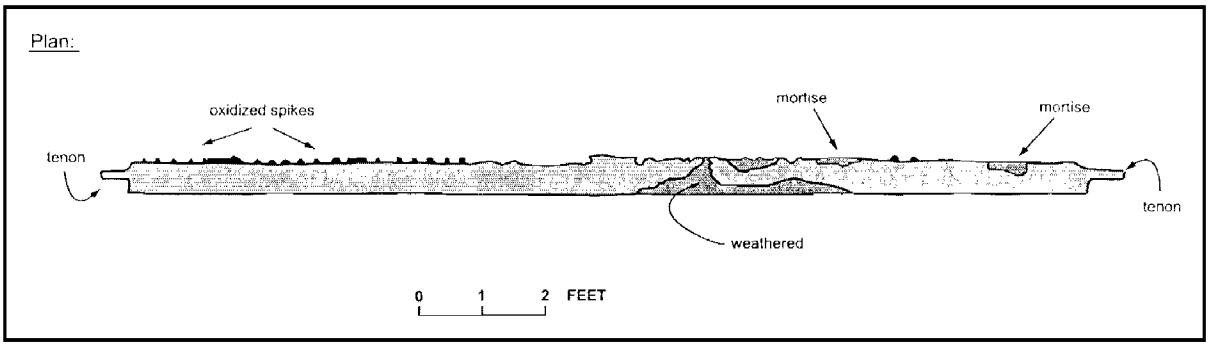


Figure 5-15. Timber 1, Plan View (elevation not drawn).

Two mortises had been cut into the north face of the timber, east of center (Figure 5-16). Each notch measured 3.5 inches wide, 7-8 inches long, and 4-4.5 inches deep. The mortises had been cut into the lateral face of the timber and extended through the upper face, apparently due to weathering from the persistent water flow across the mill structure. Tenoned timbers that might fit into the mortises were not present. The original, unweathered dimensions of the mortises were estimated at 3x9x6 inches, based on the dimensions of less weathered tenons and mortises present on other timbers.

Sheet pilings were situated along the northern (downstream) face of the timber (Figure 5-17). The sheets consisted of milled pinewood, cut with a reciprocating saw, and they were present in two sizes: 1x8 inches and 1x10 inches. The end of each plank was double-beveled, planed to a point relative to its thickness, and finished with a single bevel relative to its width (Figure 5-18). The pointed finish allowed the planks to be driven more easily into the clayey subsoil, while the single bevel acted to force each plank against the adjacent piece (Figure 5-19). As the wood became wet and swelled, pressure on the joint would have increased, producing a watertight fit.

The alignment of sheet plies extended beyond both ends of Timber 1: an additional 6 feet to the east, and 4.5 feet to the west. At the eastern end, the sheets were smaller sizes, consisting of 1x8-inch planks. The remaining sheets were 1x10-inch planks. A series of closely spaced cut nails located along the north face of Timber 1 indicated that the sheets were originally connected to the timber. In two locations, one near the eastern end of the alignment and one near the center, beneath Timber 1, a single 1x10-inch sheet had been placed perpendicular to the south face of the alignment.

Figure 5-16. Timber 1, view west.

Figure 5-17. Sheet Pilings east of Timber 1, view north.

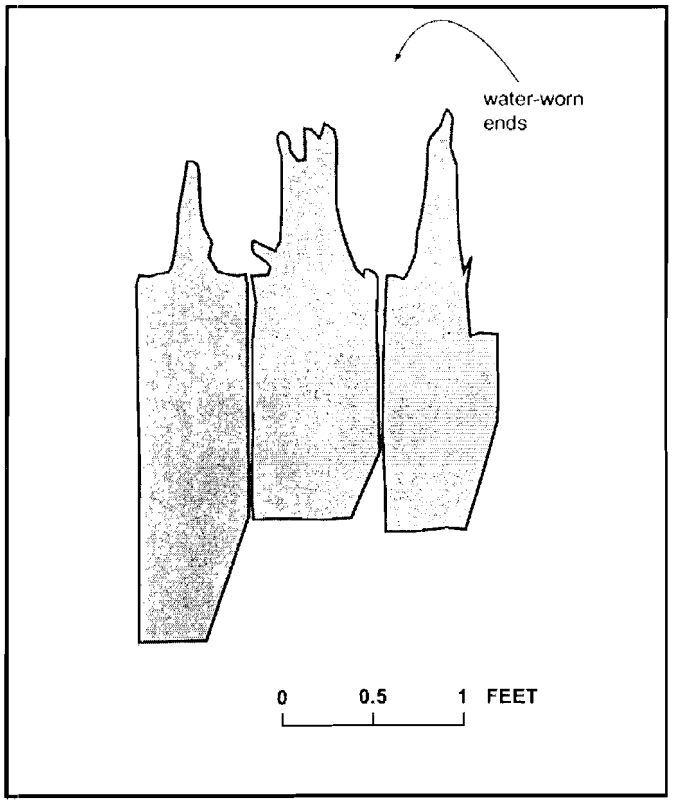


Figure 5-18. Excavated Sheet Pilings Showing Single Bevel at Ends.

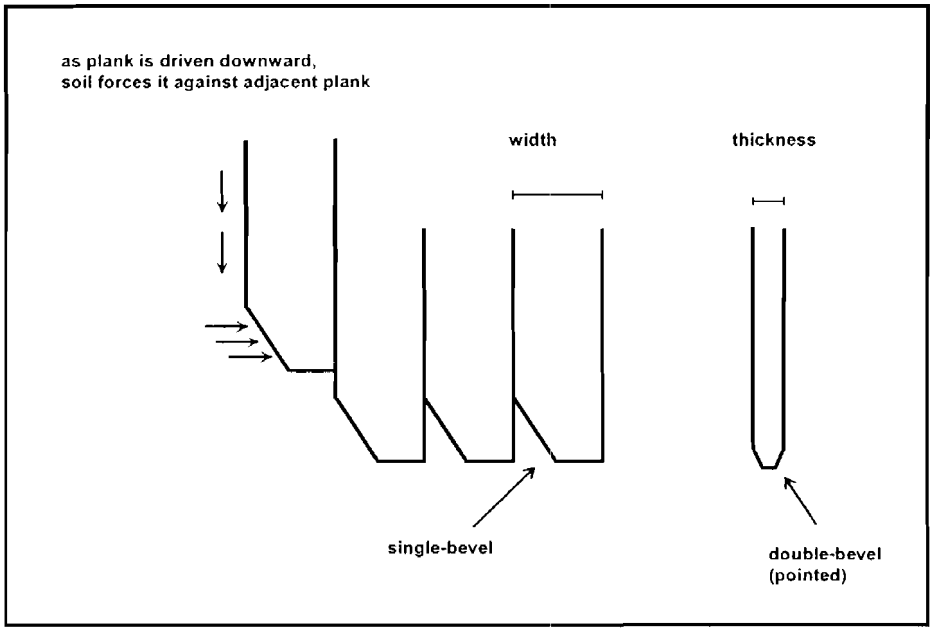


Figure 5-19. Schematic Diagram of Sheet Piling Installation.

No structural supports were found directly beneath Timber 1, but posts or structural pilings were located north and south of the timber.

Timber 2

Measured Dimensions: Length: 16 feet 9 inches
Width: 9.5 inches
Thickness: 8.5 inches

Estimated Dimensions: Length: 17 feet
Width: 12 inches
Thickness: 12 inches

Wood Species: white oak

Description: Timber 2 was the second of three cross members that were visible at the base of the mill structure (Figure 5-20). The timber lay across the watercourse, approximately perpendicular to the axis of the stream and parallel with Timbers 1 and 3. All three parallel timbers were evenly spaced on 3-foot centers. Tenons were present at both ends of Timber 2 (Figure 5-21). Each measured approximately 6 inches long, 7 inches wide, and 2 inches thick. The tenons were oriented horizontally, and each contained a peg hole to secure the attachment with the respective mortise. The peg holes were badly weathered and thus

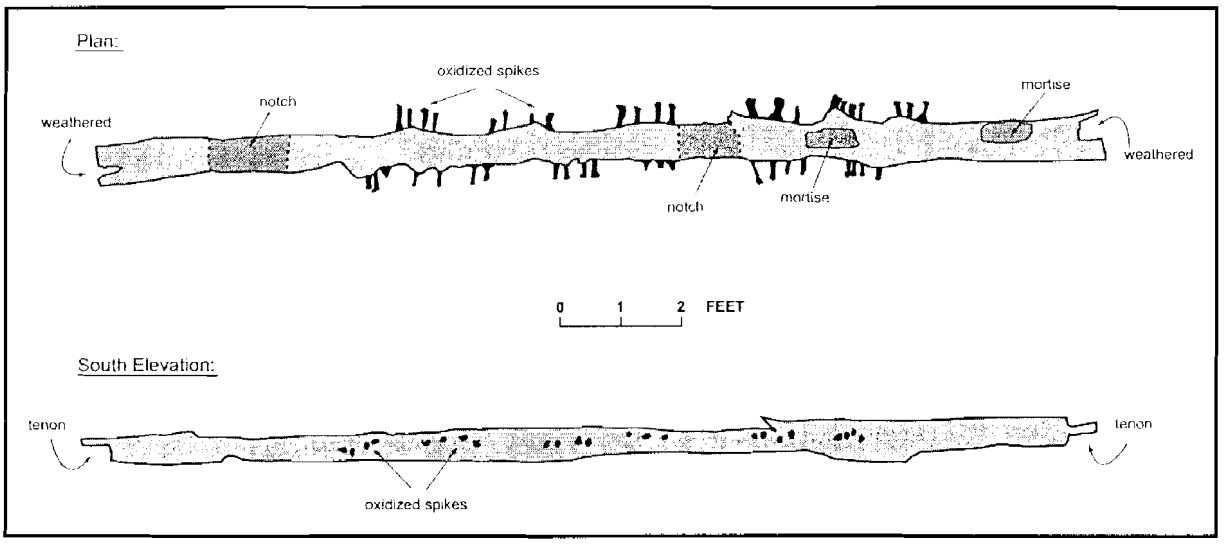


Figure 5-20. Timber 2, plan view and south elevation.

dimensions could not be measured. The wood comprising the remainder of the timber was also deteriorated. The original dimensions of the piece, as listed above, were estimated from the positions of nails along the northern and southern faces (16 inches) minus the thickness of the sheet pilings the nails had been driven through (2 inches each).

Figure 5-21. Mortise, Tenon, and Peg Hole on the East End of Timber 2.

Two mortises were cut into the upper face of Timber 2, with centers approximately 1.5 and 4.5 feet from the eastern end of the timber. The mortises measured approximately 3.5 inches wide, 10-11 inches long, and 4-4.5 inches deep. They were extensively weathered, the easternmost example having worn through the north face of the timber. Based on the dimensions of mortises and tenons present on less weathered timbers, the original dimensions of the mortises on Timber 2 were estimated to have been 3x9x6 inches. A small iron plate lay at the base of the western mortise, measuring approximately 2x4 inches.

Wide and deep notches had been cut into the upper face of the timber, positioned to receive a second course of structural elements that were no longer present (Figure 5-22). The notches were badly weathered, measuring 12-15 inches wide and at least 3 inches deep.

Wooden sheet pilings lined both the north and south faces of Timber 2. The sheets consisted of 2x10-inch planks. Nail patterns on both faces of the timber indicated the original attachment of the sheets. None of the pilings associated with Timber 2 was removed during the current archaeological investigation, but on the basis of the 2x10-inch sheets from other locations, the planks would have consisted of milled pinewood cut with a reciprocating saw. The ends that were driven into the subsoil would have had bi-pointed bevels relative to thickness, and single bevels relative to width (see Figure 5-19).

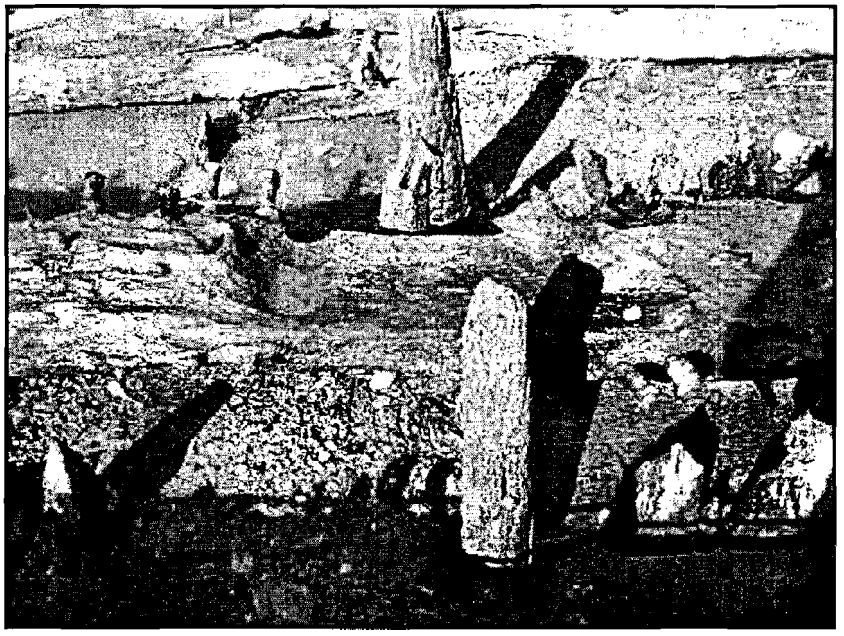


Figure 5-22. Notch in East Portion of Timber 2.

Timber 3

Measured Dimensions:	Length:	16 feet 9 inches
	Width:	9 inches
	Thickness:	5.5 inches
Estimated Dimensions:	Length:	17 feet
	Width:	12 inches
	Thickness:	12 inches

Wood Species: white oak

Description: Timber 3 was the southernmost of three intact cross members that were visible at the base of the mill structure. The timber lay across the watercourse, approximately perpendicular to the axis of the stream and parallel with Timbers 1 and 2. The three timbers were evenly spaced on 3-foot centers (Figure 5-23). Tenons were present at both ends of Timber 3, each measuring approximately 6 inches in length (Figure 5-24). The tenon at the western end of the timber was the least weathered, measuring 9 inches in width and 4 inches in thickness. The east tenon measured 5.5-6 inches in width and 2 inches in thickness. Both tenons were oriented horizontally. The eastern tenon exhibited an extensively weathered peg hole; no evidence of a peg hole was present on the less weathered west tenon. The timber was considerably smaller than its original configuration due to weathering. It was in fact the most weathered of the three cross timbers, possibly due to its position upstream, where it received more direct impact from the stream flow. The original dimensions of the timber as listed above were estimated from the positions of nails along the northern face as well as from the width of the relatively unweathered western tenon.

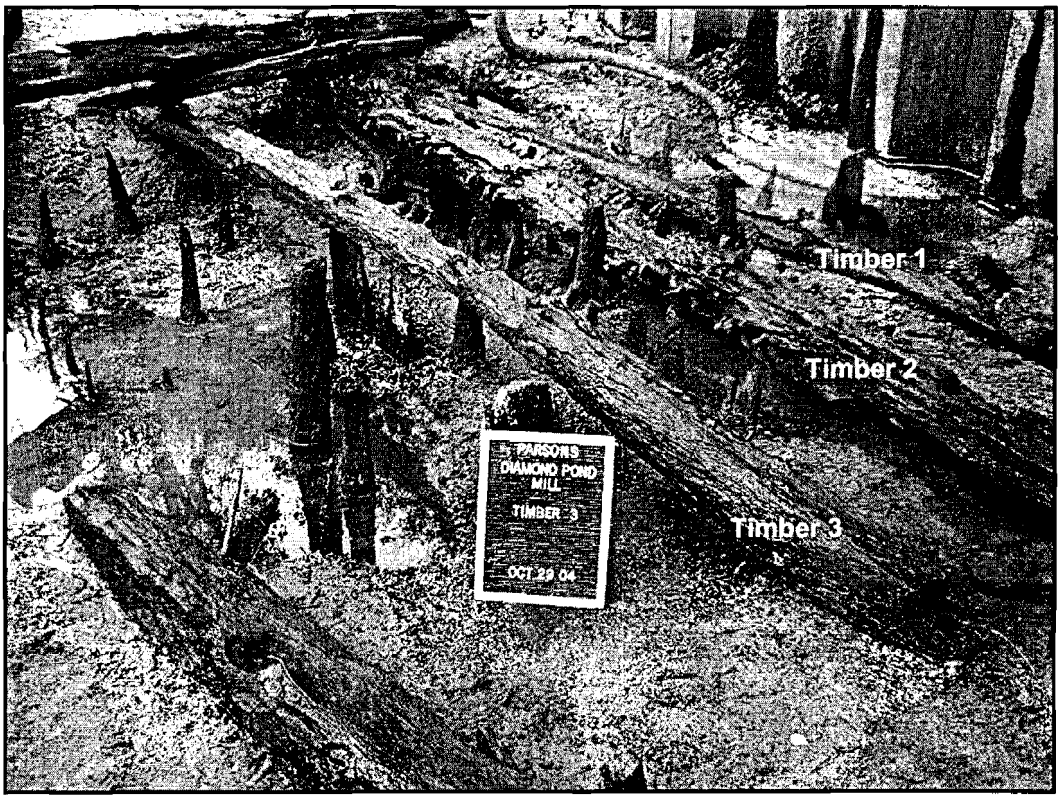


Figure 5-23. Timber 3, Showing Parallel Alignment with Timbers 1 and 2, to Left, view northwest.

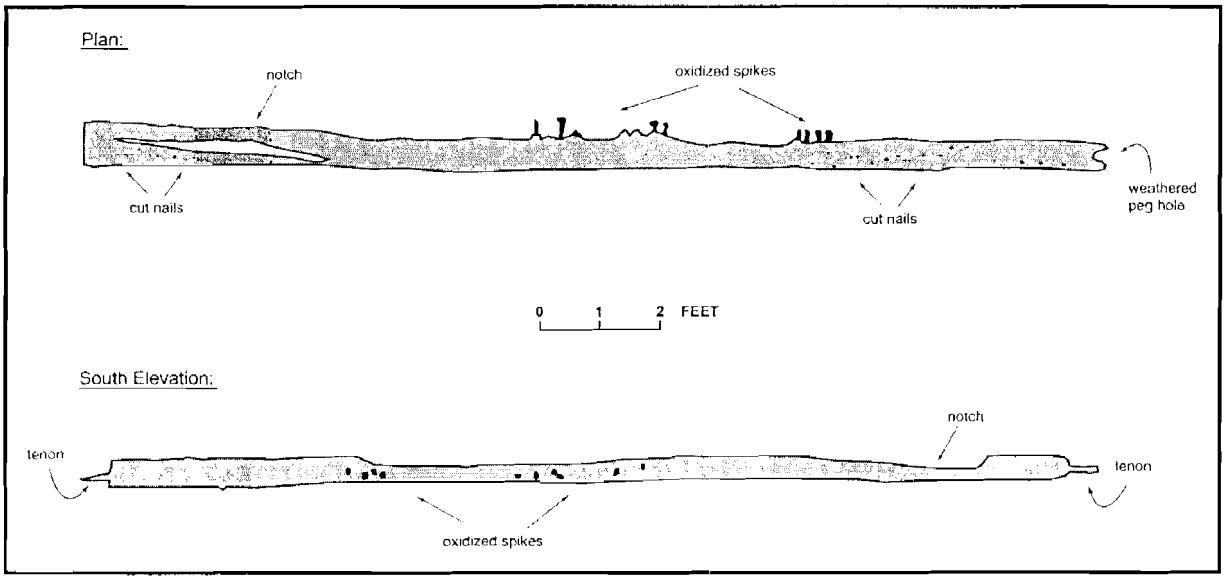


Figure 5-24. Timber 3, plan view and south elevation.

A deteriorated notch was located between 2 and 3 feet from the west end of the timber, aligning with the notch in Timber 2 and designed to accommodate Timber 6, a portion of which remained attached perpendicularly atop Timber 3 by two large iron pins (Figure 5-25). No evidence was noted of either a notch or of mortises aligned with those on the east end of Timber 2. While the east end of Timber 3 was heavily weathered, which may have obscured a notch, evidence of a mortise cut would have been visible should one have originally been present. Cut nails were located sporadically along the northern face of the timber, indicating the presence of wooden sheet pilings at one time, although few were noted in place during the current excavations. Nails were also observed on the upper surface of Timber 3, near both the eastern and western ends. Whether or not they originally secured flooring was unclear, since no evidence of the wood planking remained, and nails were not noted in similar locations on the other cross timbers.

