

Table 45 (Concluded)

Date(s)	Construction and Rehabilitation History
	Section D of the south pier. About 470 tons of the 50- to 300-lb ballast stone was placed into or along the north revetment.
1985	An inspection of the structures indicated the north pier to be in fair to poor condition. Fill stone had again settled, and the superstructure was still in poor condition because of cracking, settlement, tilting, etc. The south pierhead was in a poor to near failed condition (Figure 119, Section A), while the remaining portion of the pier is in a condition of fair to poor similar to the north pier. The only exception is Section F! which is still considered to be in good condition.
1986	A major rehabilitation study for the piers is under way. Consideration is being given to using rubble-mound structures as opposed to vertical steel sheetpiling. An aerial photo of the Saugatuck Harbor Piers is shown in Figure 121.

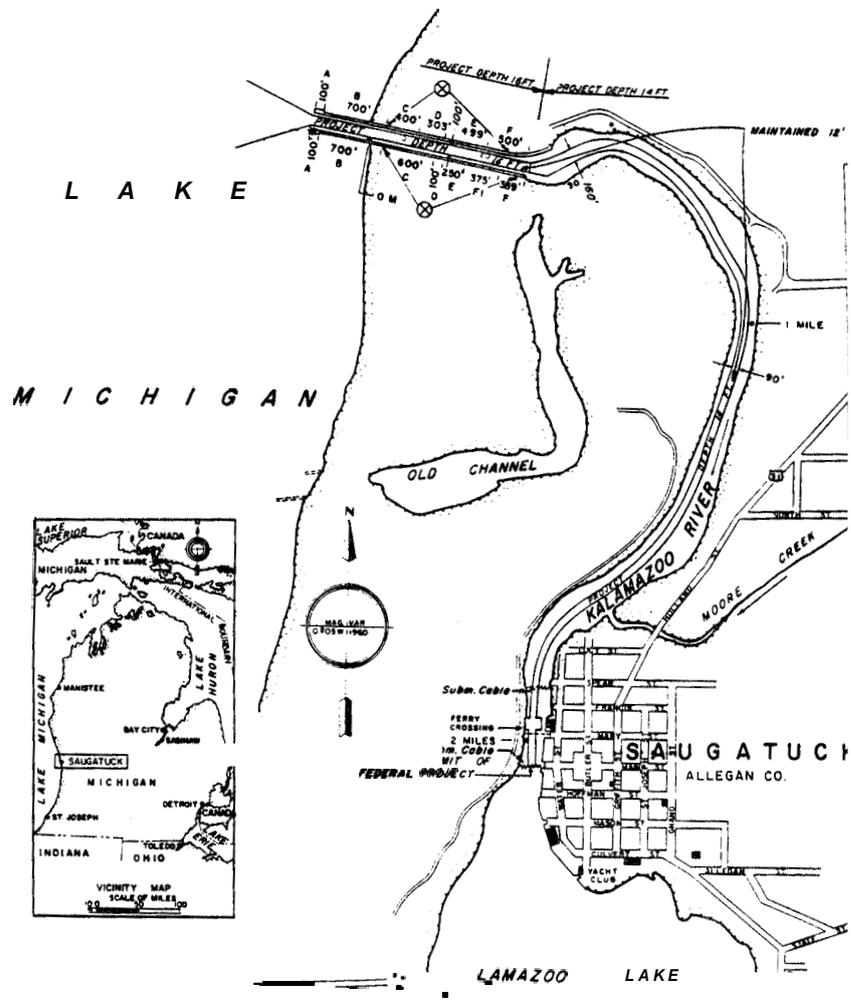


Figure 119. Saugatuck Harbor, Michigan

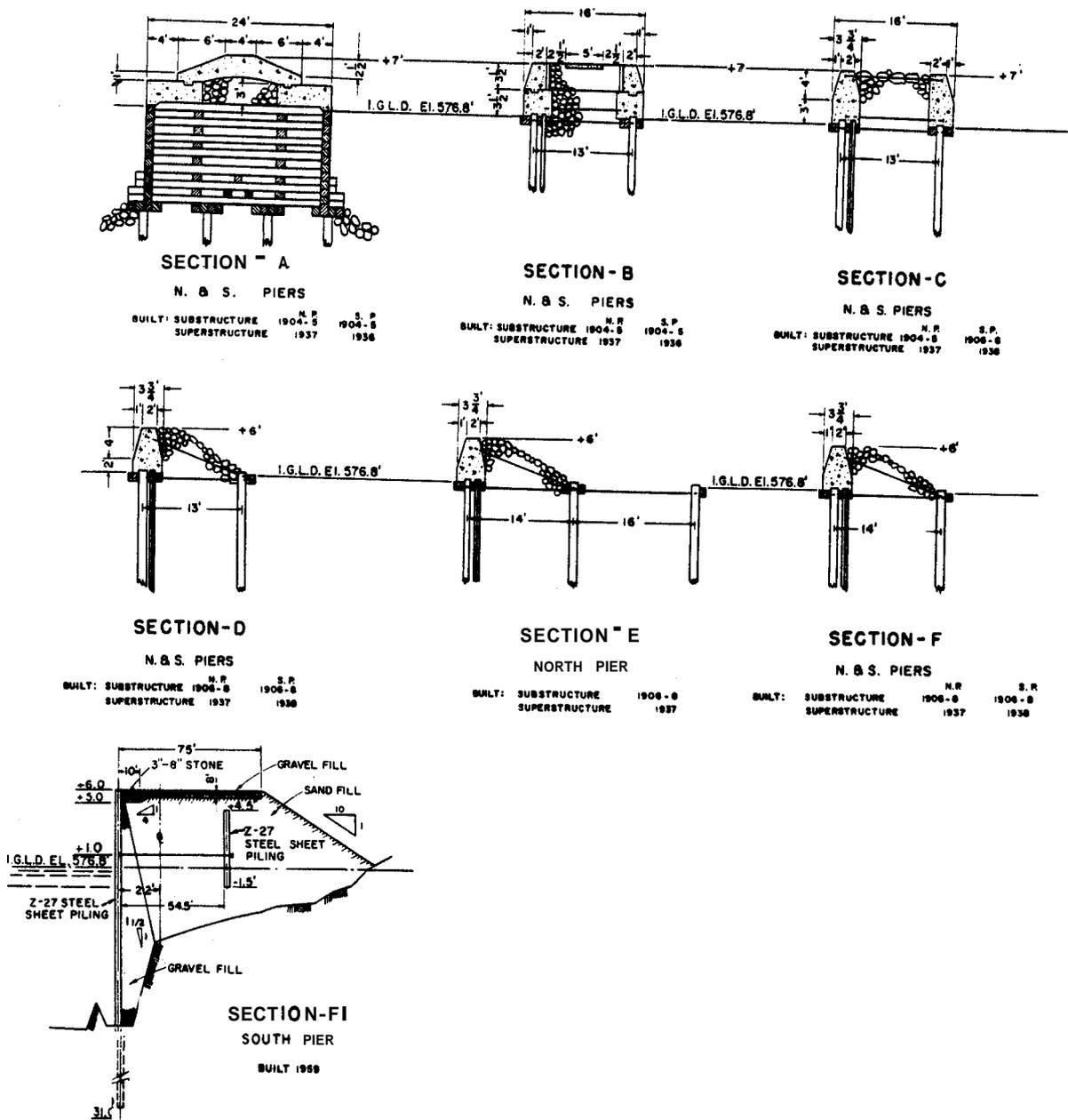


Figure 120. Typical pier cross sections, Saugatuck Harbor, Michigan

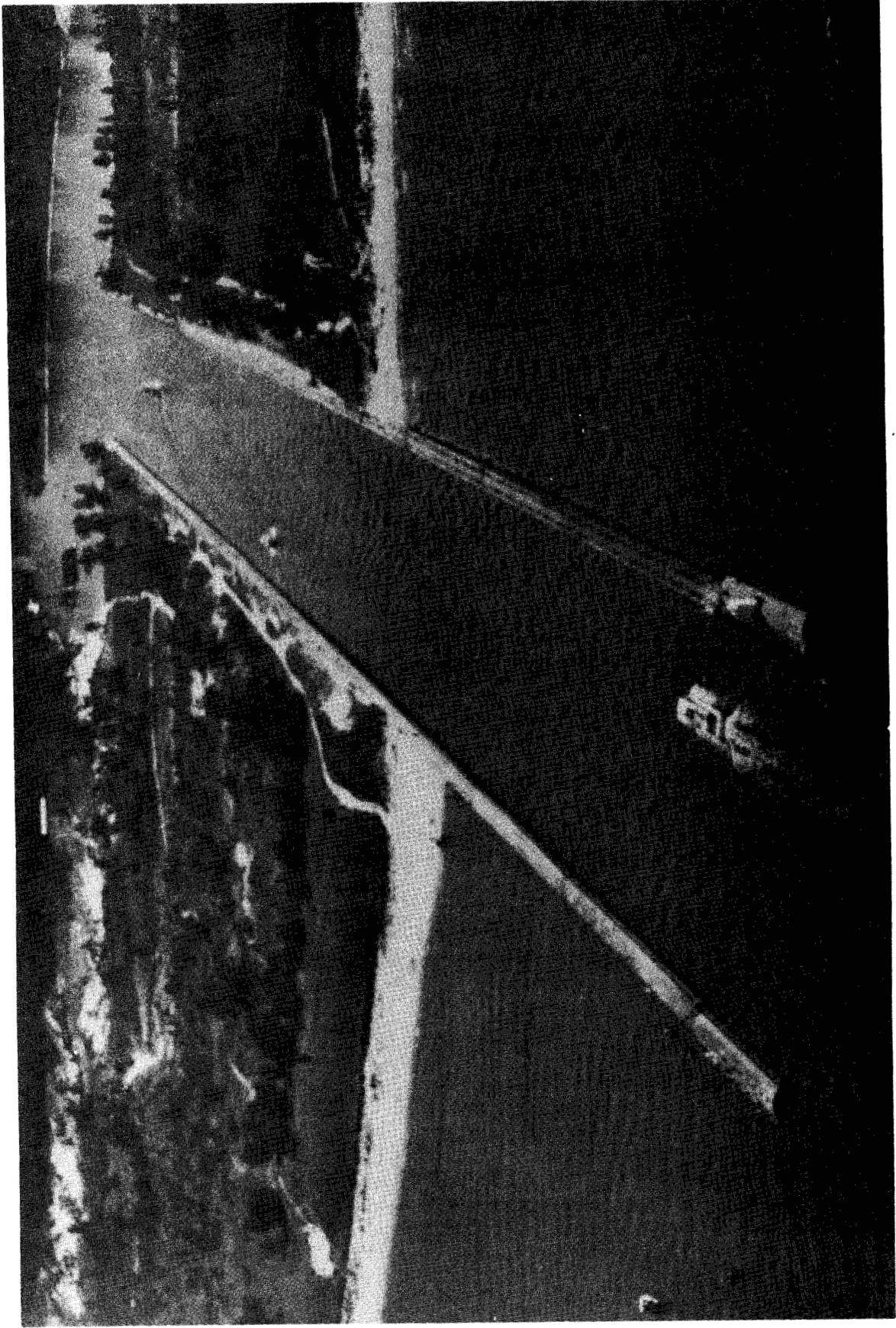


Figure 121. Aerial view of Saugatuck Harbor, Michigan

Table 46
Holland Harbor Structures
Holland, Michigan

Date(s)	Construction and Rehabilitation History
1868- 1879	Construction of the south pier (Figures 122, 123 and 124, Sections I and J) and a portion of the north pier (Figure 123, Section D) was completed at the site (Figure 122) during this period of time. The north pier (Section D) consisted of woodpilings driven about 24 ft apart and filled with earth and stone, while the south pier (Sections I and J) involved a 20-ft-wide, stone-filled timber crib structure.
1875- 1876	Construction of the lakeward end of the north pier (Figure 123, Section C) was completed during this period. The pier consisted of a 20-ft-wide stone-filled timber crib structure.
1906- 1909	Construction of the north and south arrowhead breakwater arms (Figure 123, Sections Al, A and B) was completed at the site (Figure 122). The lakeward portions (Sections Al and A) were constructed with 30-ft-wide stone-filled timber cribs, while the shoreward portions of the breakwater (Section B) were built with 24-ft-wide stone-filled timber cribs.
1908- 1909	Construction of the breakwater pier connections (Figure 123, Section Q) was completed during this period. They consisted of woodpilings driven 12 ft apart and filled with stone. The el was +2.0 ft lwd. Rubble was placed on each side of the structure to the +2 ft lwd crest el and extended down on a slope of 1V:1.5H.
1929	The north pier (Figure 123, Sections C and D) was capped with a concrete and stone superstructure. The el of the lakeward end of the pier (Section C) was +7.1 ft lwd, and the shoreward end (Section D) was installed at a crest el of +6.1 ft lwd.
1932- 1933	The south pier (Figures 123 and 124, Sections I and J) and both breakwaters (Figure 123, Sections Al, A, and B) were capped with stone and concrete superstructures during this time. The south pier and both breakwaters were constructed to els of +7.1 ft lwd.
1958	The north pier (Figure 123, Sections C and D) was repaired. Steel sheetpiling was installed on each side of the structure, and the voids were filled with stone and capped with concrete. The width of the lakeward portion (Section C) was 32 ft, and that of the shoreward portion (Section D) was 33.8 ft.
1963- 1964	Rehabilitation of the lakeward heads of the breakwaters (Figure 123, Section Al), the pier connections (Figure 123, Section Q), and the south pier (Figures 123 and 124, Sections I and J) was completed.

(Continued)

Table 46 (Concluded)

Date(s)	Construction and Rehabilitation History
	Steel sheetpiling was driven on each side of the breakwater heads (Section Al) forming a structure 40.3 ft in width. The voids were stone filled and capped with concrete. The pier connections (Section Q) were capped with an 8-ft-wide precast concrete slab at an el of +4.5 ft lwd. Stone was added to the channel side and the lake-side of the structure with slopes of 1V:2H and 1V:1.5H, respectively. Steel sheetpiling also was added along the sides of the south pier (Figures I and J). The voids were filled with stone, and a concrete cap was added.
1979	An inspection of the structures indicated that the breakwaters and north pier were in good condition, while the south pier revealed cracks, settlement, and erosion of concrete and was considered in fair condition. It was noted that replenishment of riprap stone was required in some areas along the breakwater.
1980	Riprap stone was placed around the lakeward end of the north breakwater (Section Al) on the lakeside. The north and south pier connections underwent replenishment of stone in areas that had settled. The lakeward 55 ft of the south pier (Section I) and a 55-ft-long portion of Section J were rehabilitated. Precast concrete caps were installed.
1983- 1984	A 142-ft-long portion of the north breakwater (Figure 123, Section B) and a 124-ft-long portion of the south breakwater (Section A) were encased with steel sheetpiling, filled with stone, and capped with concrete. The remaining portions of Section B (north breakwater) and Section A (south breakwater) were encased with protection stone. Approximately 80,000 tons of stone was used, and the cost was approximately \$3,000,000.
1985	An inspection of the structures revealed them to be generally in good condition. Fill stone replenishment was recommended, however, at the lakeward heads of the breakwaters (Figure 123, Section Al). An aerial view of Holland Harbor Structures is shown in Figure 125.

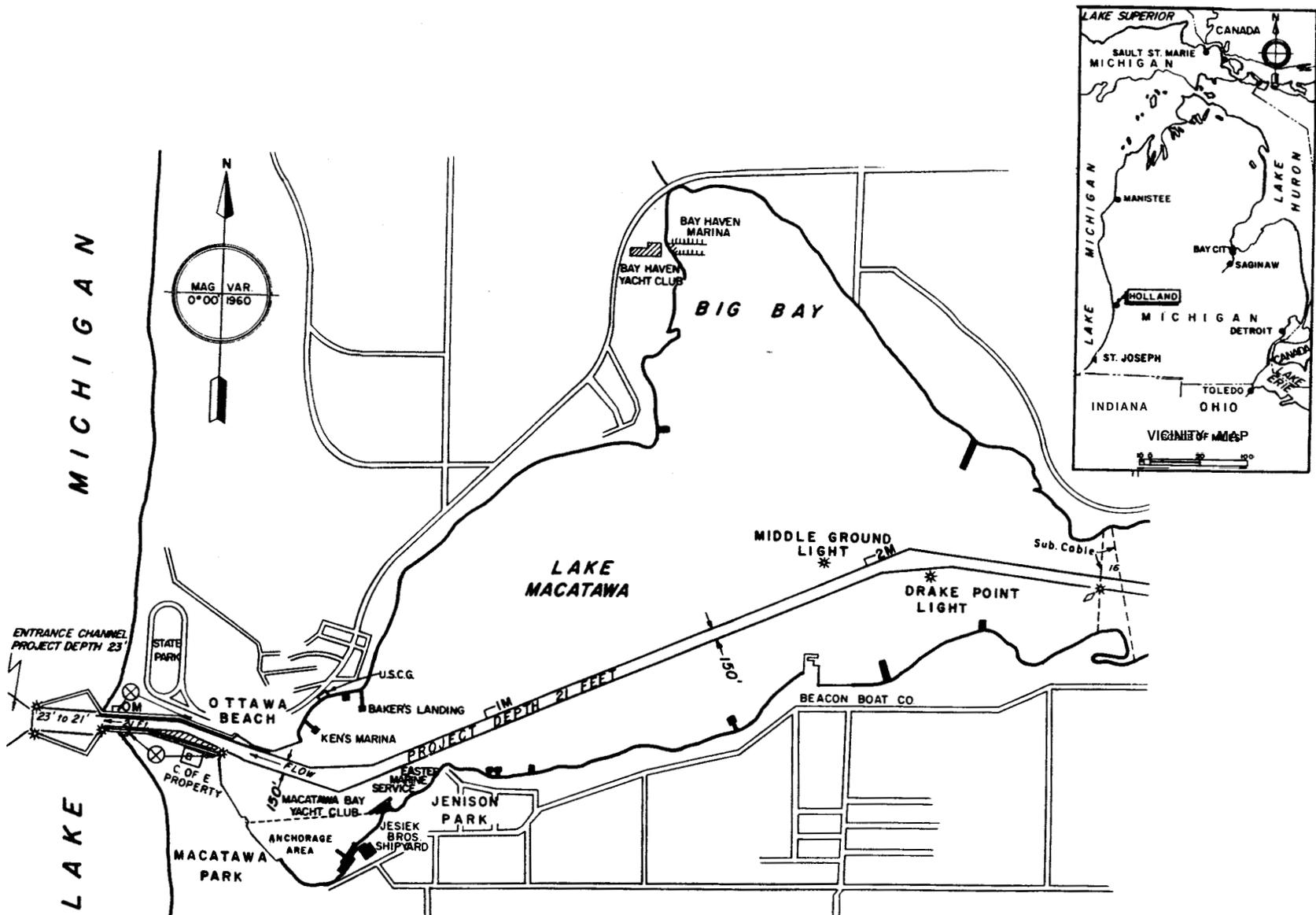


Figure 122. Holland Harbor, Michigan

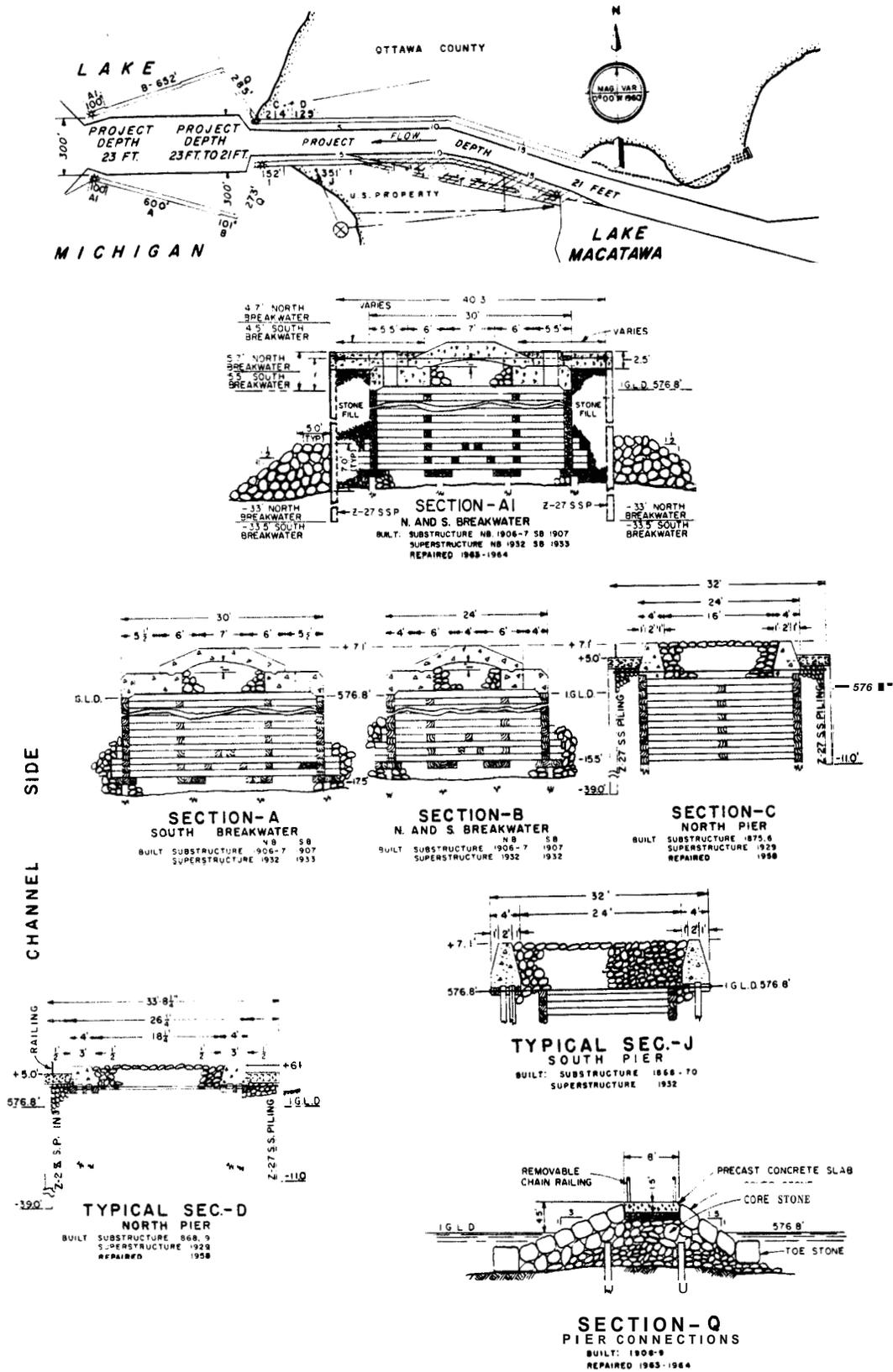
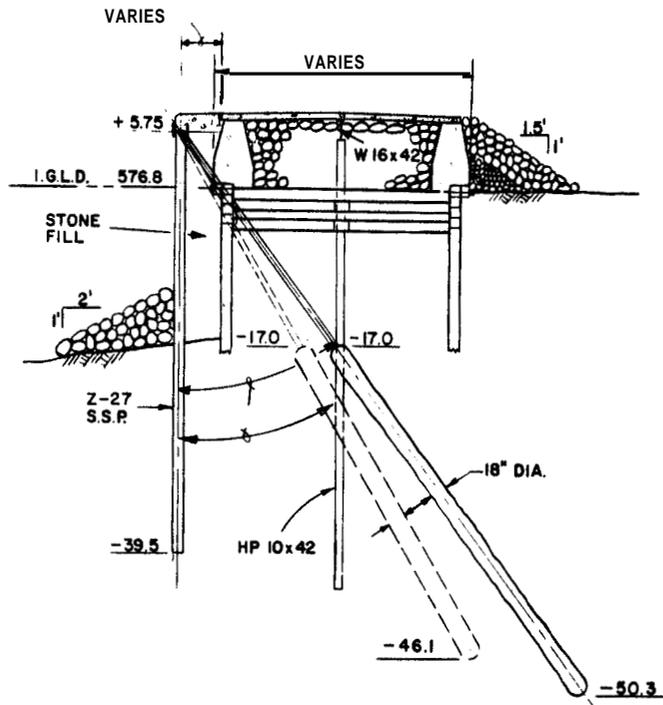
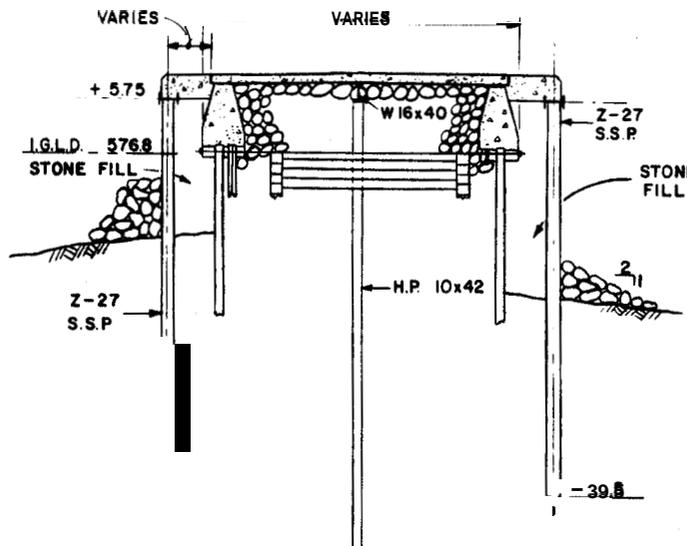


Figure 123. Typical breakwater and pier cross sections, Holland Harbor, Michigan



TYPICAL SEC.-J



TYPICAL SEC.-I

Figure 124. Typical structure cross sections, Holland Harbor, Michigan

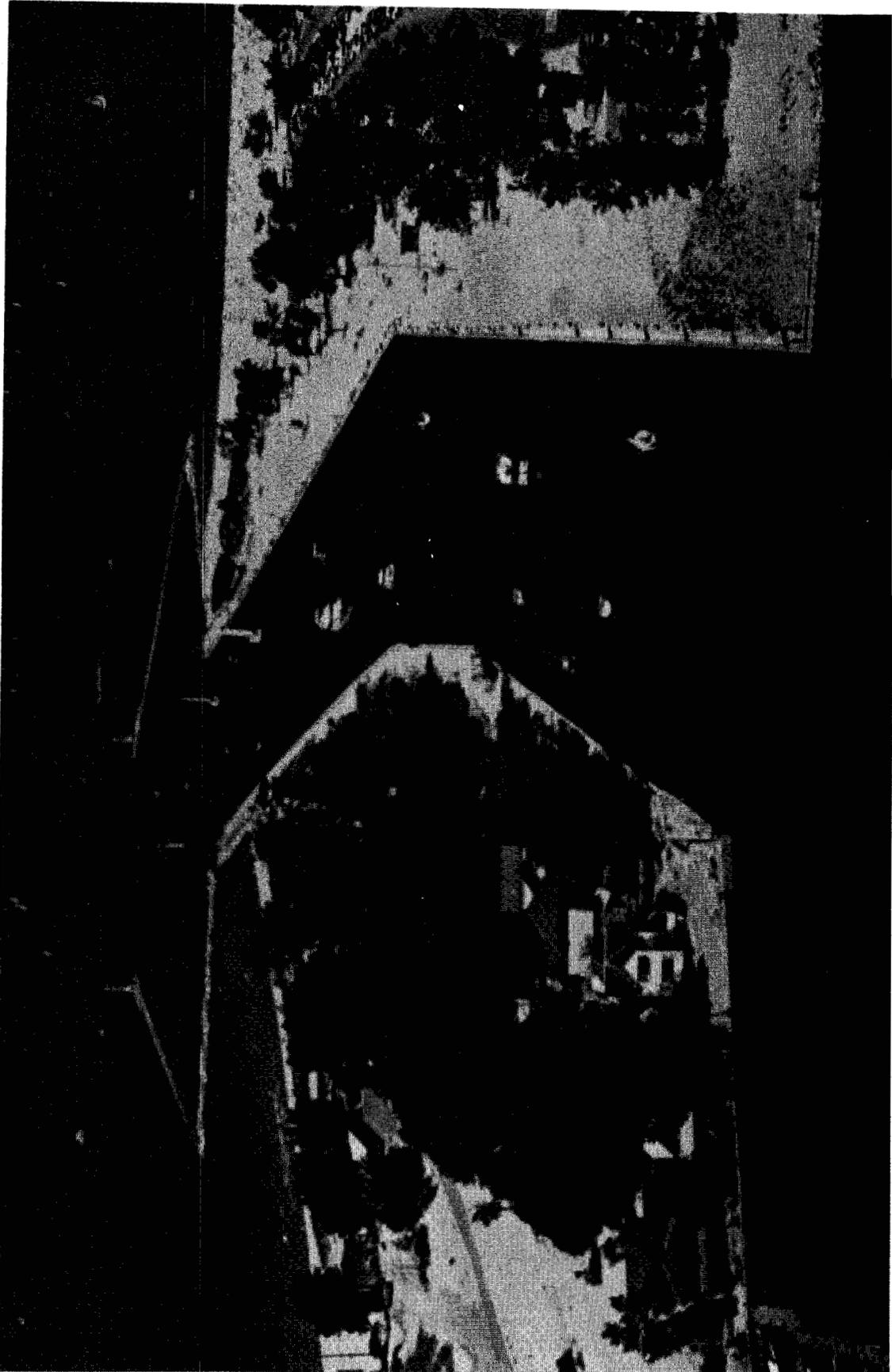


Figure 125. Aerial view of Holland Harbor, Michigan

Table 47
Grand Haven Harbor Piers
Grand Haven, Michigan

Date(s)	Construction and Rehabilitation History
1867- 1869	Construction of the shoreward 396 ft of the south pier (Figure 126, Sections K, J1, and J) was completed during this period. The pier consisted of timber piling spaced approximately 30 ft apart and filled with stone (Figure 128, Sections K, J1, and J).
1875- 1879	Construction of the shoreward 605 ft of the north pier (Figure 126, Section B) was completed during this time. The pier was constructed with a 30-ft-wide stone-filled timber crib structure (Figure 127, Section B).
1882- 1887	The south pier was extended by 1,000 ft (Figure 126, Sections H1 and I). This extension consisted of stone-filled timber crib structures (Figure 128, Sections H1 and I) built on a stone base. The cribs were about: 30 ft wide.
1887- 1894	The south pier was extended by 119 ft (Figure 126, Section H) and the north pier by 811 ft (Figure 126, Sections A, A1, and A2) during this time. The extensions were constructed with stone-filled timber cribs on stone bases (Figure 127, Sections A, A1, and A2; and Figure 128, Section H). The width of the structures were 30 ft.
1916- 1922	The north and south piers (Figure 126) were capped with stone and concrete superstructures during this period. The north pier (Figure 127, Sections A, A1, A2, and B) ranged in el from +7.1 to +8.0 ft lwd, and the south pier (Figure 128, Sections H, H1, I, J, J1, and K) had a crest el ranging from +6.3 to 9.1 ft lwd.
1952- 1960	The north and south piers (Figure 126) were repaired during this time. The existing structures were encased in steel sheetpiling (Figures 127 and 128). The voids between the sheetpiling and the existing structures were filled with gravel or stone, and the pier edges were capped with concrete. The north pier ranged from about 34 to 36 ft in width (Figure 127, Sections A, A1, A2, and B), and the south pier was from 37 to 51.5 ft in width (Figure 128, Sections H, H1, I, J, J1, and K).
1976	Riprap stone was placed along the outer 210 ft of the lakeside portion of Section H-1 (Figure 126) of the south pier. Fill stone also was replenished in the cells of Section K of the south pier, and they were capped with concrete.
1980	Riprap was placed along portions of the north (Figure 126, Sections A and A1) and south (Sections J, J1, and H) piers.