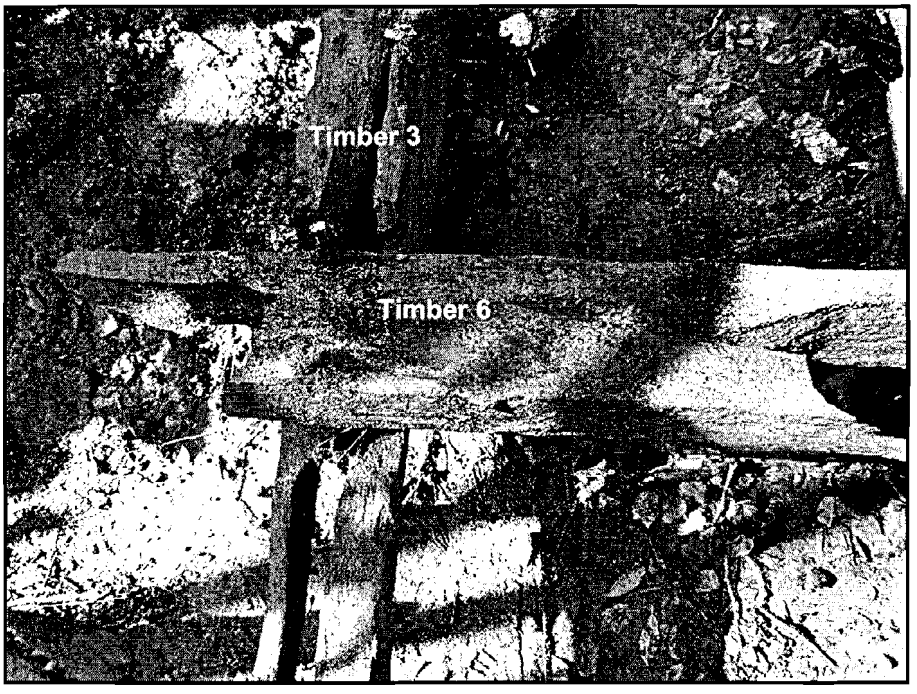


Figure 5-25. Timber 6 Situated in a Notch in Timber 3 and Secured by Iron Pins, view west.

Timber 4

Measured Dimensions:	Length:	18 feet	
	Width:	12 inches	
	Thickness:	9.5 inches	
Estimated Dimensions:	Length:	30 feet	(in combination with Timber 5)
	Width:	12 inches	
	Thickness:	12 inches	

Wood Species: white oak

Description: Timber 4 was one of two large timber fragments at the southern end of the mill (Figure 5-26). Timber 4 was originally combined with Timber 5, to the east, comprising a much larger timber that formed the southern end of the mill structure. Water flow had completely weathered through the massive timber to form two separate fragments (Figure 5-27).

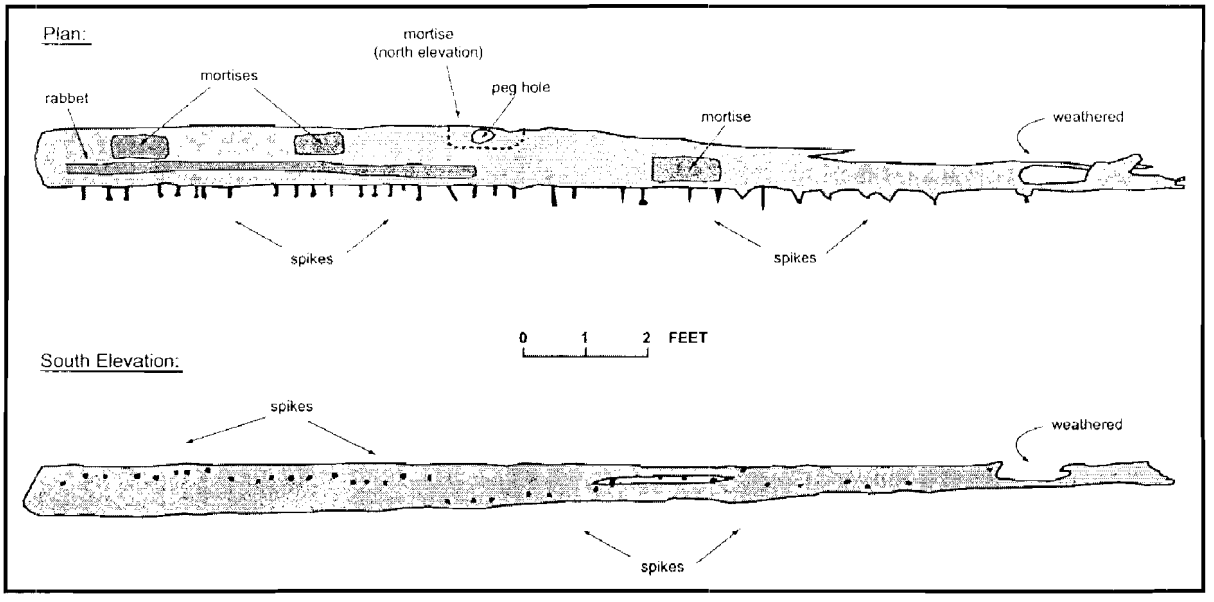


Figure 5-26. Timber 4, plan view and south elevation.

The west end of the timber had been beveled, although the cut did not appear to have been functional. A pair of mortises were cut into the upper surface of the timber near the west end, one centered 1.5 feet from the end, the second just under 3 feet to the east. Both were weathered, measuring 3x8.5x4.5 inches. The original, unweathered dimensions of the mortises were estimated to have been 3x9x6 inches, based on the dimensions of less weathered portions of other timbers. A linear groove or rabbet had been cut into the top of the timber near its southern edge. The rabbet measured 2 inches in width, $^3/_8$ inch deep, and extended from the west end of the timber for a distance of 8.5 feet. A third mortise occurred on the top of the timber approximately 10 feet from the west end. Being closer to the center of the stream, this mortise was more weathered that the two at the west end of the timber, presently measuring 5x12x4 inches. The mortise was not aligned with the westernmost mortises, but was set closer to the southern edge. A final mortise was cut into the north face of the timber. In its weathered condition it measured 4x13x4.5 inches. A peg hole extended through the top and bottom of the timber at the mortise, measuring 2-2.25 inches in diameter (Figure 5-28).

Wooden sheet pilings lined the south face of Timber 4. Nail patterns on the south face of the timber indicated the original attachment of the sheets, although the timber had pivoted out of alignment to end at an angle of just less than 20 degrees from the line of pilings. Four of the pilings associated with Timber 4 were removed during the current archaeological investigation. They consisted of 2x9-inch planks of milled pinewood (Figure 5-29a). The

Figure 5-27. Timber 4, view northwest.

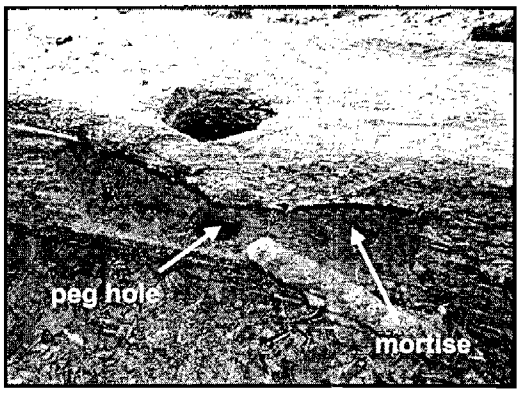


Figure 5-28. Mortise with Peg Hole in North Face of Timber 4.

piles had been driven into the subsoil approximately 6 feet below the top of Timber 4. The ends of each sheet were bi-pointed relative to thickness, and had single bevels relative to width (see Figure 5-19).

A sample of spikes was removed from Timber 4 (Figure 5-30). All were cut/wrought nails of similar size. Based on examination each timber at the site, the spikes appeared to be representative of those exposed on the remaining timbers.

A series of posts lay below the timber supporting it. Two of the posts, designated LL and KK, were excavated (Figure 5-29b). Both posts measured 4x4.5 inches in cross section and 6 feet 4 inches in length. The upper surfaces were sawn flat, and the opposite end was bi-pointed. A section of post LL was submitted for species analysis and was determined to be red oak. Timber 4 rested on the posts without attachment or notch.

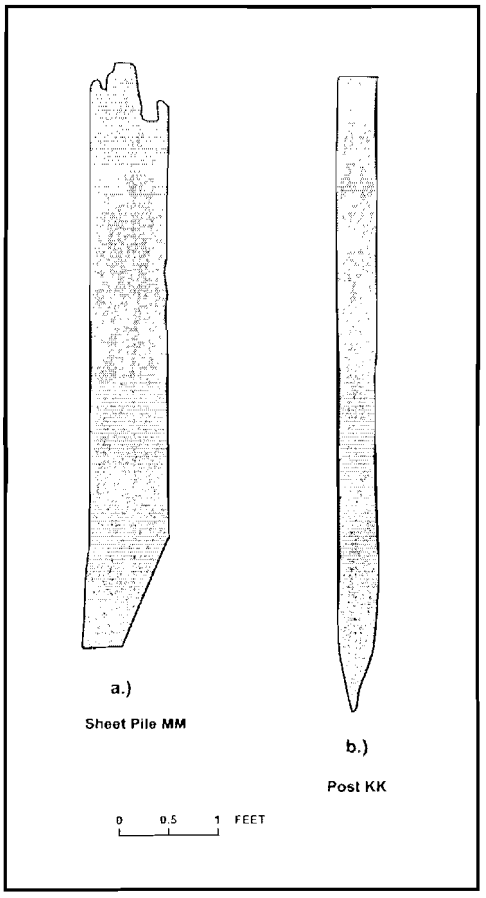


Figure 5-29. Sheet Piling and Post Associated with Timber 4.

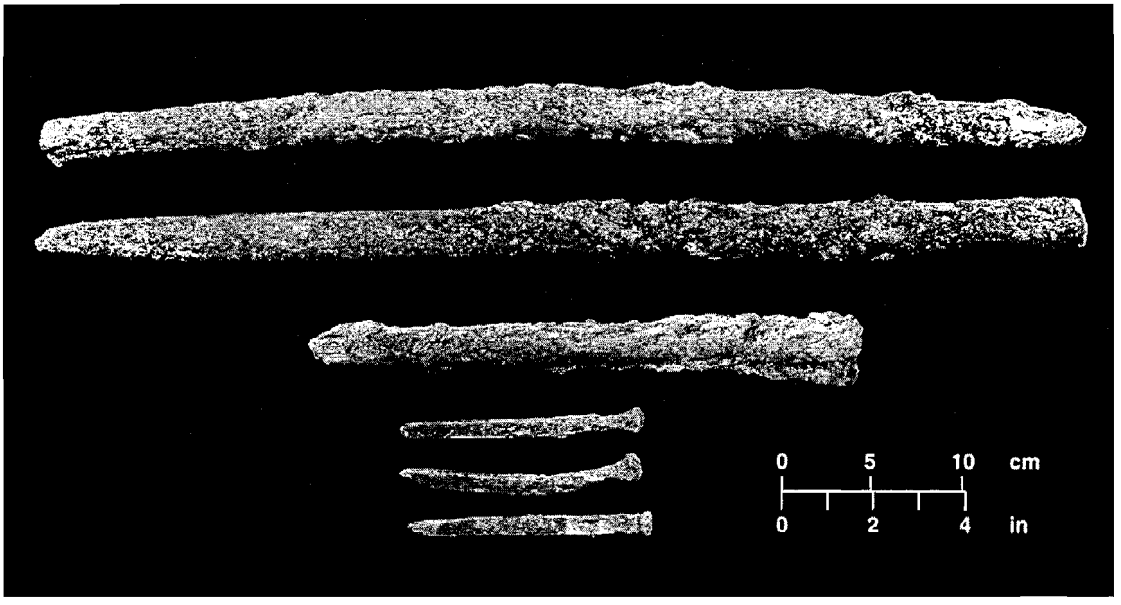


Figure 5-30: Assorted Spikes and Nails from Timber 4.

Timber 5

Measured Dimensions: Length: 13 feet 2 inches
Width: 9.5 inches
Thickness: 8.5 inches

Estimated Dimensions: Length: 30 feet (in combination with Timber 4)
Width: 12 inches
Thickness: 12 inches

Wood Species: white oak

Description: Timber 5 was one of two large timber fragments at the southern end of the mill (Figure 5-31). It was originally combined with Timber 4, to the west, comprising a much larger timber that formed the southern end of the mill structure. Water flow had completely weathered through the massive timber to form two separate fragments (Figure 5-32).

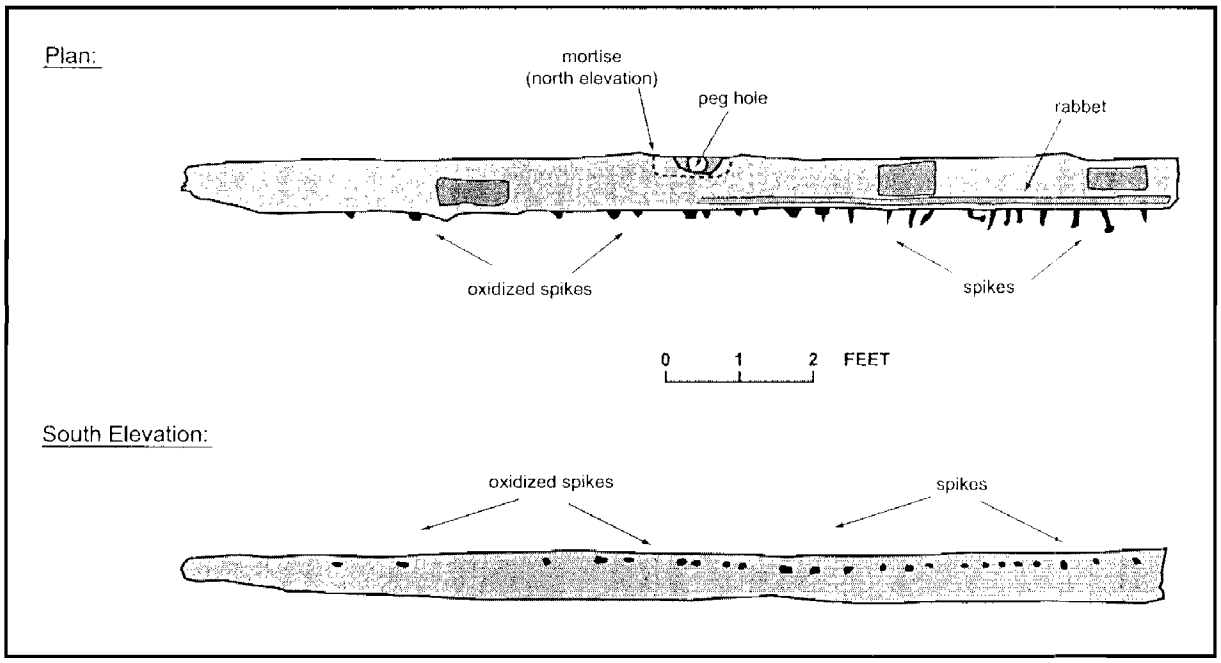
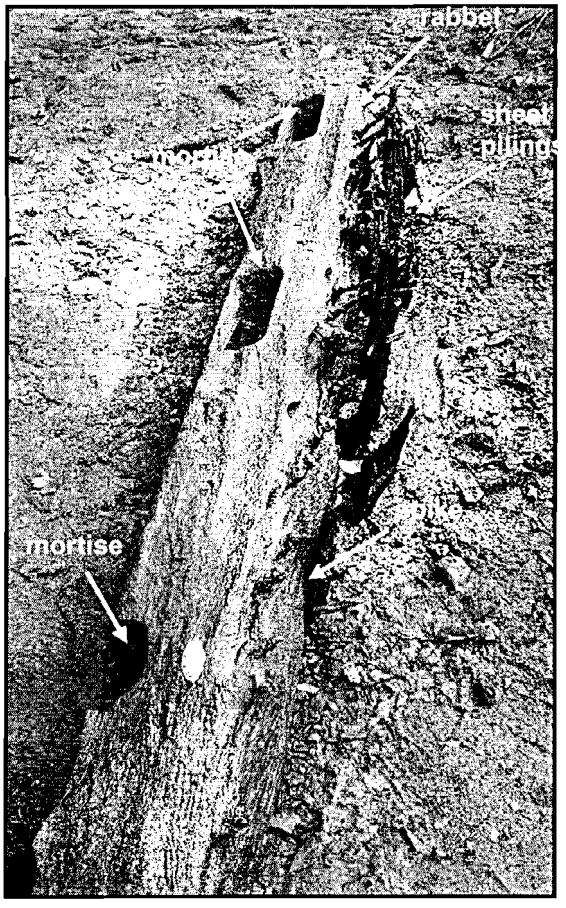


Figure 5-31. Timber 5, plan view and south elevation.

The pattern of mortises on Timber 5 mirrored the pattern on Timber 4 (Figure 5-33). A pair of mortises occurred near the east end of the timber; one centered 9 inches from the end, the second 3.5 feet to the west. Both were weathered, with dimensions of approximately 3x8.5x4.5 inches. The original, unweathered mortises were estimated to have measured 3x9x6 inches, based on the dimensions of less weathered portions of other timbers. A third mortise had been cut into the top of the timber approximately 9.5 feet from the east end. This notch was slightly more weathered than the two at the east end of the timber, measuring 5x12x4 inches. It was not aligned with the easternmost mortises, but was aligned with the matching mortise on the upper face of Timber 4. A final mortise was found on the north face

Figure 5-32. Timber 5, view northwest.

Figure 5-33. Detail of Timber 5 Showing Mortises, Rabbet, and Sheet Pilings.



of Timber 5. In its weathered condition it measured 4x12x4.5 inches. A peg hole extended through the top and bottom of the timber at the mortise (Figure 5-34). The peg hole was very weathered: it had worn through to nearly the full extent of the mortise on the upper surface; while on the bottom surface, it measured at least 3 inches in diameter. Although highly weathered and thus indistinct, evidence was present of a rabbet along the southern edge of the timber, similar to the slot on the west end of Timber 4.

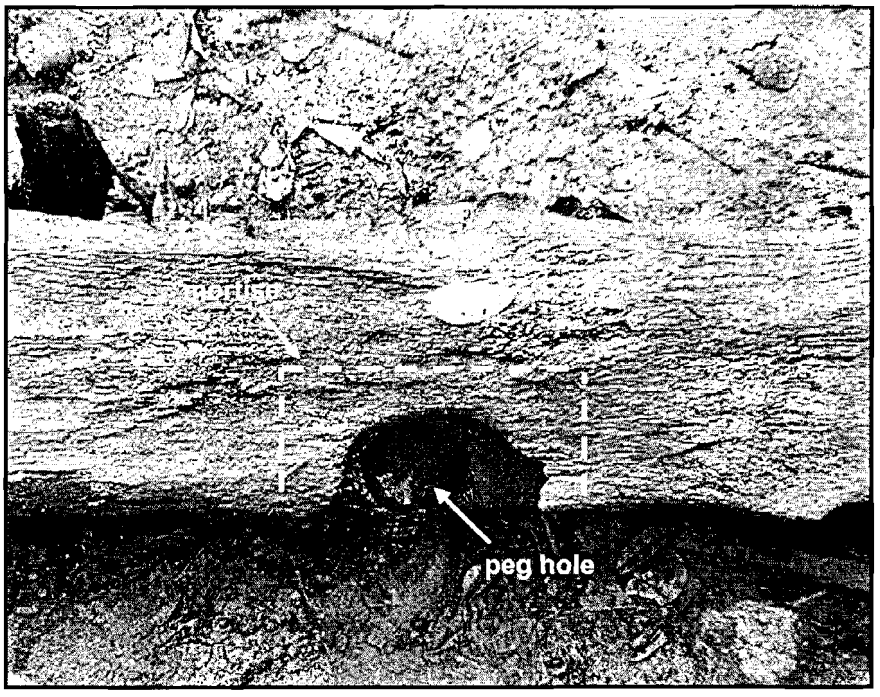


Figure 5-34. Timber 5, Detail of Peg Hole
(mortise has partially worn through upper surface of timber).

Wooden sheet pilings lined the south face of Timber 5, and nail patterns on the south face of the timber indicated the original attachment of the sheets. Like Timber 4, Timber 5 had broken free of the pilings and pivoted slightly from its original alignment, although at an angle of approximately 7 degrees, the deviation was less severe. Several of the pilings associated with Timber 5 were removed. They consisted of 2x10-inch planks of milled pinewood. The piles had been driven into the subsoil to a depth of approximately 4.5 feet below the top of Timber 5. The ends of the sheets were bi-pointed relative to thickness, and had single bevels relative to width (see Figure 5-19).