(Continued)

Table 47 (Concluded)

Date(s)	Construction and Rehabilitation History
1983	Additional riprap stone was placed along the north (Figure 126, Sections A and AI) and south (Section H) piers.
1985	A site inspection indicated the structures were generally in very good condition. An aerial photo of the Grand Haven Harbor Piers is shown in Figure 129.

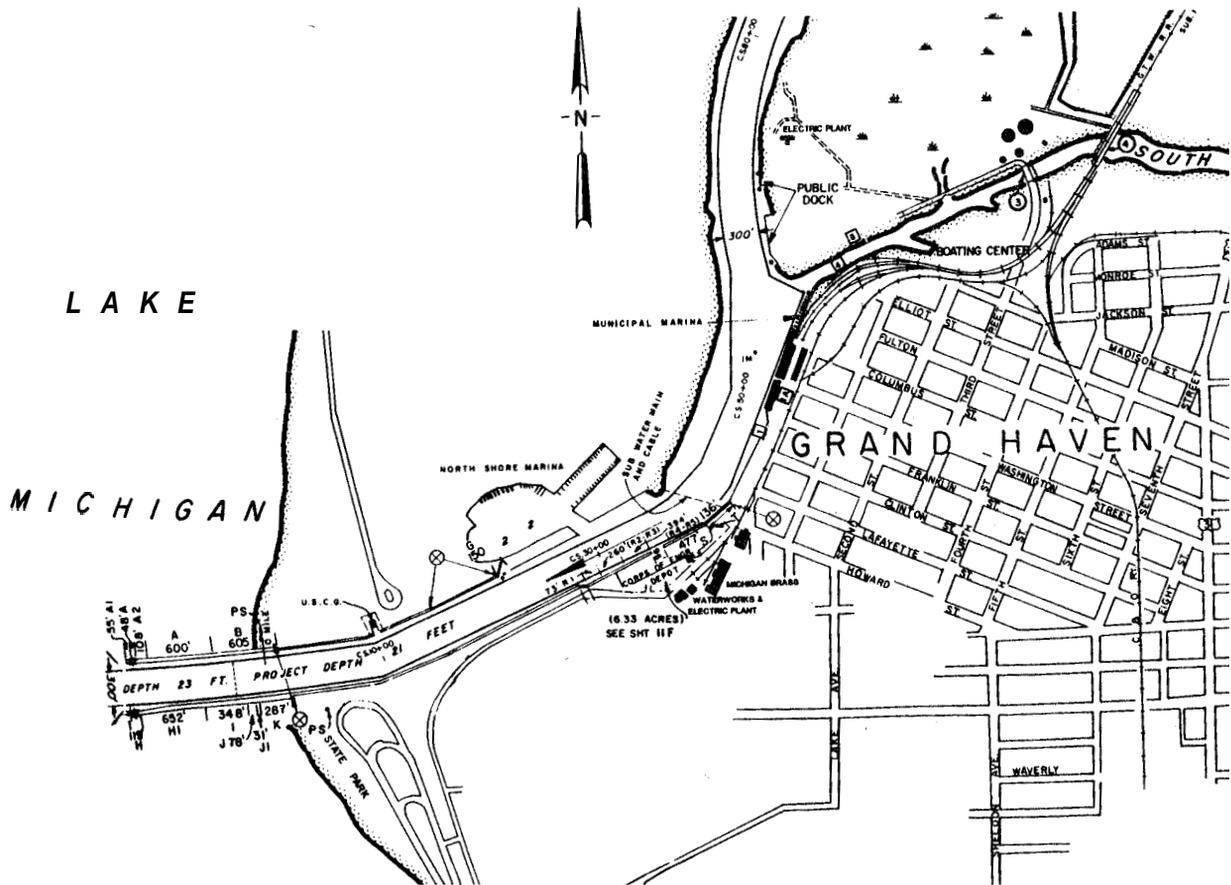


Figure 126. Grand Haven Harbor, Michigan

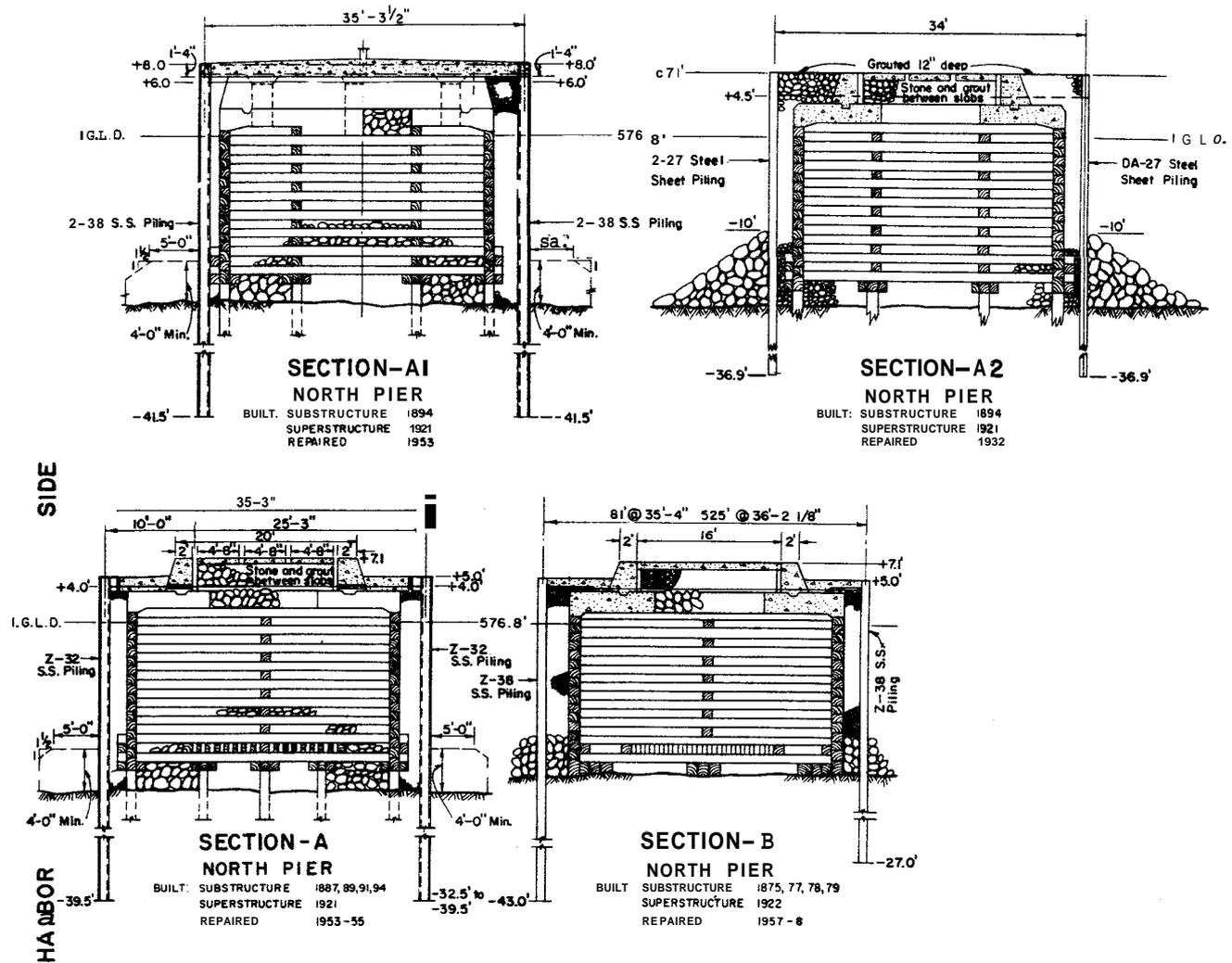


Figure 127. Typical north pier cross sections, Grand Haven Harbor, Michigan

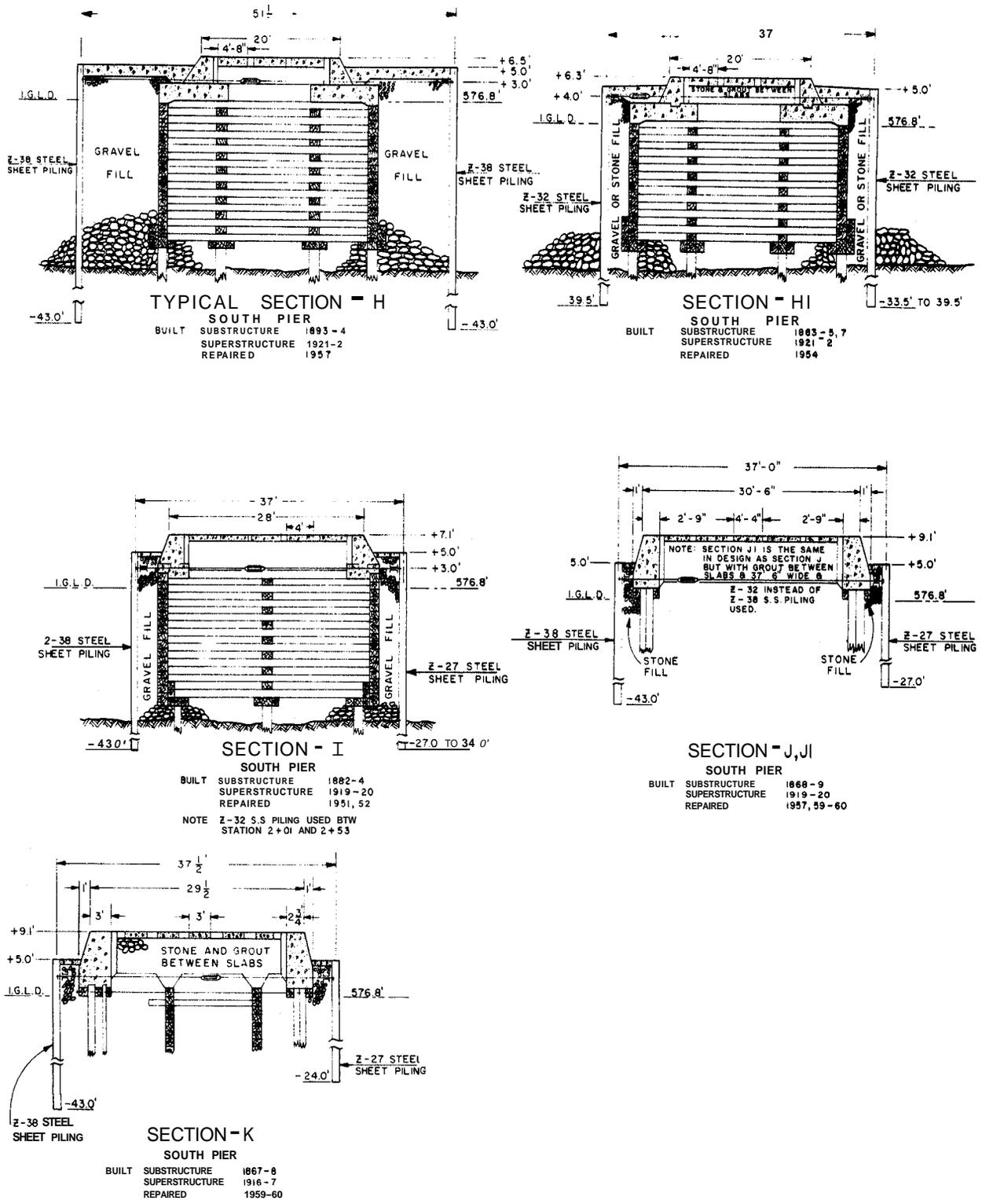


Figure 128. Typical south pier cross sections, Grand Haven Harbor, Michigan

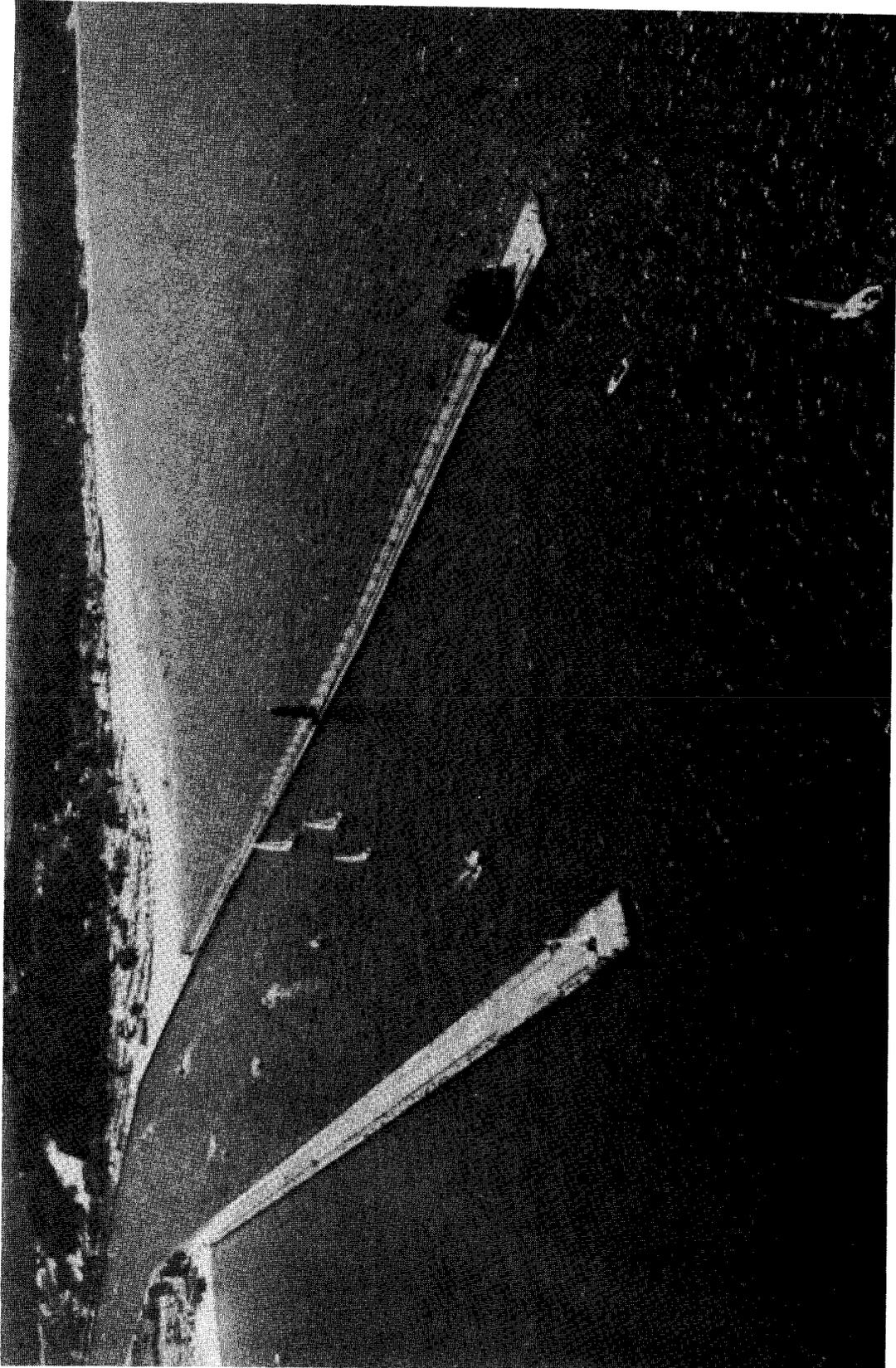


Figure 129. Aerial view of Grand Haven Harbor, Michigan

Table 48
Muskegon Harbor Structures
Muskegon, Michigan

Date(s)	Construction and Rehabilitation History
1868- 1890	Construction of a 703-ft-long north pier and a 692-ft-long south pier (Figure 130) was completed during this time. The piers were originally built with woodpilings and ranged from 18 to 32 ft in width. The area between the pilings was filled with stone and timber, and the piers were capped with a timber superstructure.
1906	The north pier was rebuilt with timber pilings similar to the original construction.
1927- 1931	Construction of the north and south breakwaters (Figure 130) was completed. (Figures 130, 131, and 132 illustrate structures at Muskegon Harbor.) The north breakwater was a rubble-mound structure (Figure 132, Sections A and B) that was capped with 8- to 10-ton armor stone (Section A) with the exception of the shoreward end (Section B) which had 1- to 5-ton armor protection. The crest el of the structure was about +8.5 ft lwd, and side slopes were 1V:1.5H. The lakeward portion of the south breakwater (Figure 132, Sections C, D, and E) was constructed with stone-filled concrete caissons on woodpilings. These structures had concrete caps that were 7.3 ft wide at the crest with an el of +7.1 ft lwd. The shoreward portion of the south breakwater (Figure 132, Sections F, G, and H) was composed of woodpiling with a stone fill and concrete and stone superstructures. The structures ranged from 14 to 17 ft in width and had crest els ranging from +7.1 to +7.4 ft lwd. The outer 54 ft of the south breakwater consisted of two rectangular stone-filled concrete caissons. Riprap with a 1-V;2-H side slope was placed along the sides of most of the structure.
1932- 1934	The north and south pier superstructures were rebuilt and consisted of concrete and stone construction (Figure 131, Sections N, O, and P).
1942- 1954	During this period a total of 16,757 tons of riprap stone was placed along the sides of the south breakwater (Figure 132, Sections C, D, E, F, and G).
1960- 1963	An additional 4,832 tons of riprap was placed along the south breakwater at Sections E and F (Figure 130).
1966	The south pier (Figure 130, Sections N, O, and P) was rehabilitated by encasing it in steel sheetpiling. The voids were filled between the sheetpiling and the existing structure, and the pier was capped with concrete. The new el was +8.5 ft lwd, and the width ranged from 35 to 45 ft. A portion of the south breakwater (Figure 130, Sections F and G) was rehabilitated also. Fill-stone replenishment and regrouting of the superstructure was accomplished, and additional riprap stone was placed along the shoreline.

(Continued)

Table 48 (Concluded)

Date(s)	Construction and Rehabilitation History
1975	Stone was placed along the lakeward end of the north breakwater (Figure 130, Section A) in areas of settlement and along the lakeward end of the south breakwater (Figure 130, Section D) for protection against wave and ice action.
1979- 1980	The entire north pier (Figure 130) was removed, and the structure was replaced with a rubble-mound pier (Figure 131). The crest el of the pier was +8.5 ft lwd, and side slopes were 1V:2.5H on the channel side and 1V:1.5H on the lakeside. Approximately 1,000 tons of stone was placed along the navigation light at the head of the north breakwater. Riprap stone also was placed along the south breakwater head.
1981	Approximately 510 tons of riprap stone was again placed at the head of the north breakwater around the navigation light (Figure 130). Riprap also was again placed around the head of the south breakwater. Fill stone in the entire south pier (Figure 130, Sections N, O, and P) was replenished, and the structure was recapped with concrete.
1982	The stone at the head of the west breakwater (Figure 130) again was washed out, and approximately 1020 tons of 8- to 16-ton riprap stone was placed around the navigation light. Also added were 50 tons of 3- to 10-in. fill stone, 247 tons of 50- to 300-lb core stone, and 312 tons of 500-lb to 3-ton riprap to the north breakwater (Figure 130, Section A). Repairs to the head of the south breakwater (Section C) included the addition of 324 tons of 500-lb to 3-ton riprap as core stone along the lakeside face and 1,038 tons of 3- to 16-ton riprap around the breakwater head. In addition, 800 tons of 500-lb to 3-ton riprap stone was placed as toe protection along the channel side of the south pier.
1983	The north pier (Figures 130 and 131) was repaired with the placement of larger cover stone, and 8- to 12-ton riprap stone was placed around the navigation light at the head of the west breakwater (Figure 130).
1984	Major riprap placement at the south breakwater (Figure 130, Sections C, D, and E) for protection against waves and ice action was completed which involved approximately 86,770 tons of 10- to 26-ton cover stone (with stones as large as 49 tons in some areas). This placement encompassed the south breakwater head and both the lake and harbor sides. The stone was placed to an el of +8.0 ft lwd.
1986	Reconstruction of the head of the north breakwater was initiated and involved (Figure 130) removal of the existing cover and core stone and the placement of a steel sheetpiling with a concrete cap breakwater head structure. Also initiated was rehabilitation of the south breakwater concrete caps which are extensively spalled with large pieces cracked and broken off causing a hazard to the public. After these repairs, the structures will be in good condition. An aerial view of Muskegon Harbor structures is shown in Figure 133.

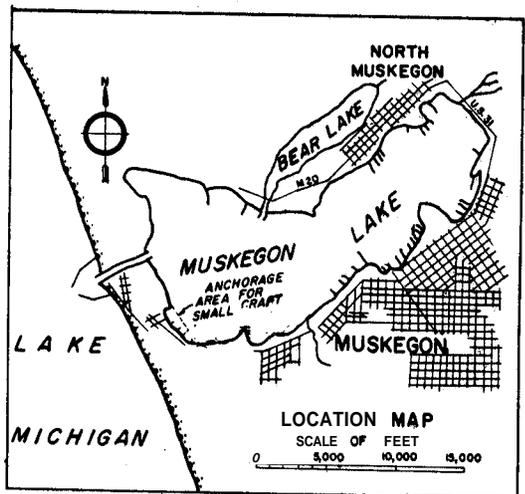
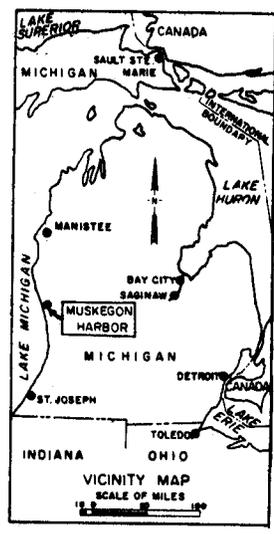
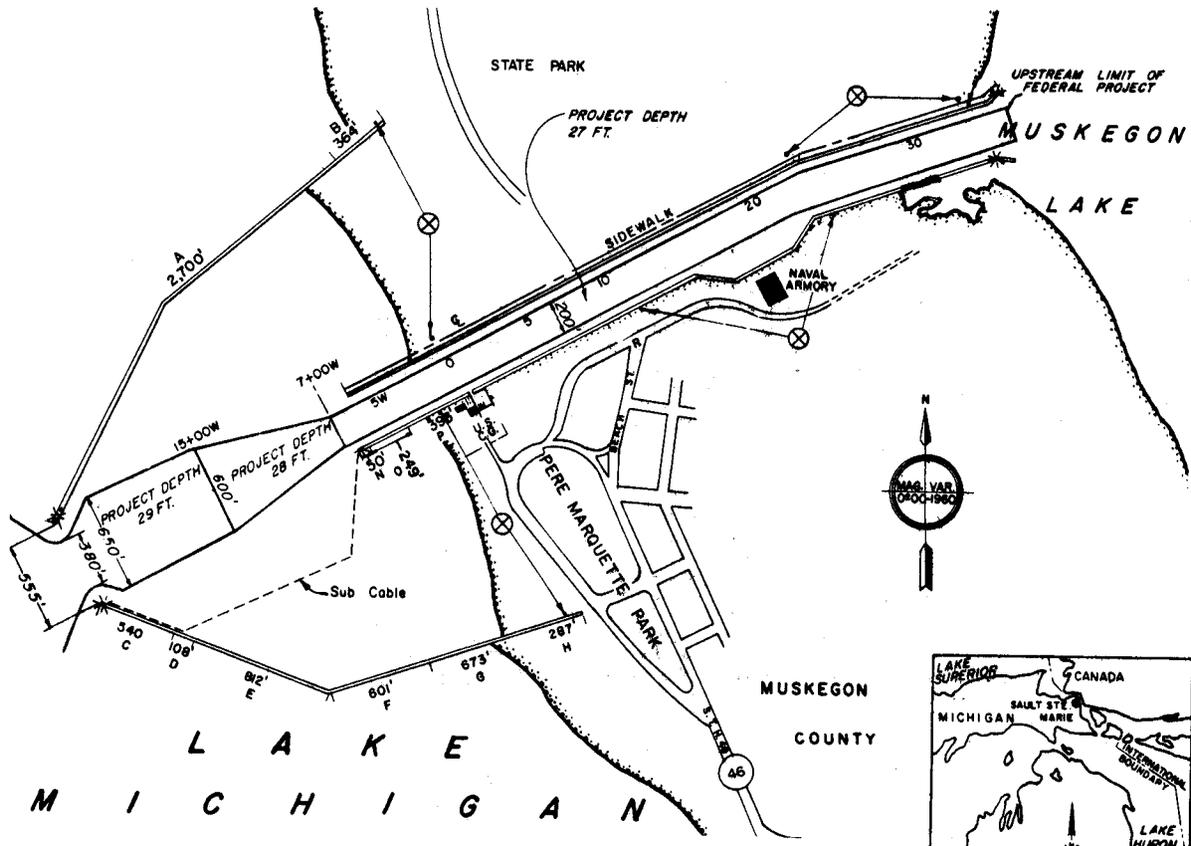


Figure 130. Muskegon Harbor, Michigan

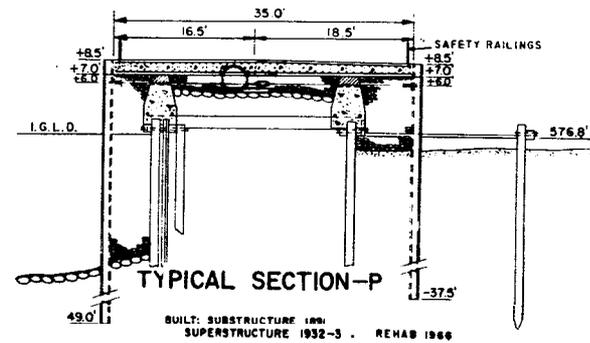
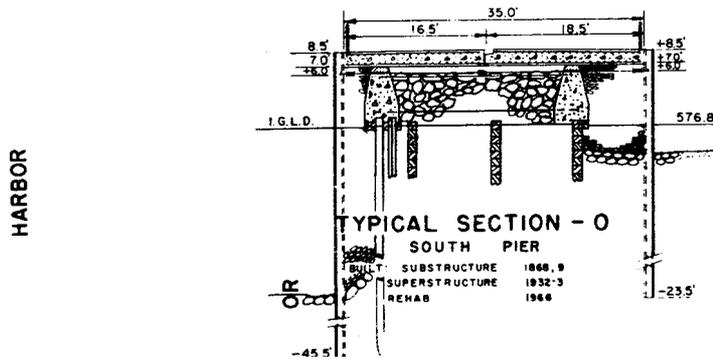
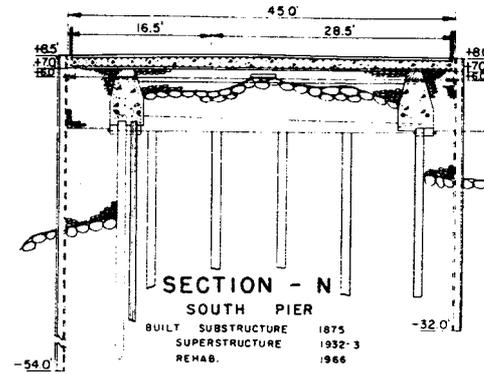
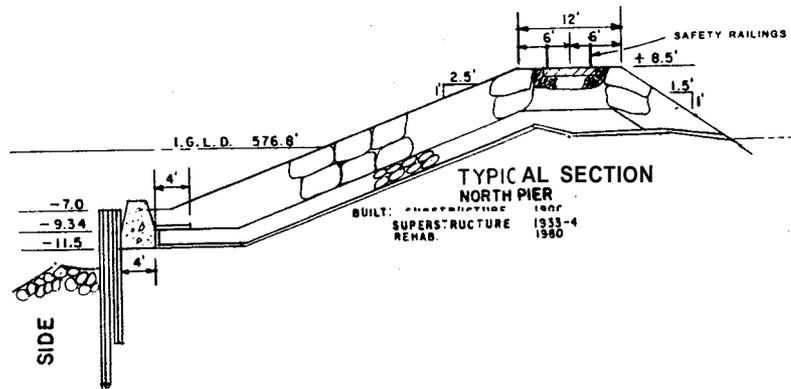


Figure 131. Typical structure cross section, Muskegon Harbor, Michigan

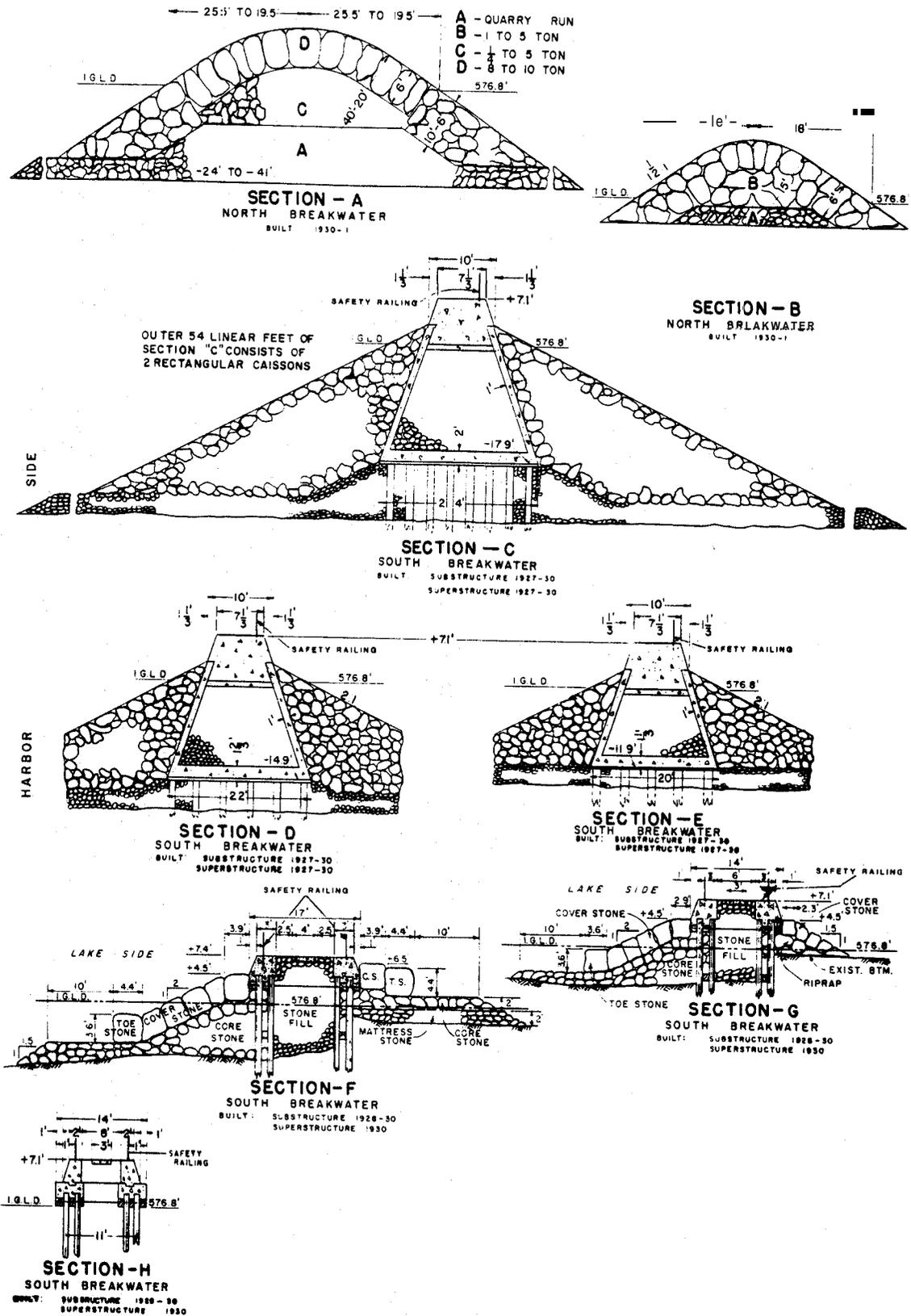


Figure 132. Typical breakwater cross sections, Muskegon Harbor, Michigan

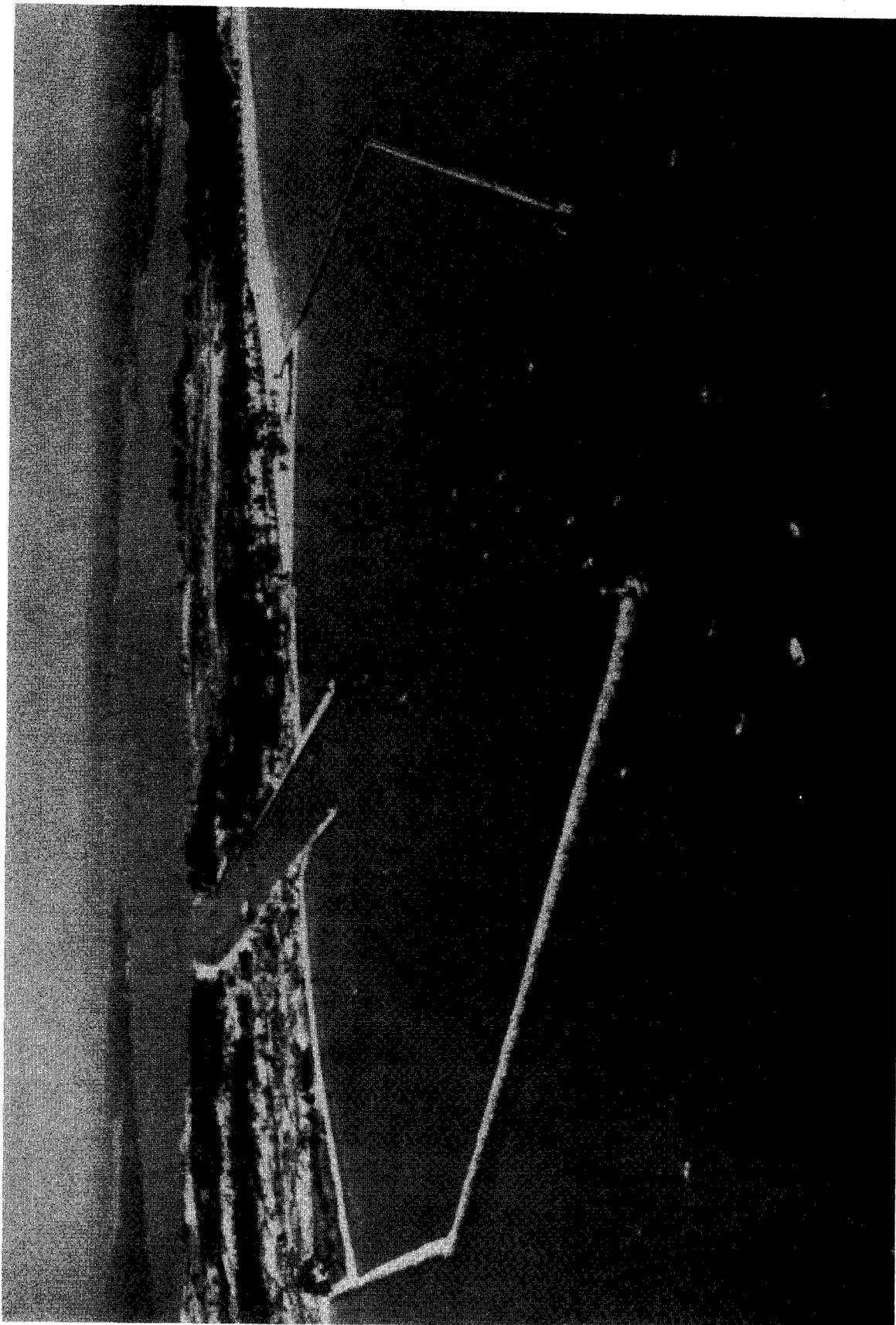


Figure 133 Aerial view of Muskegon Harbor, Michigan

Table 49

White Lake Harbor PiersWhite Lake, Michigan

Date(s)	Construction and Rehabilitation History
1870-1872	A 495-ft-long north pier was constructed at the site (Figure 134, Section G) during this time frame. The pier was constructed of woodpilings driven from 21 to 29 ft apart and filled with stone (Figure 135, Section G).
1899	A 673-ft-long south pier (Figure 134, Sections C, D, and E) was constructed. The inner 369 ft was constructed with woodpilings (Figure 135, Sections D and E). The piers were stone filled and ranged in width from 22 to 26.5 ft. The outer 304-ft-long portion (Figures 134 and 135, Section C) consisted of a stone-filled timber crib structure that ranged from 28 to 30 ft in width.
1900	The north and south piers were extended by 200 and 150 ft, respectively (Figure 134, Sections A and B). The extensions were stone-filled timber crib structures and were built on a stone base (Figure 135, Sections A and B). The north pier (Section A) was 24 ft in width, and the south pier (Section B) was 34 ft wide.
1936-1937	The north and south piers were capped with concrete and stone superstructures (Figure 135, Sections A-E and G). The crest elevations of the pier were +7.0 ft lwd.
1971	Fill stone was replenished in the shoreward portion of the north pier (Figure 134, Section G). An underwater examination of the lakeside of the south pier revealed signs of deterioration of the timber piling along Sections C and D (Figure 134) and fill stone being washed out between these pilings.
1982	Fill stone was replenished in the lakeward portion (Figure 134, Section A) of the north pier and the south pier (Figure 134, Section B). Riprap stone around the head of the south pier (Section B) also was placed.
1983	Riprap stone around the heads and along the lake and channel sides of Section A (Figure 134) was placed. In addition, stone fill was again placed in open pockets of the superstructures of this portion of the pier and grouted over.
1985	An inspection of the structures indicated that the substructures of both piers are deteriorating, resulting in superstructure settlement and cracking, considerable misalignment and tilt, and loss of fill stone. Both structures are considered to be in poor condition, Reconstruction and/or rehabilitation has been recommended within the next 2 to 3 years.

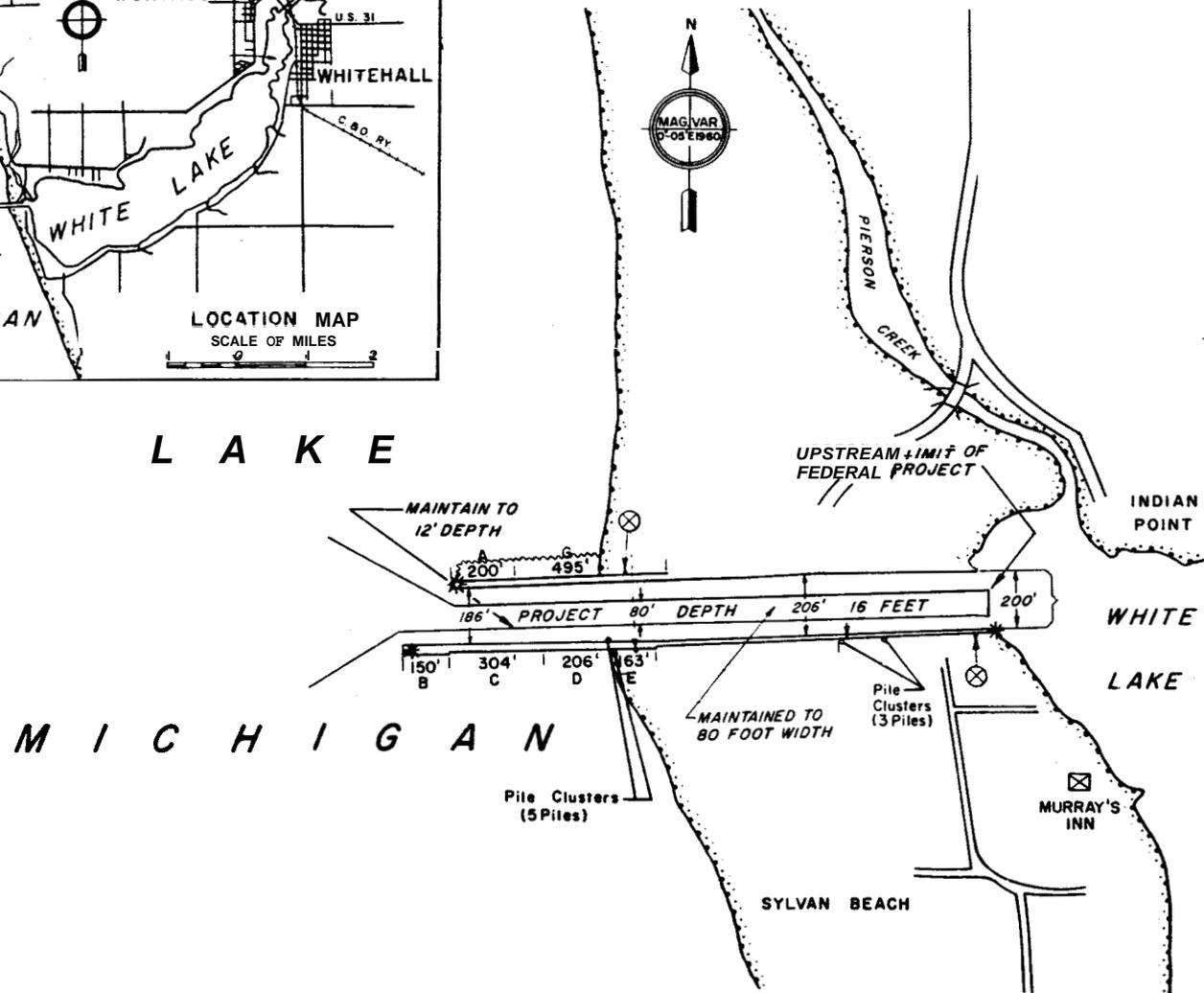
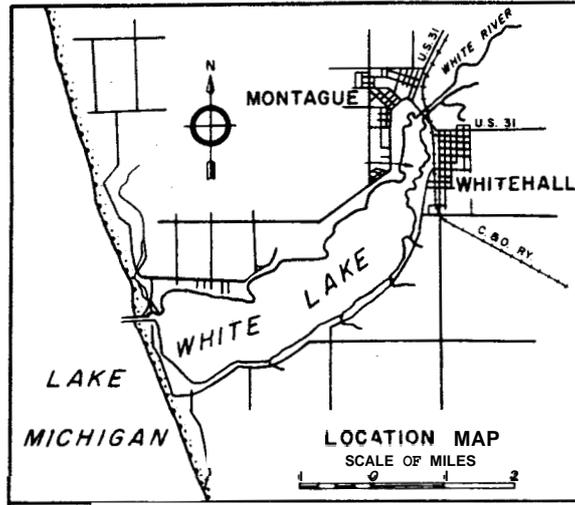


Figure 134. White Lake Harbor, Michigan

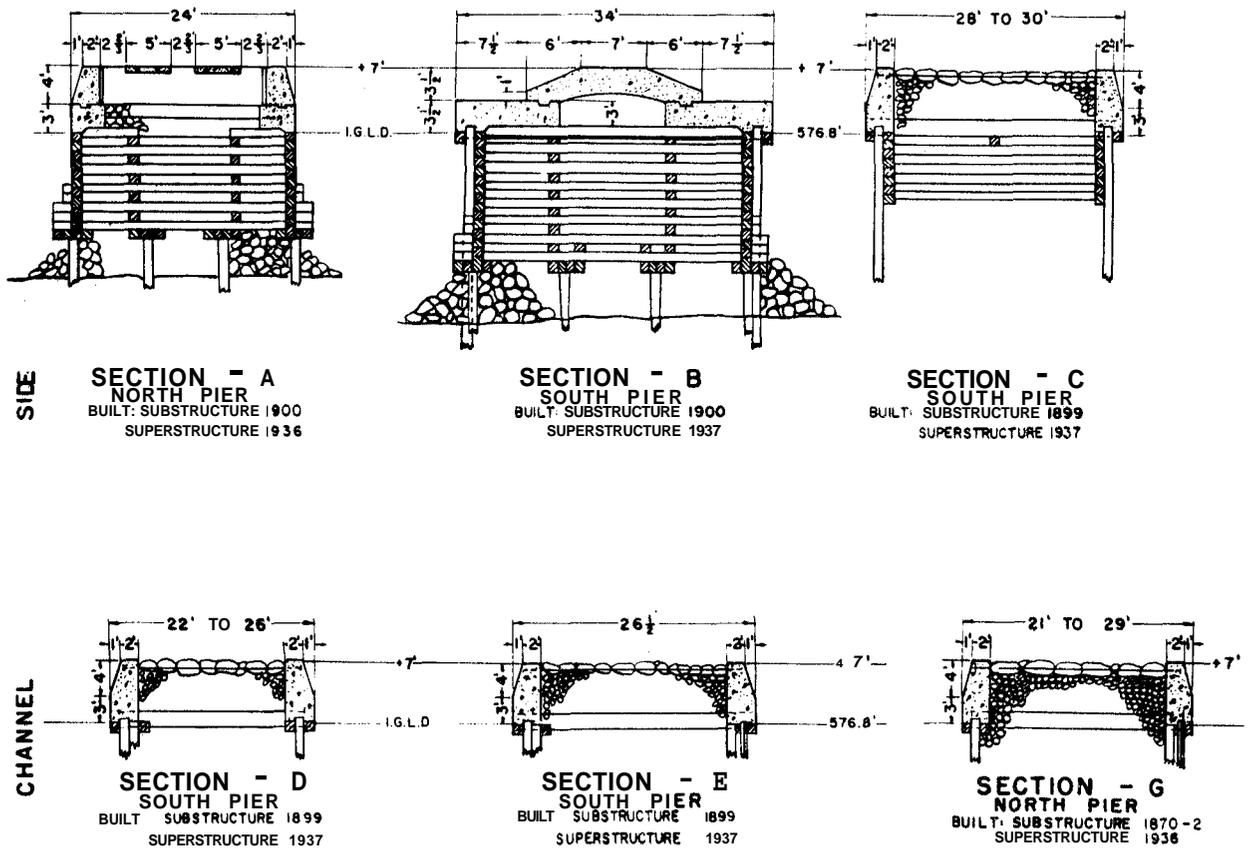


Figure 135. Typical pier cross sections, White Lake Harbor, Michigan

Table 50
Pentwater Harbor Piers
Pentwater, Michigan

Date(s)	Construction and Rehabilitation History
1868-1870	Construction of a 606-ft-long north pier (Figure 136, Sections B, C, D, and E) and a 620-ft-long south pier (Figure 136, Sections B, H, and J) was completed during this period. The shoreward 439 ft of the north pier was constructed with woodpilings (Figure 137, Sections D and E) that were spaced 14 ft apart and stone filled. The remaining portions of the north pier and the entire south pier (Figure 137, Sections B, C, J, and H) were constructed with stone-filled timber crib structures. The width of the timber cribs at the north pier (Sections B and C) were 20 ft, and the south pier timber crib structures (Sections B, H, and J) ranged from 20 to 32 ft in width.
1872	The north pier was extended by 34 ft (Figure 136, Section A) with a timber crib structure. The pier extension was 30 ft wide and filled with stone (Figure 137, Section A).
1887	The south pier was extended by 101 ft (Figure 136, Section G). The extension included a 30-ft-wide stone-filled timber crib structure (Figure 137, Section G).
1938	The north and south piers were capped with concrete and stone superstructures (Figure 137). The crests of the piers were installed at an el of +7.0 ft lwd. The piers ranged in width from 18 to about 37.5 ft. The widths of two portions of the north pier (Figure 137, Sections A and C) were increased by installing woodpilings on the channel side and filling the voids with stone prior to capping the structures.
1959	A 60-ft-long rubble-mound extension to the north pier was completed (Figure 136). The structure had a 10-ft-wide crest width and an el of +5.0 ft lwd (Figure 137). Side slopes were 1V:2H, and 9-ton (min) toe stones were utilized.
1971	Riprap stone was placed around the head and on the lakeward side of the rubble-mound portion of the north pier (Figure 136), and stone replenishment and regrouting was completed for the remaining portion of the north pier (Sections A, B, C, and D). Riprap also was placed around the head of the south pier, and fill stone placement and regrouting were completed for Section B (Figure 136) of the south pier.
1981	Riprap was placed along the lakeside of a portion of the south pier (Figure 136, Section H).
1982	Small core stone was placed into gaps of the rubble-mound portion of the north pier (Figure 136) between the cover stones. Fill stone

(Continued)

Table 50 (Concluded)

Date(s)	Construction and Rehabilitation History
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replenishment and concrete capping were completed to Sections A, B, C, D, and E of the north pier and Section G of the south pier (Figure 136).

1985 A site inspection of the structures indicated that the rubble-mound extension of the north pier (Figure 136) has settled up to 1 ft throughout. The remaining portions of the north pier (Sections A, B, C, D, and E) and the south pier (Sections G, H, B, and J) are bulging, tilting, leaning, cracked and misaligned. These factors, along with loss of fill stone, indicate substructure deterioration. The structures are considered in poor condition; however, major rehabilitation has been recommended and is scheduled for 1987. An aerial view of the Pentwater Harbor piers is shown in Figure 138.