Posts lay beneath Timber 5 providing support. The easternmost of these supports, labeled Post HH, was exposed and removed (Figure 5-35). Like the square posts supporting Timber 4, Post HH was cut from red oak and was square in cross section, measuring 4x4.5 inches. The full length of the post was not determined. Backhoe excavation extended in excess of 6 feet below the top of Timber 5. The post remained embedded in the underlying clay subsoil, and it eventually snapped during attempts to dislodge it. Similar posts beneath Timber 4 measured 6.5 feet in length.

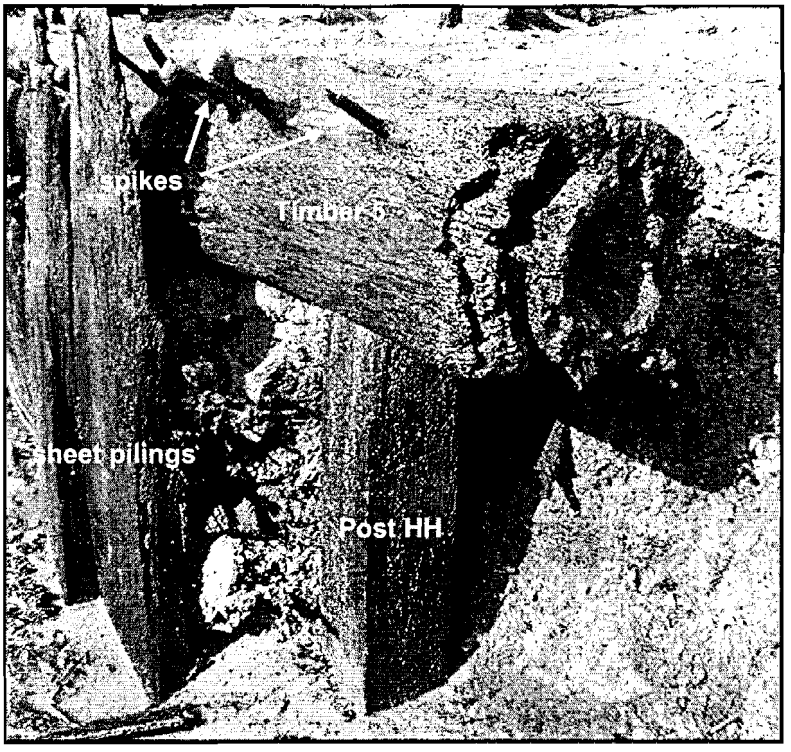


Figure 5-35. Timber 5, Detail of Support Post HH and Sheet Pilings.

Timber 6

Measured Dimensions:	Length:	6 feet
	Width:	8.5 inches
	Thickness:	5.5 inches
Estimated Dimensions:	Length:	at least 10 feet
	Width:	12 inches
	Thickness:	8 inches

Wood Species: white oak

Description: Timber 6 was the only surviving structural element above the lowest course. It consisted of a fragment of a larger timber that spanned two of the cross pieces, Timbers 2 and 3 (Figure 5-36). Timber 6 was oriented perpendicularly to the underlying structure and was connected by means of large iron pins, or drifts, that would have been driven through pre-drilled holes. The timber was extensively worn. Neither end was complete, while both the width and thickness of the timber were substantially reduced in size (Figure 5-37). The estimate of the original width of the timber was based on the positions of the large pins connecting Timber 6 with the underlying timbers, while the thickness estimate was based on the vertical dimensions of the pins.

Figure 5-36. Timber 6, Attached to Timber 2 and Timber 3 with Iron Pins, view west.

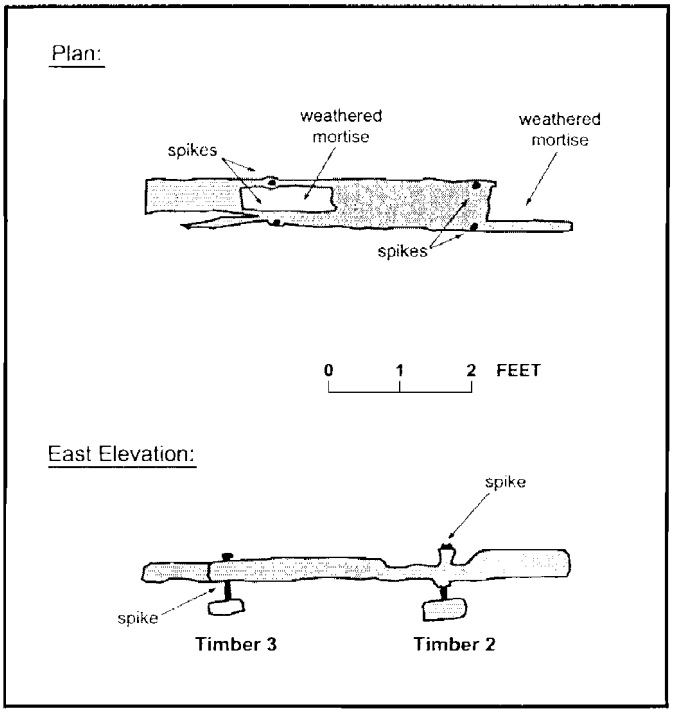


Figure 5-37. Timber 6, plan view and east elevation.

Two heavily weathered mortises were present, both of which had worn completely through the timber. One mortise was located between the pins that secured Timber 6 to Timber 2. The south end of the timber had broken off at a second mortise, which lay immediately south of the pins securing the timber to Timber 3. Due to the degree of weathering present, the dimensions of neither mortise was recorded.

Timber 7

Measured Dimensions: Length: 15 feet 2 inches
Width: 11 inches
Thickness: 7 inches

Estimated Dimensions: Length: at least 18 feet
Width: 12 inches
Thickness: 12 inches

Wood Species: red oak

Description: Timber 7 was a portion of a larger timber that originally lay parallel with the stream course, articulated with the north face of Timber 4 and the west ends of Timbers 1, 2, and 3 (Figure 5-38). The timber was somewhat out of place, having been truncated at the northern end and disconnected from each of the associated timbers. It lay at an angle of approximately 50 degrees in relation to the cross timbers, while the southern end was raised approximately 3.5 feet off the ground. The north end of Timber 7 had been truncated by the metal sheet pilings of the coffer dam.

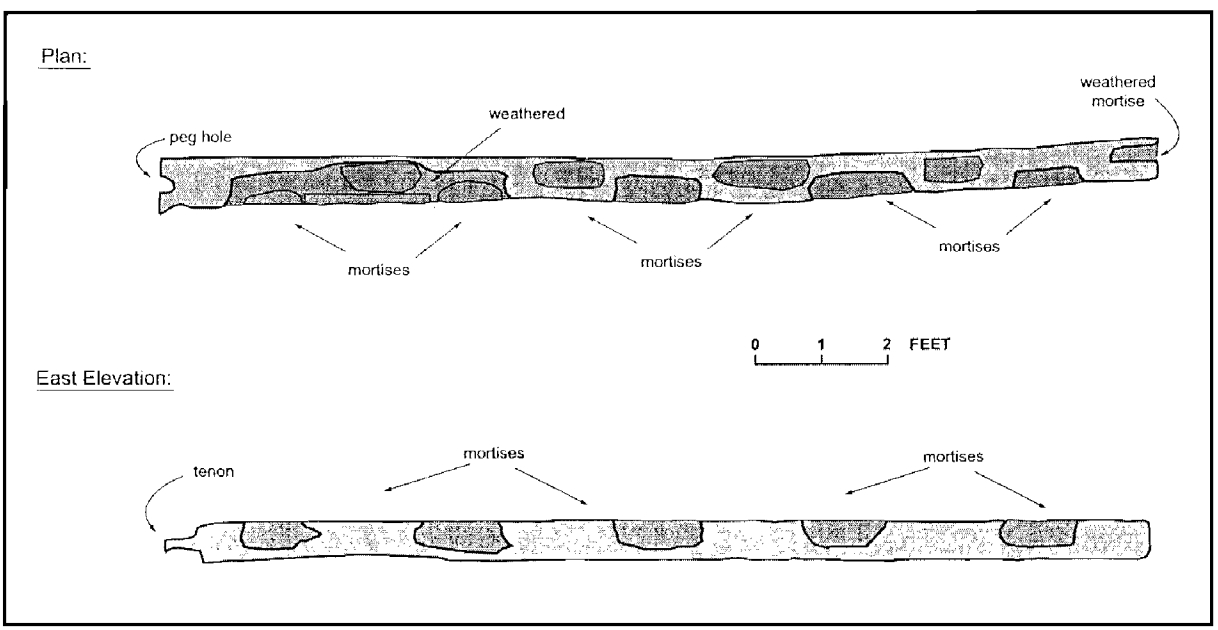


Figure 5-38. Timber 7, plan view and east elevation.

Mortises were cut into two faces of Timber 7 (Figure 5-39). The upper surface exhibited portions of five mortises that would have held uprights or risers. All were water worn and appeared to be larger than their original configurations, measuring as much as 6 inches wide and 18 inches long. Based on the dimensions of similar but less weathered features on other timbers, the mortises would originally have measured approximately 3x9x6 inches. The mortise at the truncated northern end of the timber was incomplete. Five additional mortises occurred on the east face of Timber 7. Three appeared to align with tenons on the western ends of Timbers 1, 2, and 3. All of the notches were worn to lengths approaching 15 inches, and each had worn through the top surface of the timber. Weathering had further begun to wear away the remaining wood separating the vertical and horizontal mortises in some places.

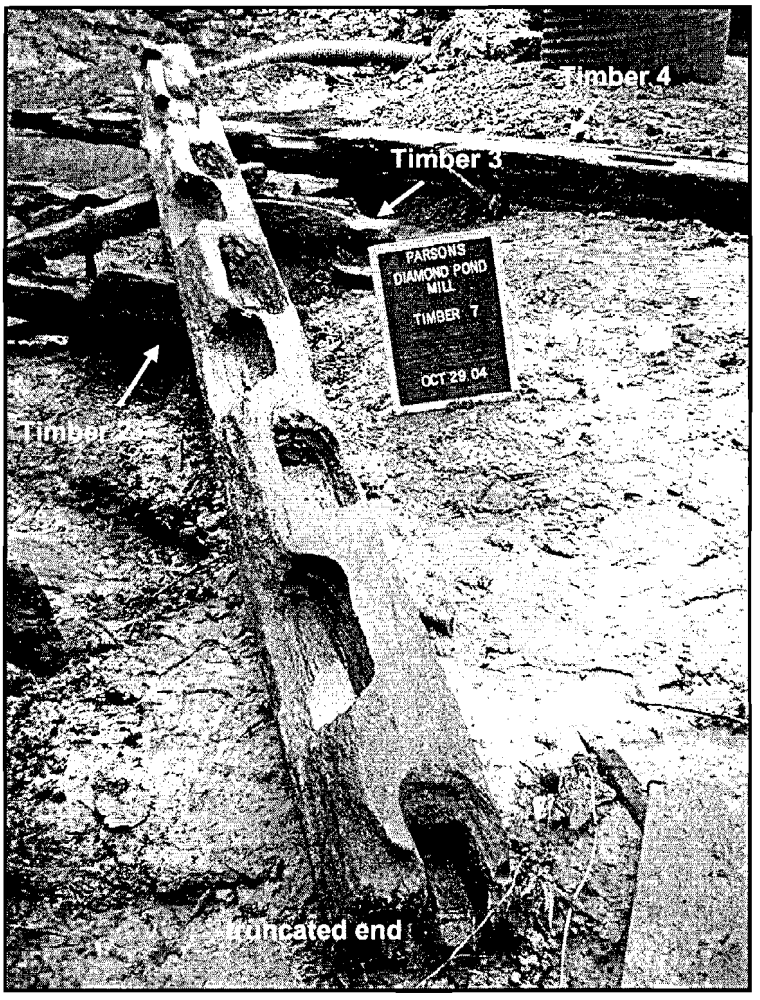


Figure 5-39. Timber 7, view southeast
(mortises on east face, to left, have worn through top surface of timber).

No nails were observed on Timber 7. The tenon on the south end of the timber measured 4 inches thick at the widest point and exhibited a peg hole (Figure 5-40). The hole measured over 3 inches in diameter, but was weathered and thus is presumed to have been smaller in its original form. Large (4x9-inch) plank pilings were located beneath Timber 7 functioning as

Figure 5-40. Tenon with Peg Hole, South End of Timber

supports. No evidence of notching or other form of attachment between the timber and posts was observed.

The estimate of the original length of Timber 7 is a minimum assessment and assumes that the mortise and final, horizontal tenon pattern observed at the south end of the timber was replicated proportionally at the north end. The width estimate is based on the width of the surviving tenon and assumes a minor degree of weathering. The estimate of thickness is based on the dimensions of the mortise on the north face of Timber 4, into which the tenon at the south end of Timber 7 would have been inserted, and on the thickness of Timber 4.

Timber 8

Measured Dimensions:	Length:	12 feet 2 inches
	Width:	8.5 inches
	Thickness:	6 inches
Estimated Dimensions:	Length:	at least 18 feet
	Width:	12 inches
	Thickness:	12 inches

Wood Species: red oak

Description: Timber 8 was a portion of a larger timber that originally articulated with the north face of Timber 5 and the east ends of Timbers 1, 2, and 3 (Figure 5-41). The timber was somewhat out of place, having been truncated at the northern end by the metal sheet pilings of the coffer dam. It had become disconnected from the timbers with which it originally articulated, lying at an angle of about 10 degrees from the cross timbers. The southern end of the timber was raised approximately 3 feet from the stream bed, while the northern end was buried in the sand against the coffer dam (Figure 5-42).

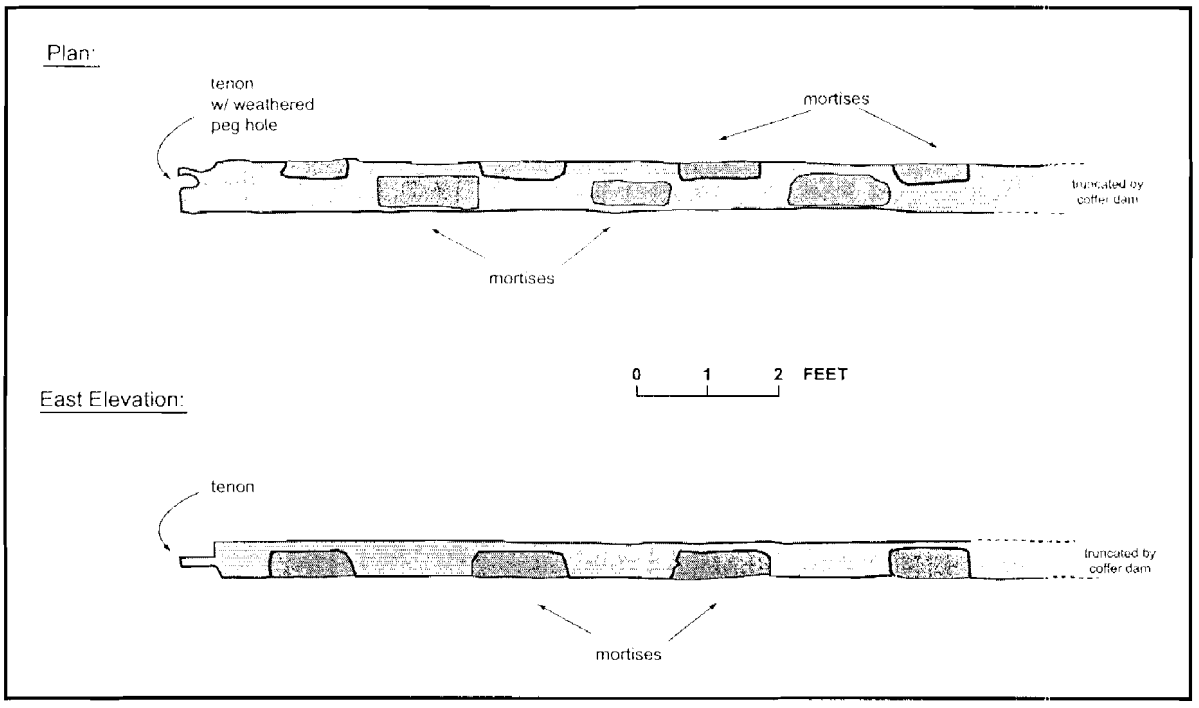


Figure 5-41. Timber 8, plan view and east elevation.

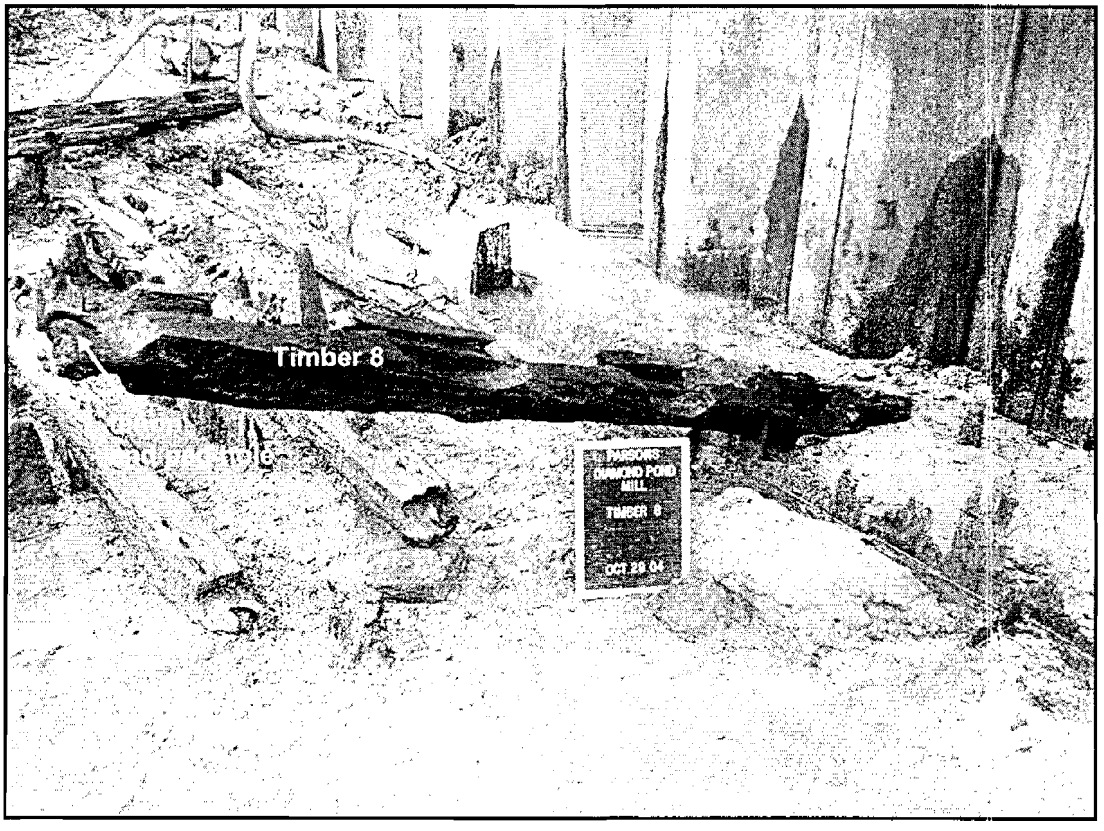


Figure 5-42. Timber 8, view northwest.

Mortises had been cut into the top and west faces of Timber 8. The upper surface contained three mortises that would have received uprights or risers. The notches were water worn, and currently measured as much as 5 inches wide and 13 inches long. Portions of four mortises appeared on the west face of the timber, where they would have articulated with the east ends of the cross pieces, Timbers 1, 2, and 3. These mortises were also water worn, measuring up to 5 inches wide and 14 inches long. The mortises had worn through the top surface of the timber.

No nails were observed in Timber 8. The southern end of the timber had been finished with a wide tenon, measuring 6 inches in length, 8 inches in width, and 2 inches in thickness. A worn peg hole was present that measured 2.5-3 inches in diameter. Large plank pilings (see description below, Post D) were located beneath Timber 8, functioning as supports. No evidence of notching or other form of attachment between the timber and posts was observed.

Estimates of the original dimensions of Timber 8 were based on an assumption that the timber matched Timber 7 in size and structural function.

Note: Timbers 9 through 12 were associated with cribbing beneath the concrete culvert of the twentieth-century bridge. They are described separately, following descriptions of all of the mill-related elements.)