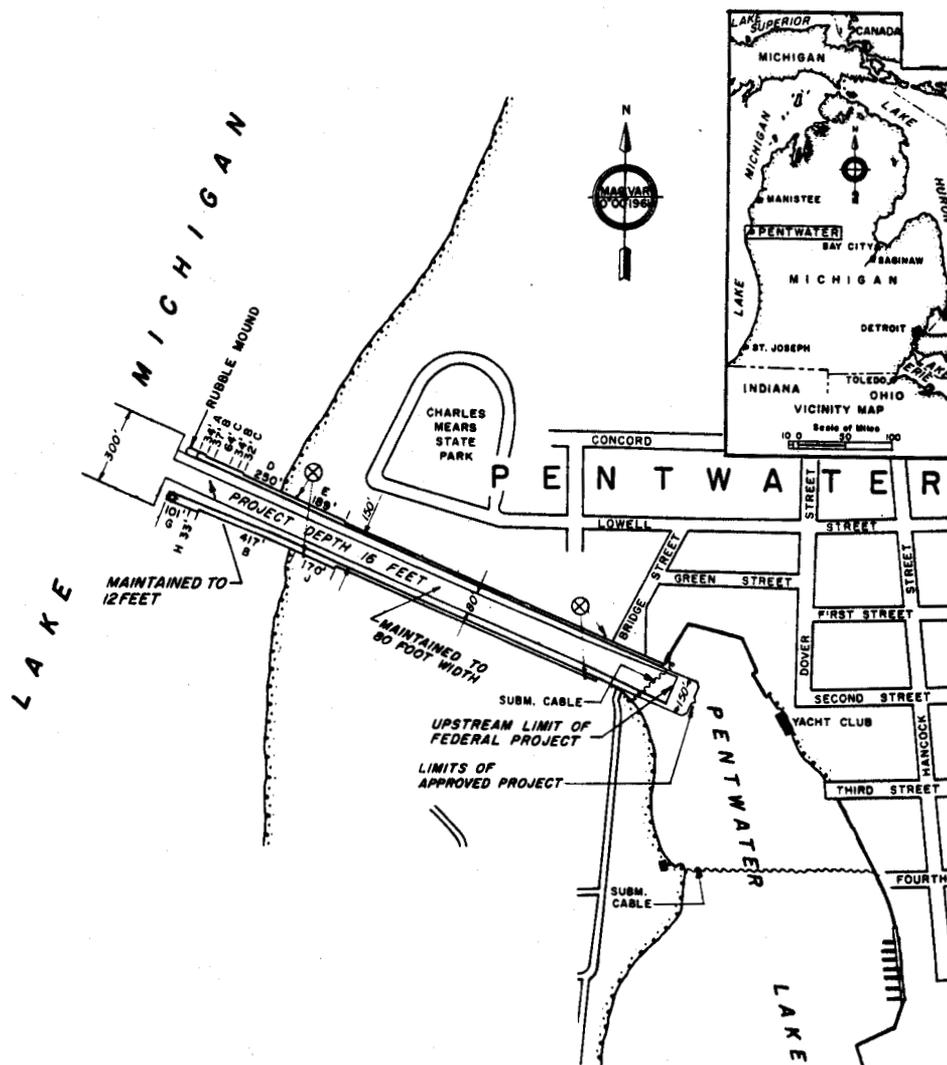


Figure 136. Pentwater Harbor, Michigan

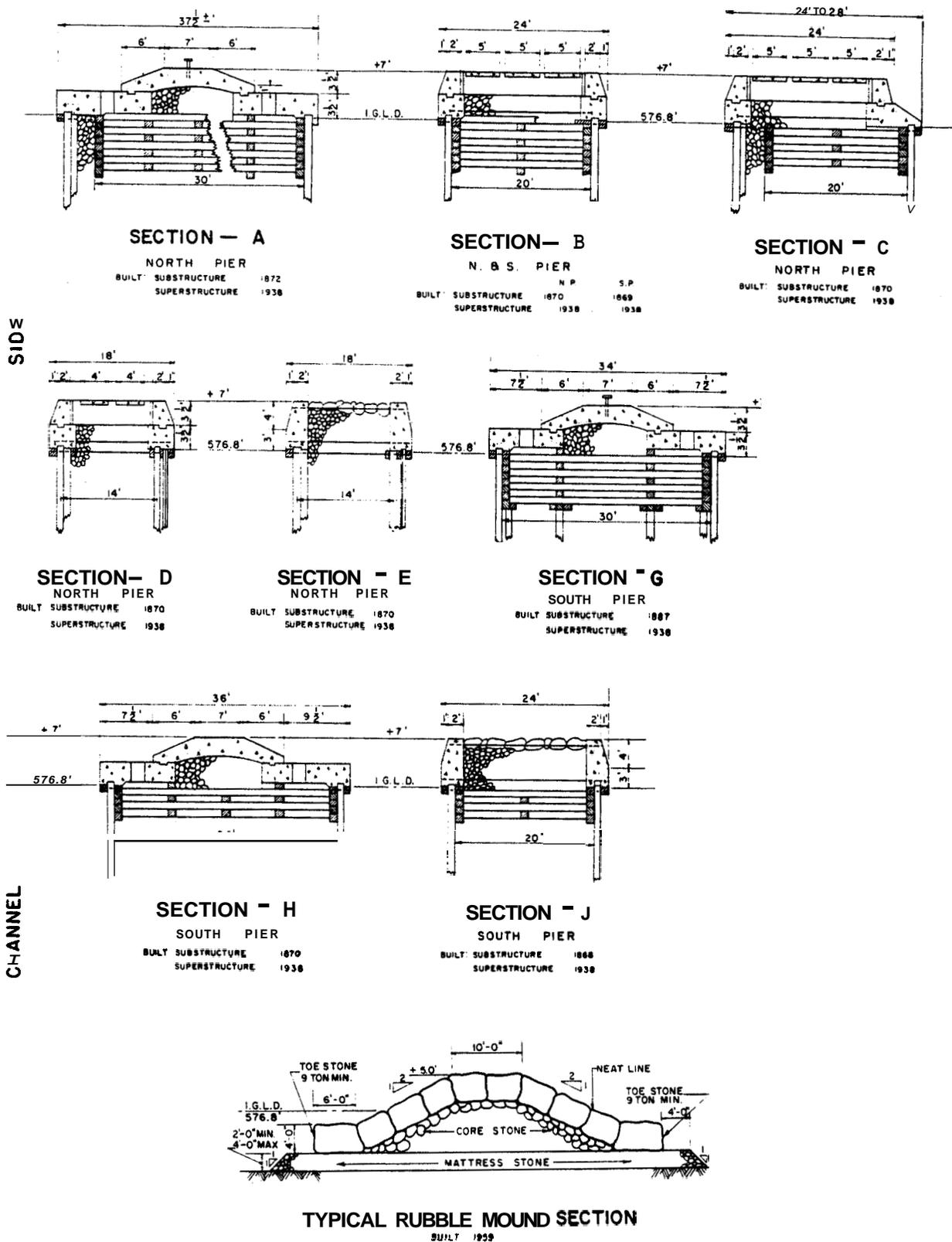


Figure 137. Typical structure cross sections, Pentwater Harbor, Michigan

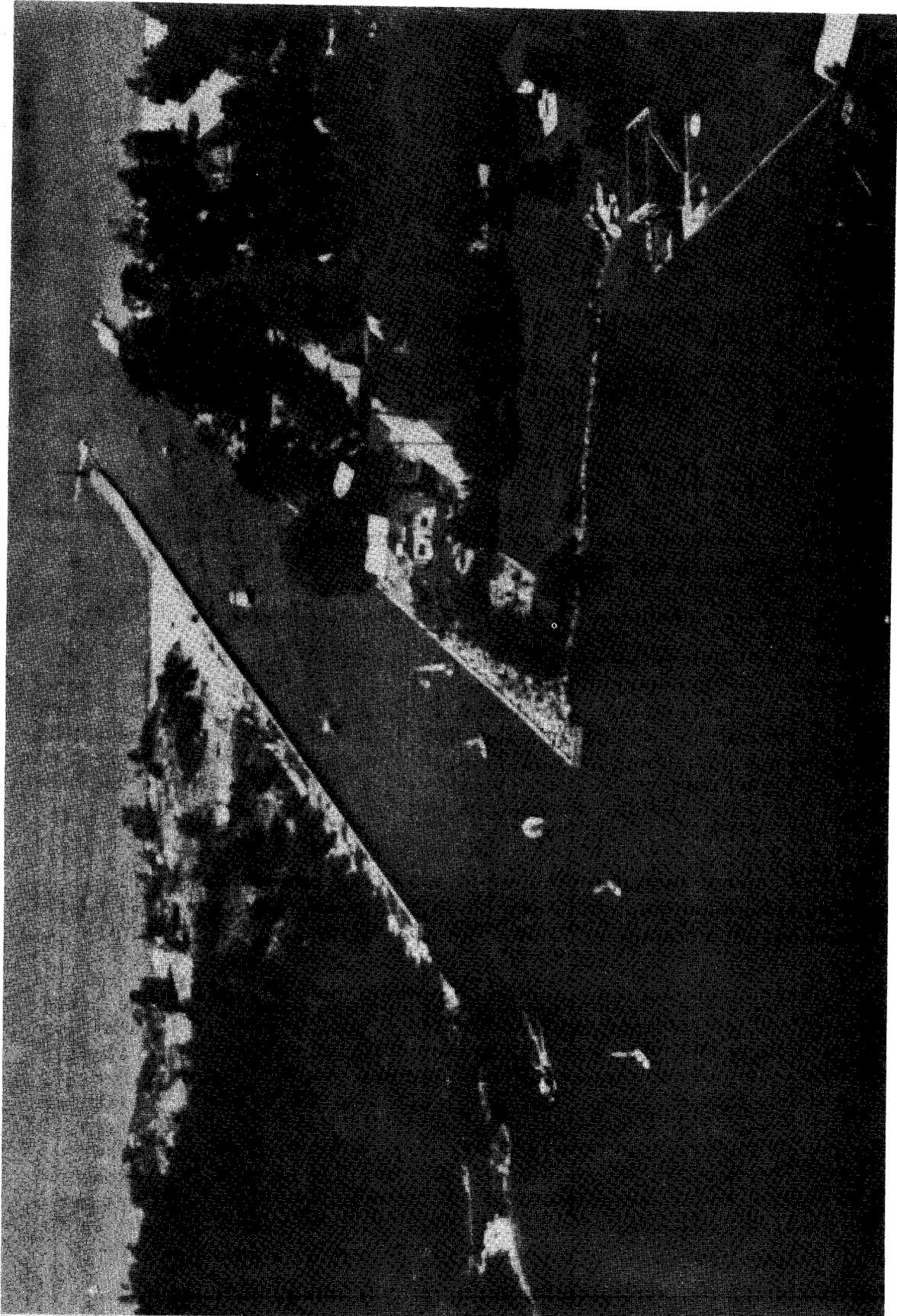


Figure 138. Aerial view of Pentwater Harbor, Michigan

Table 51
Ludington Harbor Structures
Ludington, Michigan

<u>Date(s)</u>	<u>Construction and Rehabilitation History</u>
1866- 1874	Construction of a north (Figure 139 Sections J and J1) and south (Figure 139, Sections L, M, and N) pier was completed during this period. The north pier consisted of stone-filled timber cribs about 20 ft in width (Figure 140, Sections J and 31). The south pier originally consisted of stone-filled 20-ft-wide timber cribs (Figure 139, Sections L and M) and woodpilings (Figure 137, Section N) spaced about 20 ft apart and filled with stone.
1879- 1880	The north pier was extended (Figure 139, Sections G and H) by 311 ft. The extension involved the construction of stone-filled timber cribs (Figure 140, Sections G and H) with a width of about 24 ft.
1907- 1914	Construction of the north and south breakwaters (Figure 139) was completed in this time frame. The lakeward portions of the breakwaters (Figures 139, 141, and 142, Sections A, B, C, D, and E) were constructed with stone-filled timber cribs with a width of 30 ft. The structures were built on a stone base. The shoreward portions of the breakwaters (Figures 139 and 142, Sections F and F1) were constructed with woodpiling with widths ranging from 12 to 20 ft.
1922- 1929	The north pier (Figures 139 and 140, Sections G, H, J, and J1), the south pier (Figure 139, Sections L, M, and N) and the lakeward portions of the north (Figures 139 and 141, Sections A and B) and south (Figures 139 and 142, Sections C and D) breakwaters were capped with stone and concrete superstructures during this period. The crest els of the north and south piers were +6.0 ft lwd, and those of the north and south breakwaters were approximately +7.1 and +6.75 ft lwd, respectively.
1936- 1937	The shoreward portions of the north and south breakwaters (Figures 139, 141, and 142, Sections C, F, and F1) were capped with stone and concrete superstructures. The crest els of these structures ranged from about +6 ft to +7.1 ft lwd.
1954- 1964	The north pier (Figure 139, Sections G, H, J, and J1) and the lakeward end of the south breakwater (Figure 139, Sections D and E) were repaired during this time. The north pier was encased with steel sheetpiling. The lakeward portion of the pier (Figure 140, Sections G, H, and J) included gravel fill and a concrete cap. The repaired pier was about 32 ft wide and had a crest el ranging from +7.0 ft lwd (Section G) to +7.5 ft lwd (Sections H and J). The shoreward portion of the pier (Figure 140, Section J1) was stone filled on the channel side with a concrete cap. The structure was backfilled with sand at an el of +6.0 ft lwd. Repairs to the south

(Continued)

Table 51 (Concluded)

Date(s)	Construction and Rehabilitation History
	breakwater (Figure 142, Sections D and E) involved the placement of new core stone over the existing riprap and cover stone on each side of the structure. The cover stone was 8 tons (minimum 10-ton average) with a crest el of +3.0 ft lwd and side slopes of 1V:1.5H .
1970- 1971	Portions of the north and south breakwaters (Figure 139, Sections A, B, C, and F1) were repaired. The lakeward portion of the north breakwater (Figure 141, Sections A and B) included the placement of new core stone over the existing riprap and 8-ton minimum to 10-ton maximum cover stone with an el of +3.0 ft lwd on each side of the breakwater and 1-V:1.5-H side slopes. Repairs to Sections C and F1 of the north breakwater and Section F1 of the south breakwater (Figures 141 and 142) included core stone and 8- to 12-ton cover stone on the lakeside of the structures with an el of +3.0 ft lwd and 1-V:1.5-H side slopes. Toe stone on each side of the breakwaters ranged from 10 to 15 tons.
1974- 1975	A hydraulic model investigation was conducted (Crosby and Chatham 1975) to determine optimum design features at the breakwater entrance which would allow the passage of larger and deeper draft vessels while still providing wave protection at the existing docking facilities.
1977- 1981	The south pier (Figure 139, Sections L, M, and N) was reconstructed. The new pier consisted of a rubble-mound structure with a concrete cap which ranged from 9.5 to 11 ft in width (Figure 143, Sections L, M, and N) and had a crest el of +7.0 ft lwd. The lakeward portion of the pier included 3- to 6-ton cover stone (Sections L and M), and the remaining portion had 100- to 250-lb cover stone. Side slopes of the pier were 1V:1.75H . A wave absorber was installed adjacent to the north pier (Figure 140) with a slope of 1V:1.5H and an el of +7.0 ft lwd. Cover stone ranging from 2.5 to 5 tons was utilized.
1985	Site inspection of the structures indicated that they were generally in fair condition with the breakwater caps in need of maintenance. An aerial view of the Ludington Harbor structures is presented in Figure 144.

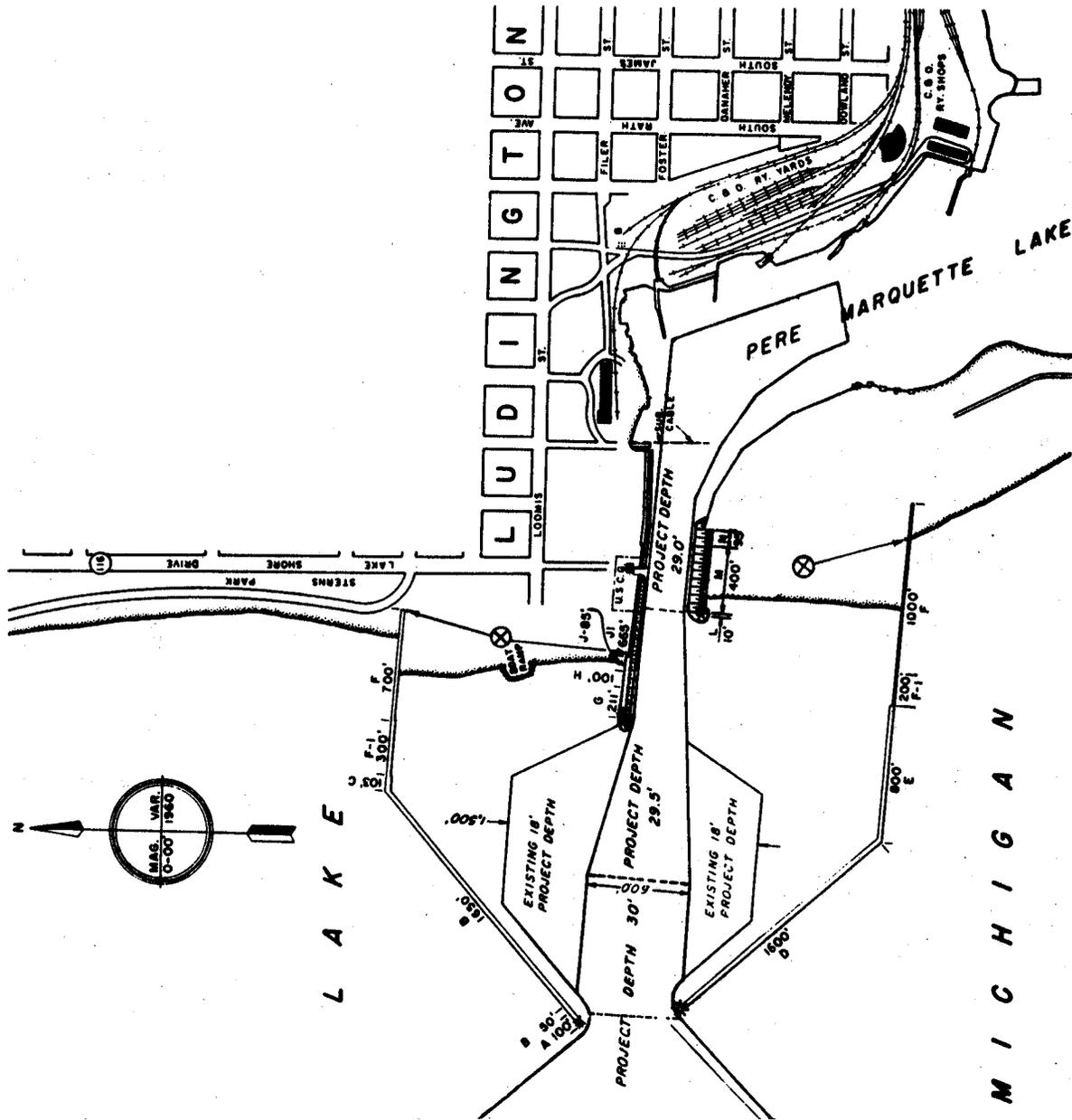
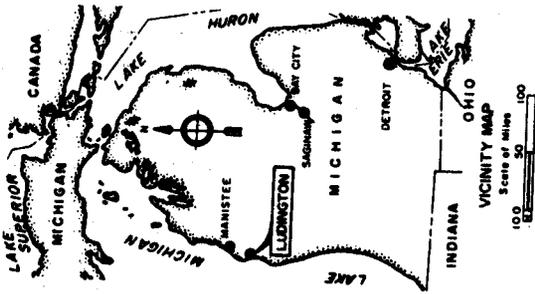
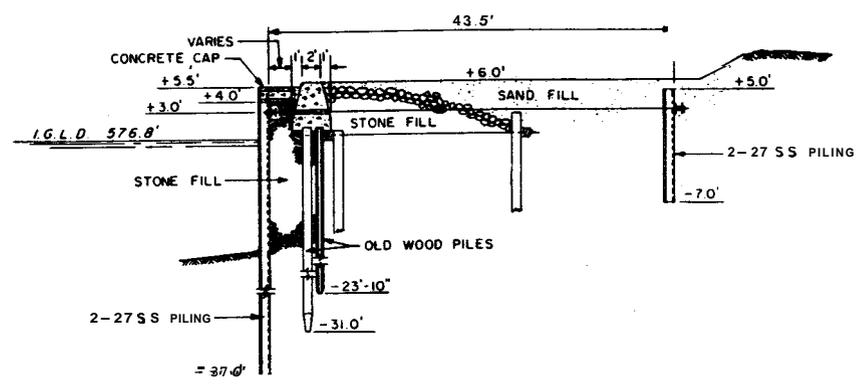
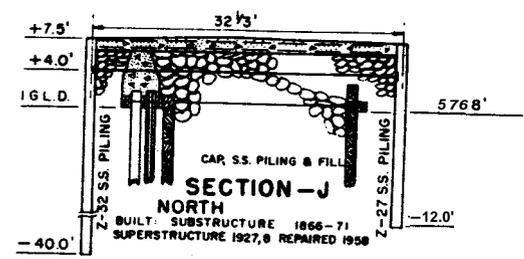
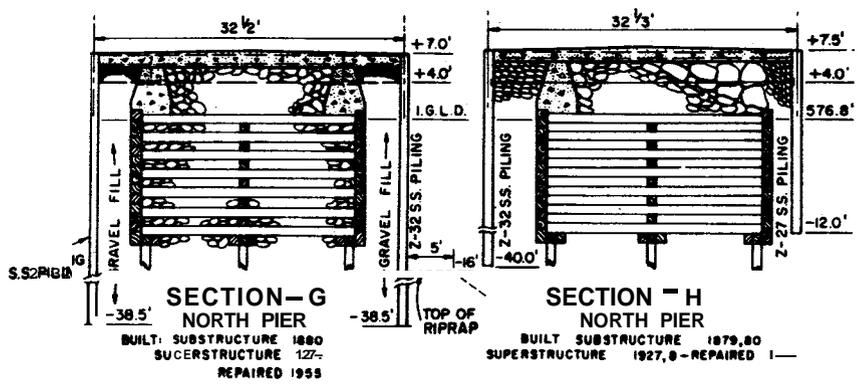
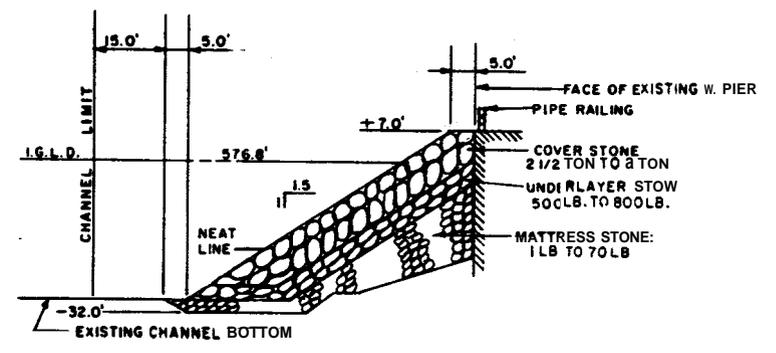


Figure 139. Ludington Harbor, Michigan

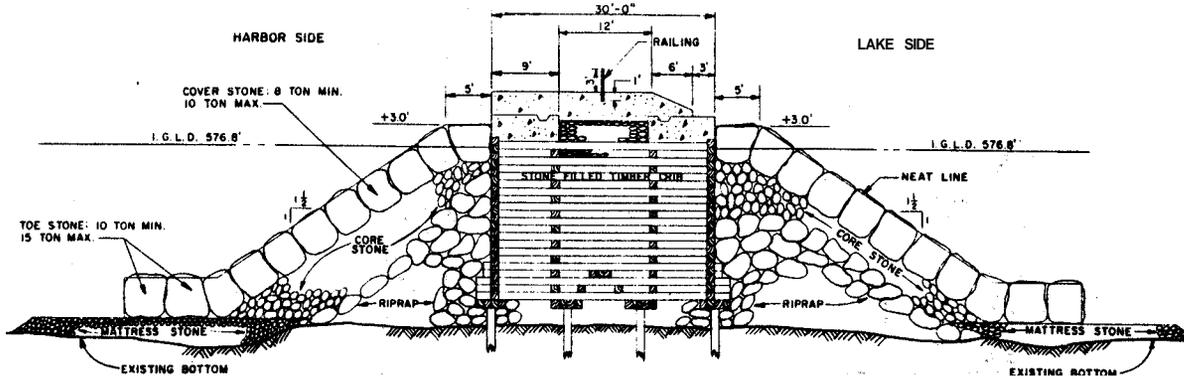


TYPICAL SECTION - J1
NORTH
 BUILT: SUBSTRUCTURE 1866 - 71
 SUPERSTRUCTURE 1928
 RE-CONSTRUCTED 1964

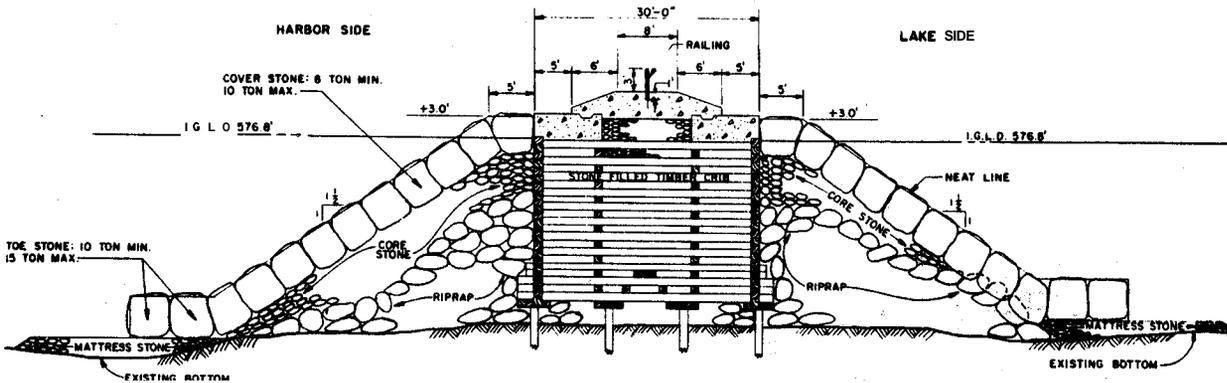


TYPICAL WAVE ABSORBER
NORTH PIER
SECTIONS G, H, J & J-1
BUILT: 1981

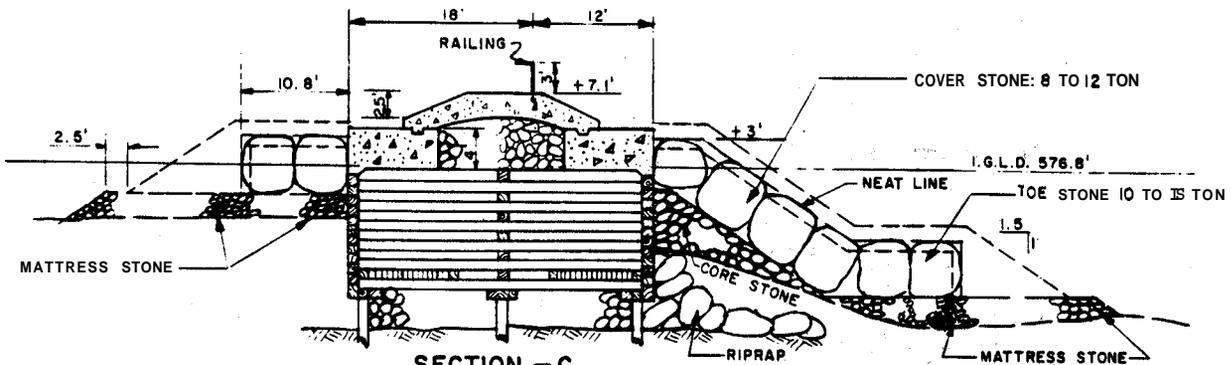
Figure 140. Typical structure cross sections, Ludington Harbor. Michigan



TYPICAL SECTION A
 NORTH BREAKWATER
 BUILT: SUBSTRUCTURE 1909
 SUPERSTRUCTURE 1922, 4
 REPAIRED 1970-71

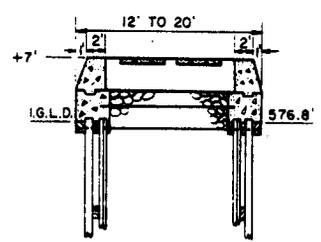
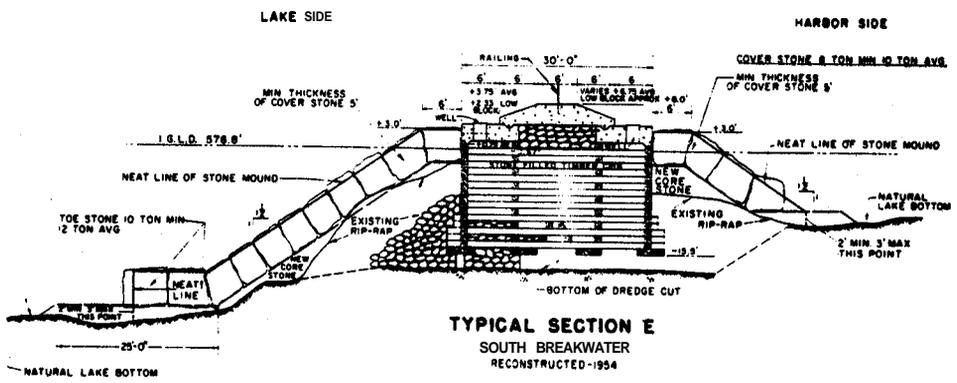
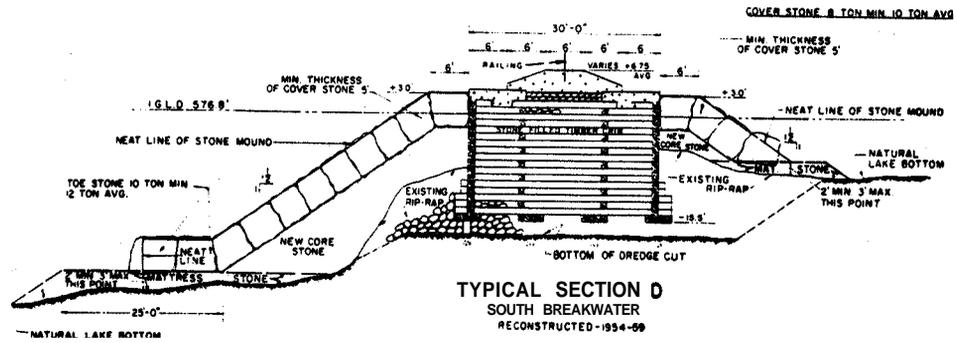


TYPICAL SECTION B
 NORTH BREAKWATER
 BUILT: SUBSTRUCTURE 1909-11
 SUPERSTRUCTURE 1924
 REPAIRED 1970-71

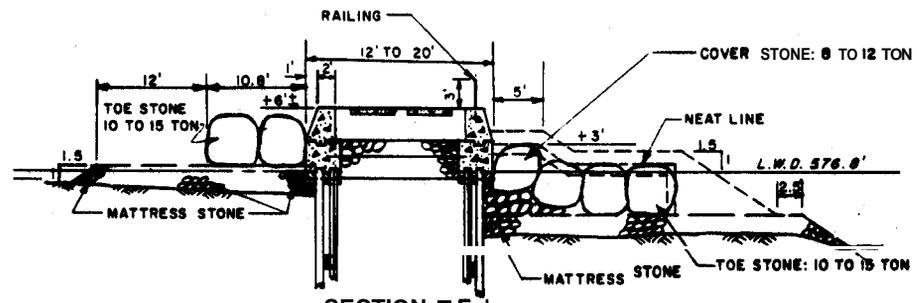


SECTION - C
 NORTH BREAKWATER
 BUILT: SUBSTRUCTURE 1914
 SUPERSTRUCTURE 1936 '37
 REPAIRED 1970-71

Figure 141. Typical north breakwater cross sections, Ludington Harbor, Michigan

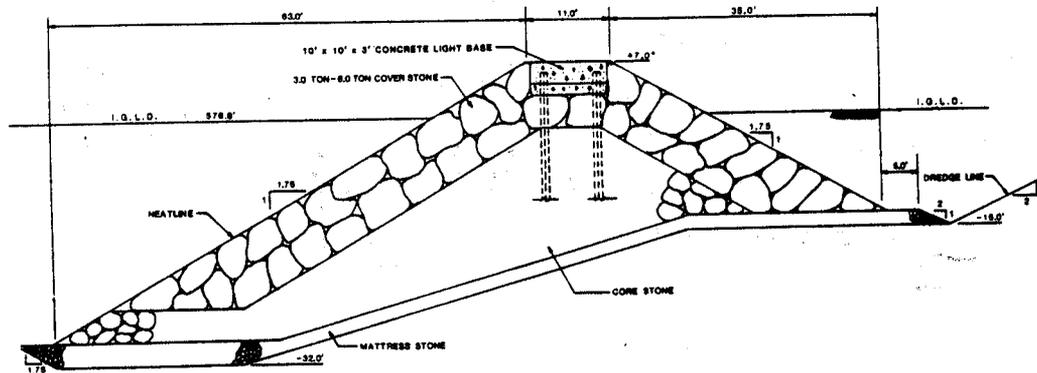


BUILT: SUBSTRUCTURE 1914 N.P. 1913-4 S.P.
SUPERSTRUCTURE 1936-7 1936-7 1936-7

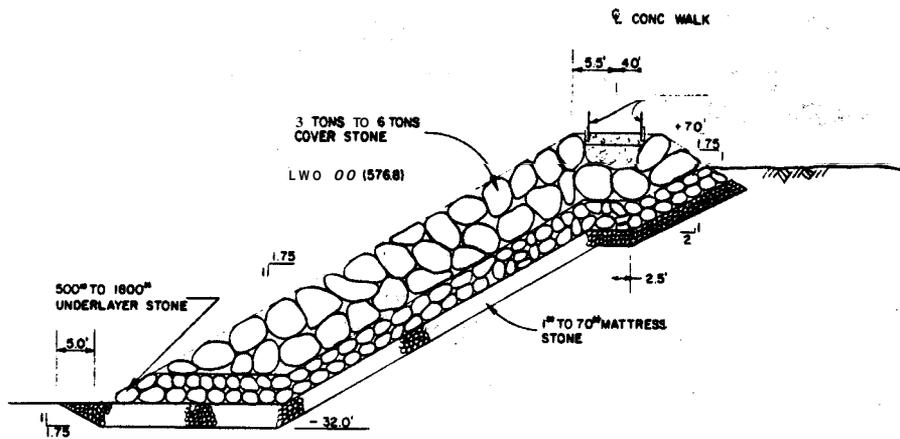


BUILT: SUBSTRUCTURE 1914 N.P. 1913-6 O.P.
SUPERSTRUCTURE 1936-7 1936-7 1936-7
REPAIRED 1970-71

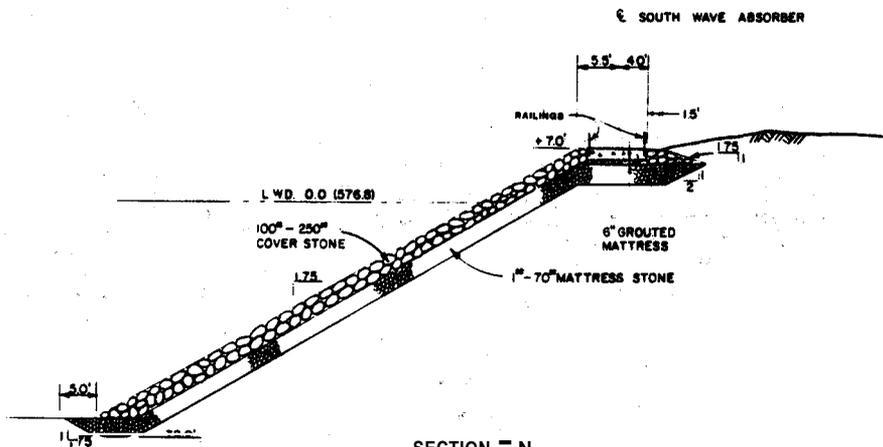
Figure 142. Typical breakwater cross sections, Ludington Harbor, Michigan



SECTION - L
SOUTH PIER
BUILT 1977



SECTION - M
CONSTRUCTED 1991



SECTION - N
CONSTRUCTED 1991

Figure 143. Typical structure cross sections,
Eudington Harbor, Michigan

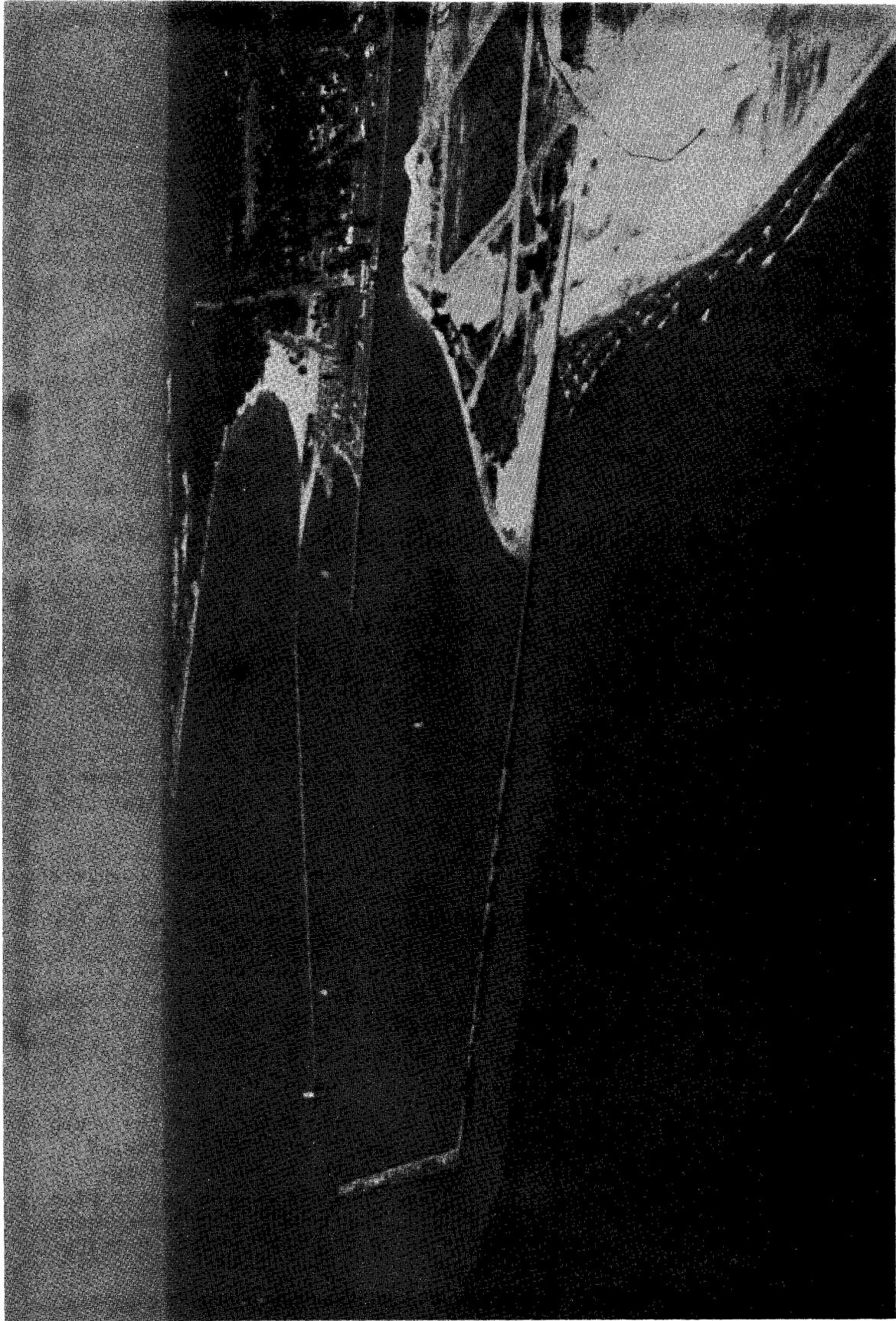


Figure 144. Aerial view of Ludington Harbor, Michigan

Table 52
Manistee Harbor Structures
Manistee, Michigan

Date(s)	Construction and Rehabilitation History
1912- 1915	Construction of the lakeward portions of the north pier (Figure 145, Sections A-1, A, B, C, D, and E) and the south breakwater (Figure 145, Sections B-1 and B) was completed during this time. These structures consisted of stone-filled timber cribs. The width of the north pier ranged from 24 to 30 ft (Figure 146), and that of the south breakwater was 30 ft (Figure 147, Sections B and B-1).
1917- 1920	Construction of the shoreward portion of the south breakwater (Figure 145, Sections M, N, O, O-1, P, and Q) was completed. The breakwater consisted of stone-filled woodpilings spaced from 9 to 17 ft apart (Figure 147). The breakwater was capped with a stone and concrete superstructure (Figure 147) that ranged from +5.7 ft (Section P) to +6.7 ft (Sections M, N, O, and O-1) lwd.
1926	The lakeward end of the north pier (Figure 145, Sections A1-A, and B) was capped with a concrete and stone superstructure (Figure 146, Sections A, A-1, and B). The crest el of the pier was +7.1 ft lwd.
1933- 1935	The lakeward end of the south breakwater (Figure 145, Sections B and B1) and the shoreward end of the north pier (Figure 145, Sections C, D, and E) were capped with concrete and stone superstructures. The crest el of the structures was +7.1 ft lwd (Figures 146 and 147).
1942	A 350-ft-long shoreward extension of the north pier (Figure 145, Section F) was constructed. The extension consisted of woodpilings filled with stone (Figure 146, Section F). A concrete superstructure was installed on the channel side to an el of +6.0 ft lwd.
1949- 1950	Construction of the south pier (Figure 149, Section J) was completed. This structure consisted of steel sheetpiling spaced 15.7 ft apart and filled with stone (Figure 146, Section P). The crest el of the pier was +7.0 ft lwd.
1953	The north pierhead (Figure 145, Section A-1) was rebuilt by encasing it in steel sheetpiling. The structure width was increased to 35.3 ft, voids were filled with stone, and a concrete cap was installed at a crest el of +8.0 ft lwd (Figure 146, Section A-1).
1964- 1966	Portions of the north pier (Figure 145, Sections A-F) and the south breakwater (Sections B1, M, N, O, O-1, and P) were rehabilitated during this time. Sections C through E of the north pier (Figure 146) were encased with steel sheetpiling which resulted in pier widths ranging from about 31 to 38 ft. Voids were filled with stone, and a concrete cap was installed at an el of +8.0 ft lwd. Section F

(Continued)

Table 52 (Concluded)

Date(s)	Construction and Rehabilitation History
	<p>(Figure 146) of the north pier was enclosed in steel sheetpiling with a concrete cap from the channel piling to the existing concrete and stone fill from that point shoreward. The el of this section was +6.0 ft lwd. Rehabilitation to Sections M, N, O, and O1 of the south breakwater (Figure 147) involved the placement of stone to each side of the breakwater. Stone was placed to an el of +2.0 ft lwd with 1V:1.5H side slopes. Cover stone ranging from 5 (min) to 7 tons (max) was placed adjacent to Sections M and N, while cover stone ranging from 1.5 (min) to 2.5 tons (max) was placed adjacent Section O and O-1. Stone was placed only on the lakeside of Sections P and B1 (Figure 147). Cover stone ranging from 7 (min) to 10 tons (max) was used at the pierhead (Section B1), while 0.5-ton riprap was placed adjacent to Section P. Side slopes were 1V:1.5H, and crest els were +2.0 ft lwd.</p>
1980	<p>Approximately 1,016 tons of riprap (0.5 to 4 tons) was placed along the channel side of the north pier to reduce scouring, and about 110 tons of stone fill was placed in the cells of the south breakwater.</p>
1982	<p>Riprap (2,024 tons) ranging from 3 to 16 tons was placed along the lakeside of the south breakwater, and about 2,545 tons of 0.5- to 3-ton riprap was installed on the channel side of the structure as toe protection. A total of 529 tons of riprap was placed along the channel side of the north pier as toe protection. This stone ranged from 0.5 to 3 tons in weight. Stone fill was replenished at the head of the south breakwater and on the channel side of the south pier also during this year.</p>
1985	<p>An inspection of the structures revealed them to be, generally, in fair condition. Minor settlement and cracking of the concrete cap was observed along the north pier indicating some fill stone settlement. Loss of fill stone and superstructure misalignment, settlement, and cracking indicates substructure deterioration of the south breakwater. Repairs consisting of stone replenishment and new concrete caps along with additional riprap within the next 2 years have been recommended. An aerial photo of Manistee Harbor structures is shown in Figure 148.</p>

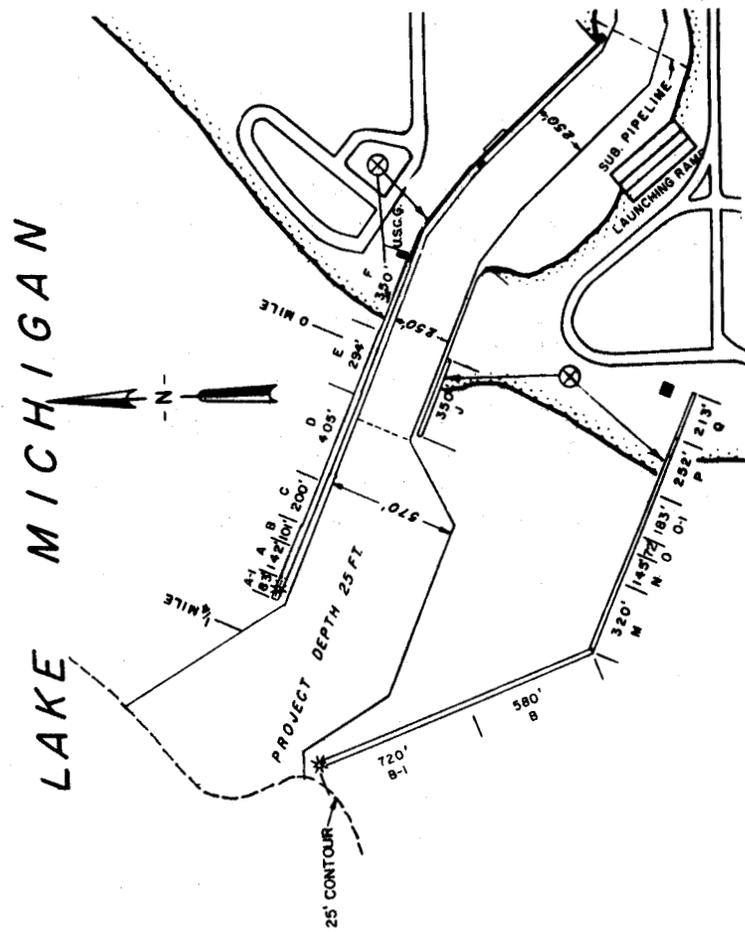
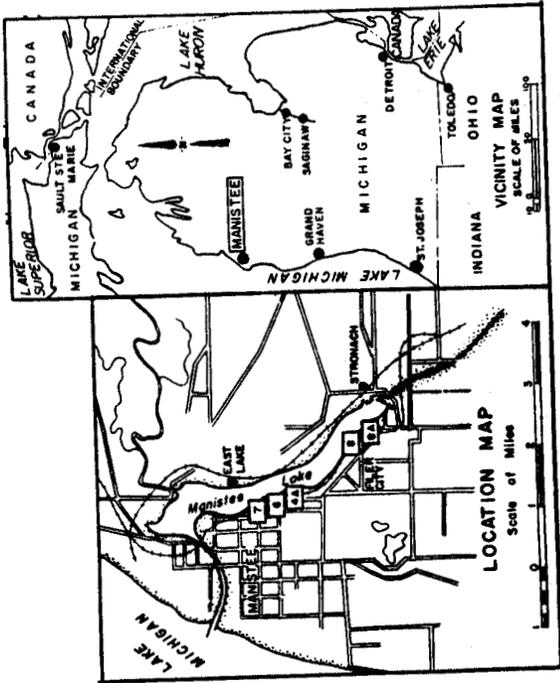


Figure 145. Manistee Harbor, Michigan

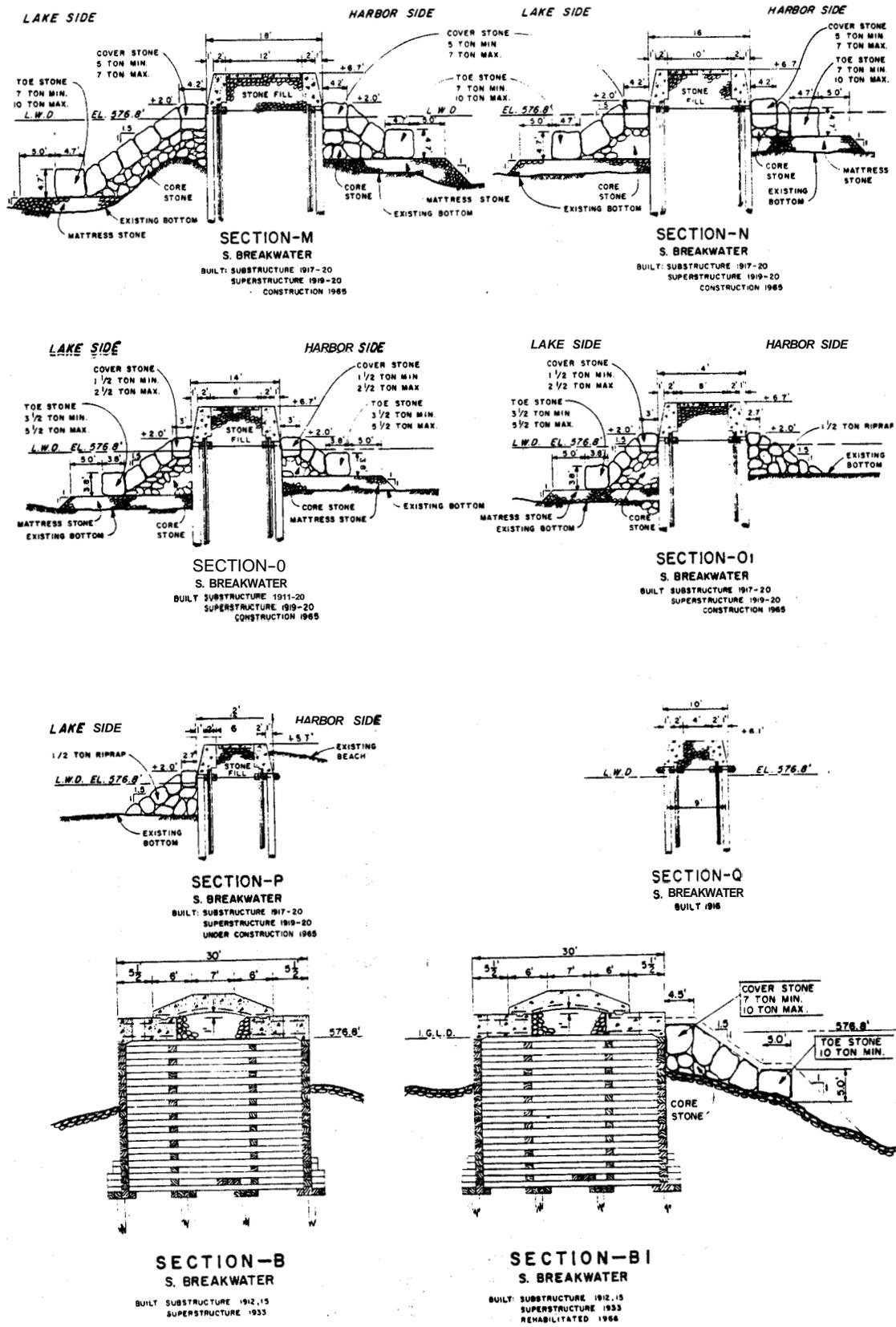


Figure 147. Typical breakwater cross sections, Manistee Harbor, Michigan

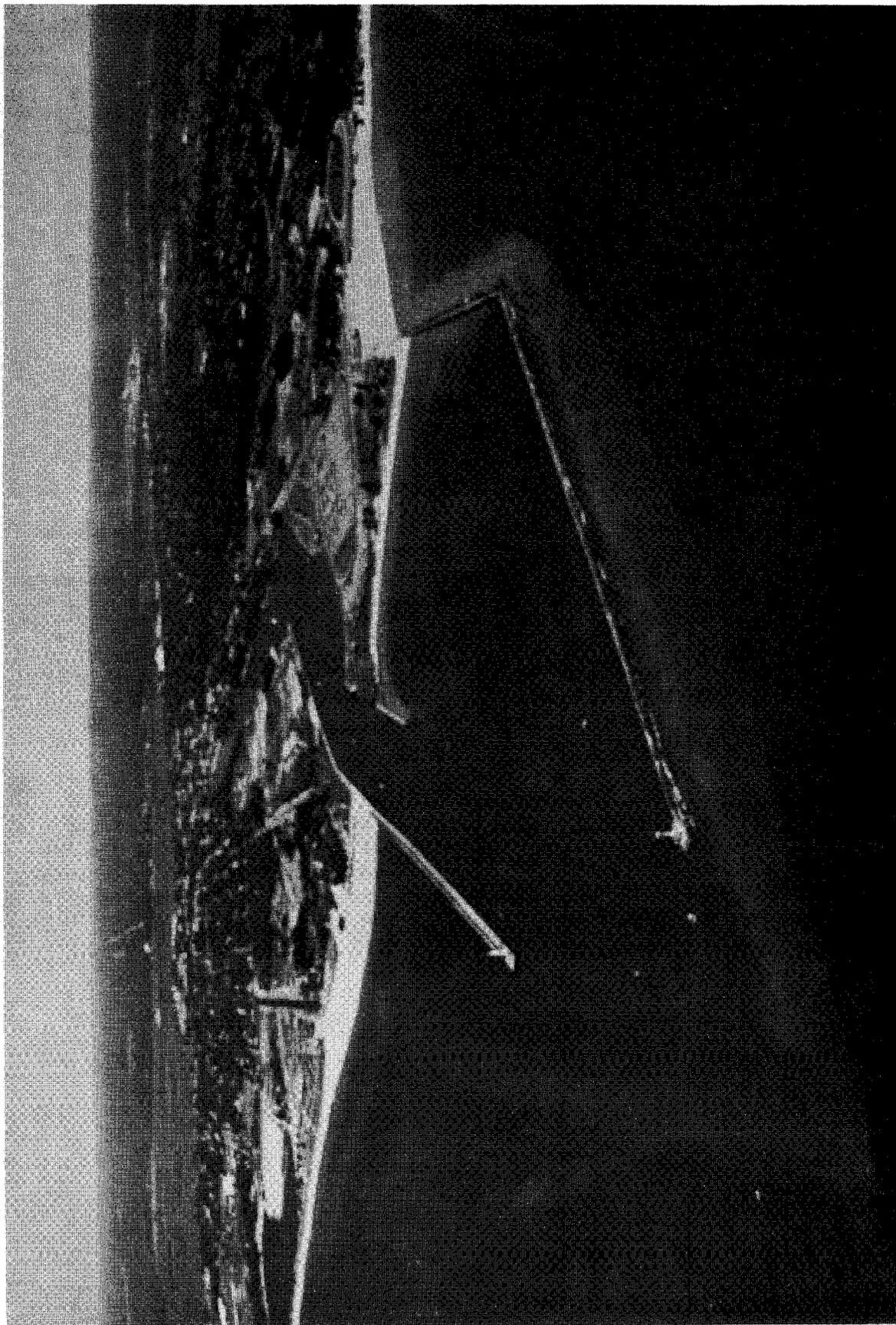


Figure 148 Aerial view of Manistee Harbor Michigan

Table 53
Portage Lake Harbor Piers
Portage Lake, Michigan

Date(s)	Construction and Rehabilitation History
1883- 1888	Construction of a 1,149-ft-long north pier and a 383-ft-long south pier (Figure 149, Sections B, C, E, and F) was completed during this time. The lakeward end of the north pier was built with 24-ft-wide, stone-filled, timber cribs (Figure 150, Section B) on a stone base. The south pier and the shoreward end of the north pier consisted of woodpilings with a stone fill.
1900- 1901	The north pier was extended lakeward by 200 ft (Figure 149, Section A), and the south pier was extended 900 ft (Figure 149, Sections A and B). The lakeward 200 ft of each pier consisted of 30-ft-wide stone-filled timber cribs (Figure 150, Section A) built on a stone base. The trunk portion of the south pier was similar except it was 24 ft in width (Figure 150, Section B).
1939- 1940	The shoreward ends of the piers (Figures 149 and 150, Sections C, E, and F) were rebuilt with woodpilings spaced from about 18 to 24 ft apart and filled with stone. Concrete and stone superstructures were constructed along the entire length of each pier (Figure 150) to a crest el of +7.0 ft lwd.
1980- 1981	Riprap stone was placed around the heads of the north and south piers (Figure 149, Section A) during this period, and stone fill was replenished at various areas along both piers. After replenishment, the concrete caps were repaired.
1985	An inspection of the site indicated the piers were, in general, in fair condition. Settlement and cracking of the superstructure and fill stone loss indicate some substructure deterioration. Replenishment with large fill stone has been recommended along with additional riprap installation. An aerial view of Portage Lake Harbor piers is shown in Figure 151.

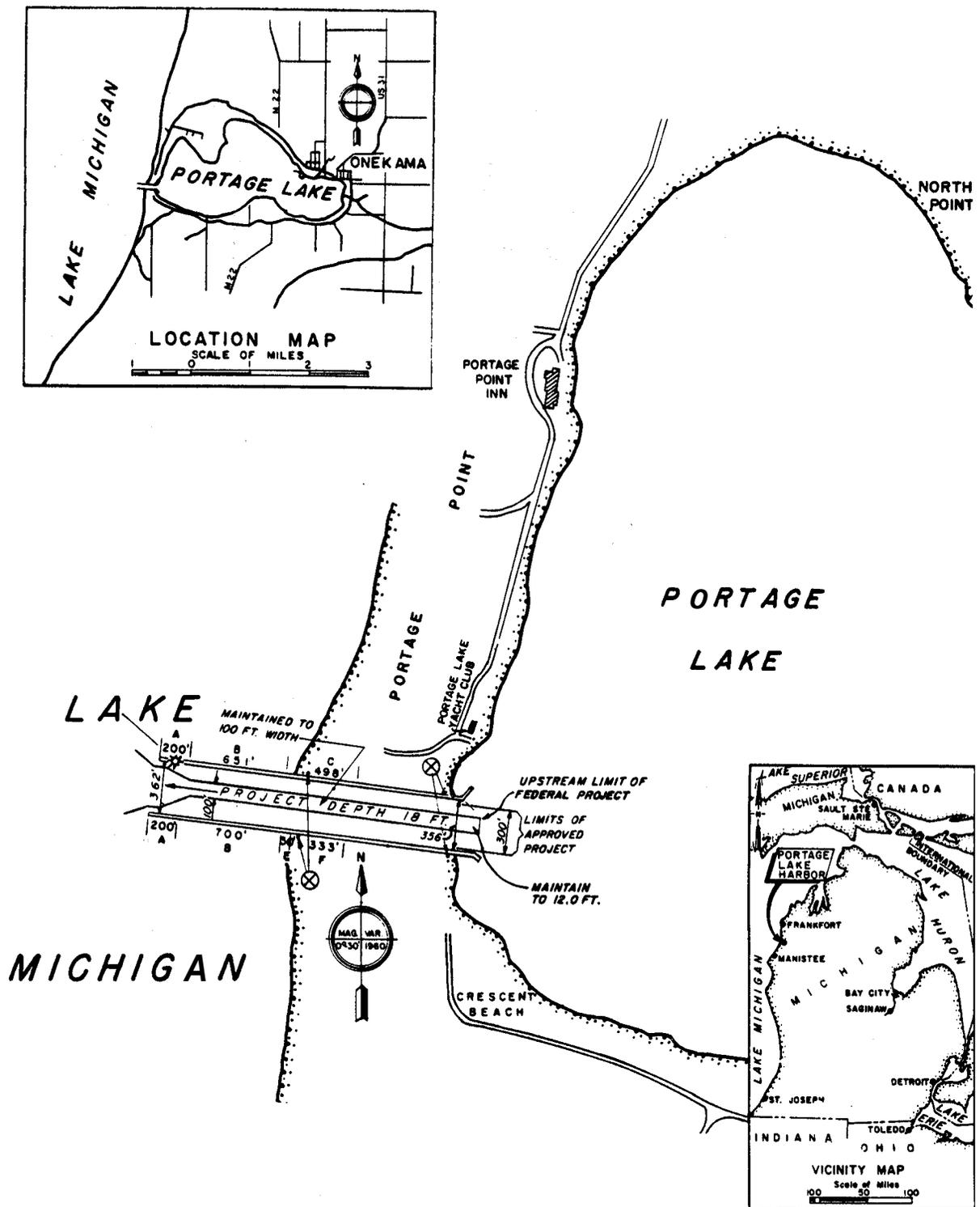


Figure 149. Portage Lake Harbor, Michigan

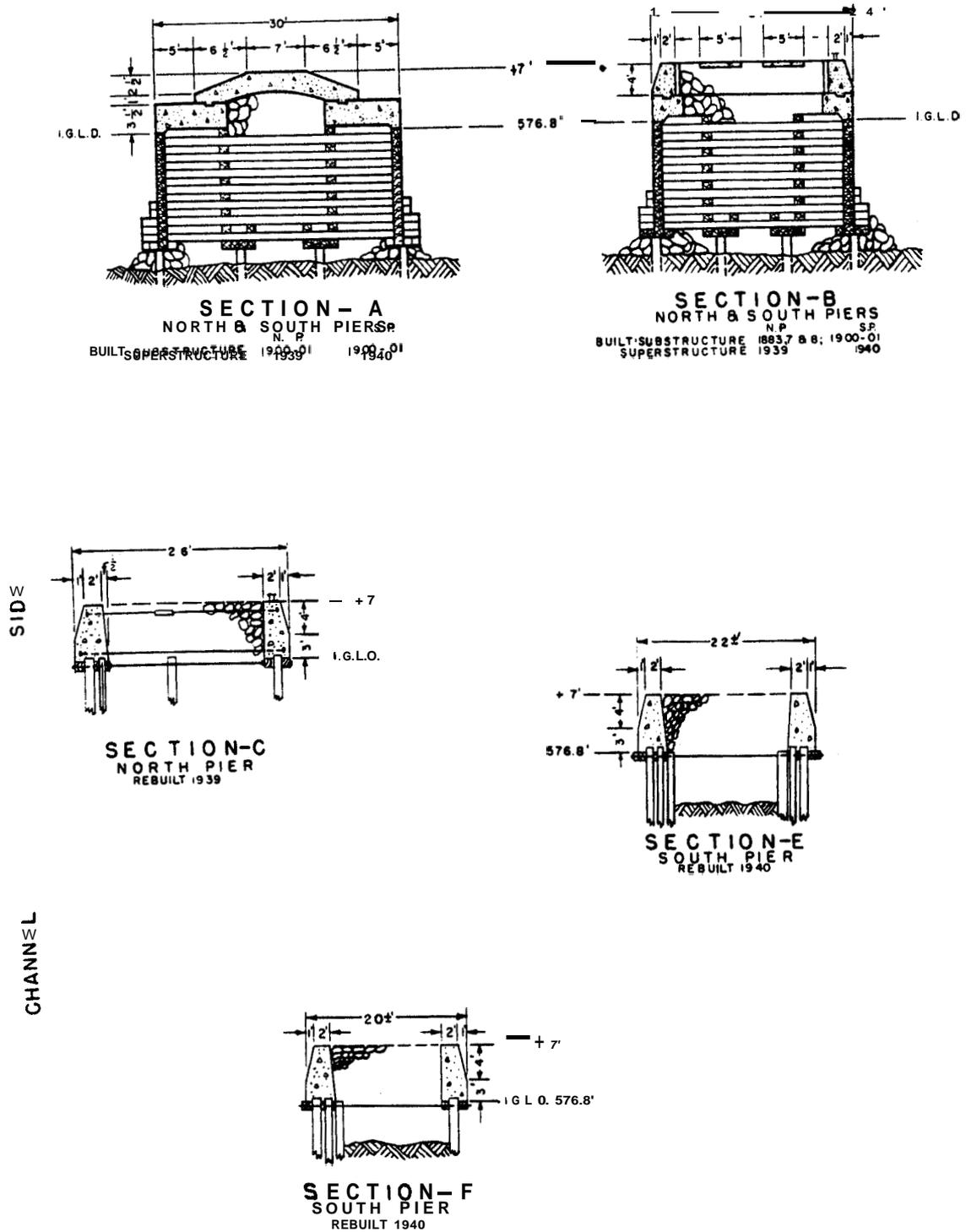


Figure 150. Typical pier cross sections, Portage Lake Harbor, Michigan

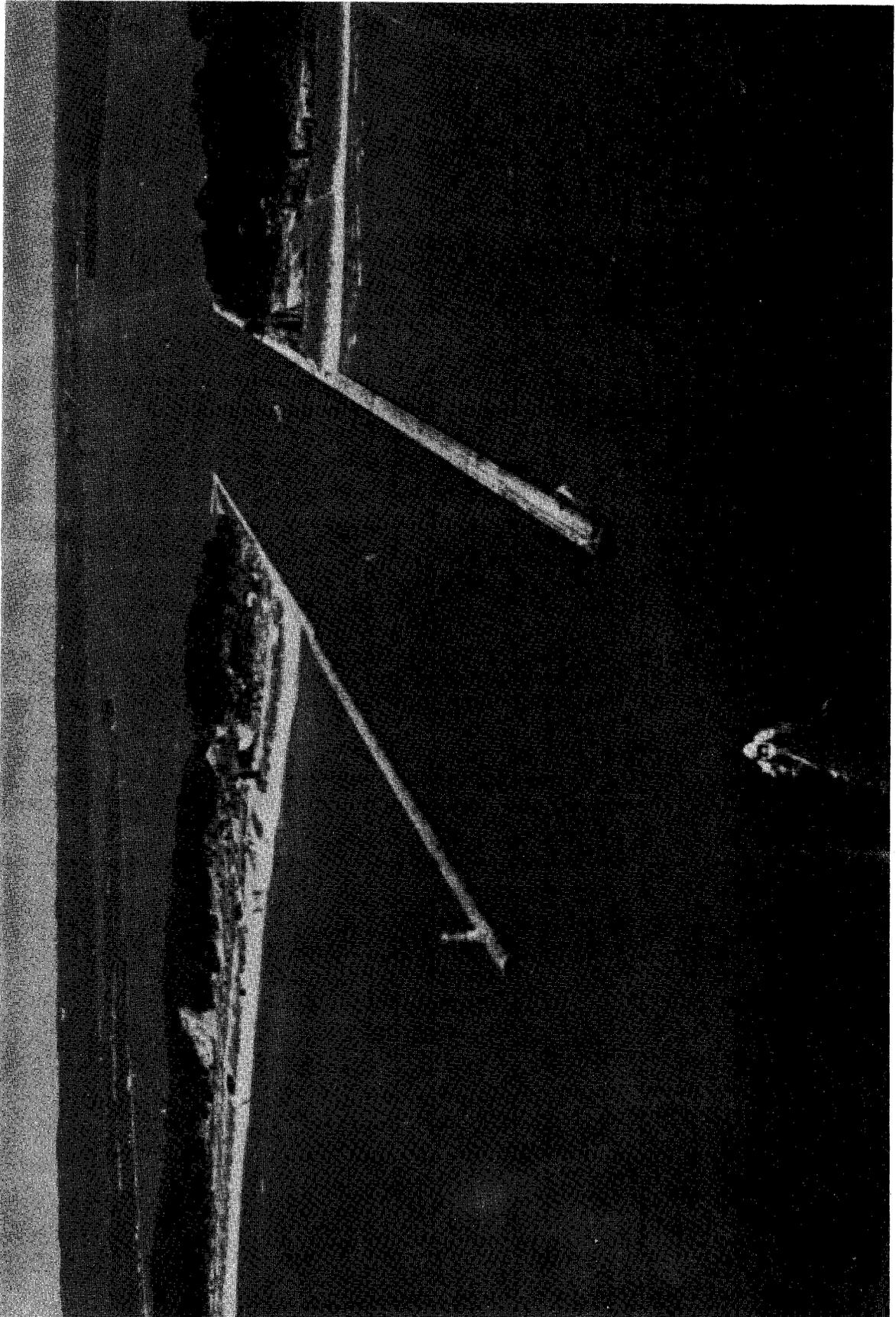


Figure 151 Aerial view of Portage Lake Harbor, Michigan

Table 54
Arcadia Harbor Piers
Arcadia, Michigan

Date(s)	Construction and Rehabilitation History
1909	Construction of a 620-ft-long north pier and a 790-ft-long south pier (Figure 152) was completed by private interests. The north pier is a stone-filled timber crib, and the south pier consists of stone-filled timber cribs and steel sheetpiling with concrete caps. The outer end of the south pier is a 20-ft semicircular steel sheet-pile cell with a concrete cap.
1971	Maintenance of the project by the Corps was authorized. Maintenance of the piers prior to this time was performed by private interests and the Michigan Department of Natural Resources.
1973	Riprap stone was placed along and into the water along 490 ft of the north pier which was in a very poor to failed condition.
1983	Fill stone was placed in the steel sheet-pile cell at the head of the south pier, and riprap stone was placed around and on top of the cell. A 35-ft breached area and a 10-ft breach near the shoreline of the south pier also were repaired with fill/core and riprap stone.
1985	An inspection of the site indicated settled and/or washed out stone in numerous areas of the north pier. Water is washing through the voids of the structure, and three areas are nearly breached. The steel sheet-pile cell at the head of the south pier is completely broken out, and most of the grout cap along the entire length of the pier is missing with stone being washed out. The condition of the piers is very poor, and immediate reconstruction/rehabilitation has been recommended.