Timber 13

Measured Dimensions: Length: 14 feet 5 inches
Width: 17 inches
Thickness: 13 inches

Wood Species: white oak

Description: This large timber differed from the structural timbers described above on several counts. While most of the other timbers were discovered only slightly displaced from their original points of articulation, Timber 13 was found wedged beneath the upstream face of Timber 5, but apparently not directly associated with it. One end of Timber 13 ended in a tenon, yet no peg hole was present (Figure 5-43), and no corresponding mortise was observed on Timber 5. Moreover, unlike the other structural timbers, Timber 13 had no mortises cut into it. Instead, it bore wooden pegs that occurred throughout its length.

The timber was half finished, either cut or milled flat on one face, but left rounded on the remaining sides (with no bark remaining). In total, 54 pegs and 18 peg holes were recorded on the flat face of the timber. Among the pegs, 19 were square and 35 were round. They varied in size from 1 inch to 2.5 inches, either in diameter or on the diagonal. Pegs of both shape, square and round, were scattered throughout the length of the timber, although most of

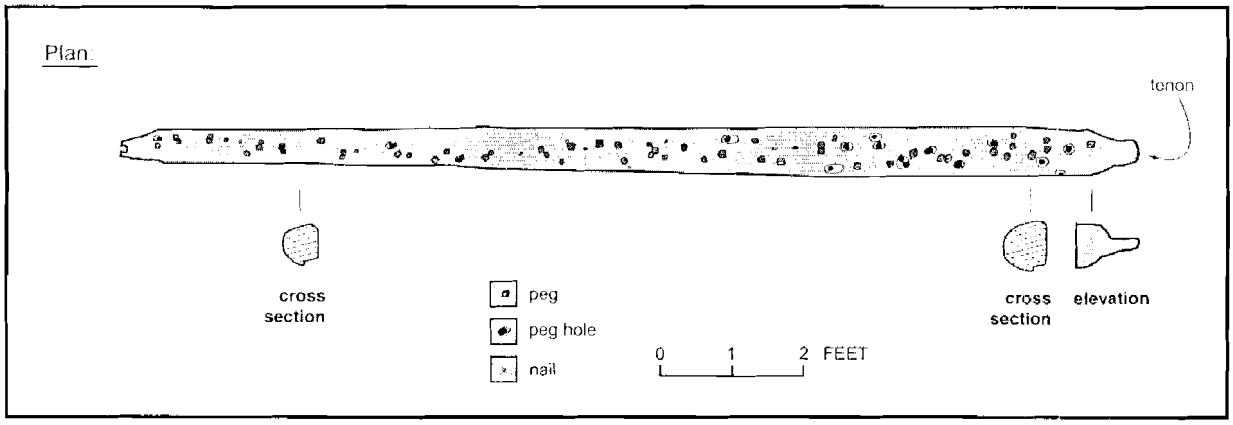


Figure 5-43. Timber 13, plan view with cross sections.

the square pegs occurred on one half of the timber, and most of the round on the other. In a sample of eight pegs, three were of white oak, five of southern pine. The peg holes were weathered, but most appeared to have been approximately 1 inch in diameter when originally drilled. Several of the peg holes and several pegs occurred at an angle to the plane of the timber. No clear pattern could be identified in the positioning of the pegs, which was presumed to represent evidence of extensive reuse.

Posts

Individual posts were more difficult to document due to the degree of deterioration evidenced by many of their features. They were often not well protected from stream action, and thus the upper portions of most examples had largely worn away (Figures 5-44, 5-45). In some instances, the upper parts were no longer visible, in which case their locations were determined using a metal probe.

Three main types of post were noted. One consisted of relatively small, square or nearly square posts that supported the large timber represented by Timber 4 and Timber 5. The second consisted of larger, plank-like posts that supported Timbers 7 and 8, where they articulated with the cross pieces, Timbers 1, 2, and 3. The third type consisted of round posts in the central part of the structure. While the exact functions of the round posts are unclear, some may have supported now missing timbers that stretched perpendicularly across Timbers 1, 2, and 3.

The posts were labeled alphabetically in the order in which they were documented on the site map. A representative sample was excavated with the aid of the mini-excavator. The excavated posts were measured and documented in full, and they are described below, in alphabetical order.

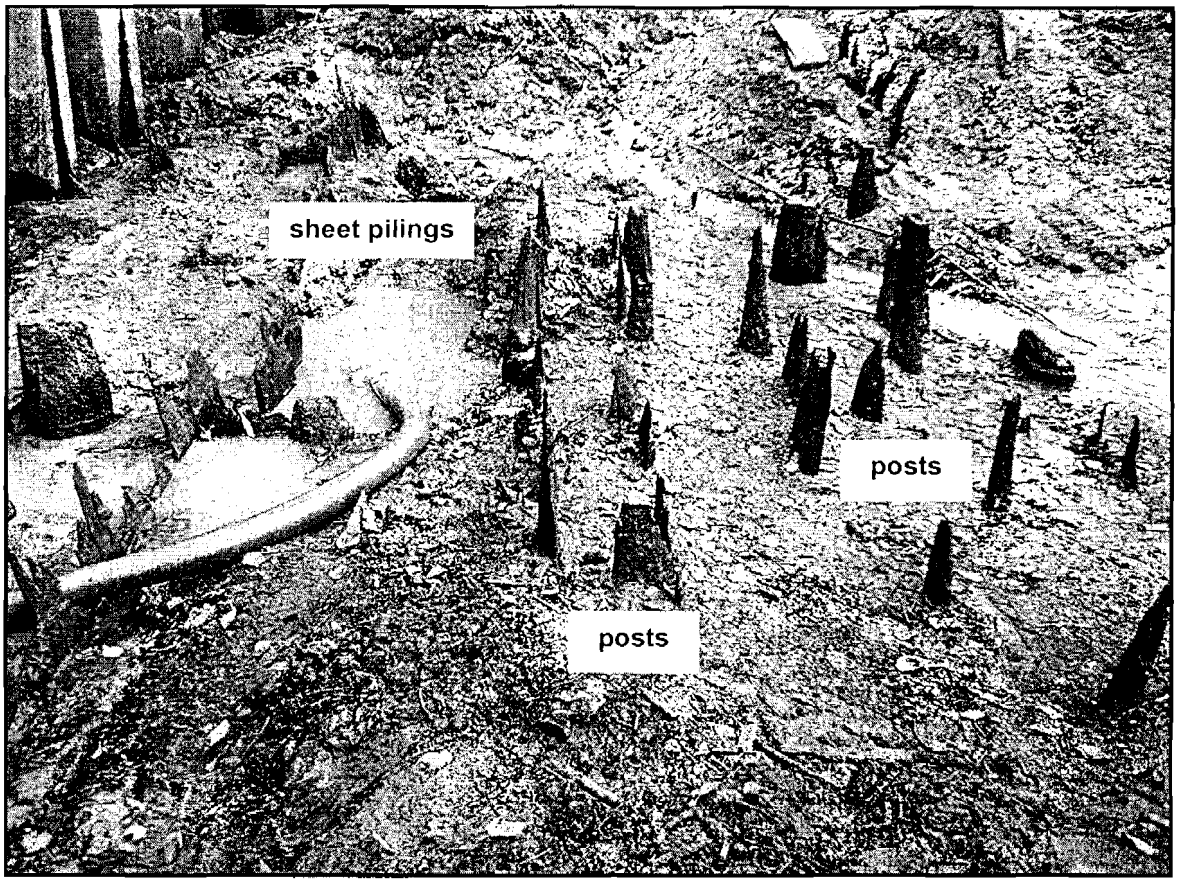


Figure 5-44. Posts and Sheet Pilings after Removal of Structural Timbers.

Post A

Measured Dimensions: Length: 7 feet 10 inches
Width: 9.5 inches
Thickness: 5.5 inches

Wood Species: n/a

Description: Post A was a large plank-like piling located south of Timber 5. The post had been milled on three sides (cut marks indicated a reciprocating saw) and remained unfinished on one face. The exposed or top end of the post was badly deteriorated, so that the original length of the plank could not be measured. The opposite end, which had been driven into the clayey subsoil, was finished at a 1.25 foot-long point that was tapered on all four faces. Post A was aligned with several other posts, including Post D and Post F, that had originally supported Timber 8, and thus it may have supported elements of the mill that were no longer present. Wood species analysis was not conducted on this post. Field observations suggested that the wood consisted of black walnut, although similar posts (e.g., Post D) were analyzed as white oak.

Figure 5-45. Excavated Posts (pointed ends driven into subsoil are in foreground, weathered ends are in background).

Post D

Measured Dimensions: Length: 7 feet 4 inches
Width: 9 inches
Thickness: 4 inches

Wood Species: white oak

Description: Post D was a large plank-like piling located below Timber 8, north of the mortise for Timber 3. The post had been milled on three sides (cut marks indicated a reciprocating saw) and was unfinished on one face. The top end of the post was deteriorated, but presumably little of the original length of the plank was missing, since it had supported Timber 8 at approximately this height. The end driven into the subsoil was finished at a 1.5-inch-long point that was tapered on all four faces. Post D was one of a line of posts,

including Post F and possibly Posts A and JJ to the south, that buttressed the east side of the structural remains.

Post AA

Measured Dimensions: Length: 6 feet 4 inches
Diameter: 6.5 inches

Wood Species: pine

Description: Post AA was a round piling situated south of Timber 1. The post was unfinished, with several branches cut off flush with the circumference of the tree bole. No evidence of nails or other fasteners was observed on the feature. Post AA was located in the center of the stream bed, and the top end of the post as extensively weathered, with the diameter worn down to less than 3 inches. The base of the post was pointed, with a long, 12-inch taper on two sides and a shorter 3-4-inch taper on the opposite sides.

Post HH

Measured Dimensions: Length: 3 feet 5 inches
Width: 4.5 inches
Thickness: 4 inches

Wood Species: red oak

Description: Post HH was a square piling that supported the east end of Timber 5. It had been milled on all four sides and had no nails or other fasteners attached to it. The post was not fully excavated. Although the excavator reached a depth of over 6 feet, the post remained securely embedded in the clayey subsoil and eventually snapped part way along its length. Based on the dimensions of similarly shaped posts supporting the west end of Timber 4, Post HH was at least 6.5 feet in length with a bi-pointed end.

Post KK

Measured Dimensions: Length: 6 feet 5 inches
Width: 4.5 inches
Thickness: 4 inches

Wood Species: n/a

Description: Post KK was a square piling that supported the west end of Timber 4. The post had been milled on all four sides and had no evidence of nails or other fasteners attached to it. The base of the post was tapered on all sides to a point. Wood species analysis was not conducted on this post, although it was similar in size, form, and appearance to post LL, which also supported Timber 4 and was analyzed as red oak.

Other Posts

Note that Post R and Post Z were located on either side of Timber 2 at the notch for the perpendicular timber (no longer present) that matched Timber 6. The posts rose above what would have been the top of Timber 2 (in its unweathered state), and thus would have supported the cross timber. Posts O and Q were in a similar location relative to Timber 3, a little out of line with R and Q. Post AA was in the same location relative to Timber 1. The posts may have drifted over the years in the wet sediments at the base of the stream bed, causing the apparent mis-alignment that was documented in the present investigation.

Wooden Peg

Measured Dimensions: Length: 7 inches
Diameter: 1.1 inches

Wood Species: white oak

Description: A small wooden peg was recovered from the fill during the excavation of Post A. The peg had been manufactured with a draw knife, and it was fully tapered from one end to the other, with no straight shank portion. Little evidence of wear was present, either at the pointed end or along the shaft, nor was there evidence of mushrooming at the opposite end resulting from hammering. Although it's provenience was uncertain, the artifact appeared to have been associated with mill construction, possibly lost or discarded during construction or refurbishing of the mill structure.

5.2.3 Unrelated Structural Features

The concrete box culvert of the modern bridge sits on wooden cribbing and posts, most of which lay beneath the culvert out of reach of the investigation. Since the culvert was not being replaced as part of the highway improvement project, access to this material was limited. It was thus not possible to determine conclusively whether the wood was from construction of the bridge in 1917 or from an earlier bridge. Heavy cribbing was exposed at the west end of the culvert Figure 5-46). This material was documented, and appeared to be a combination of reused timbers dating to the construction of the bridge in the early twentieth century. The main elements are described below.

Timber 9

Measured Dimensions: Length: 8 feet
Width: 9 inches
Thickness: 8 inches

Estimated Dimensions: Length: at least 10 feet
Width: 9 inches
Thickness: 8 inches

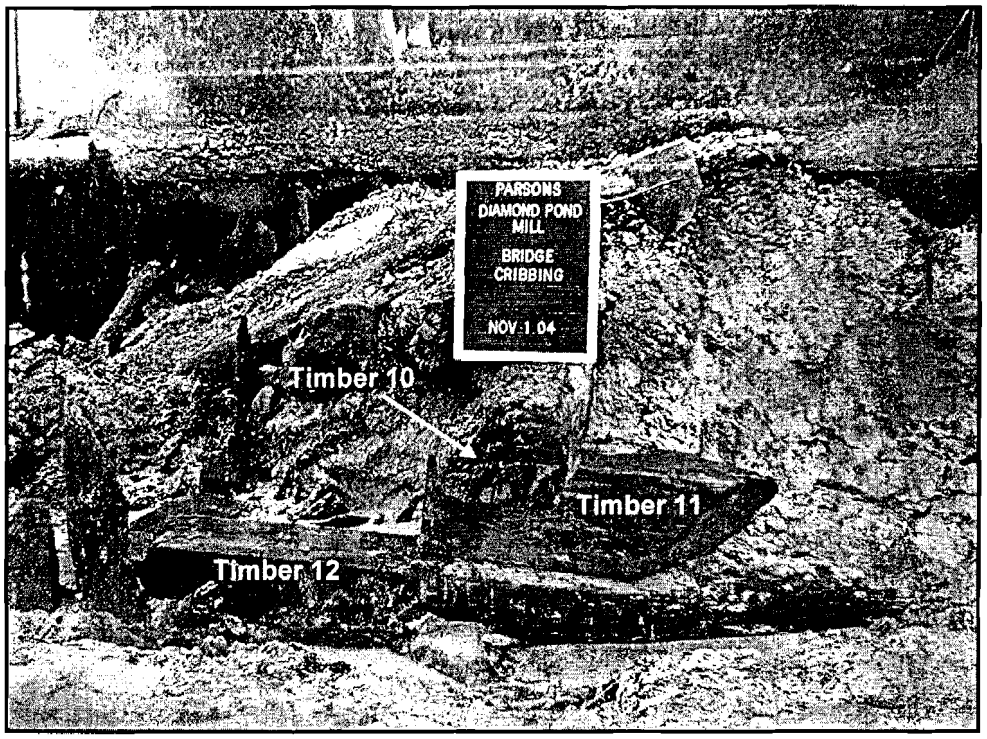


Figure 5-46. Timber Cribbing below Modern Bridge Culvert, north elevation.

Wood Species: white oak

Description: Timber 9 was part of the cribbing below the twentieth-century concrete bridge culvert (Figure 5-47). The timber was oriented perpendicular to the Bridge 3-806 roadway near the western stream bank. Timber 9 rested on fine sediments approximately 8 feet below the bridge deck. The top, bottom, and eastern sides of the timber were sawn flat. Although no bark was present, the western side was unmodified. An incomplete mortise was present on the top face the timber. The mortise was located at the extreme end of the timber, which had been sawn flat. The remaining portion of the mortise measured 5x5x3 inches. Prior to excavation, the timber had been completely covered by stream sediments and as a result, the exposed portion exhibited little decay or weathering.

Timber 10

Measured Dimensions:	Length:	2 feet 5 inches
	Width:	11 inches
	Thickness:	9 inches
Estimated Dimensions:	Length:	at least 5 feet
	Width:	11 inches
	Thickness:	9 inches

Wood Species: white oak

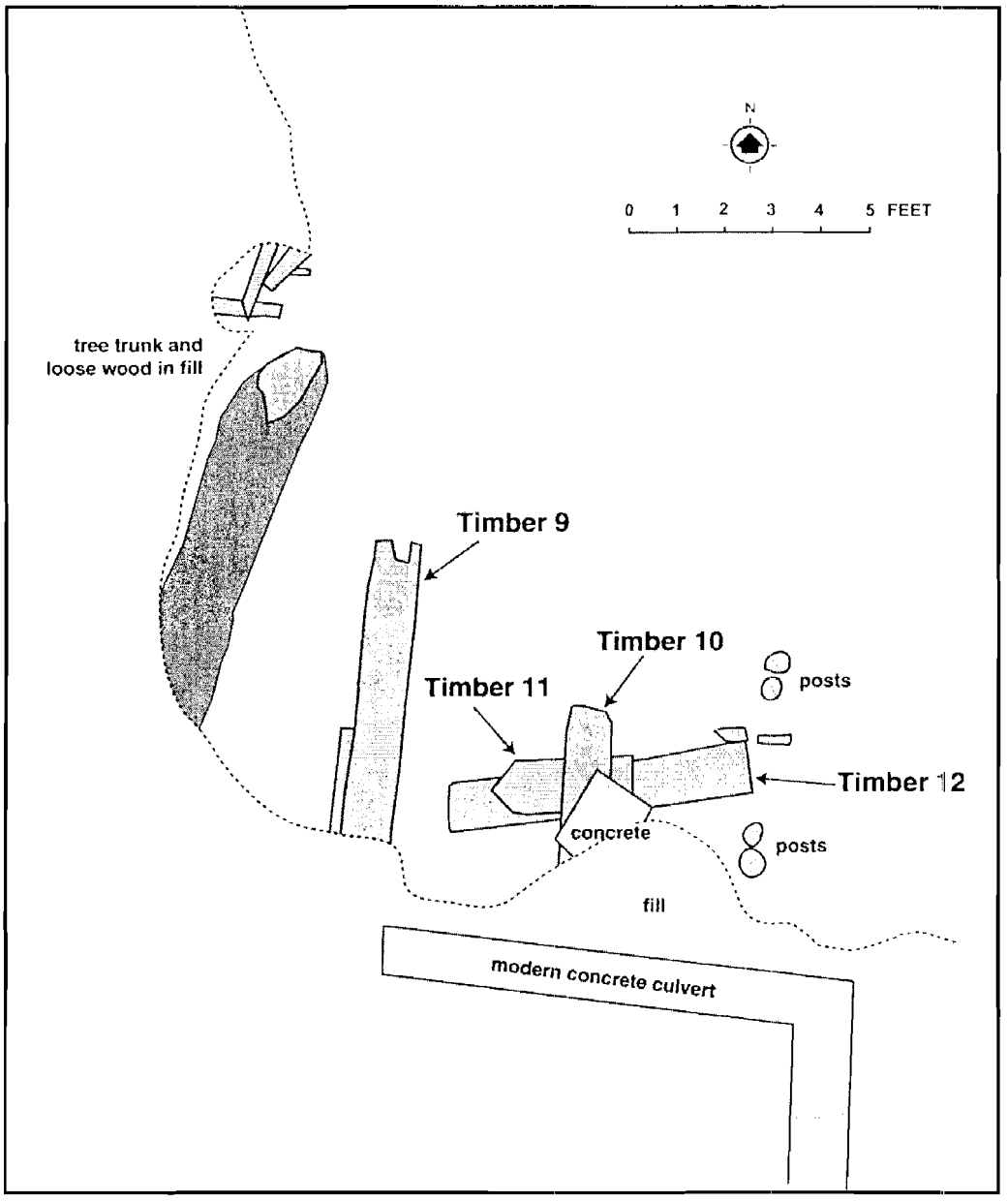


Figure 5-47. Plan View of Timbers Associated with Bridge Cribbing.

Description: Timber 10 was part of the cribbing below the twentieth-century concrete bridge culvert (Figure 5-47). The end of the timber was sawn flat and the sides were roughly finished. A small 2x3x2 inch mortise had been cut into the eastern top edge, 8.5 inches from the end of the timber. The timber extended from beneath the northwestern retaining wall of the bridge culvert. The exposed end of Timber 10 lay below a layer of concrete rubble and on top of Timber 11, which was oriented perpendicular to Timber 10.

Timber 11

Measured Dimensions: Length: 2 feet 6 inches
Width: 8.5 inches
Thickness: 9 inches

Wood Species: n/a

Description: Timber 11 was part of the cribbing below the twentieth-century concrete bridge culvert (Figure 5-47). The east end of Timber 11 was sawn flat, and the west end was sawn to a point by two cuts. All of the sides of the timber were sawn flat. The timber rested on top of and parallel to Timber 12. Timbers 11 and 12 lay roughly parallel to the Bridge 3-806 roadway, 2.5 to 3 feet north of the bridge culvert. The end of Timber 10 rested on top of Timbers 11 and 12, which may have functioned as support for the cross members of the bridge cribbing.

Timber 12

Measured Dimensions: Length: 6 feet 6 inches
Width: 8 inches
Thickness: 8 inches

Wood Species: n/a

Description: Timber 12 was part of the cribbing below the twentieth-century concrete bridge culvert (Figure 5-47). The east end of the timber ended in a tenon, which was oriented parallel to the ground surface. The west end was sawn flat. The timber lay roughly parallel to the Bridge 3-806 roadway beneath Timbers 10 and 11. Timber 12 lay directly on the stream sediments. A total of five posts were located near the tenon end of the timber. The posts consisted of two pairs of round posts located approximately 1 foot to the north and south of the timber. The fifth post abutted the south side of the timber at its end. This post exhibited two flat faces, with the remainder left rounded. These posts may have supported a cross member that mated with the tenon of Timber 12. As mentioned above, Timbers 11 and 12 may have functioned as support for the cross members of the bridge cribbing.

5.2.4 West Bank Excavations

Excavations were conducted on the west bank of the stream to determine if intact mill remains extended into the bank. The mini-excavator was used to remove brush and debris that had accumulated during the present phase of construction work. Following removal of the debris, the bank was sectioned using the excavator to the limit of construction disturbance. In addition, the ground on top of the bank the between the coffer dam and bridge cribbing was probed with a one-half-inch diameter metal rod. No structural elements were encountered, either in the cut bank or buried behind the cut. The profile section was cleaned by hand and drawn to scale (Figure 5-48). The exposed profile consisted of four strata. The first stratum (topsoil) measured 1-to-1.5 feet thick and consisted of organic

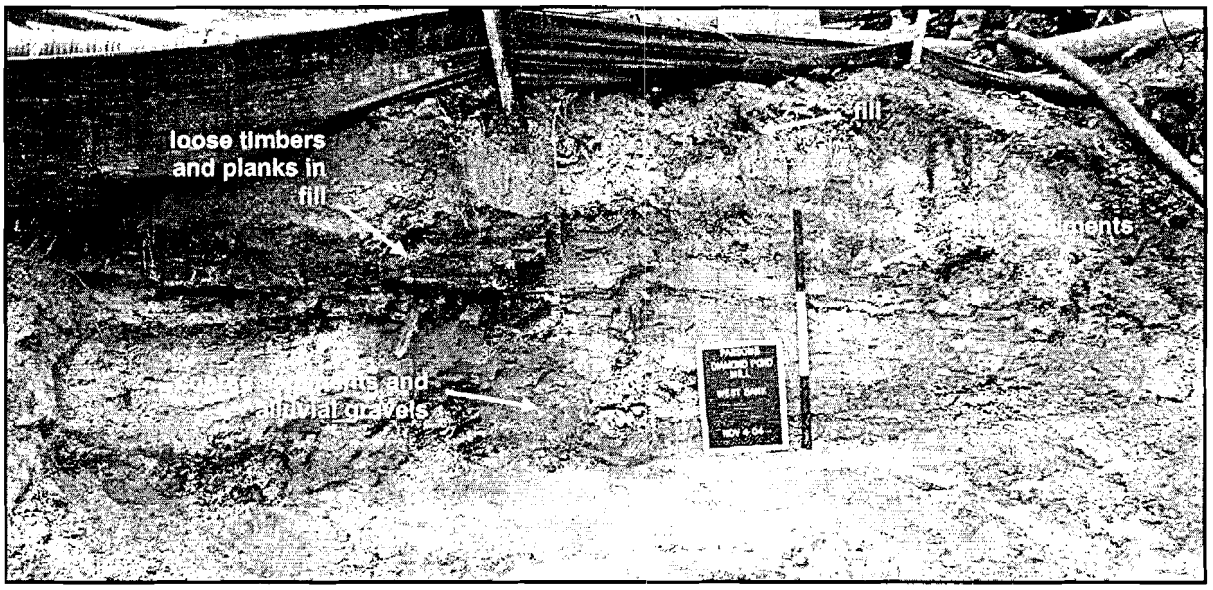


Figure 5-48. Profile Section of West Bank of Stream.

material, modern trash, and rubble in a matrix of loamy sand. This stratum was disturbed by recent construction activities and likely represented fill introduced during previous road and bridge improvements. The second stratum also consisted of disturbed or redeposited material. The stratum was 8-to-15 inches thick and contained decomposed timbers and planks in a loamy sand and gravel matrix. The third stratum consisted of fine stream sediments that ranged from 1-to-2 feet thick. No debris or inclusions were observed in this layer. The bottom stratum exposed in the profile section consisted of a layer of coarse-grained alluvial sand and gravel similar to that observed in the present stream channel.

5.2.5 Artifacts

Artifacts were found throughout the area behind the coffer dam, contained in the coarse sands of the stream bed. Since the structural elements of the mill straddled the main course of the active stream, many artifacts had collected against the timbers and sheet pilings where they had been deposited by stream flow. Large and small branches, leaves, wood and bark chips, and other organic debris had also collected against the mill remains, in some cases buried in the alluvial sands. With the exception of fragments of structural timbers obviously related to the mill (including two large wood fragments with tenons, and a wooden peg), none of the artifacts observed during the course of the investigation could be confidently associated with the mill structure. Among the most common artifacts noted in and around the mill structure were complete and fragmentary bottle and vessel glass that ranged in date from the early through the late twentieth century. A sample of potentially identifiable glass and ceramic artifacts pre-dating 1950 was collected for general diagnostic purposes (Figure 5-49). A complete list appears in Appendix C. The artifacts included fragments of painted and undecorated ironstone; decal-decorated whiteware; transfer-printed porcelain; Bristol-glazed, sponge-decorated stoneware; Albany-slipped stoneware; press-molded glass (dish and bowl); blown-in-mold glass (baking powder bottle); several machine-made glass bottles with maker's marks or embossing indicating manufacture near the end of the first quarter of

the twentieth century (Toulouse 1971); and amber and aqua colored glass electrical insulators manufactured by the Hemingray Glass Company in the early part of the twentieth century (McDougald and McDougald 1990).

Figure 5-49. Sample of Glass and Ceramic Artifacts Collected from Sandy Sediments in and around Mill Timbers.

Among the non-diagnostic artifacts that were observed at the site, window glass was common, particularly on the west side of the stream. In addition, an assortment of larger items was noted, including strands of wire and lengths of rebar; a large amount of monofilament (fishing line); numerous fishhooks and lures; various wooden planks; three sections of a sluice gate (based on their size and metal fittings, they were from the gate that controlled water outflow on the south side of the twentieth-century bridge culvert); a plastic baseball bat; a radio; a video cassette and video cassette recorder; and a small outboard motor. The majority of the material encountered during the archaeological investigation appeared to be rubbish thrown over the side of the bridge. Although the sample was not systematically collected, the potentially diagnostic glass and ceramic artifacts appeared to date from the 1920s to 1930s. Notably, the existing concrete bridge and culvert were constructed around 1917. The artifacts appeared to be confined to the period following that construction episode—nothing related to nineteenth-century use of the site as a mill could be confidently identified.

5.3 INTERPRETATIONS

5.3.1 Sawmilling: A Brief Historical Context

Though known from first century B.C. Greece, mills are thought to have originated in the steep valleys of the Near East, where small horizontal wheels were placed directly into moving water and millstones were attached to the spindle of the wheel (Derry and Williams 1961). The first design for a vertical wheel is attributed to the Roman engineer, Vitruvius, around 20 B.C., though the idea again may be traced to the Near East in the form of a water lifting wheel known as the *saqiya* (Derry and Williams 1961). The Vitruvian design was geared to transfer power 90 degrees, from the horizontal shaft of the wheel to the vertical shaft connected to the millstone. This basic design remained unchanged until the latter half of the nineteenth century, when horizontal wheels were reintroduced in the form of the more efficient turbine (Reynolds 1970).

Water Power

The most important factor in the establishment of a mill was the presence of an adequate water source. Mills were operated by hydraulic force, generated by the downward motion of water striking the paddles of a water wheel (Figure 4A). In most cases water was controlled by means of a dam, which would ensure an adequate and measured supply of water to power the wheel. It has been noted that the building of the dam was often the most demanding aspect of mill construction in terms of the skill and ingenuity of the millwright, as the conditions of the particular stream—the type of bottom, for example, or the volume of flow—dictated the most appropriate design (Leung 1981). "There are as many opinions on the proper way to build them as there are milldams in use," wrote Hughes (1867: 117). The mill would be placed on the dam or, occasionally, well downstream with the water channeled to the mill through an artificial canal referred to as the millrace. A gate was often placed at the dam to control the flow of water entering the race, and depending on the arrangement, one or more spillways would be placed on the dam as safety valves to protect the wheel in cases of flooding. The final approach to the mill was usually a wooden trough, referred to as the flume or penstock, which carried water to the proper position on the wheel. The flume was often provided with a weir or trash rack to guard against damage to the wheel from large debris, a sluice gate to close off the flow of water when necessary for maintenance, and occasionally a further spillway (Howell and Keller 1977).

The power generated by the water wheel depended on either the volume and force of stream flow or by the available head. The available head of water is defined as the distance between the points at which the water entered and left the mill (Evans 1972). Three main wheel designs were in use in the eighteenth and nineteenth centuries, and the design chosen for a particular mill was dependent mainly on the head which could be generated (Figure 5-50). Undershot wheels were used where there was little or no available head. Water from the stream to flow was channeled directly beneath the wheel striking it at its base and imparting motion in proportion to the strength of the current. A second design, the breast wheel, was commonly used for a head measuring between 6 and 10 feet. Water was carried by the flume to the breast or middle of the wheel's height, passing under the wheel and moving it through a combination of the momentum of the flow and the weight of the water as it filled the

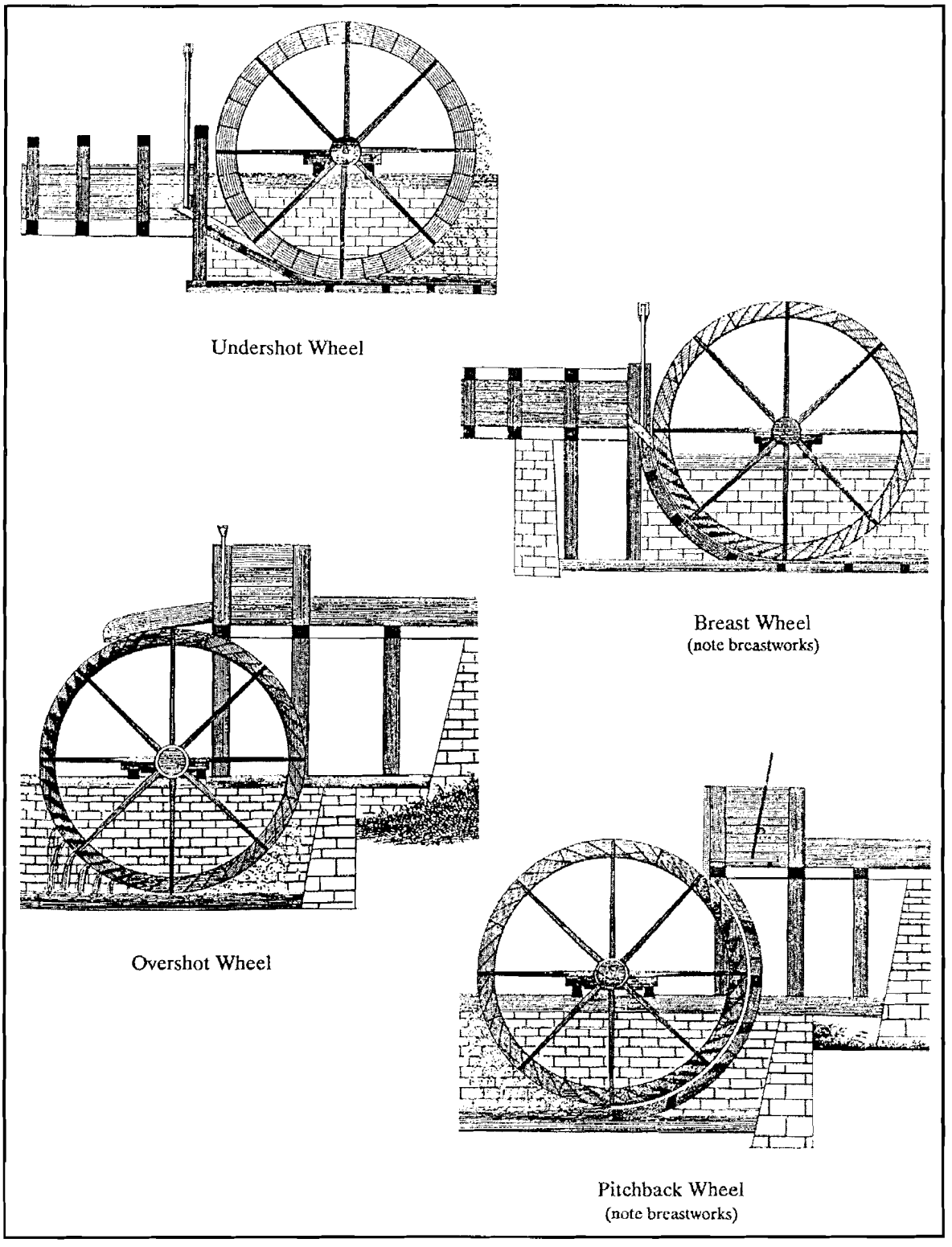


Figure 5-50. Water Wheels
(Evans 1972).

buckets. The third design, the overshot wheel, was employed with a high fall or head, generally of 10 feet or more. In the most common version, water struck the wheel just beyond the highest point of the arc of the wheel, passing over it and turning the wheel mainly by the weight of the water. A variation of the overshot wheel was referred to as pitched or pitchback, so called because water was fed just behind the highest point of the wheel's circumference turning the wheel in the opposite direction to the overshot wheel.

Each type of wheel had its advantages and disadvantages. The breast and overshot wheels were the most popular mainly due to greater efficiency in comparison with the undershot wheel. In the mid-eighteenth century, it was determined that the overshot wheel delivered up to 60 percent of the potential energy from a flowing stream, the breast wheel up to 45 percent, and the undershot 30 percent (Leung 1981). Later estimates ranged to 75 percent, 60 percent and 30 percent respectively (Zimiles and Zimiles 1973), the increases probably reflecting advances in wheel design. An advertising claim from the Fitz Water Wheel Co., of Hanover, PA, dated December, 1928, maintained an over 90 percent efficiency for their "modern Steel Overshoot Water Wheel" (Fitz Water Wheel Co. 1928).

Backwash was a matter of concern for each type of wheel, but most importantly for the overshot wheel. The bases of the undershot, breast, and pitchback wheels all turned in the direction of the flow of water out of the mill (in an area referred to as the tailrace), though with the breast and pitchback wheels it was necessary to construct an apron, sometimes referred to as the breast, conforming to the back edge of the wheel, which prevented the buckets from emptying too soon, releasing their energy before it was fully utilized, and creating turbulence in the tailrace. Turbulence was a matter of fact with the overshot wheel, since the base of the wheel ran opposite to the flow of water out of the race. To compensate, the wheel was suspended above the water level in the wheel pit and the tailrace was constructed to draw the water away from the wheel pit as efficiently as possible. Evans (1972), for example, recommended 8 to 9 inches of clearance between the wheel and water level in the wheel pit, while Hughes (1867) suggested that the pit be at least 2 feet deep and that the tailrace be well sloped. And yet, even with these design related features in place, it was necessary to regulate the flow of water so that the wheel pit did not fill and decrease the efficiency of the wheel. Downstream flooding was a further hazard and one that was difficult to control.

Sawmills

The origin of the sawmill has been variously placed in Germany (Apps and Strang 1980), and Scandinavia (Zimiles and Zimiles 1973). A review of the literature resulted in two findings relevant to the design of sawmills: first, much less has been written about saw milling in comparison with the milling of grain; and second, sawmills were less standardized in lay out than were grist mills. Sawmills were often housed in open, shed-like buildings that were long and narrow. The description, below, of a typical sawmill and the machinery contained within it follows the design presented by Thomas Ellicott in Evan's *Young Mill-Wright* (1972).

Throughout much of the nineteenth century, mechanized sawing was done using an up and down, or reciprocal, motion of the saw, in the manner of hand-held saws. The mill building

was thus usually long, high, and open ended, with one side often left open as well (Figure 5-51). A flutterwheel, a low and wide version of the undershot wheel, was the most commonly used wheel, preferred for the power which could be generated from paddles or floats which were up to 6 feet in length and capable of turning 100 to 120 revolutions per minute, an appropriate speed for the running of a reciprocal saw blade without complex gearing. Rather than a round face gear used in a grist mill, the wheel was connected to a crank, which translated the circular motion of the wheel to an alternating vertical motion. As a consequence, the flutterwheel was usually of heavy construction, allowing it to act as its own flywheel, counteracting the jerking motion of the crank and blade.

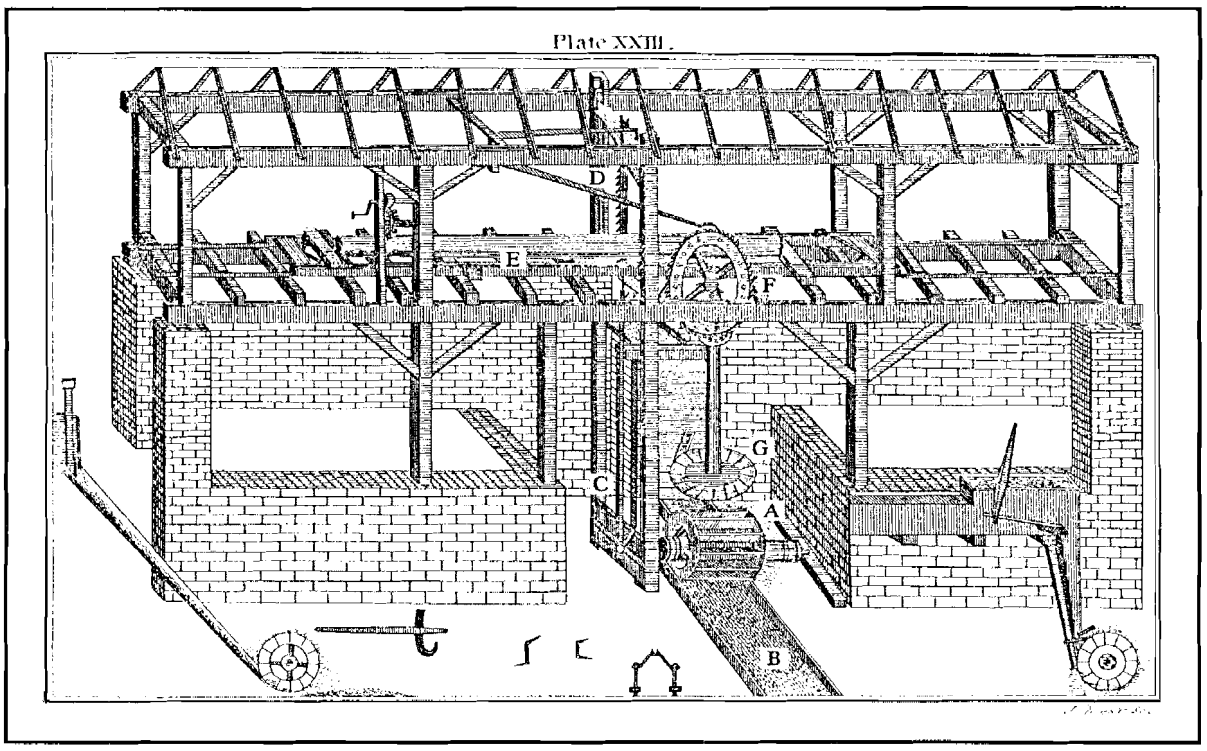


Figure 5-51. Ellicott's Design for a Sawmill
(Evans 1972): A) flutterwheel; B) tailrace; C) pitman; D) saw blade; E) log carriage and log; F) rack wheel; G) tubwheel.