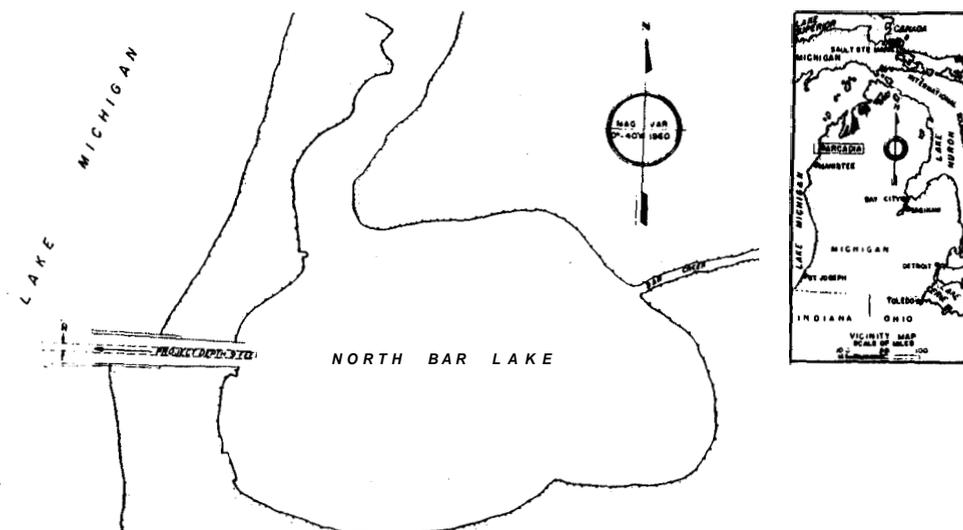


Figure 152. Arcadia Harbor, Michigan

Table 55
Frankfort Harbor Structures
Frankfort, Michigan

Date(s)	Construction and Rehabilitation History
1868- 1873	Construction of the south pier (Figure 153, Sections N-1, N, and O) was completed during this time frame. The lakeward end of the pier was constructed with 20-ft-wide stone-filled timber cribs (Figure 154, Sections N and N-1). The shoreward portion (Section O) was composed of woodpilings spaced about 21 ft apart and filled with stone and sand.
1870- 1879	Construction of the shoreward 603-ft length of the north pier (Figure 153, Sections L-1 and L) was completed. The pier was a 20-ft-wide stone-filled timber crib structure (Figure 154, Sections L-1 and L).
1889- 1895	A 200-ft-long extension of the north pier was completed (Figure 153, Section K). The extension consisted of a stone-filled timber crib structure that was 24 ft in width (Figure 154, Section K).
1928- 1932	Construction of the north and south breakwaters (Figure 153) was completed during this period. The lakeward portions of the structures consisted of stone-filled concrete breakwaters (Figure 156, Sections A, B, and C). The crest widths were slightly more than 7 ft with els of +7.1 ft lwd. The outer ends of the breakwaters each included 2 rectangular caissons for a distance of 54 ft. The shoreward ends of the breakwaters were woodpilings spaced from 11 to 14 ft apart (Figures 155 and 156, Sections D, E, F, G, H, I, and J). The structures were stone filled and capped with concrete and stone superstructures. The north and south breakwaters ranged from 14 to 17 ft in width and had crest els of +7.1 and +7.3 ft lwd, respectively (Figures 155 and 156).
1933- 1963	A total of 71,496 tons of riprap was placed along the sides of the lakeward ends of the north and south breakwaters (Figure 156, Sections A, B, and C).
1934	The north and south piers (Figure 153) were capped with concrete and stone superstructures (Figure 154, Sections K, L, L-1, N, N-1, and O). The piers ranged from 23 to 27 ft in width with crest els of +7.0 ft lwd.
1950	The shoreward end of the south pier (Figure 153, Section O) was reconstructed by the installation of steel sheetpiling on the channel side (Figure 154, Section O). The void between the existing structure and the new steel sheetpiling was filled with stone and capped with concrete at an el of +7.0 ft lwd.
1953	The lakeward 36 ft of the south pier (Figure 153, Section N-1) was repaired by encasing it in steel sheetpiling (Figure 154, Section N-1). The new width of the pier was 27 ft. Voids between the

(Continued)

(Sheet 1 of 3)

Table 55 (Continued)

Date(s)	Construction and Rehabilitation History
	existing structure and the steel sheetpiling were filled with stone and the area capped with concrete.
1958	Construction of a new north pier head and repair of the adjacent 200 ft of the north pier (Figure 153, Sections K-1 and K) was completed. The pier head consisted of a circular steel sheet-pile cell with a diameter of 23.75 ft. The cell was stone filled and capped with concrete to an el of +5.0 ft, and riprap was placed around its base on a 1-V:1.5-H slope. Section K was encased in steel sheet-piling (Figure 154). Voids were filled with stone, and the area between the existing pier and the new steel sheetpiling was capped with concrete at an el of +5.0 ft lwd. The new pier width was 33 ft.
1960- 1961	The shoreward portion of the north pier (Figure 153, Sections L-1 and L) was encased in steel sheetpilings (Figure 154) resulting in a new pier ranging from 29.75 ft (Section L) to 33 ft (Section L-1) in width. The voids between the new steel sheetpiling and the existing piers was filled with stone and capped with concrete (Figure 154).
1966	The shoreward portion of the south breakwater (Figure 153, Sections F, G, H, and I) was rehabilitated. Rehabilitation consisted of the placement of stone along the structures (Figure 155) on slopes of 1V:1.5H. Cover stone ranged from 9 (min) to 12 tons (max) along Section F, 6 (min) to 8 tons (max) along Section G, and 3.5 (min) to 5.5 tons (max) along Section H (Figure 155) on both sides of the breakwater. Riprap (1 ton) cover stone was installed on the lakeside only of Section I.
1977	Portions of the north breakwater (Figure 153, Sections D and E) were replenished with fill stone, and the structure was grouted over with concrete.
1981	Riprap stone was placed around the heads of both the north and south breakwaters (Figure 153, Section A). The lakeward end of the south pier (Figure 153, Sections N and N-1) was repaired by encasing it in steel sheetpiling (Figure 154, Sections N and N-1). Voids between the existing pier and new steel sheetpiling were filled with stone which was covered with a concrete cap at an el of +7.0 ft lwd. Section N was 30 ft wide, and Section N-1 was 32 ft wide (Figure 154).
1982	The landward portion of the south pier (Figures 153 and 154, Section O) was repaired, and riprap was placed on the channel side of the pier with 1-V:2.5-H side slopes. Fill stone also was replenished in the north pierhead cell (Figure 153, Section K-1).

(Continued)

(Sheet 2 of 3)

Table 55 (Concluded)

Date(s)	Construction and Rehabilitation History
1984	Riprap stone was placed along the lakeward end of the south breakwater (Figure 153, Section A).
1985	An inspection of the structures indicated that the breakwaters were, generally, in fair condition. Their superstructures revealed cracks, settlement, and misalignment in areas, which indicate some substructure deterioration. Riprap was also needed in areas. The piers were considered in good condition during the inspection. An aerial view of the Frankfort Harbor structure is shown in Figure 157.

(Sheet 3 of 3)

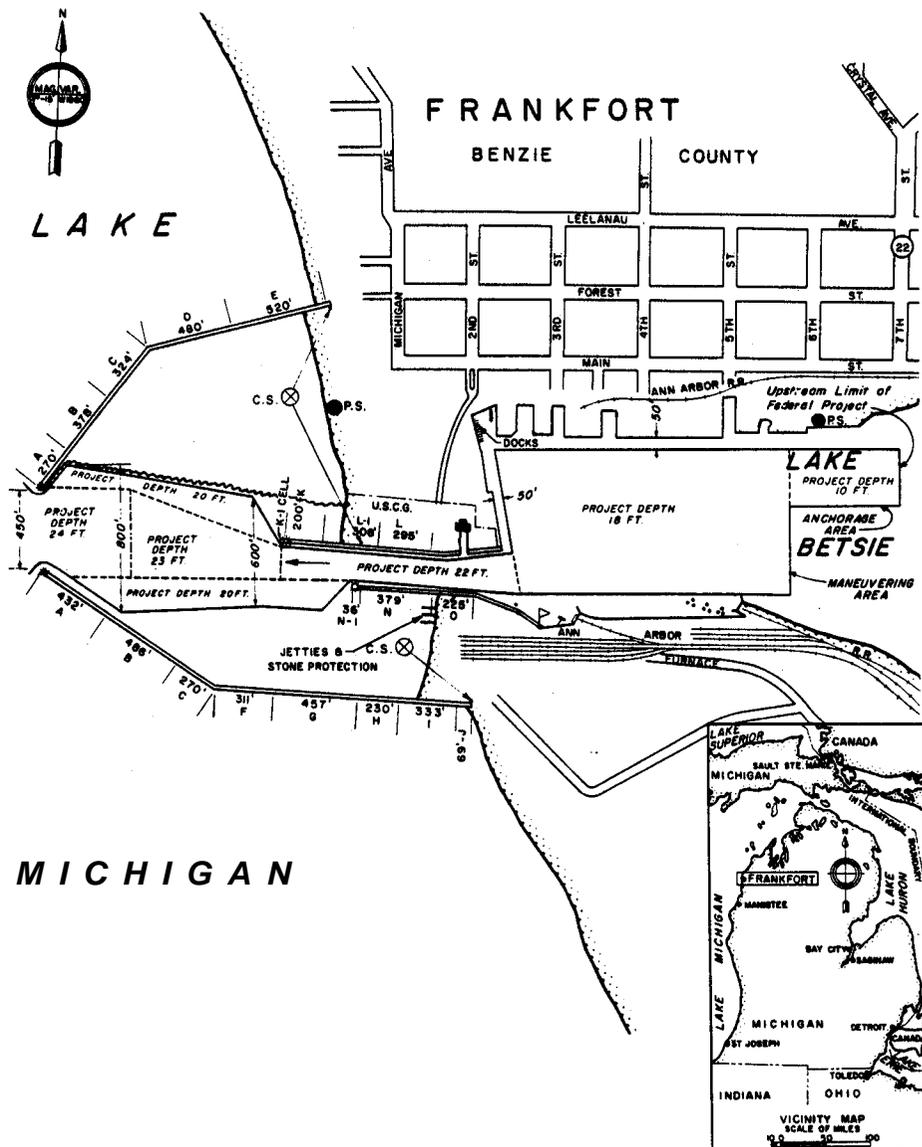


Figure 153. Frankfort Harbor, Michigan

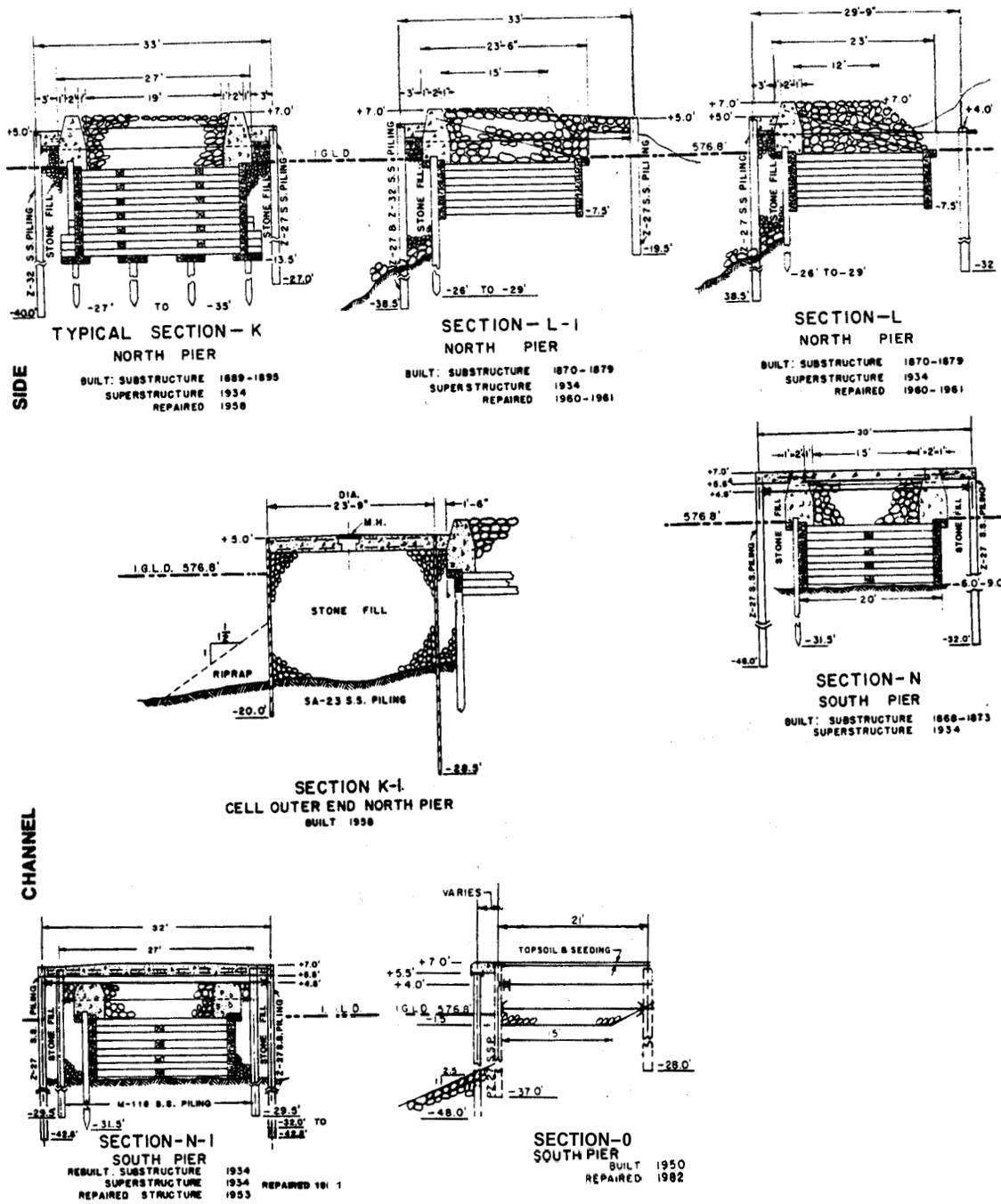


Figure 154. Typical pier cross sections, Frankfort Harbor, Michigan

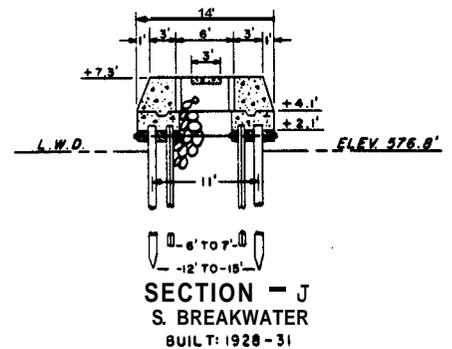
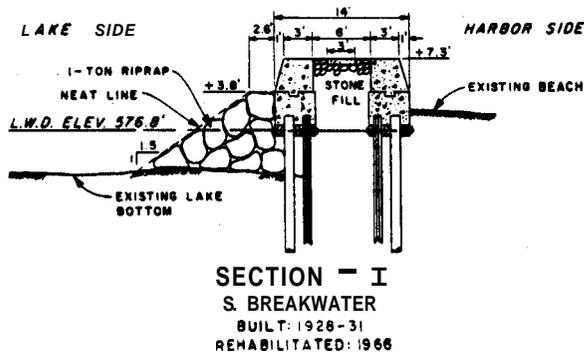
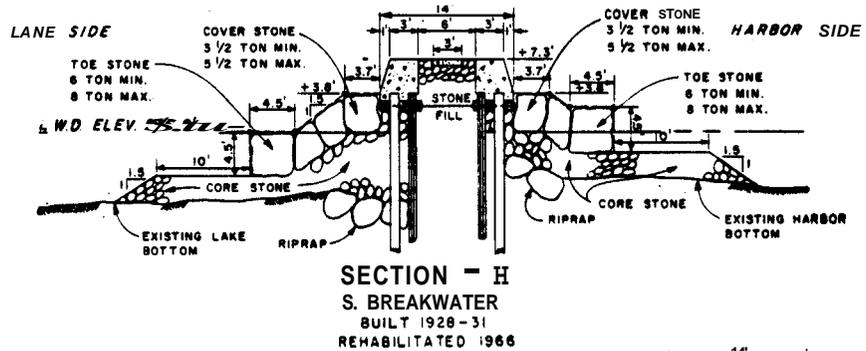
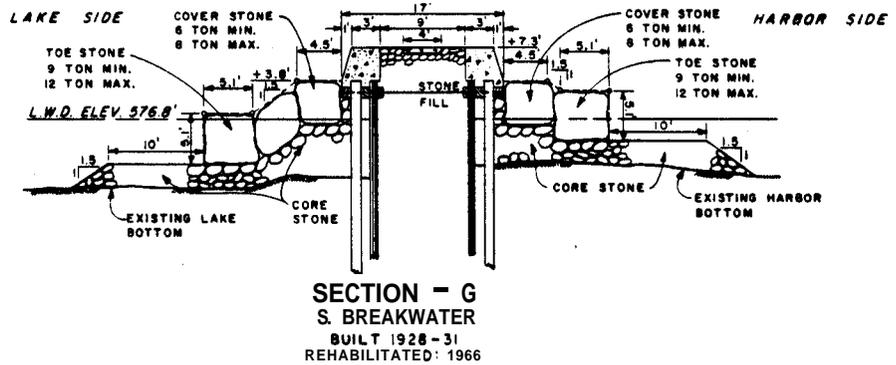
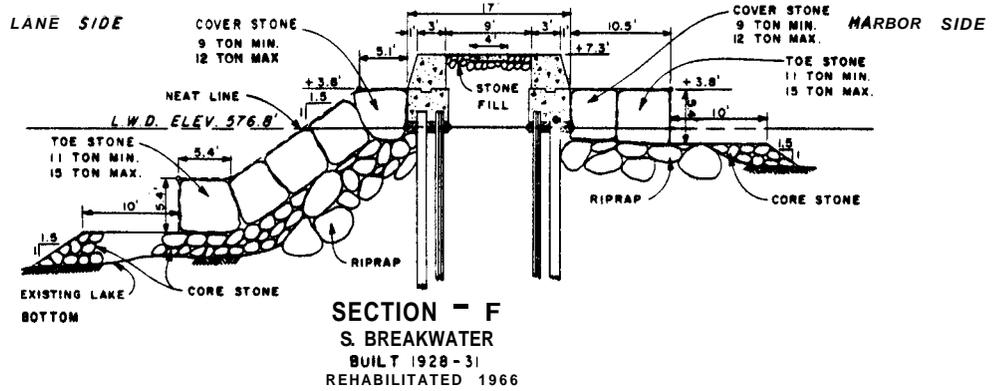


Figure 155. Typical breakwater cross sections, Frankfort Harbor, Michigan

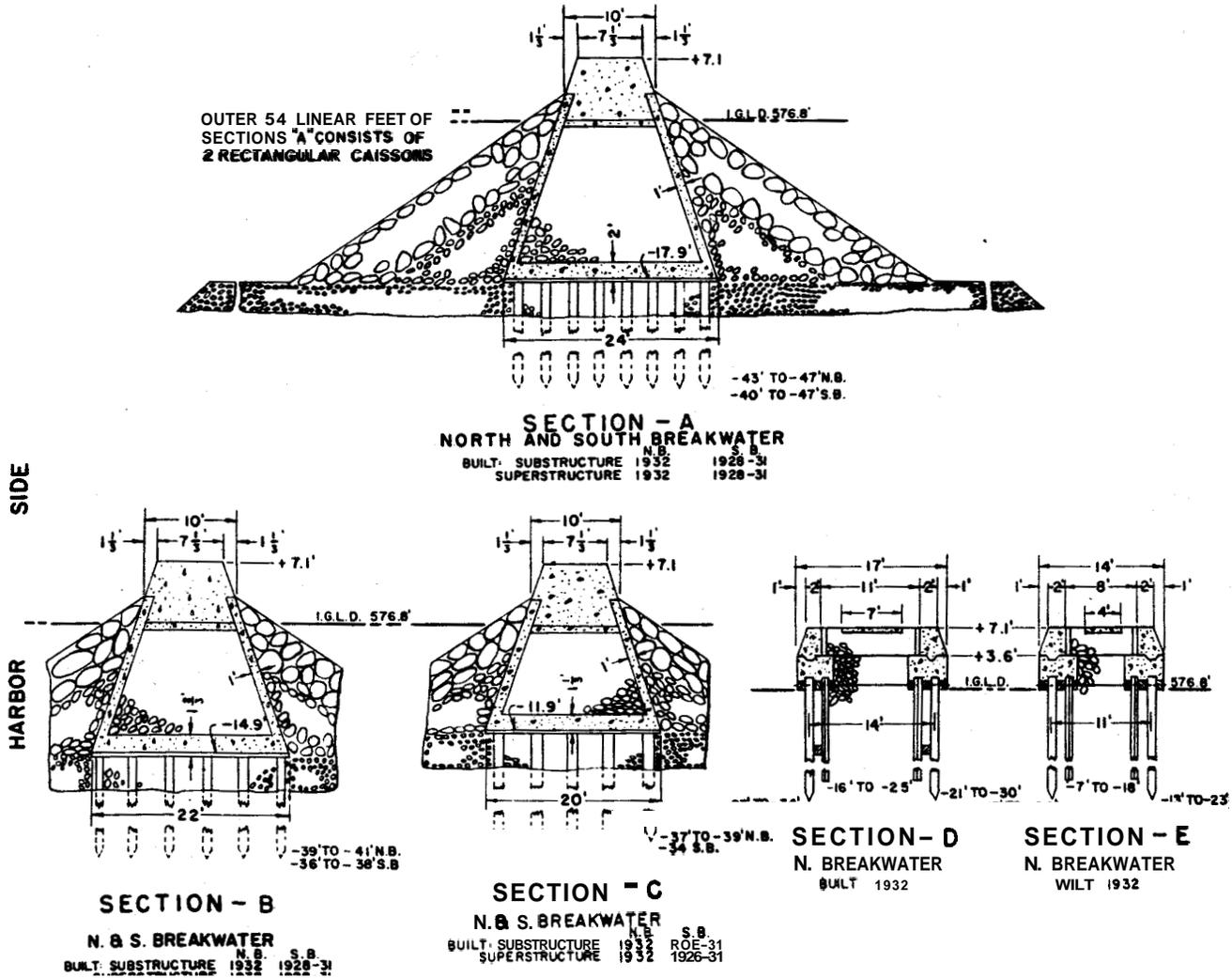


Figure 156. Typical breakwater cross sections, Frankfort Harbor, Michigan

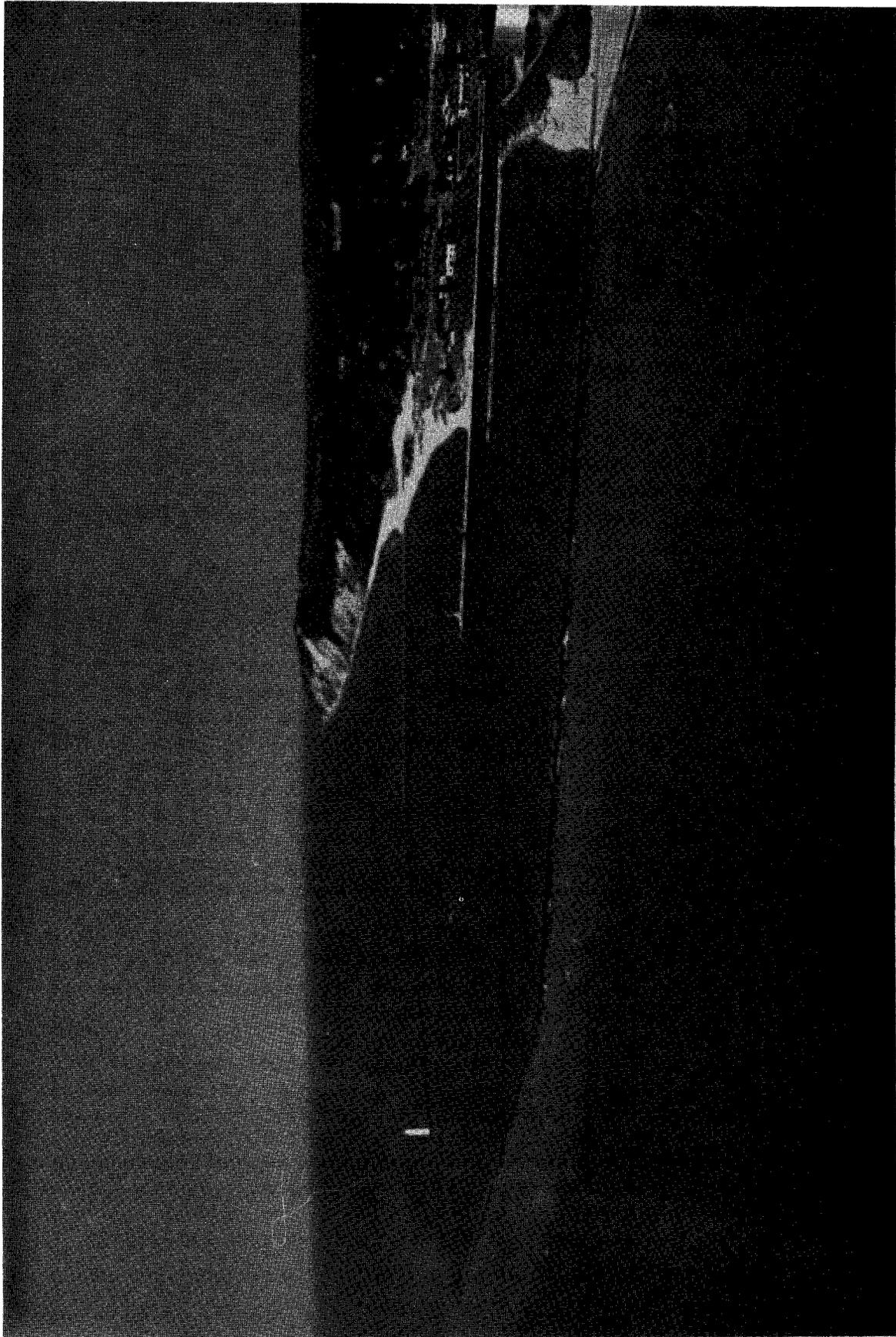


Figure 157. Aerial view of Frankfort Harbor, Michigan

Table 56
Leland Harbor Structures
Leland, Michigan

Date(s)	Construction and Rehabilitation History
1936	Construction of a 440-ft-long south pier (Figure 158, Sections B and C) was completed. The pier consisted of woodpilings spaced 11 ft apart and filled with stone (Figure 159, Sections B and C).
1952	The lakeward 33 ft of the south pier (Figure 158, Section B) was encased in steel sheetpiling. The voids were filled with stone, and the structure was capped with stone (Figure 159, Section B). The width of this portion of the south pier was 15.25 ft, and the crest el was +8 ft lwd.
1966	The lakeward 33 ft of the south pier (Figure 158, Section B) was rehabilitated, Riprap was placed on each side of the pier. It was -5 ft at its crest and had 1-V:1.5-H side slopes (Figure 159, Section B).
1968	A 407-ft-long portion of the south pier (Figure 158, Section C) was rehabilitated by the placement of stone along both sides and across the top of the pier (Figure 159, Section C). The new rubble-mound pier had an 8-ft crest width and a +8.0-ft lwd crest el. Cover stone ranged from 1 (min) to 2 tons (max), and side slopes were 1V:1.5H. A 35-ft-long extension of the south pier (Figure 158, Section A) involved the construction of two steel sheet-pile cells with diameters of 17.5 ft each. The cells were filled with coarse aggregate and capped with 500-lb (min) stone. The crest el of the cells was +8.0 ft lwd, and riprap was installed around the lakeward cell. A 1,200-ft-long offshore rubble-mound breakwater (Figure 158) also was constructed. The breakwater had an 8-ft crest width, 1-V:1.75-H side slopes on the lakeside, and 1-V:1.5-H side slopes on the harbor side (Figure 159). The 300-ft-long north shore arm had a crest el of +8.0 ft lwd (Figure 158, Section II), and the remaining 900 ft of the breakwater (Figure 158, Section I) had a crest el of +10.0 ft lwd. Cover stone of the breakwater ranged from 5 (min) to 7 tons (max), and core stone ranged from 500 to 1,000 lb.
1983	A site inspection of the harbor structures revealed them to be in fair to good condition. Settlement of cover stone and a portion of the north shore arm of the breakwater (Figure 158, Section II) was observed and has subsequently been repaired by the placement of additional stone. Stone settlement of portions of the entire south pier were observed and scheduled for replenishment.
1985	The structures are currently considered to be in good condition.