The log to be cut was placed in a wooden frame or carriage located near the top of the building, and was held in place within the carriage by clamps or dogs that were adjustable to allow the wood to be positioned for the proper width of cut. The carriage was normally set on wheels and propelled by a wrag or rack wheel which was geared to the main drive or to the crank, moving the carriage at the proper speed relative to the saw blade. The saw was usually about 6 feet in length and 6 to 9 inches wide, attached to a wooden frame or sash that was connected to the crank by a long rod known as the pitman rod, after the man who stood in the saw pit holding the lower end of a manually operated saw. When a complete pass had been made, the carriage was usually returned by means of a second wheel, such as a small tub wheel (Ellicott suggested a wheel of 4 foot diameter) geared to the rack wheel. The timber would be turned, the dogs reset, and the carriage sent on its next pass. Thus, the mill structure was at least twice the length of the longest log that was anticipated (typically about

20 feet). By the mid-nineteenth century, arguments were advanced for the use of geared mechanisms and a belt driven saw to reduce the inevitable unsteadiness of the crank and pitman combination, translating more power directly to the blade (Hughes 1867).

The more efficient circular saw was introduced in the mid-nineteenth century. Some researchers credit the idea of the circular saw to a Shaker Sister around 1810, who connected the motion of her spinning wheel with the work of the saw (Zimiles and Zimiles 1973). The first patent was actually issued to Samuel Miller, in England in 1777, with the technology arriving in the U.S. by 1814 (Apps and Strang 1980). Problems with early circular saws kept them from general use before around 1850 (Rawson 1970). These problems included maintaining the balance of the spinning blade and the production of a relatively wide kerf, the gap left in the wood by the passage of the blade—early circular blades left a $^{3}/_{8}$ to ½-inch kerf, resulting in a large amount of waste.

Circular saws were normally geared directly to the water wheel. Since the rotating blade did not require the smoothing, balancing effect of a heavy flutterwheel, the more powerful overshot wheel, and later the turbine, became the preferred power sources. Circular saws did not require the extensive and complex equipment needed to operate a reciprocating saw, and eventually, they were powered by steam engines, allowing them to become portable, eliminating the need to move heavy logs long distances to a stationary mill (Lovett 2002). The band saw, which like the circular saw was developed in England around the turn of the nineteenth century but was not used in this country until the latter part of the century, constituted a major improvement in cutting efficiency (Apps and Strang 1980). In general use by the 1890s, a band saw consisted of a wide but thin ($^{1}/_{16}$ inch) strip of supple steel. The band ran in a continuous loop, cutting with a much narrower kerf and operating more rapidly and efficiently than a circular blade. As a comparison, it has been estimated that two good sawyers could cut between 100 and 200 linear feet of lumber per day by hand, a reciprocal saw could cut between 500 and 1,000 feet, while a band saw, even in a small operation, was capable of up to 3,000 feet in one hour (Rawson 1970).

5.3.2 The Structural Remains at Diamond Pond

Sawmills were housed in buildings that differed in appearance from the typical grist mill, being long, open shed-like structures. They were long to accommodate timbers of 20 to 30 feet in length, and were often open-sided to allow the logs or lumber to be moved in and out laterally. Many sawmills, especially later mills containing circular saws with less complex machinery, were constructed quickly and abandoned after an area was logged out, the buildings demolished or allowed to deteriorate (Lovett 2002). The mill at Diamond Pond was in operation for almost a century, its relative permanence associated early on with the reciprocating saw machinery and later with the market that it apparently served, the shipbuilding industry at Milton.

Relatively little was present archaeologically at the mill in terms of structural features. Only parts of the lowest course of timbers remained, set on posts or piles and still attached to sheet pilings by means of nails. Yet, the general shape and size of the building could be inferred from these surviving structural elements. The timbers were more or less in place, and their

state of preservation allowed part of the structure to be reassembled analytically. Using three main sources of information—1) the locations in which the main timbers were found; 2) the alignments of posts and sheet pilings that appeared to have been associated with specific timbers; and 3) the positions of features such as mortises and tenons—drawings of the main structural elements were fitted together.

Schematic Reconstruction

To begin the process, the site was fully mapped, with the location of each of the large timbers precisely noted, along with the position of each post and sheet pile (Figure 5-52). Two detailed drawings were made of each timber: one consisted of a plan view of the upper surface of the timber as it was exposed in the stream bed; the second consisted of the elevation or profile that showed the most characteristic details of joinery techniques (e.g., Figure 5-41). In this manner, the positions of notches, grooves, nails, tenons, etc., were drawn to scale.

The drawings were then digitized and placed as movable figures in appropriate locations on a digital version of the site map (Figure 5-53). The individual timbers could then be re-positioned based on the patterns of posts and pilings, and on the relative locations of joinery features (Figure 5-54). Estimates of the original dimensions of the timbers were used to

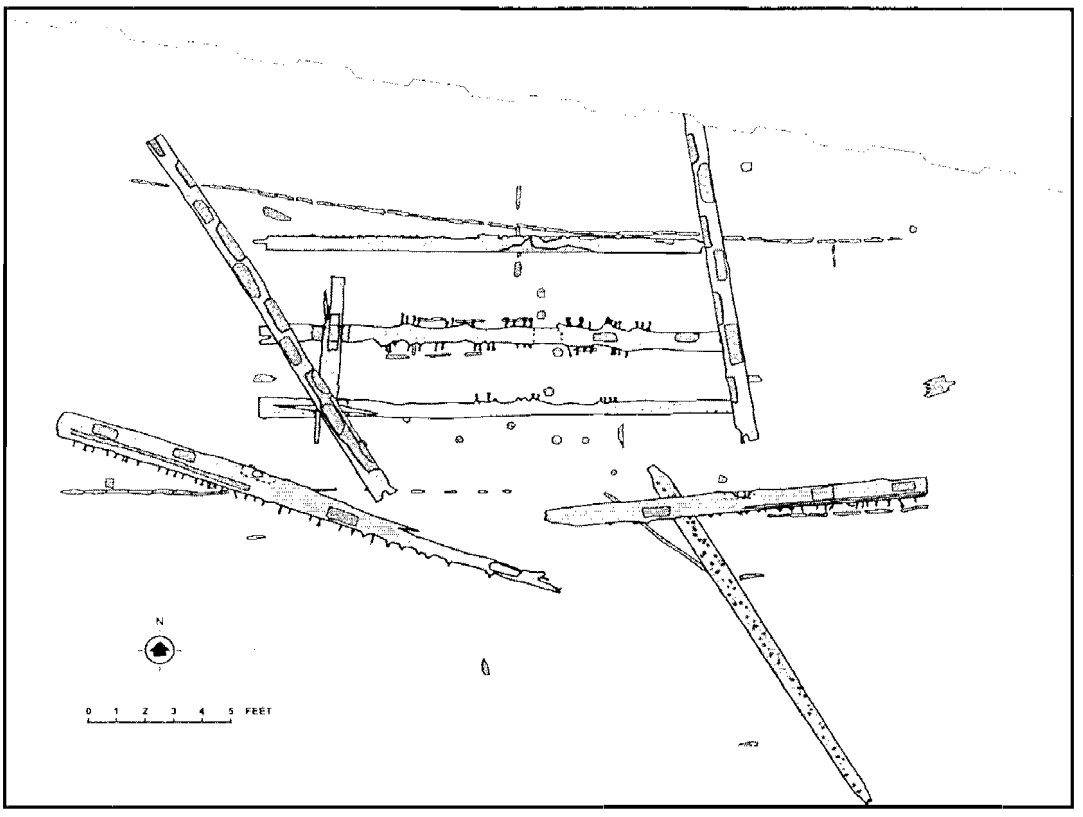


Figure 5-53. Digitized Versions of Timber Drawings Embedded in Site Map.

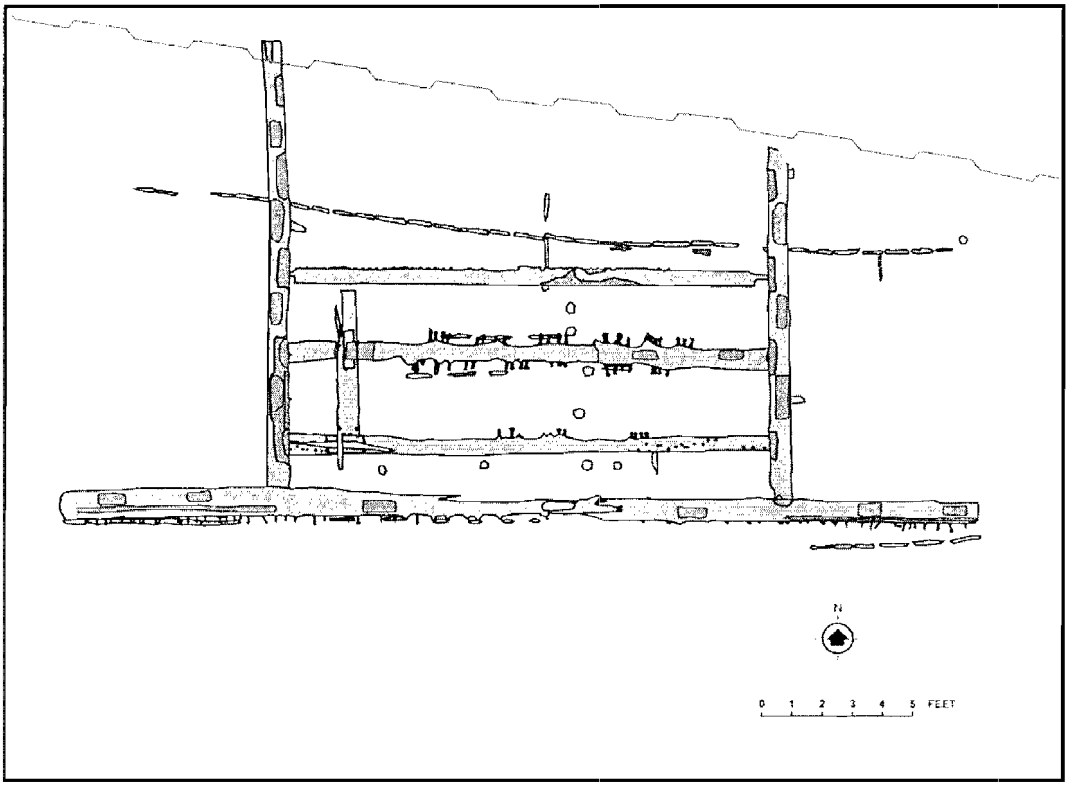


Figure 5-54. Reassembly of Timbers Based on Locations of Joinery Features and Posts and Pilings.

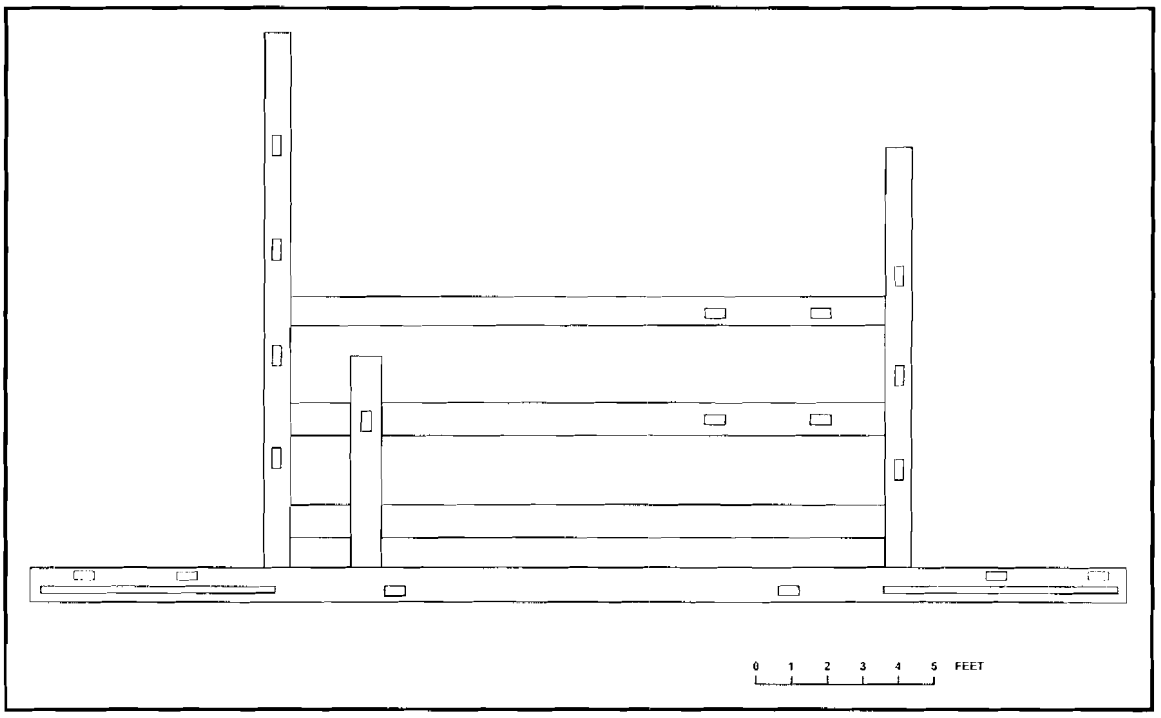


Figure 5-55. Schematic Reconstruction of the Structure.

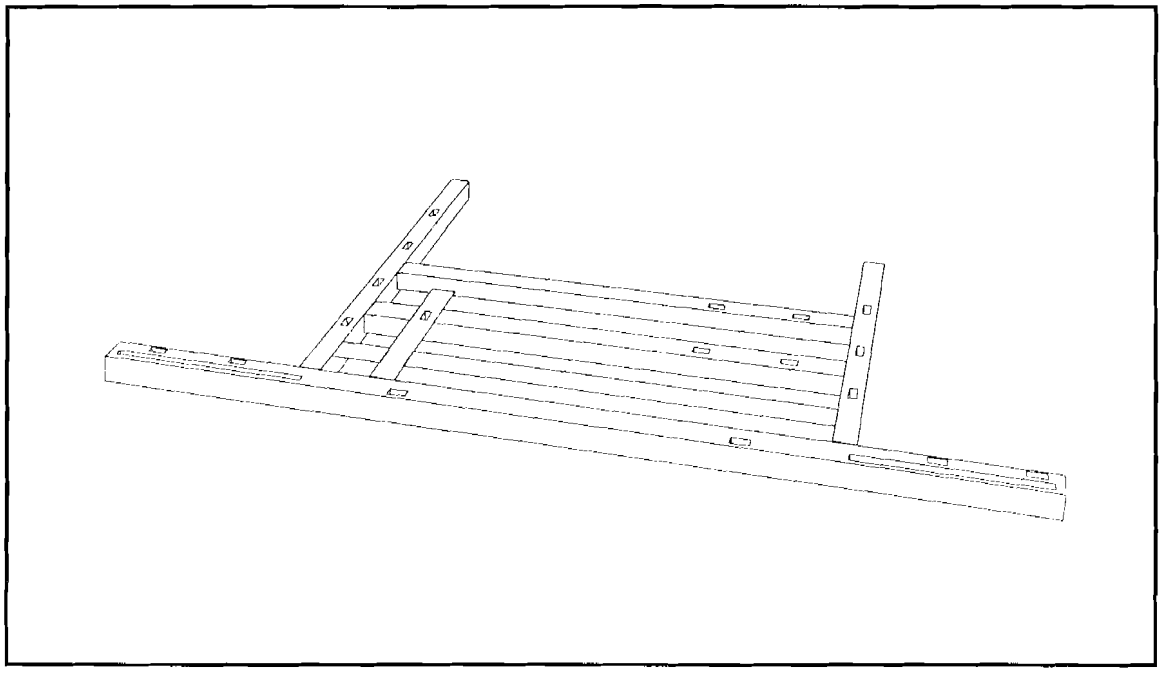


Figure 5-56. Isometric View of Reconstruction.

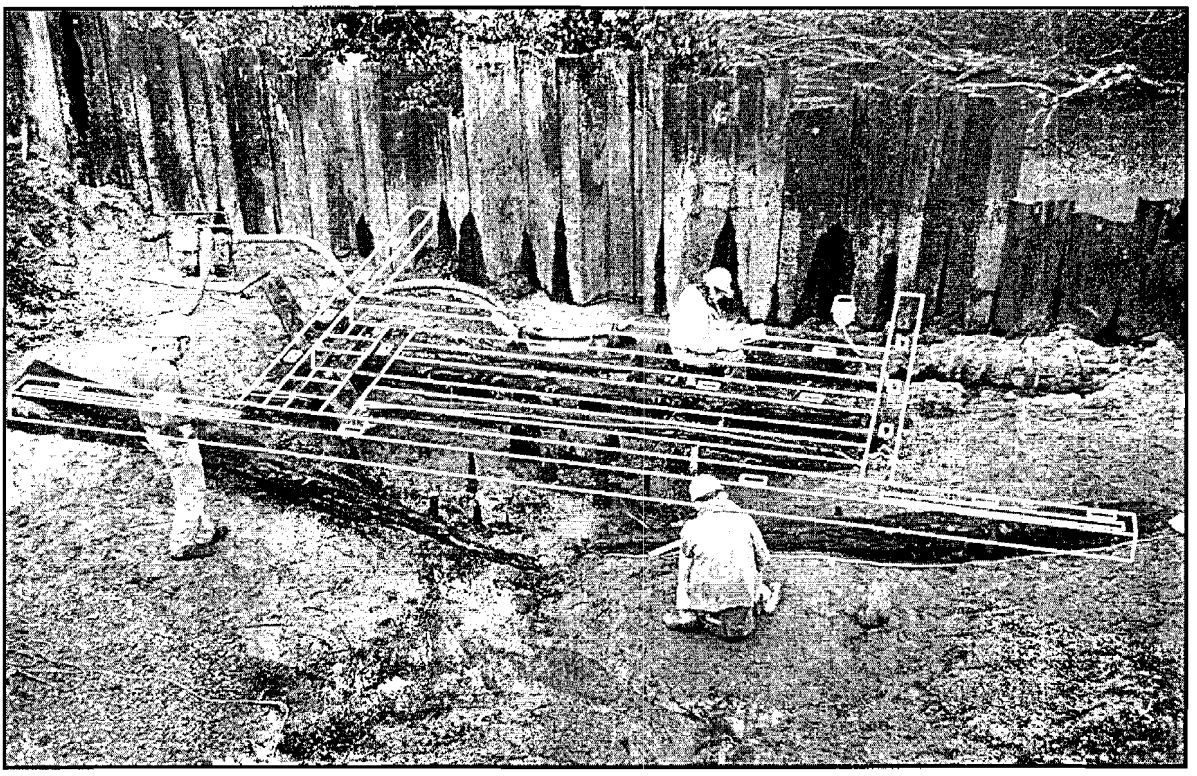


Figure 5-57. Reconstruction Superimposed on the Archaeological Remains.

redraw the structure (Figure 5-55). Perspective was added using surface mapping software (Figures 5-56) and overlaid on a photo-image of the archaeological remains (Figure 5-57).

The sheet pilings used in construction of the mill appeared to have been designed to protect the structure from undercutting and weathering related to water flow. In at least two cases--Timber 1 and Timber 3—the pilings lay on the downstream side of the timbers, opposite the prevailing direction of the current. The mill was located above the tidal zone, and thus would not have been subject to reverse stream flow during the tide cycle. Yet the area may have been prone to flooding resulting in sufficient back flow to cause the mill owner to be concerned with undermining from the downstream direction, prompting the addition of sheet pilings on the downstream side of the structure. The downstream pilings may also have served as protection against backwash from the mill wheel, if the wheel pit were situated in this part of the structure.

Timbers 4 and 5 provided the best indication of the original sizes of the structural elements of the mill. Originally the two fragments were part of a single, large timber. In its initial state this timber was longer than many of the others, apparently functioning as an exterior base support or spreader. Thus, its ends lay farther from the center of the stream where they were not subject to weathering to the same degree as the timbers at the center of the structure. While the timber was somewhat larger than others, it provided an indication of the scale of the unweathered timbers, suggesting that most were roughly 12x12 inches in cross section. The fact that the timber had weathered to the point that it had completely separated, forming

the two pieces documented archaeologically as Timbers 4 and 5, indicated the length of time that the mill structure had remained in the bed of the stream. Timber 3 was the most deteriorated of the intact structural elements. It lay at the upstream end of the structure, and after Timbers 4 and 5 separated, it would have taken the full force of the stream flow.

Mortises were documented on the sides and upper surfaces of most of the timbers. Lateral mortises were usually aligned with tenons on cross members, while mortises on upper surfaces presumably held the tenons of uprights that formed the superstructure of the mill. None of the upright timbers was identified in the archaeological remains, although Timber 13, the pegged timber, did not appear to have been associated with the articulated timbers forming the base of the mill, and thus may have been one of the uprights. In one instance, mortises were noted that did not appear to match the design of the structure. A set of mortises occurred on the north face of Timber 1, in a pattern dissimilar to that of the other cross members: while they aligned with two mortises in Timber 2, they faced downstream rather than upward. Several explanations may account for the pattern. For example, additional horizontal cribbing may at one time have been present in the downstream portion of the mill structure that attached to the mortises on the side of Timber 1. Alternatively, the timber had been reused and the mortises were from a previous structure. A further alternative suggests that the timber had rolled over 90 degrees following the deterioration of the mill and partial disarticulation of the timbers at its base. Yet, the tenons at either end of Timber 1 were incorrectly oriented to fit into the mortises in Timbers 7 and 8. In the end, the most economical explanation may be that Timber 1 originally lay with its tenons horizontal and connected with Timbers 7 and 8, and that the mortises were on the upper surface to receive vertical structural timbers paired with elements in the mortises on Timber 2. Over time, Timber 1 may have become disconnected from all of its related structural timbers and rolled over. Nails were present along the north face of the timber connecting it with sheet pilings there, suggesting that the pilings may have been a later addition, as a precaution against stream undercutting.

There did not appear to have been precise specifications for the posts and sheet pilings, since lengths, diameters, and wood types varied considerably. Yet the features did fall within a range of sizes, depending on their function. For example, the large plank posts (Posts A & D) were approximately 9 inches wide and varied in thickness from 4 to almost 6 inches. Sheet pilings throughout the site ranged from 1x8-inch to 2x10-inch planks, with little apparent functional need for the variation. Although only a sample of the sheet piles was analyzed for wood species, all appeared to be of pine wood. The pilings may have been seen as expendable, since they were designed to take the brunt of the weathering of the stream current, and thus less expensive and easily obtained pinewood was selected for their manufacture.

5.3.3 Wood Species Analysis

A total of 30 features were sampled for taxonomic identification. Samples were taken from structural timbers, post, sheet piles, and wooden pegs. An 8-to-12 inch section was cut from each of the main timbers using a chainsaw, while portions of selected posts and sheet piles, a sample of pegs from Timber 13, and a single unprovenienced peg were also sectioned. The

samples were kept immersed in water and or refrigerated prior to further sampling and submission for analysis. Small samples of the larger wooden elements were excised by a macrobotanical specialist, while small wooden artifacts (such as pegs) were submitted in their entirety.

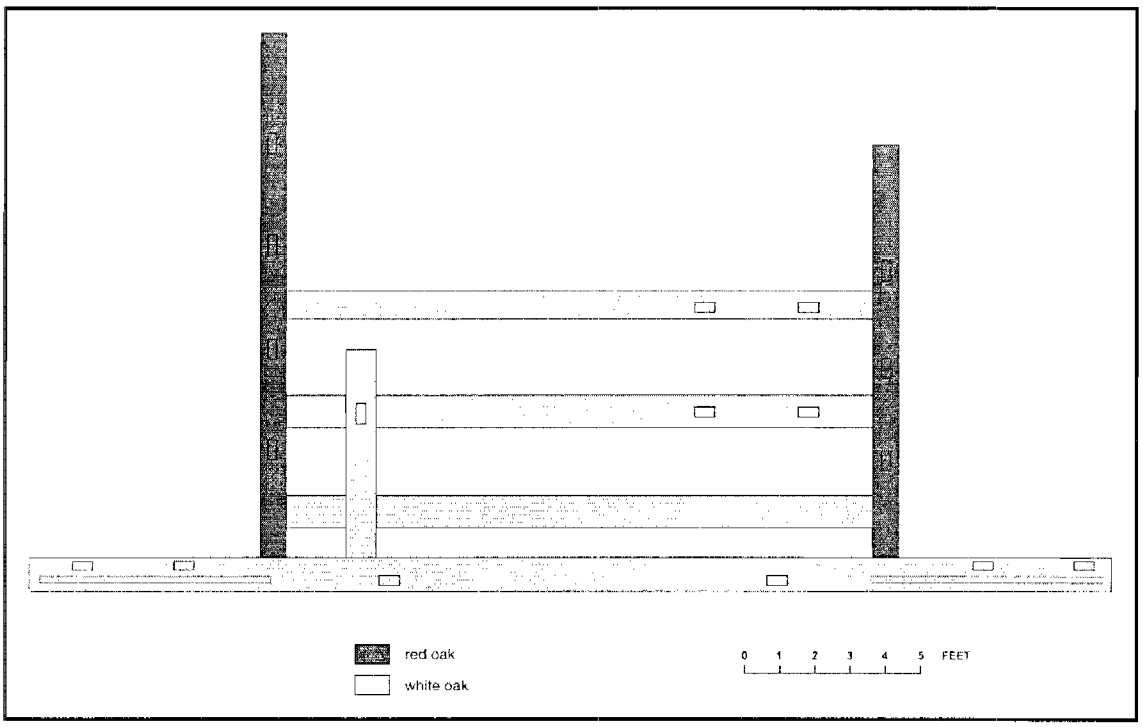


Figure 5-58. Results of Wood Species Analysis.

A detailed report of the wood species analysis is provided in Appendix B. In summary, three wood types were identified in the assemblage. The species included white oak (*Quercus spp. LEUCOBALANUS* group), red oak (*Quercus spp. ERYTHROBALANUS group)*, and yellow pine (*Pinus spp.)*. All are species that grow locally and would have been available in quantity. Figure 5-58 shows the schematic reconstruction of the mill timbers color-coded by wood species. White and red oak were used for the major structural elements of the mill remains. All of the sheet pile samples submitted for analysis were identified as yellow pine. The posts underlying the structural timbers consisted of examples of all three species. Pegs were of white oak and yellow pine.

As shown in Figure 5-58, a pattern emerges in the choice of wood species used for the side and cross timbers. All of the large cross timbers were made of white oak, while the two side timbers were made from red oak. White oak is known for its strength and resistance to decomposition owing to the presence of frothy growths, or tyloses, in the pores of the heartwood. Red oak shares many qualities of white oak, yet it lacks tyloses and is therefore porous and less resistant to rot and weathering. The pattern of wood selection in the structural elements of the mill may reflect cost considerations. The more rot resistant and presumably more valuable species were used as cross timbers as they were more exposed to the stream current and were thus more prone to weathering and eventual decay. Evidence for

this interpretation can be seen in the degree of weathering present on the cross timbers (see Figure 5-13). The centers of the cross timbers were considerably more deteriorated than either of the side timbers. Alternative explanations for the use of red oak for the side elements include a repair episode at a time when the large timbers of the stronger white oak could not easily be acquired or the general availability of wood species at the time of construction.

5.3.4 Estimation of Available Fall or Head at the Upper Mills at Diamond Pond

As mentioned above, the available head of water that powered a mill consisted of the distance between the points at which the water entered and left the mill. The available head determined the type of wheel that could be most efficiently used and the amount of horsepower that the wheel could generate. At the Diamond Pond mill, the fall or head was calculated analytically using present day elevation data. The point at which water entered the mill was estimated on the basis of a benchmark located on the top of the dam, approximately coincident with the modern road surface. The point at which water left the mill was estimated using the tops of the surviving structural timbers, which appeared to have been at least partially submerged. The benchmark was at an elevation of 17.49 feet above mean sea level (amsl). With the exception of timbers that were obviously out of place, such as the south ends of Timbers 7 and 8, that had been pushed upwards by the sheet pilings of the coffer dam, the structural timbers lay at elevations measuring between 2.47 and 4.70 feet amsl (Table 5-1). Calculating from the benchmark at the top of the dam, the potential fall or available head was estimated between 13 and 15 feet. Due to the deteriorated state of much of the structural material at the site, it was difficult to assess which timbers and posts might be more representative of the base of the mill and thus of the level of water passing into the tail race. Therefore, the mean elevation of all of the undisturbed features was presumed to be generally representative, suggesting that the available head at the sawmill was approximately 13.75 feet.

Table 5-1. Estimation of Available Fall at the Sawmill on Diamond Pond.

	Elevation of Timbers (ft amsl)	Top of Dam (ft amsl)	Available Fall (ft)
Maximum	4.70	17.49	15.02
Mimimum	2.47	17.49	12.79
Mean	3.75	17.49	13.74

5.3.5 Comparative Analysis: Sawmills in the Mid-Atlantic and Northeast

The specific layout of the sawmill at Diamond Pond is unclear from the archaeological evidence. The only image of the structure that is available is a very schematic drawing that appears on a map dated 1853 and attributed to the Sussex County Orphans Court. The drawing shows a single, narrow structure adjacent to the east end of the mill dam. The

structural features documented in association with Bridge 3-806 may have been the base of a long penstock or flume directing water from a sluice gate on the dam to a wheel and mill further downstream, in a design seen in mills such as the Nichols Saw Mill, in Merrimack County, New Hampshire (HABS 1984) (Figure 5-59). Yet most documented penstocks were less than 10 feet in width, while the Diamond Pond mill framing was nearly 20 feet wide. In addition, the large sizes and close spacing of mortises in the upper surfaces of the timbers suggested a superstructure that supported more than a simple wooden flume or chute.

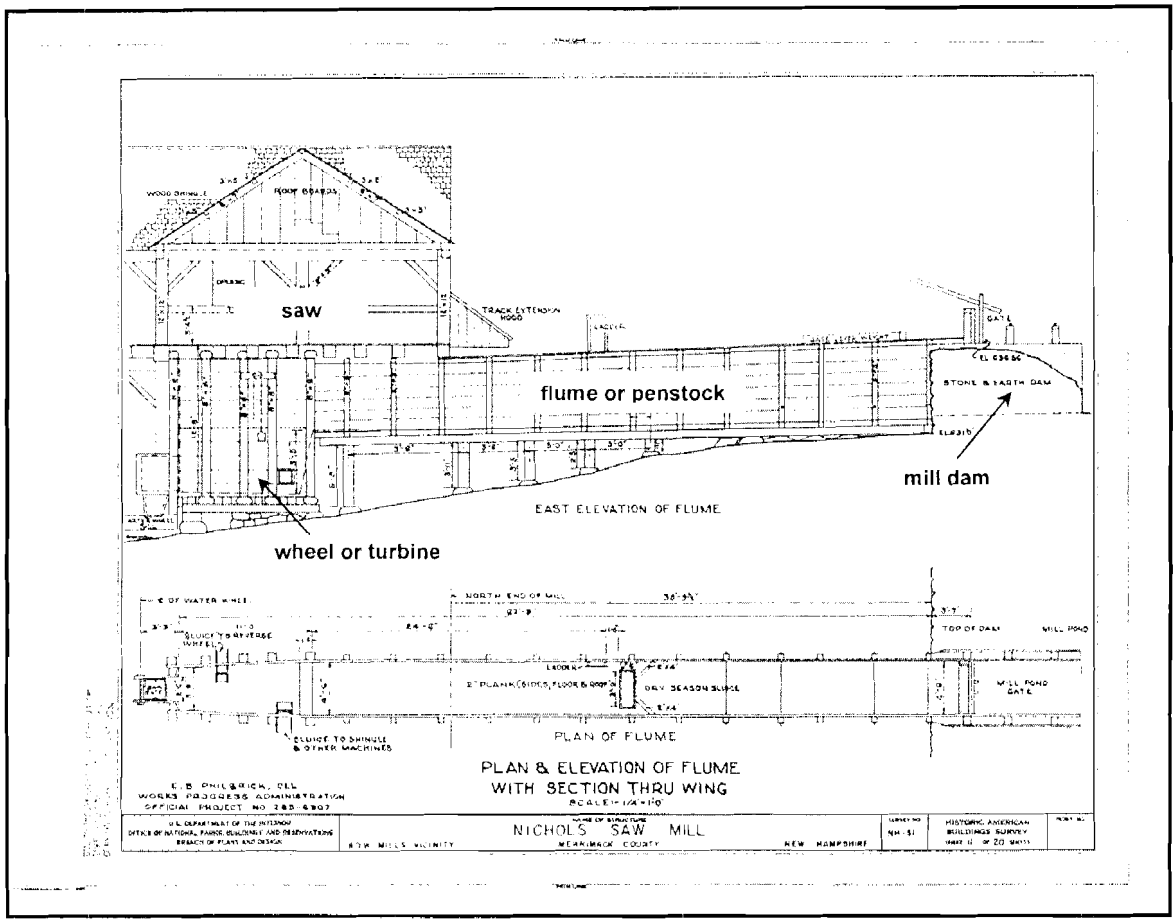


Figure 5-59. Long Flume or Penstock Bringing Water from Mill Dam to Sawmill at Nichols Saw Mill, Merrimack County, New Hampshire (HABS 1984).

Were the mill structure located farther downstream, as in the Nichols design, access would have been problematic since there would have been no bank on either side of the structure. The Orphans Court map and a later map from the Delaware State Highway Department (1933) suggest that the area was flat and marshy, as it appears at the present time. In 1853, a second mill (identified at that time as a bark mill) and miller's house are shown on the west side of the dam. The mill was situated on the edge of an outlet or gate, while the house lay on higher ground to the west and with easy access from that direction. Access to the sawmill would probably have been from the east, although in its current configuration the east bank lies at least 20 feet from the structure. There has presumably been some modification to the bank in the twentieth century.

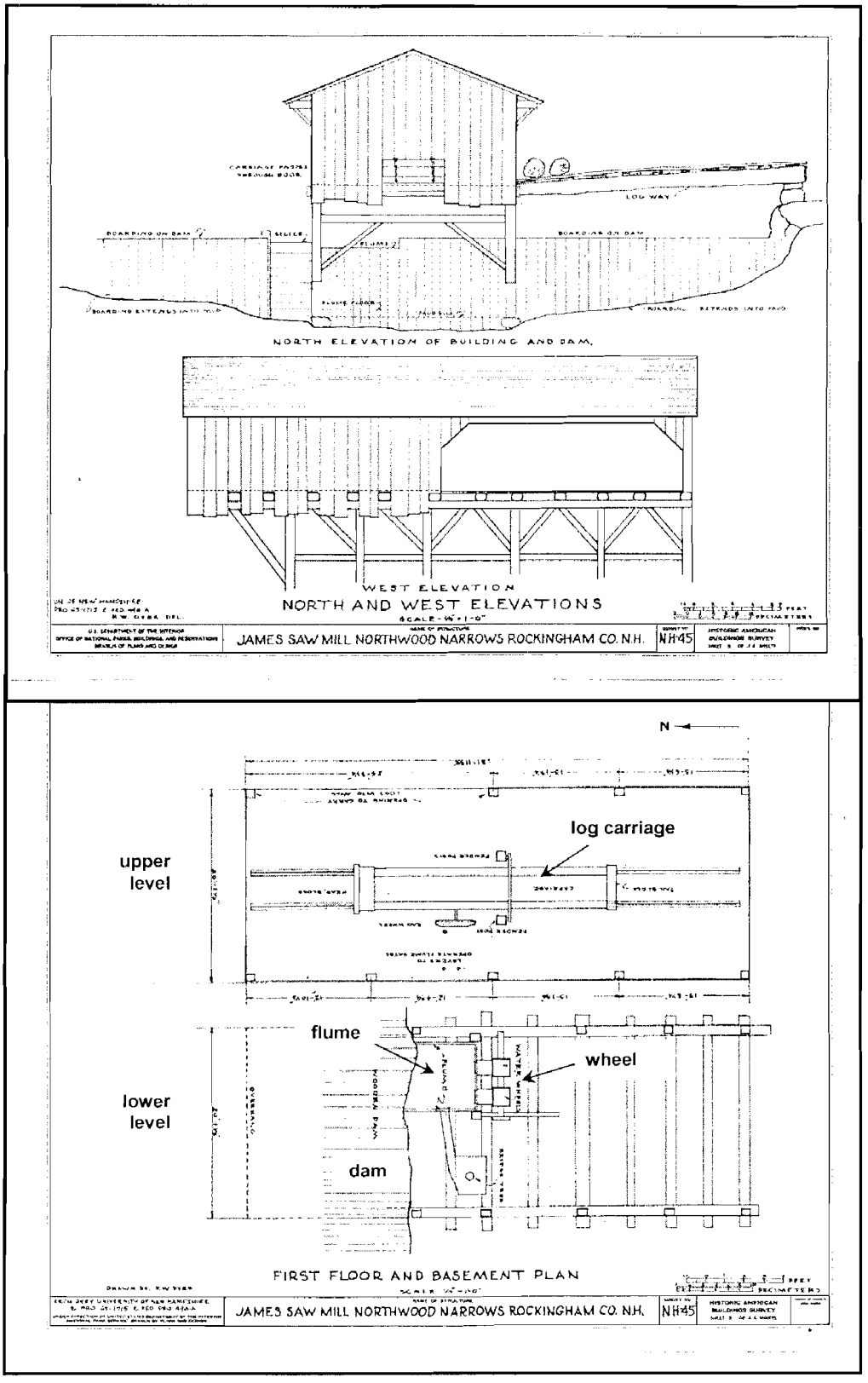


Figure 5-60 Compact Mill Situated on Mill Dam: Elevation Drawings of James Saw Mill, Rockingham County, New Hampshire (HABS 1936).

The mill at Diamond Pond was probably a small structure overall, judging from the amount and location of fast land just described. The width of the structural remains documented archaeologically appears to represent the original width of the mill, since no additional structural evidence was observed either to the east or west. The original length of the structure is unclear – only about 15 feet was exposed within the confines of the coffer dam. Additional timbers were noted downstream following removal of the dam pilings at the end of the construction project. These remains had not been noted during the archaeological investigation due to the depth of pooling caused by backwash from the pumps that diverted stream flow from the pond. A large cross-piece similar to the combined Timbers 4 and 5 was present downstream, located at least 15 feet beyond the line of the coffer dam, suggesting that the original length of the mill structure was at least 30 feet.

No evidence was noted of massive foundations or of supplementary buttressing, in spite of the fact that the structure sat on relatively soft alluvial sediments. Some studies have noted that extensive measures were often taken to shore up sinking structures that had been built on soft ground adjacent to a stream bank (Resnick and Frye 2005). The absence of such measures at the Diamond Pond sawmill suggests that the structure was small and comparatively lightweight. Spread footers, represented by the larger timber (Timbers 4 and 5), and a lattice of cross members (Timbers 7 and 8 and the cross pieces Timbers 1, 2, and 3) were apparently sufficient to distribute and support the weight of the superstructure.

The Diamond Pond sawmill may thus have been similar in design to the James Saw Mill, Rockingham County, New Hampshire (HABS 1936), in which a relatively compact rectangular structure contained all of the functional elements of the mill within a footprint on the order of 50 feet in length, 20 feet in width (Figure 5-60). The building was constructed on the mill dam in two levels or stories, with a short flume and a water wheel located on the basement level, and the log carriage and saw located above, on the first floor. A similar stacked arrangement is seen in McMurtry's Mill, Somerset County, New Jersey (HABS 1941), in a structure measuring 20 feet by 40 feet, with a very short penstock, turbine, and gearing located in the lower or basement level, the log carriage and saw on the first floor level. Other compact, multi-level mills include the Weare Mill, Rockingham County, New Hampshire (HABS n.d.), in which the penstock (~28 feet in length) and turbine were located below the mill floor that contained both saw and grist mills. An alternative arrangement that required more open ground is seen in mills such as Boxford, Essex County, Massachusetts, (HABS 1934), in which a relatively short penstock (~34 feet) was constructed to the side and at the same level as the saw and log carriage (Figure 5-61). In this design the penstock fed a turbine on a lower level.

The grist mill at Cubbage Pond (7S-C-61) was an example in Sussex County, Delaware, with the penstock and wheel to the side of the mill (Resnick and Frye 2005). First built around 1784, the Cubbage Mill initially contained a small, short penstock that measured 12 feet in length and 8 feet in width. Constructed of Altantic white cedar and red oak, the penstock carried water to an undershot wheel. The associated wheel pit was 20 feet in length, 11 feet wide, and constructed of Atlantic white cedar timbers measuring 9x9 inches in cross section. A sawmill was added in the 1860s, by which point the mill was powered by a turbine. The penstock had been lengthened to 40 feet and widened to approximately 12 feet. White oak

and tulip poplar timbers averaging 12x12 inches in cross section were used in construction of the penstock. In its final configuration in the late-nineteenth and early-twentieth centuries, the penstock was at least 45 feet in length, 12-14 feet in width, and was constructed of white oak and poplar timbers measuring 9-12 inches by 4-7 inches in cross section.