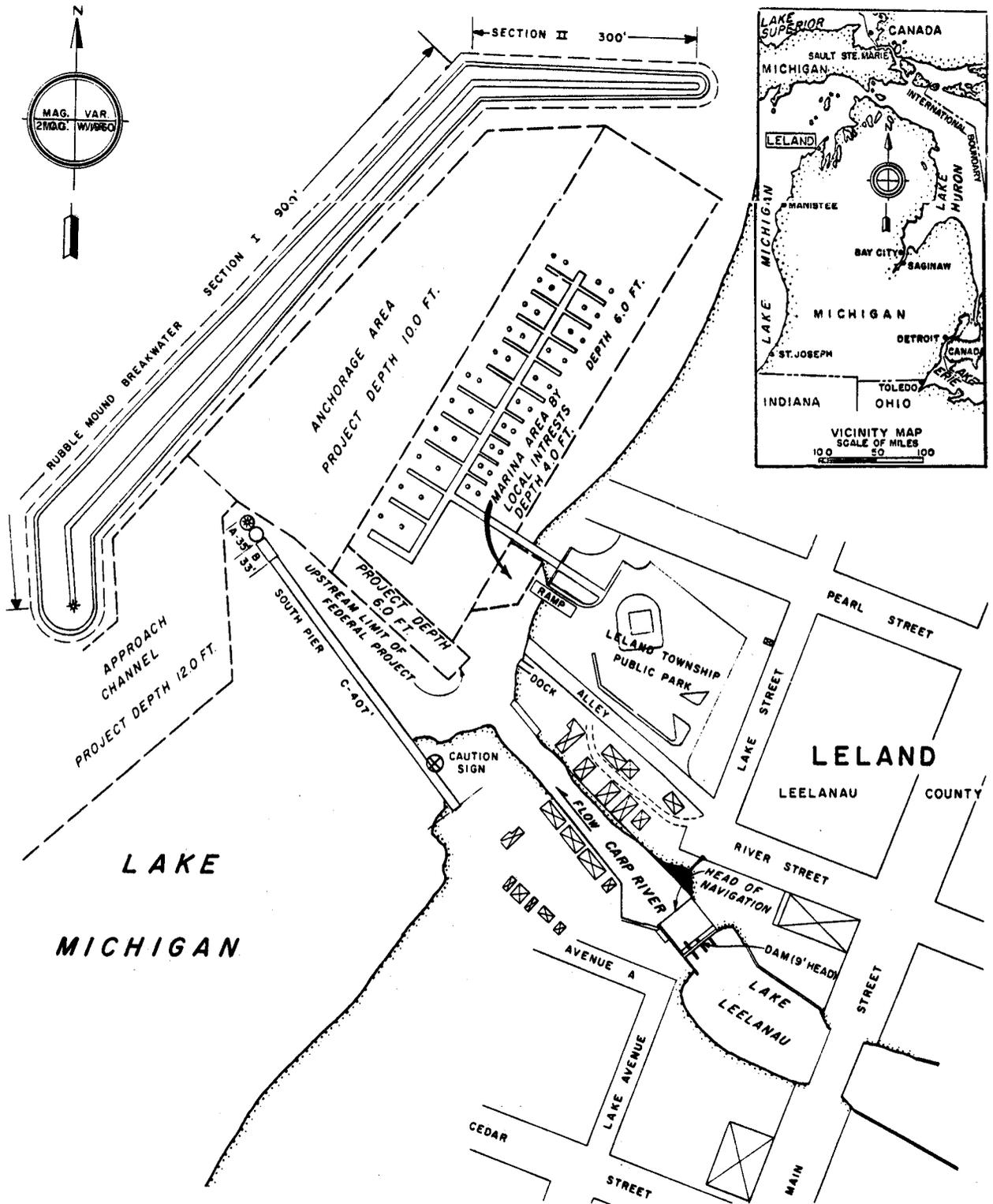


Figure 158. Leland Harbor, Michigan

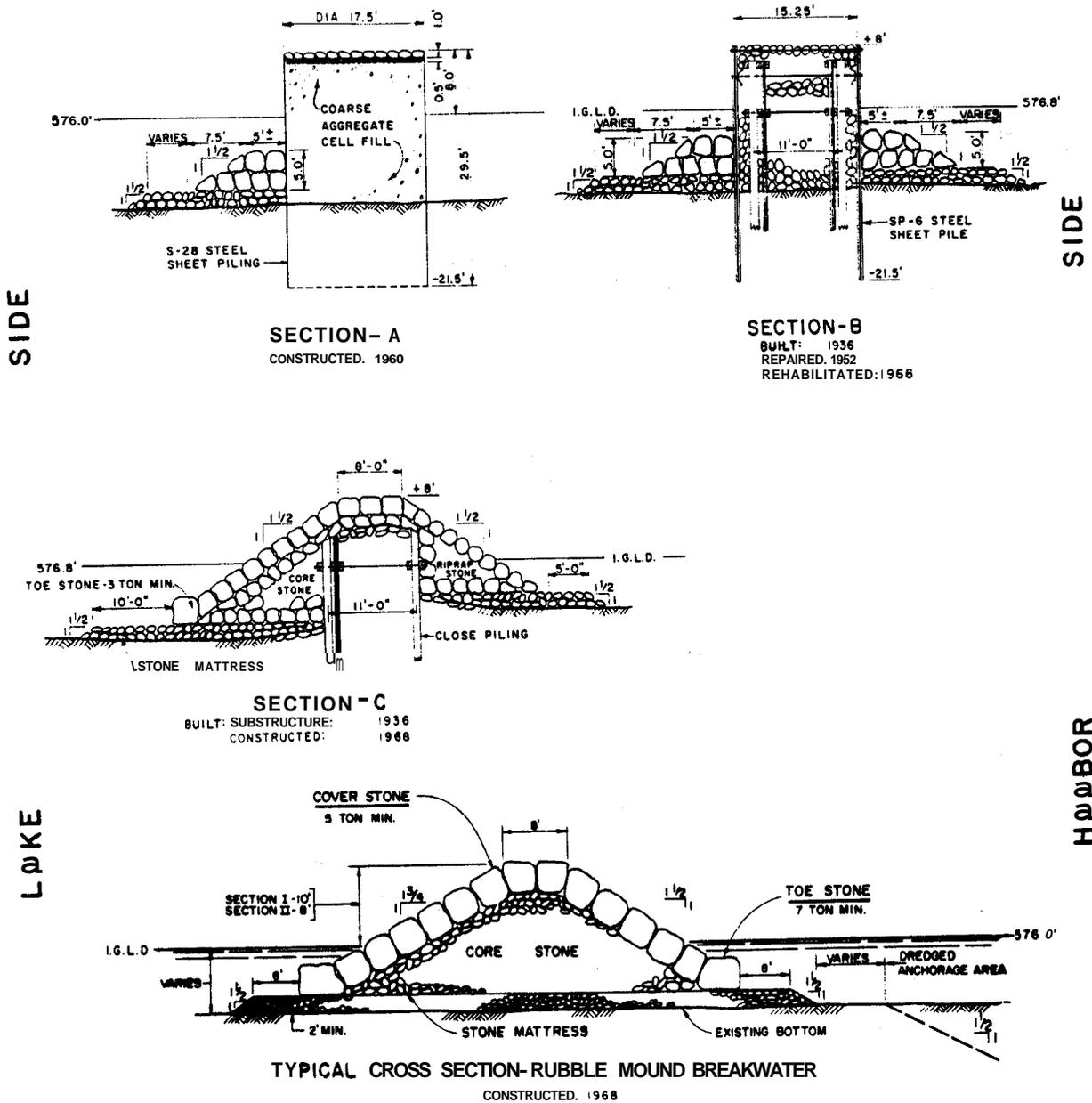


Figure 159. Typical structure cross sections, Leland Harbor, Michigan

Table 57

Greilickville (formerly Traverse City) Harbor BreakwatersTraverse City, Michigan

Date(s)	Construction and Rehabilitation History
1950	Construction of a 1,217-ft-long steel sheet-pile breakwater (Figures 160 and 161, Sections A and B) was completed. The crest el of the structure was +7.0 ft lwd.
1951	A 35.8-ft-diameter steel sheet-pile cell was constructed at the head of the breakwater (Figures 160 and 161, Section B-B). The cell was stone filled and capped with concrete at an el of +7.0 ft lwd.
1966	Construction of east and west rubble-mound breakwaters (Figure 160) was completed. Steel sheet-pile cells were installed on the channel ends of the breakwaters (Figure 160). The cells were 19.1 ft in diameter and had a crest el of +7.0 ft lwd (Figure 161). They were stone filled and capped with concrete. The east and west breakwaters had crest els of +8.0 ft lwd and crest widths of 8 ft. Cover stone ranged from 1 to 2 tons, and the breakwaters had 1-V:2-H side slopes (Figure 161).
1976	Stone was placed into a washed out area of the east end of the east breakwater (Figure 160).
1979	Stone was placed along both sides of the steel sheet-pile breakwater (Figure 160, Sections A and B) to reduce scouring and maintain structure stability.
1985	A site inspection of the breakwaters indicated that the rubble-mound east and west breakwaters were deteriorating slightly, with stones cracking and breaking into smaller pieces as a result of the low-grade limestone used in initial construction. Rehabilitation with sounder and slightly larger cover stones has been recommended. The breakwaters, however, were considered to be in good stable condition. An aerial photo of Greilickville Harbor breakwaters is shown in Figure 162.
1986	Traverse City Harbor was renamed "Greilickville Harbor," on 17 October 1986, in the 99th Congress, 2nd Session, Title XIII, Section 1304.

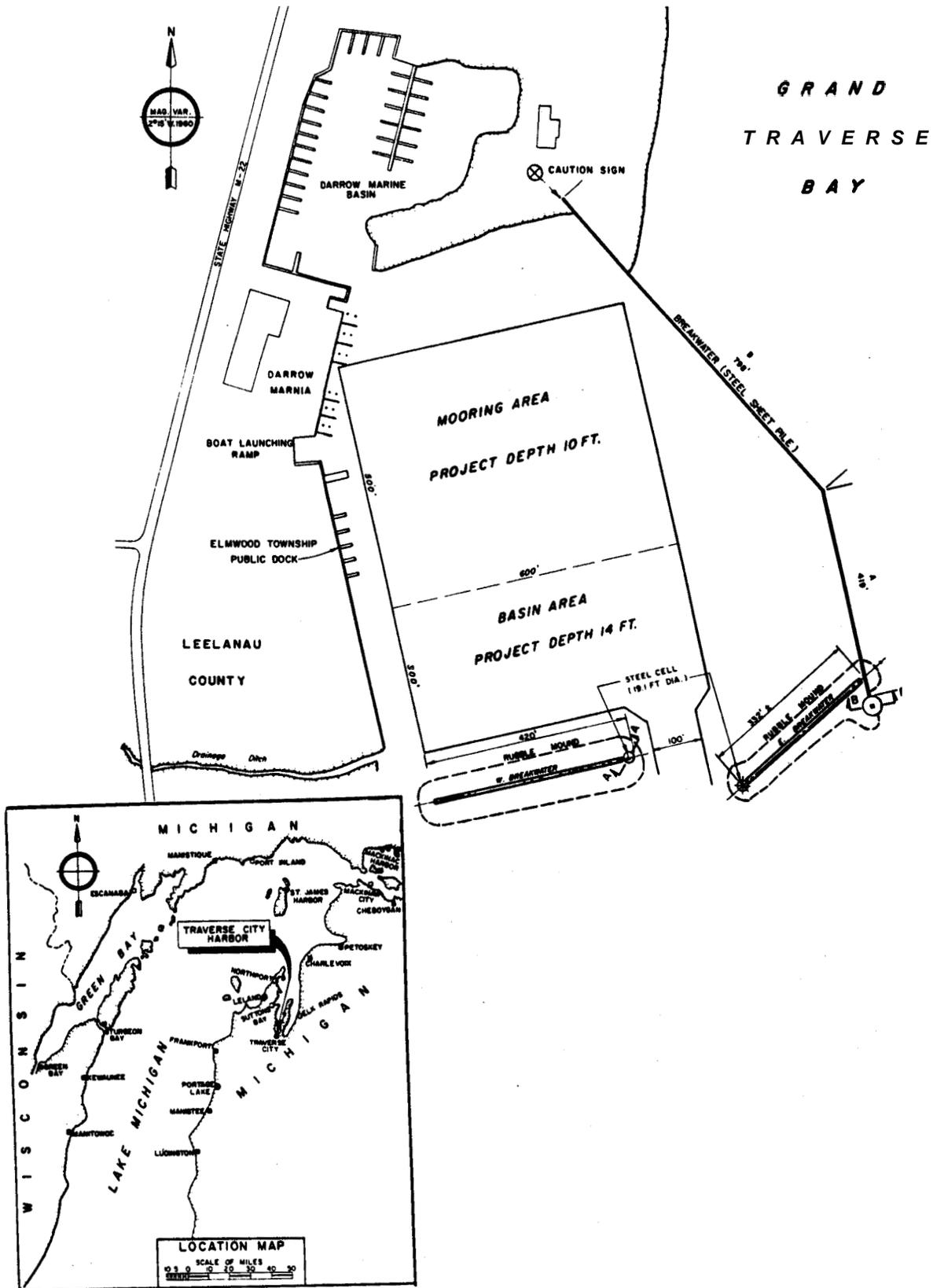
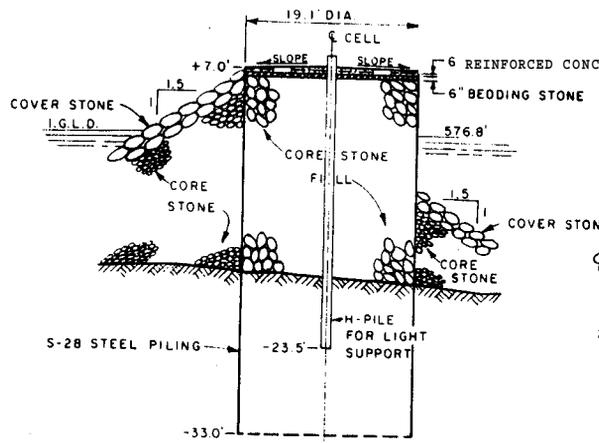
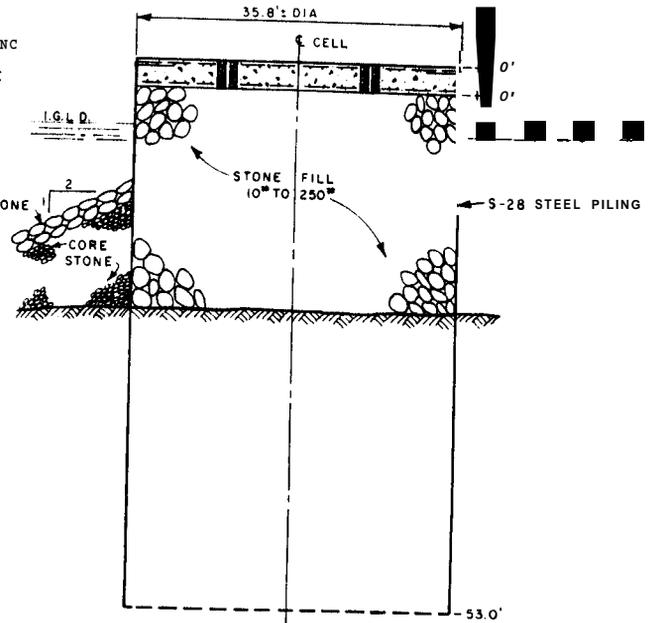


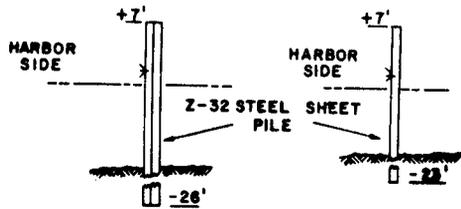
Figure 160. Greilickville Harbor, Michigan



SECTION A-A
WEST BREAKWATER
BUILT 1966



SECTION B-B
OUTER BREAKWATER
BUILT 1951



SECTION - A **SECTION - B**
WILT 1950 BUILT 1960
BREAKWATER

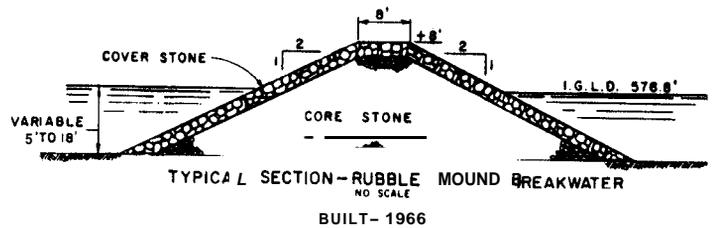


Figure 161. Typical structure cross sections,
Greilickville Harbor, Michigan

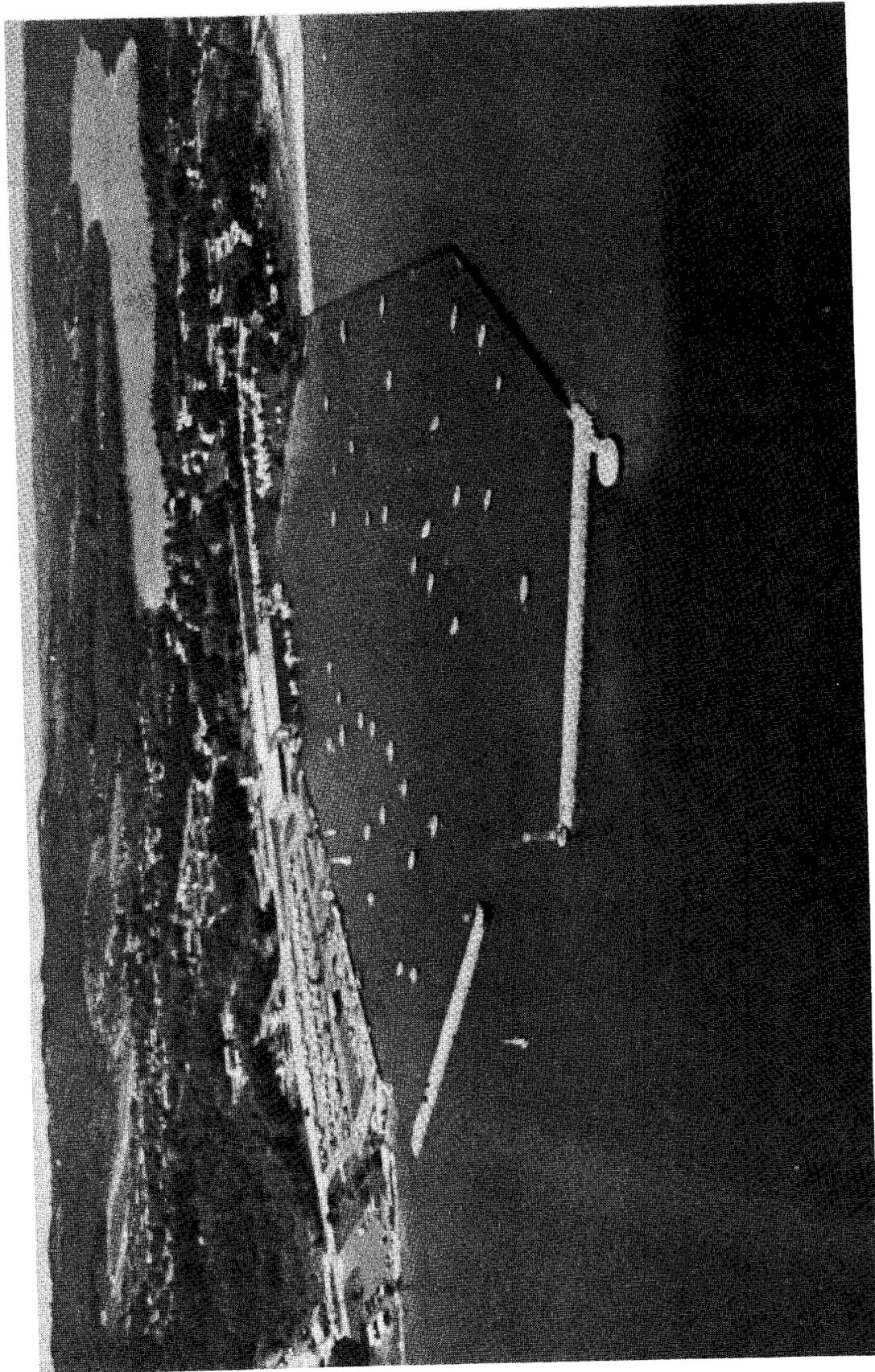


Figure 162. Aerial view of Greilickville Harbor, Michigan

Table 58

Charlevoix Harbor PiersCharlevoix, Michigan

Date(s)	Construction and Rehabilitation History
1872	Construction of a north pier (Figure 163, Section B) was completed. The structure was a 20-ft-wide stone-filled timber crib.
1879- 1880	Construction of the lakeward portions of the north and south piers (Figure 163, Sections A and A-1) was completed. The piers consisted of stone-filled timber crib structures (Figure 164, Sections A and A-1) that were 20 ft in width.
1882	Construction of a shoreward portion of the south pier (Figure 163, Section F) was completed. The pier consisted of woodpilings driven approximately 20 ft apart (Figure 164, Section F) and filled with stone.
1897	Rubble was placed along the lakeside and over the shoreward portion of the north pier (Figure 163, Section B). The crest width of the rubble structure (Figure 164, Section B) was 10 ft, and it had an el of +8.1 ft lwd. Side slopes were 1V:2H, and the cover stone used was 1,000 lb (min).
1930	The shoreward portion of the south pier (Figure 163, Section F) was repaired and capped with a concrete and stone superstructure (Figure 164, Section F). The crest el of the pier was +7.1 ft lwd.
1942	The lakeward portions of the north and south piers (Figure 163, Sections A and A-1) were capped with concrete and stone superstructures (Figure 164, Sections A and A-1) with crest els of +7.0 ft lwd.
1966	The lakeward portion of the existing north pier (Figure 163, Section A-1) was repaired by encasing it between steel sheetpiling spaced 33 ft apart (Figure 164, Section A-1). The voids between the steel sheetpiling and the existing timber crib were filled with stone and capped with concrete to an el of +6.75 ft lwd. A 35-ft-diameter steel sheet-pile cell was constructed at the head of the north pier (Figures 163 and 164, Section A-2). The pier head was filled with stone and capped with concrete to an el of +7 ft lwd. Steel sheet-piles were also installed on each side of the shoreward portion of the south pier (Figures 163 and 164, Section F). On the channel side the void was filled with stone, and the crest was grouted at an el of +6.5 ft lwd.
1971	Replenishment of fill stone was performed on the lakeward portion of the south pier (Figure 163, Section A).
1981	Portions of the north (Figure 163, Sections A and B) and south (Figure 163, Section A) piers were rehabilitated. The existing timber

(Continued)

Table 58 (Concluded)

Date(s) Construction and Rehabilitation History

cribs were encased in steel sheetpiling (Figure 164, Section A). The voids between the steel sheetpiling and the cribs were filled with stone and capped with concrete at an el of +6,75 ft lwd. The rubble portion of the north pier (Figure 164, Section B) was repaired, and a concrete cap was included which had an el of +8,5 ft lwd.

1985 An inspection of the piers revealed them to be in fair condition. Settlement and loss of fill stone are evidenced in the piers, and some of the structures are cracked and tilting. Replenishment of fill with larger stone, and placement of riprap along the piers have been recommended. An aerial view of the Charlevoix Harbor piers is shown in Figure 165.