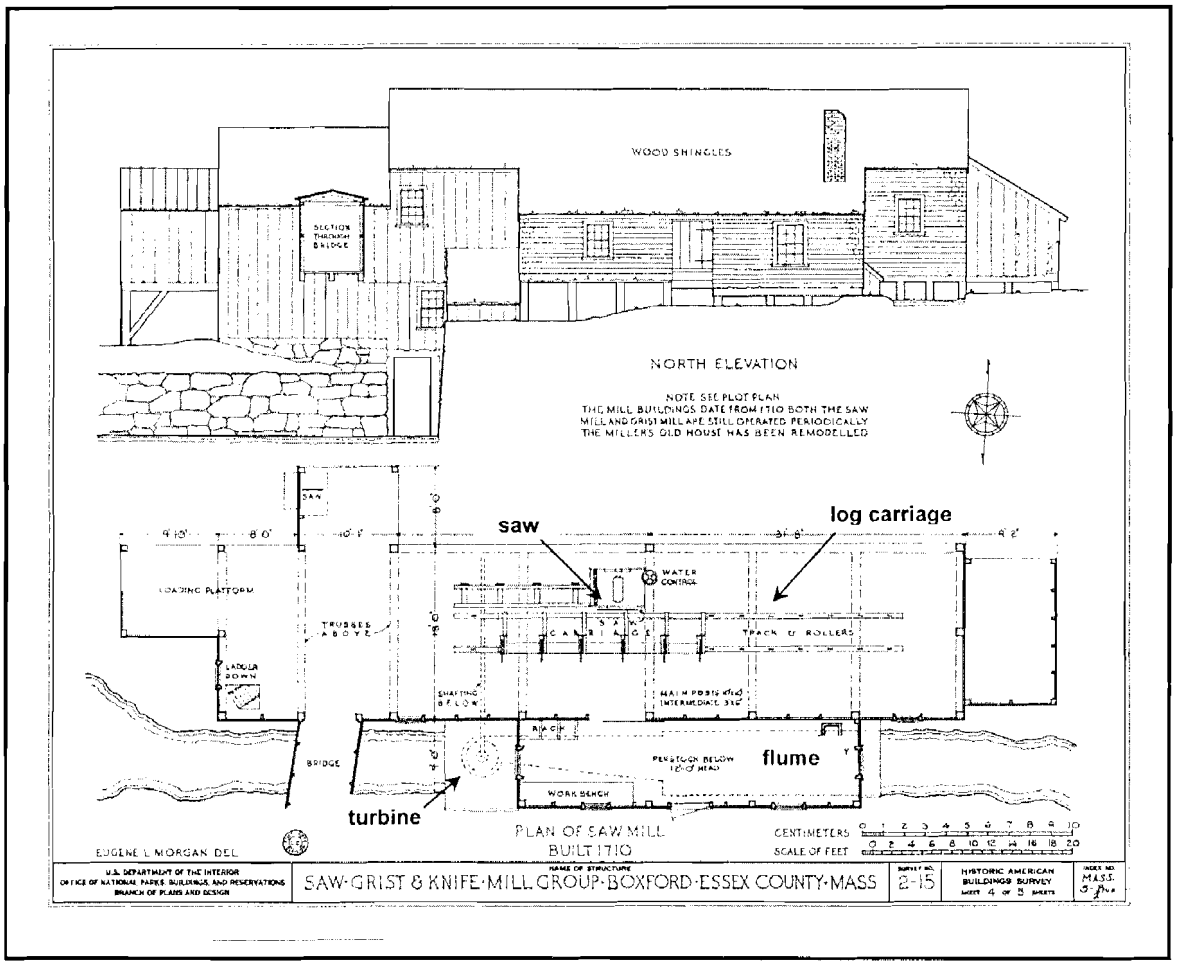


Figure 5-61. Short Flume or Penstock Located Lateral to the Sawmill at Boxford, Essex County, Massachussetts (HABS 1934).

5.3.6 Landscape Analysis: Diamond Pond Mill and Milling in Southern Delaware

In addition to examining in detail the structural features identified in the stream bed, the remains of the Diamond Pond sawmill were considered within the context of the wider landscape in order to address questions about the choices behind the mill location. A number of landscape related factors may have had a direct influence on the success of a mill, including sufficient water supply to keep the mill running; a high enough fall of water to provide adequate power for the mill; and access to transportation networks and markets. Analysis of the Diamond Pond mill focused on each of these issues.

Water Supply

The reliability of water supply to a mill depended on a variety of factors. For example, the regularity of rainfall affected the consistency with which water would be available throughout the year. A mill pond helped compensate for variations in rainfall by providing a reservoir of water for use during periods of decreased rainfall. Thus, the capacity of the mill's pond determined the size of the reservoir of available water. And finally, the size of the watershed that the mill drew upon influenced the stability of the water source, since the larger the mill's watershed, the more reliable it's water supply was likely to be.

To examine the significance of watershed size for the Diamond Pond mills in relation to the other mills in Sussex County, the watersheds for known mills in the county were estimated. As a first stage in this process, the locations of all the mills shown on Beer's 1868 Atlas were placed on digital raster graphics of USGS 7.5-minute quad sheets for Sussex County. The watershed for each location was then calculated in two steps. First, topographic data based on a 30-meter digital elevation model for the county were analyzed with hydrological modeling tools developed for ArcView. Secondly, the watersheds were edited using USGS digital line graphs for streams in the county.

Table 5-2 lists all of the Sussex County mills shown in Beer's Atlas, along with the size of their respective watersheds, height of fall, approximate elevation of the mill, the number of mills upstream and downstream, and the distance to the nearest mills up and downstream. Figure 5-62 shows the resulting distribution of mills superimposed on a shaded elevation map (30-m digital elevation model) for Sussex County. The approximate watershed for each mill is also shown. The analysis shows that most of the mills were located within a 3-to-6-mile wide band along the margins of the drainage divide that runs roughly north to south across the county separating the Chesapeake Bay from the Delaware Bay and Atlantic Ocean watersheds. Elevations in the county overall range from sea level to 140 feet above mean sea level (amsl). The mills were located within a narrow range between 5 and 40 feet amsl, with 81 percent located between 10 and 35 feet amsl.

Available Head or Fall

The height of water fall, or head fall, was also an important factor for nineteenth-century mills. The higher the fall, the more power the mill could generate for its operations. As noted earlier (Section 5.3.4), the height of head fall at the Diamond Pond sawmill was estimated to have been over 13 feet, based on the change in elevation from Diamond Pond to the stream below the mill. In order to compare this dimension with that of other mills in Sussex County, estimates were made of the height of fall for each of the mills mapped in Sussex County (Table 5-2). In locations where the mill ponds are still present today, the head falls were estimated from the difference in elevation between the pond and the stream level below. In locations where clear evidence of the original pond is no longer present, estimates were based on the maximum height for a mill dam that the stream banks at each location would have allowed.

Table 5-2. Mills in Sussex County Appearing in Beer's Atlas.							
Mill Name	Elevation (ft)	Fall (ft)	Watershed Acres	Number of Mills Upstream	Number of Mills Downstream	Nearest Upstream Mill (meters)	Nearest Downstream Mill (meters)
Abbotts Grist Mill	30	5	460.516	none	3	none	4500
Bacon and Richards Mills	30	5	904.722	none	2	none	2800
Beaver Dam Creek Mills	10	7	420.436	1	none	2500	none
Betts Grist Mill	18	5	373.724	none	1	none	2500
Bett's Pond Mills	20	5	56.551	4	2	2000	1100
Big Mills Sawmill and Gristmill	10	10	1061.313	2	none	1730	none
Blackwater Creek Gristmill	10	5	359.115	none	none	none	none
Boston Mills	10	7	1307.231	1	none	4300	none
Bradleys Sawmill	11	5	287.236	2	1	1200	520
Burton Pond Mills	10	5	438.034	none	none	none	none
Cannon Mills	25	10	1898.045	none	1	none	6000
Catfish Branch Gristmill	28	5	239.360	none	3	1500	5400
Cedar Creek Sawmill	40	5	191.136	none	6	none	1200
Clendaniel Pond Mills	20	7	523.381	2	3	3500	1500
Collins Forge Mills	30	5	2015.083	1	1	4800	none
Collins Sawmill	23	7	432.529	1	2	1940	1480
Comons Gristmill	29	5	758.475	none	none	none	none
Cubbage Pond Gristmill	13	3	615.483	4	2	1500	1200
Deals Mills	20	5	963.377	1	2	2000	1500
Diamond Pond Mills	**10**	**13**	**692.372**	**2**	**1**	**3400**	**1000**
Dutton Ditch Branch Mills	25	7	577.373	none	2	none	3400
Elliott and Delaney Mills	16	10	4161.436	11	none	1500	none
Elliotts Sawmill	20	5	484.618	1	2	1495	2000
Elzeys Gristmill	21	10	610.878	3	none	1480	none
Famys Branch Sawmill	20	10	367.265	1	2	2200	2500
Famy's Branch Sawmill	5	7	53.144	none	none	none	none
Flours Mills	25	5	466.084	none	none	none	none
Fooks Gristmill	30	5	1987.541	none	1	none	4100
Frankford Sawmill	5	5	123.671	none	1	none	3000

Table 5-2. Mills in Sussex County Appearing in Beer's Atlas.

Mill Name	Elevation (ft)	Fall (ft)	Watershed Acres	Number of Mills Upstream	Number of Mills Downstream	Nearest Upstream Mill (meters)	Nearest Downstream Mill (meters)
Goslee Millpond Gristmill	10	7	586.245	none	none	none	none
Greens Mills	25	10	3583.191	4	none	3800	none
Griffith Lake Mills	10	7	659.928	none	3	none	1840
Harris Sawmill	10	10	413.027	none	none	none	none
Haven Lake Mills	35	10	1541.048	3	1	1840	940
Hearn Mill	20	5	795.312	none	3	none	2030
Herring Branch Sawmill	25	5	229.948	none	2	none	3000
Hitchs Mill	33	5	1711.199	5	2	2010	3450
Hopkins Mills	25	5	594.842	2	3	2130	2930
Horsey's Sawmill	33	10	1006.224	1	1	2800	1730
Hudson Pond Gristmill	5	5	319.302	1	5	1200	3500
Hurls Sawmill	23	7	231.121	none	none	none	none
Ingram Pond Mills	30	3	916.546	2	4	2000	2100
James Sawmill	20	5	826.362	none	none	none	none
Jos. Hunter Sawmill	30	10	286.473	none	2	none	2500
Knowles Sawmill	9	5	109.321	none	3	none	976
Marshall Millpond Mills	10	7	420.755	1	none	3000	none
Middleford Mills	8	7	7459.962	5	none	4700	none
Millsboro Mills	40	5	437.735	14	none	1400	none
Moore's Sawmill	35	5	288.274	none	3	none	1100
Morens Sawmill	25	3	394.515	1	2	1100	1940
Morris Gristmill	20	7	1216.252	2	2	1600	5400
Nicholsons Sawmill	10	7	148.289	none	1	none	1700
Omar Sawmill	18	7	331.151	1	none	3000	none
Owens Mills	20	7	4817.624	2	1	6000	4700
Owens Sawmill	6	6	137.591	1	2	1000	1200
Paynters Gristmill (Milton)	13	5	1257.701	4	none	1000	none
Pepper Creek Mill	6	7	367.871	none	none	none	none
Phillips Cod Cr Sawmill	25	5	320.710	3	none	550	none

Table 5-2. Mills in Sussex County Appearing in Beer's Atlas.							
Mill Name	**Elevation (ft)**	**Fall (ft)**	**Watershed Acres**	**Number of Mills Upstream**	**Number of Mills Downstream**	**Nearest Upstream Mill (meters)**	**Nearest Downstream Mill (meters)**
Phillips Sawmill	17	5	112.906	3	none	520	none
Polks Gristmill	8	10	3042.267	8	1	3460	1970
Red Mill Pond Gristmill	18	7	437.529	none	none	none	none
Reynolds Pond Mills	35	7	365.016	none	1	none	3700
Russells Mills	30	3	1536.136	none	2	none	4800
Scotts Sawmill	35	5	199.669	none	1	none	3800
Sharps Sawmill	35	10	634.241	none	none	none	none
Shoals Branch Sawmill	30	8	340.840	none	6	none	2000
Shorts Sawmill	10	5	261.674	none	3	none	1500
Silver Lake Bark Mill	30	5	1618.261	5	none	940	none
Simpler Branch Sawmill	25	5	359.421	none	1	none	3000
Spicer Mills	22	5	1121.944	none	none	none	none
Stockley Branch Gristmill (lower)	32	7	397.140	1	2	2300	5675
Stockley Branch Gristmill (upper)	30	5	287.154	none	3	none	2300
Sunset Branch Sawmill	6	5	350.344	none	3	none	2000
Swiggetts Pond Mills	35	7	1040.015	5	none	1200	none
Tindalls Sawmill	35	4	501.494	none	2	none	1800
Trap Mill	30	7	887.637	1	3	2400	2010
Tresham Mill	15	10	866.830	1	2	2030	3860
Tubbs Mills	7	10	226.277	1	none 0	1200	none
Wallace Sawmill	40	5	482.158	1	none	3800	none
Wallers Sawmill Grays Branch	40	5	269.093	none	4	none	2060
Wallers Sawmill South	10	5	232.050	none	4	none	2300
Waples Pond Gristmill	40	4	903.292	2	none	3700	none
Wootens Mills	5	5	365.966	none	4	none	2400
Wright Sawmill	**21**	5	182.711	1	none	1700	none
Average		**6**	**848**	**1**	1	**1184**	**1570**

Based on these calculations, the Diamond Pond sawmill appears to have had one of the highest available head falls in Sussex County. While the estimation of the fall at Diamond Pond is relatively secure, the reliability of estimates at other mills may be less certain. Developing more dependable assessments would entail detailed historical research for each of the locations, requiring effort beyond the scope of the current study. While historical records are unlikely to record the actual height of fall, some records may show the size and shape of the original pond, which can provide important, though indirect information about the elevation of the dam. Nevertheless, it is clear that that dam at Diamond Pond produced one of the largest falls in the county. Cubbage Mill, in contrast, had a fall of approximately 3 feet. Until the introduction of turbines in the latter half of the 19th century, the mill was probably powered by a simple undershot wheel (Resnick and Frye 2005). Fall was estimated at Middleford Mills, on the Nanticoke River, as 7-8 feet. No direct evidence was found as to the type of wheels used to power the mills there, but alternatives included an undershot wheel or a turbine (Crane et al. 2003). While the type of wheel employed at the Diamond Pond sawmill is not recorded, the available head would have been adequate to operate an overshot wheel of about 10 feet in diameter. Notably, early sawmills tended to use smaller, sturdier flutterwheels as a power source, since they more easily withstood the vibrations resulting from the up-and-down motion of the reciprocating saw blade. Yet, with the switch to smoother operating circular saws in the mid-nineteenth century, an overshot wheel might have been the power source of choice. Even more efficient turbines were introduced at about the same time, and thus the sawmill may have been powered by a large overshot wheel for just a short period.

In order to calculate the horsepower generated by a mill, it is necessary to know the flow rate of the water as well as the efficiency of the wheel. One method of calculating horsepower is found in Lovett (2002:259):

> The size of an existing water wheel may be used to estimate its horsepower potential and the extent of the machinery it could operate. For a Fitz wheel [a late-19th-early-20th-century iron wheel] find the diameter and width in feet. Add 2.5 feet to the diameter to obtain the approximate operating head (H) of water. Allow 2.7 cubic feet per second (cfs) of water flow per foot of wheel width (use 2.4 cfs for a W.J. Savage wheel), and call this Q. Assume the water wheel's efficiency (E) is about 89% (this may be a bit of exaggeration by the manufacturer). The horsepower of the wheel is therefore approximately found by the following formula:
> horsepower = (0.1135)(Q)(H)(E)

The approximate head is known for Diamond Pond, but not the width of the wheel. If we assume, however, that the wheel were approximately 5 feet wide, with a head of 13 feet the formula above yields 1.36 horsepower. Estimation of the power generated at a given mill site should be among the research goals for future mill research in Delaware.

Discussion

How all of these variables weighed out in practice is still unclear. It is possible that an inverse relationship between the height of fall and watershed size that may have influenced the siting of mills. This is intuitive in the sense that the further downstream a mill is located, the larger its watershed will be. But in general, lower relief at lower elevations will likely mean a lower head fall, and thus less power, thus suggesting a trade-off between power and reliability. These may indeed have been issues related to the construction of the upper and lower mills at Milton.

Extrapolation outward from the Milton region to the rest of Sussex County is difficult. The results of the analysis of mill siting indicated relatively little variation in available fall among the mills in this part of the state. While explained in part by the lack of relief in the region, the accuracy of the estimates may be questioned due to reliance on modern topographic data. The locations of the 1868 mills are not precise, and the landscape has in many cases changed sufficiently in the last 140 years to make estimates of the original fall based on modern topographic maps uncertain. It remains a question worth further investigation, but will require more detailed historical research at each of the mill locations to determine the actual height of the dam, the subsequent head fall, and the size of the mill pond produced.

The number of mills on a given stream may also have had an effect on water supply. Having a large number of mills upstream could have slowed the flow of water to a downstream site, particularly in dry periods when water would have been conserved in upstream ponds. A mill too close downstream could slow water flowing out of a mill if the lower pond backed up as far as the mill's tailrace. The sawmill at Diamond Pond appears to have been fairly typical of mills in Sussex County in this regard, with mills situated both upstream and downstream (Table 5-2). Yet in both cases, the sites appeared to have been sufficiently distant to have had little effect on the operation at Diamond Pond except in cases of extreme drought or flooding.

Figure 5-63 shows the watershed feeding the Diamond Pond mills. In 1815, a new dam was constructed downstream from Diamond Pond at the confluence of Pemberton Branch and Ingram Branch, creating Wagamon's Pond and a source of water for a grist mill (Heite 1991). Reliability of water supply may have been one of the reasons for the new construction. According to the petition submitted to the State Assembly regarding permits for the new pond, water flow in the single branch at the Upper Mill (Diamond Pond) was reportedly not sufficient to supply power year round (Hancock and McCabe 1982: 78). Owing to generally low relief, the average head fall for mills in Sussex County appears to have been between 5 and 10 feet (Table 5-2). The exact height of head for the Upper Mills (Diamond Pond) and Lower Mills (Wagamon's) at Milton is not known. Estimates from the current study at Diamond Pond suggest a head of over 10 feet at the sawmill, while a head of less than five feet is indicated for the lower mills at Wagamon's Pond. Thus, even though the lower mills had a significantly lower head fall than the upstream locale, they drew on a watershed nearly twice the size of that for Diamond Pond (Figure 5-64)—more than 1258 acres at Wagamon's, 692 acres at Diamond Pond, while the average for the county at that time was somewhere between, at

848 acres. The ponds were less disproportionate, Wagamon's Pond measuring more than 50 acres in comparison with 40 acres represented by Diamond Pond.

Market Pressures and Saw Milling at Diamond Pond

The location of the sawmill at Diamond Pond was originally a factor of both physiography and economics. An adequate water supply was present in the form of Ingram Branch. While no records have been found describing the mill location prior to construction of the mill pond, the site must have provided a good physical location for the dam, with relatively high stream banks and possibly a constriction in what would otherwise have been a wide and shallow stream valley. The siting of the sawmill was also market-driven in that it supported the shipbuilding industry that grew up in Milton on the upper reaches of the Broadkiln estuary in the early-to-mid nineteenth century. The forests in the region supplied what at first may have appeared to be a vast source of first-growth timber particularly suited to wooden ship building.

While three shipyards were operating in Milton in the late nineteenth century (Hancock 1976), the shipbuilding industry there was in decline. Iron and steel-hulled ships were increasingly popular by the turn of the century. A market still existed for wooden ships, but the vessels that were typically produced were large, and the channel of Broadkiln Creek was neither wide nor deep enough to accommodate the drafts of such large craft once they were constructed. Moreover, the high-quality shipbuilding timber that was once freely available in the regional forests had long been consumed, forcing the local industry became increasingly dependent on less desirable pine wood. In the end, larger, mechanized urban shipyards grew up elsewhere effectively ending the industry locally (Hancock and McCabe 1982:69-71). This and the development of efficient and portable steam-powered sawmills meant the end of the need for water powered mills producing large quantities of lumber in Sussex County. Other industries developed in Milton in the late nineteenth century to fill the gap left by the decline of shipbuilding, including brick manufacturing, clothing manufacturing, and an emerging local food processing industry that included factory dried fruit and several canneries.