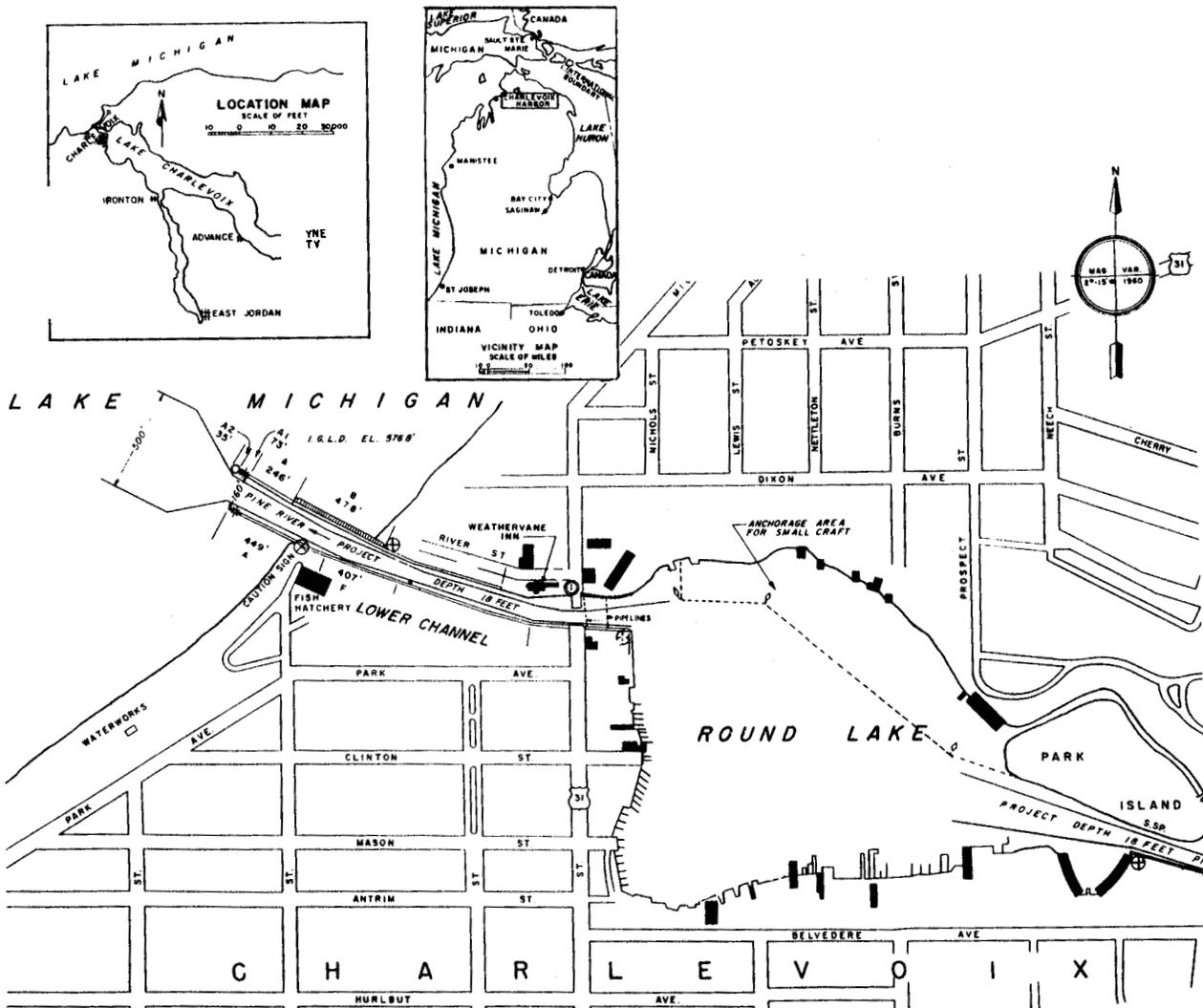


Figure 163. Charlevoix Harbor, Michigan

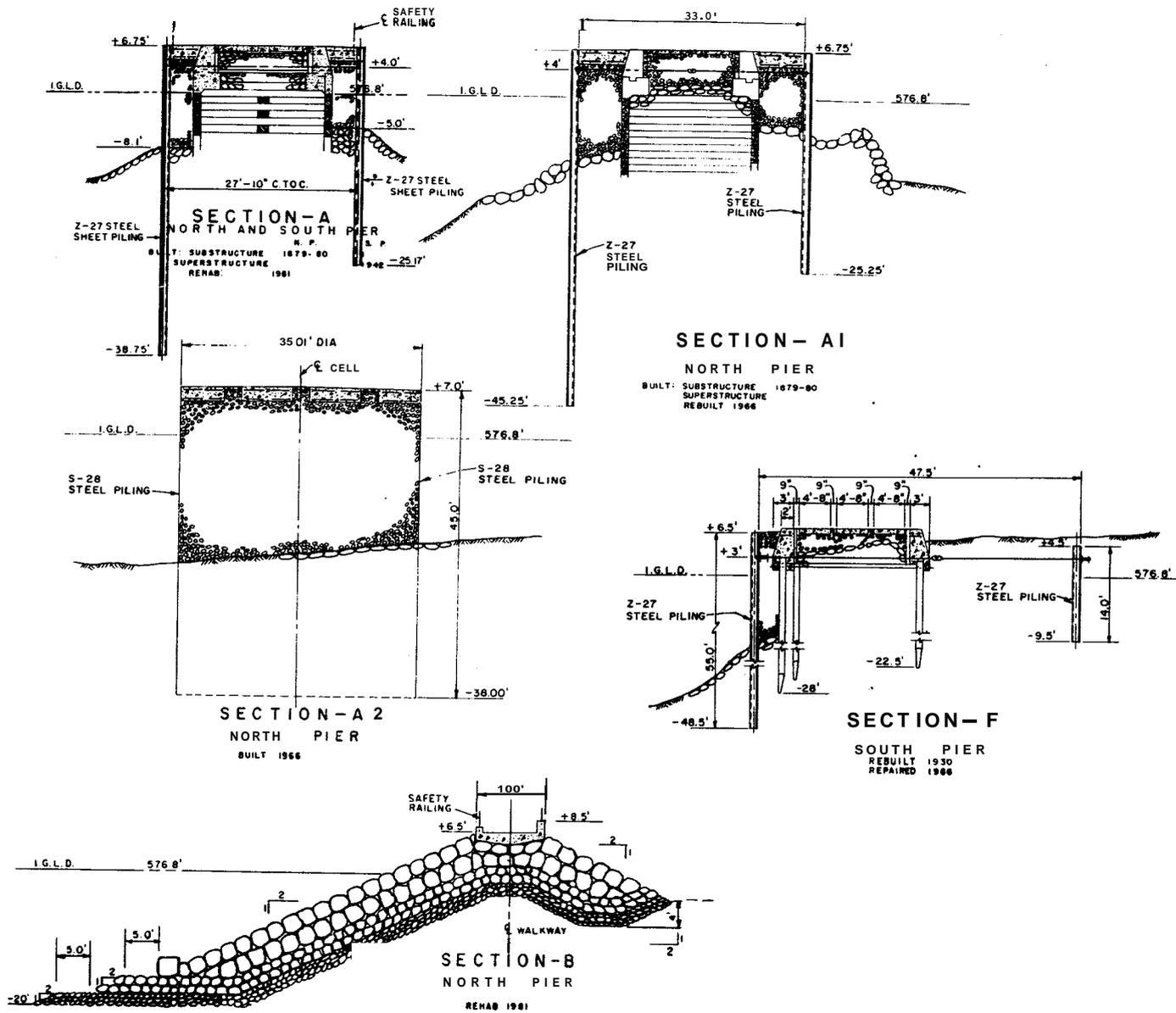


Figure 164. Typical pier cross sections, Charlevoix Harbor, Michigan

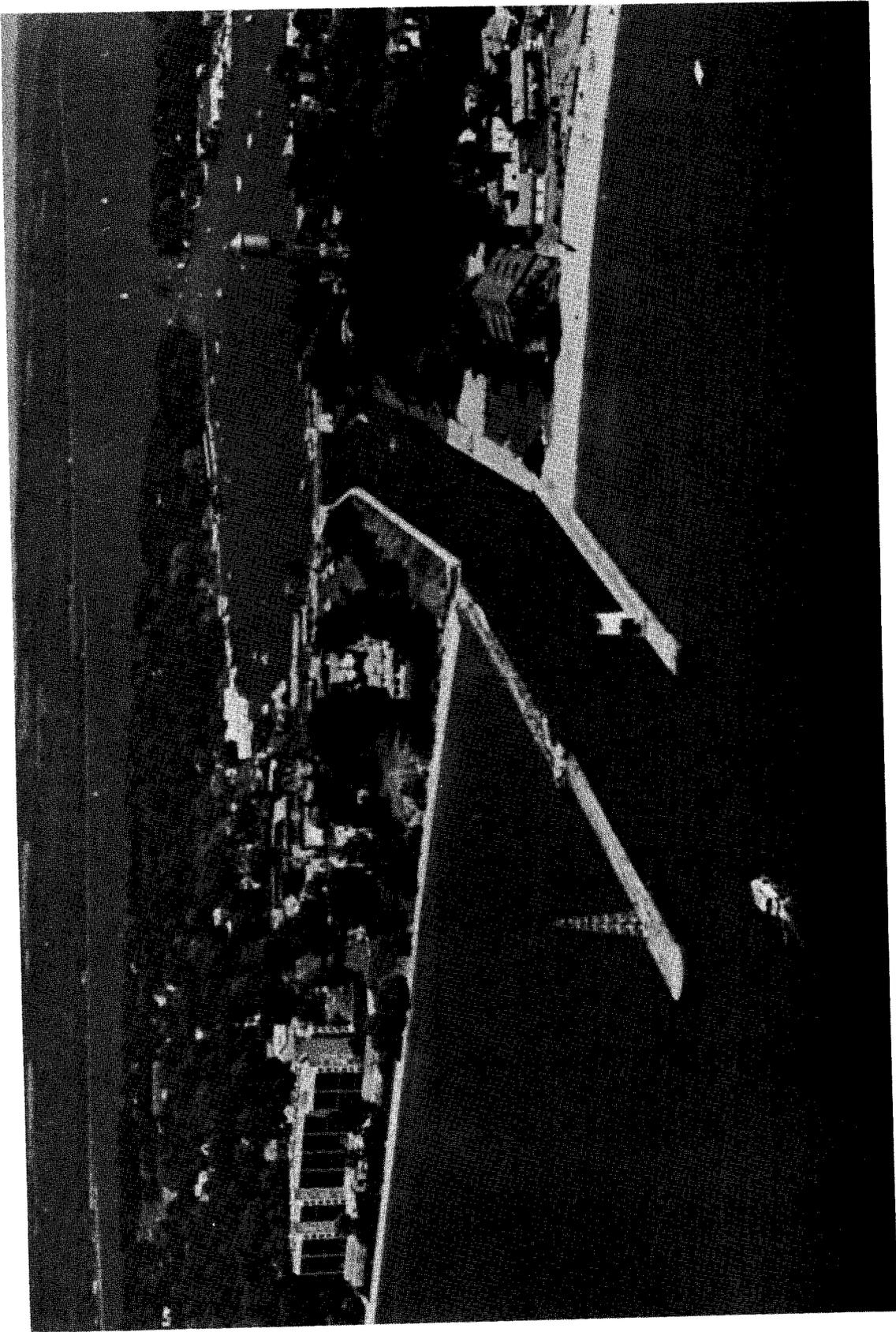


Figure 165. Aerial view of Charlevoix Harbor, Michigan

Table 59

Petoskey Harbor BreakwaterPetoskey, Michigan

Date(s)	Construction and Rehabilitation History
1895- 1896	Construction of a 600-ft-long portion of the breakwater (Figure 166, Sections B and C) was completed. This breakwater consisted of stone-filled timber cribs built on a stone base (Figure 167, Sections B and C). Part of the breakwater was 26 ft wide (Section B), and the remaining portion (Section C) was 28 ft wide.
1897	Construction of the 355-ft-long shoreward portion of the breakwater (Figure 166, Sections D and E) was completed. This portion of the breakwater was rubble mound with a 10-ft crest width and a +7.0 ft lwd crest el (Figure 167, Sections D and E). A concrete walkway was also installed on its crest.
1905- 1907	Construction of the lakeward end of the breakwater (Figure 166, Section A) was completed. This portion of the breakwater was a 30-ft-wide stone-filled timber crib built on a stone base (Figure 167, Section A).
1930	The lakeward 895 ft of the breakwater (Figure 166, Sections A, B, and C) was capped with a stone and concrete superstructure. The crest el of the breakwater was +7.0 ft lwd (Figure 167, Sections A, B, and C).
1949	The rubble-mound portions of the breakwater (Figure 166, Sections D and E) were rehabilitated.
1970	The rubble-mound sections of the breakwater (Figure 166, Sections D and E) were rebuilt (including the concrete walkway).
1973	Riprap stone (1 to 6 tons) was placed along both sides of the rubble-mound portion of the breakwater (Figure 166, Sections D and E).
1977	Riprap stone was placed in areas along both sides of the timber crib breakwater (Figure 166, Sections A, B, and C).
1978	Replenishment of fill stone was performed in the timber cribs (Sections A, B, and C), and additional riprap was placed along areas of the timber crib breakwater where stone was not placed in 1977. Riprap was also placed along the rubble-mound breakwater (Sections D and E) where washouts and voids existed.
1985	A site inspection of the breakwater indicated superstructure tilt, settlement, cracking, and loss of fill stone along the timber-crib portion of the structure (Sections A, B, and C) which suggests substructure deterioration. The rubble-mound portion of the breakwater

(Continued)

Table 59 (Concluded)

Date (s)	Construction and Rehabilitation History
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(Sections D and E) had stone voids and washouts in areas, and the concrete walkway was undermined. New stone (2,750 tons) was placed at the base of the structure, and about 300 tons of stone was recovered and replaced at the harbor by hired labor. The structure is considered to be in fair condition, and rehabilitation has been recommended. An aerial view of the Petoskey Harbor breakwater is shown in Figure 168.

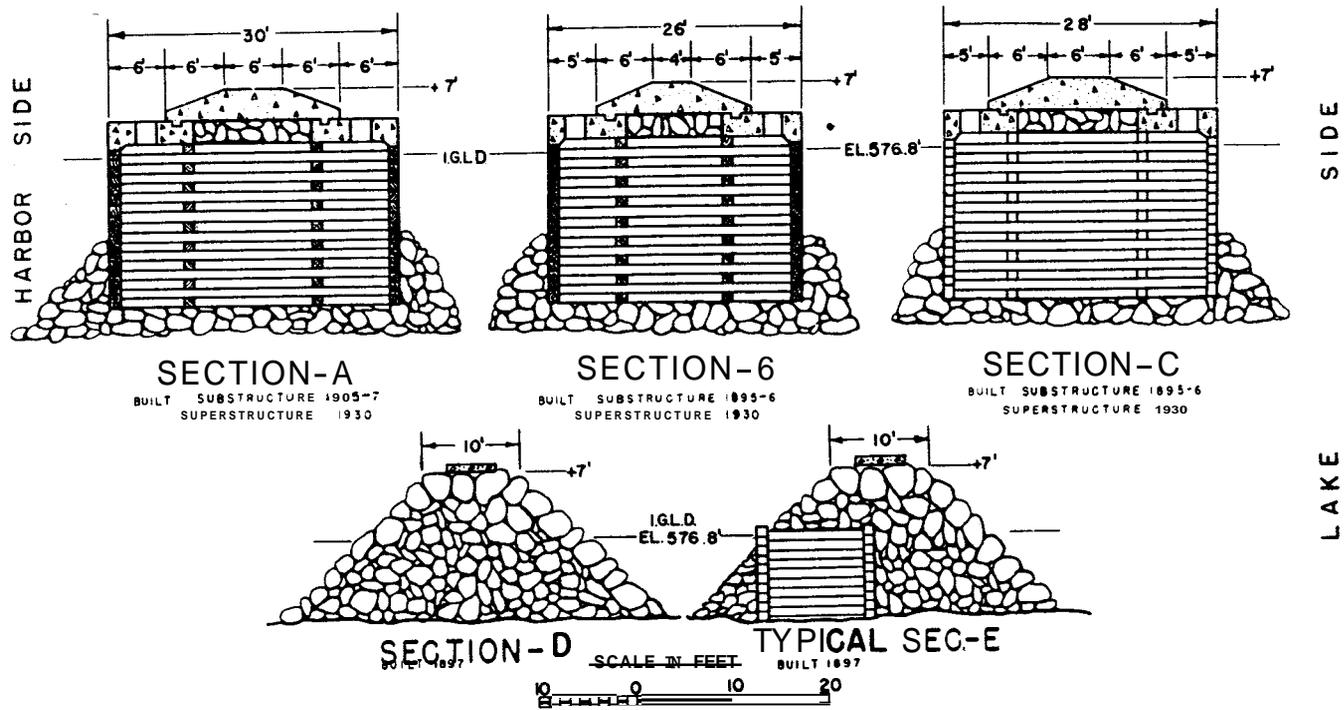


Figure 167. Typical structure cross sections, Petoskey Harbor, Michigan

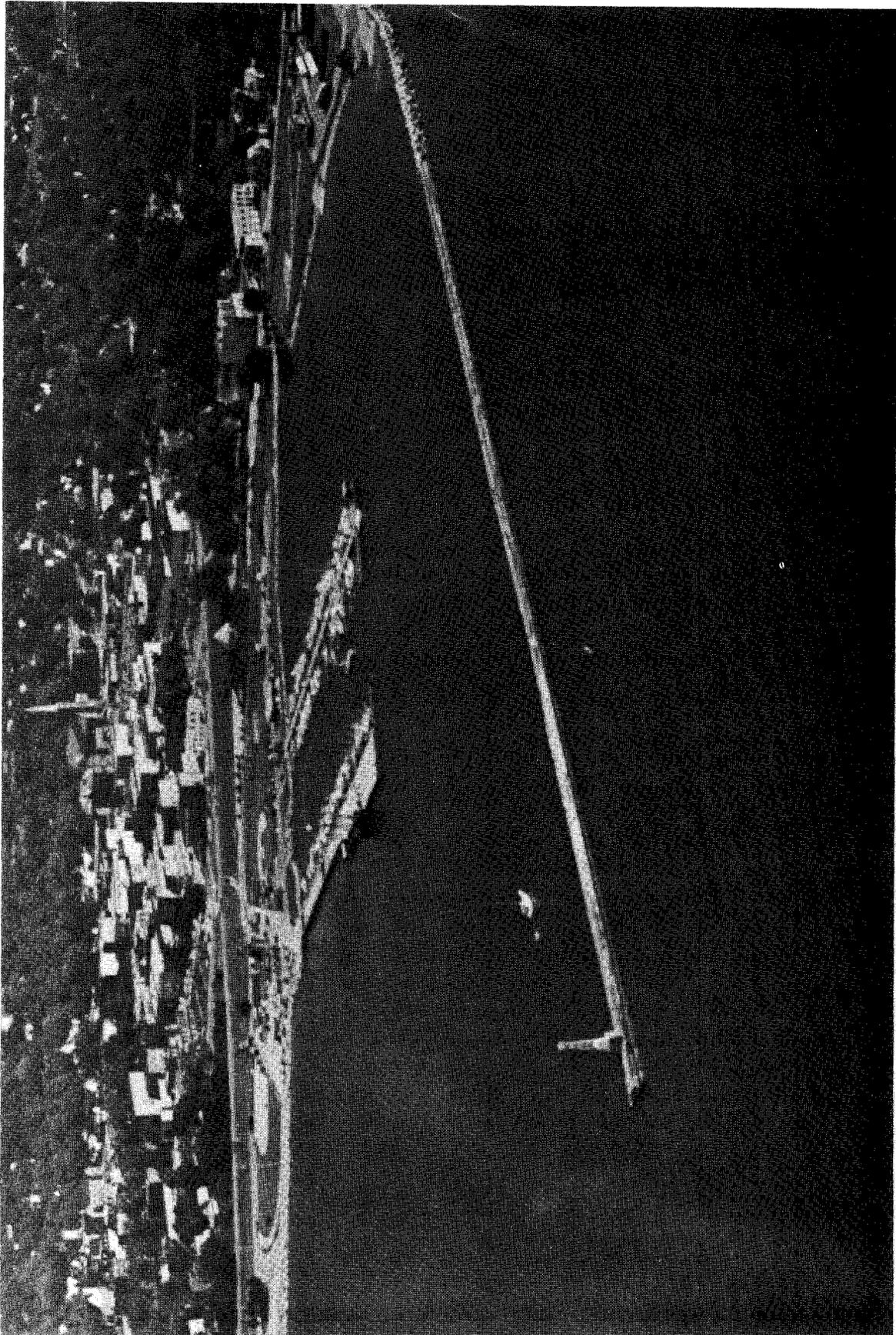


Figure 168. Aerial view of Potoski Harbor, Michigan

Table 60

Detour Harbor Breakwater
Detour Village, Michigan

Date(s)	Construction and Rehabilitation History
1982	Construction of a 1,310-ft-long rubble-mound breakwater (Figure 169) was completed for a cost of about \$2,000,000. The crest of the breakwater was installed at an el of +7.8 ft lwd. It was 11 ft wide and included a concrete walkway. Cover stone ranged from 950 to 1,800 lb and was placed on 1-V:1.5-H side slopes.
1986	The present condition of the breakwater is considered good.

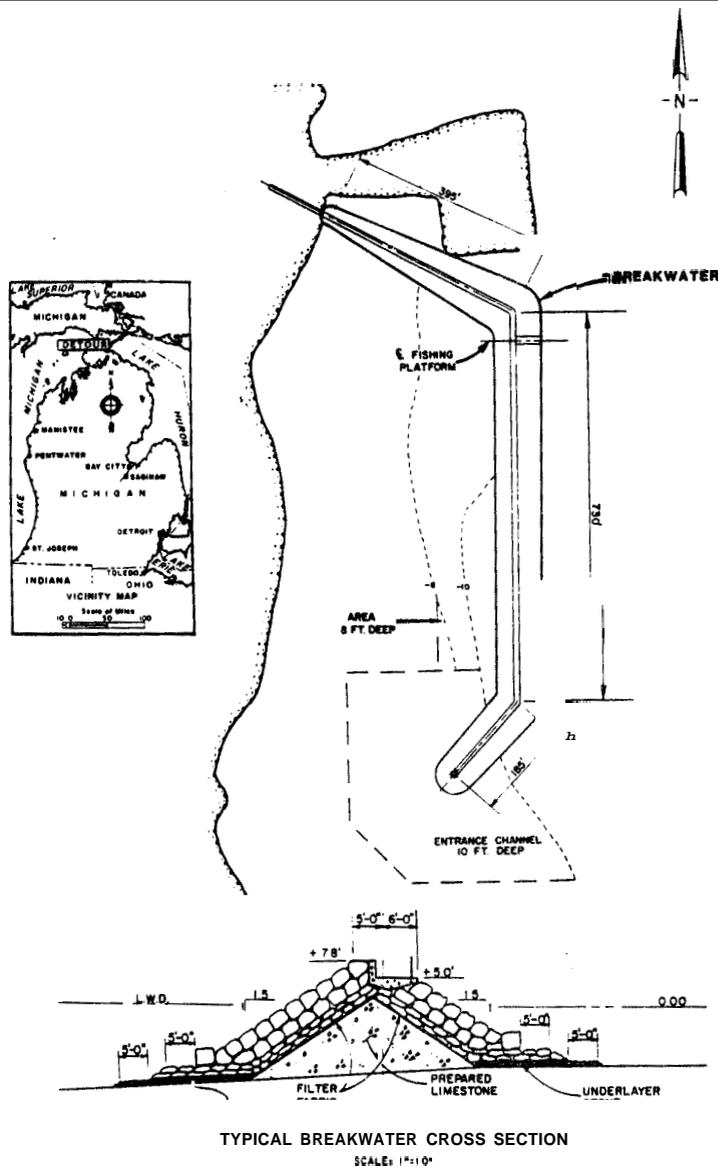


Figure 169. Detour Harbor, Michigan

Table 61

Mackinac Island Harbor BreakwatersMackinac Island, Michigan

Date(s)	Construction and Rehabilitation History
1914	Construction of a 410-ft-long east breakwater and a 950-ft-long west breakwater (Figure 170) was completed. The breakwaters were rubble mound with a crest width of 10 ft and an el of +6.0 ft lwd. Side slopes were 1V:1.5H .
1967	A 500-ft-long lakeward rubble-mound extension to the east breakwater (Figure 170) was completed. The extension had a crest el of +8.5 ft lwd and a crest width of 8 ft. Stone was placed on 1-V:1.5-H side slopes, and cover stone ranged from 3 to 5 tons at the breakwater head and from 2.5 to 4.5 tons on its trunk.
1986	The stone in the breakwaters has been replenished and replaced periodically during its lifetime, and the structures are presently in fair condition. An aerial view of the Mackinac Island Harbor breakwaters is shown in Figure 171.

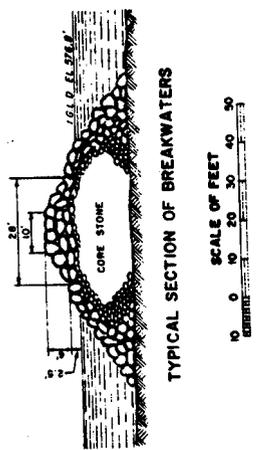
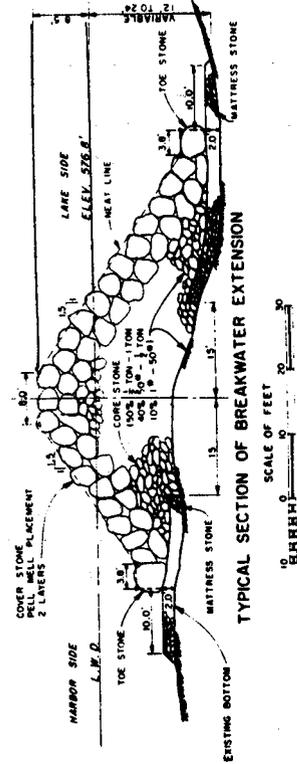
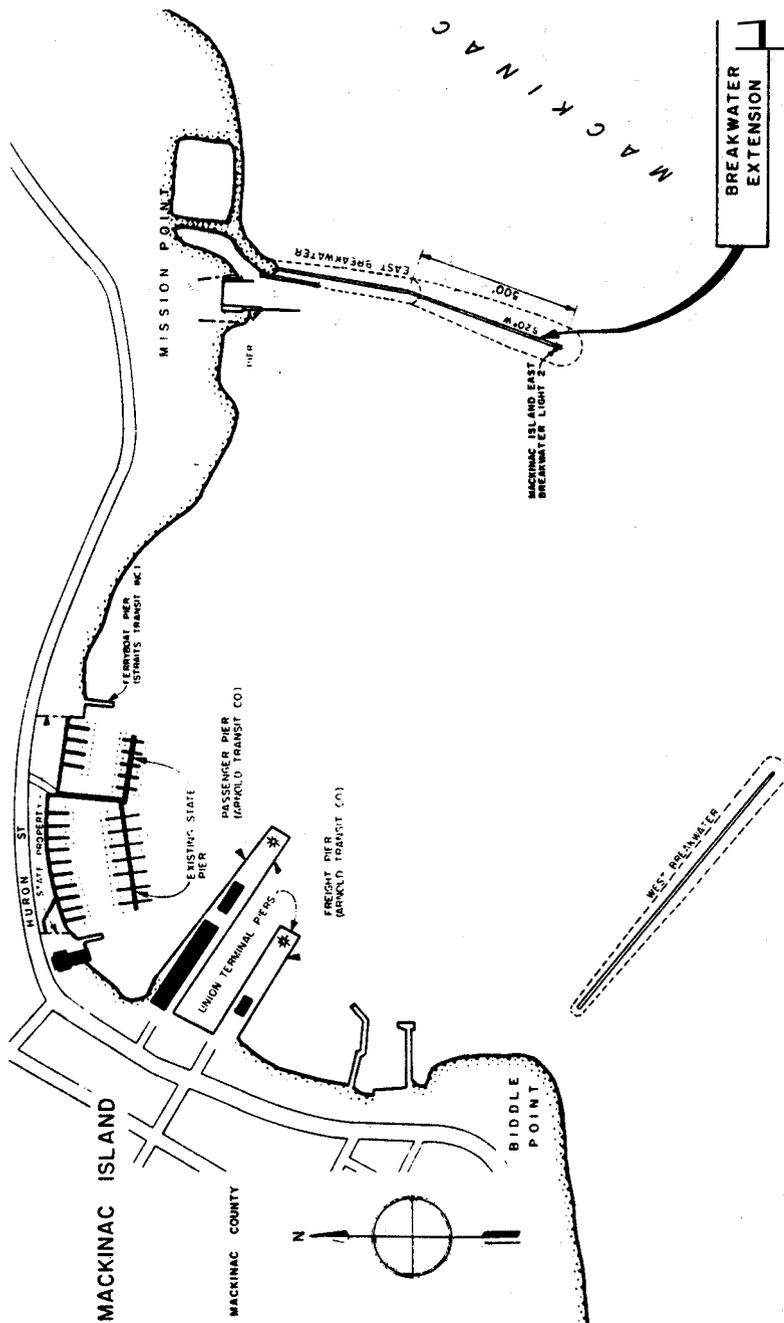
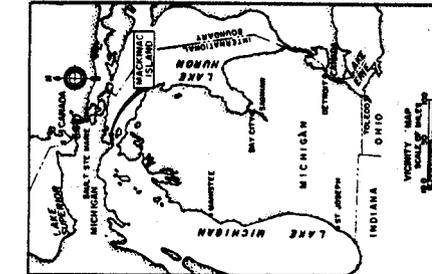


Figure 170. Mackinac Island Harbor, Michigan

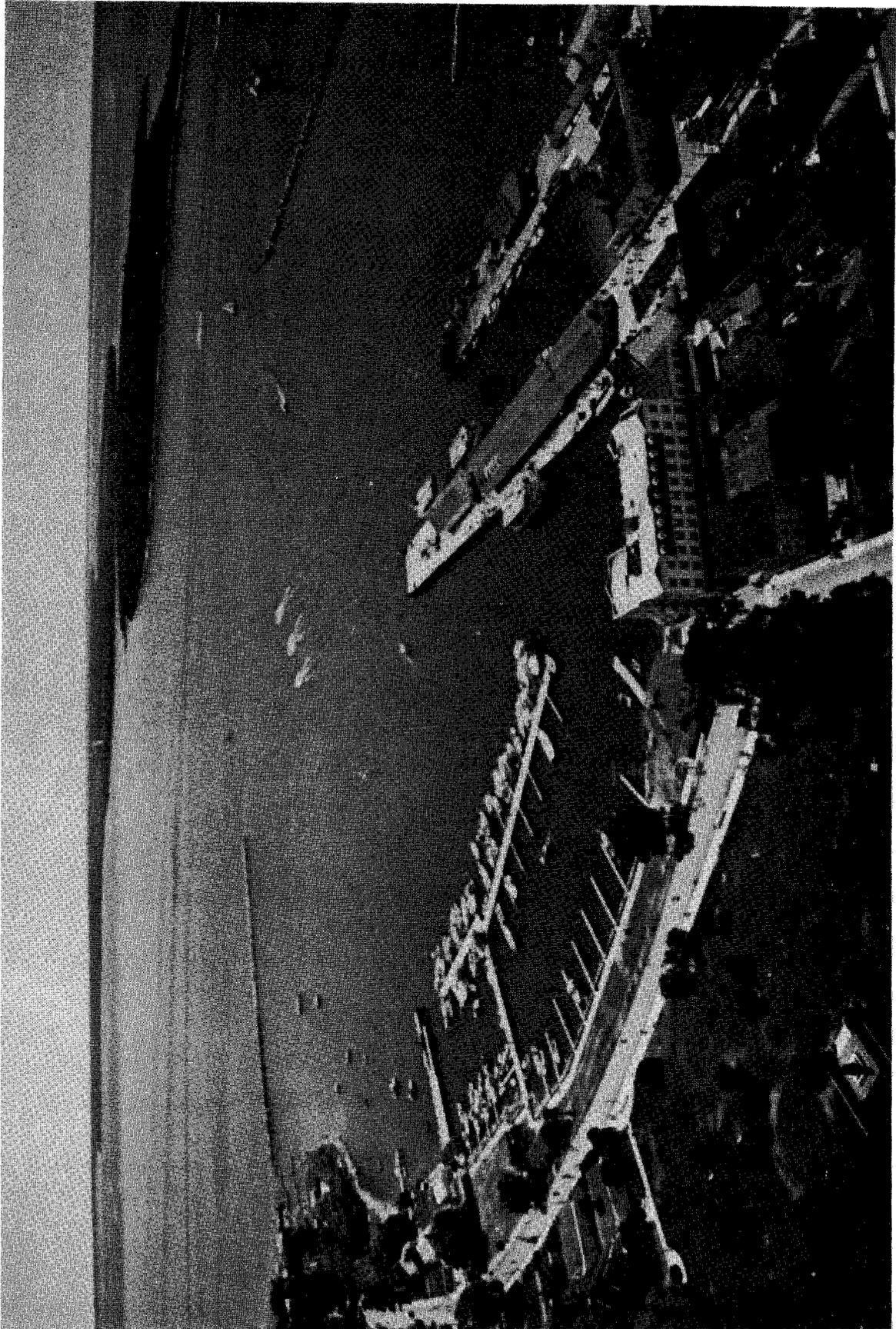


Figure 171. Aerial view of Mackinac Island Harbor, Michigan

Table 62

Mackinaw City Harbor Breakwaters
Mackinaw City, Michigan

Date(s)	Construction and Rehabilitation History
1955	Construction of a 600-ft-long causeway, which serves as a breakwater, was completed by local interests (Figure 172). The structure was built of rock and concrete. The harbor side of the structure was lined with vertical sheetpiling, and the lakeward side was constructed with rubble-mound materials with side slopes of about 1V:1H (the natural angle of repose).
1967	Construction of a 430-ft-long rubble-mound breakwater (Figure 172) was completed. The breakwater had a crest el of +8.8 ft lwd with a width of 8 ft. One- to two-ton cover stone was used in construction along with side slopes of 1V:1.5H (Section B-B). The outer 200 ft of the existing breakwater was authorized for federal maintenance.
1986	The breakwaters presently are considered to be in good condition. An aerial photo of the Mackinaw City Harbor breakwaters is shown in Figure 173.

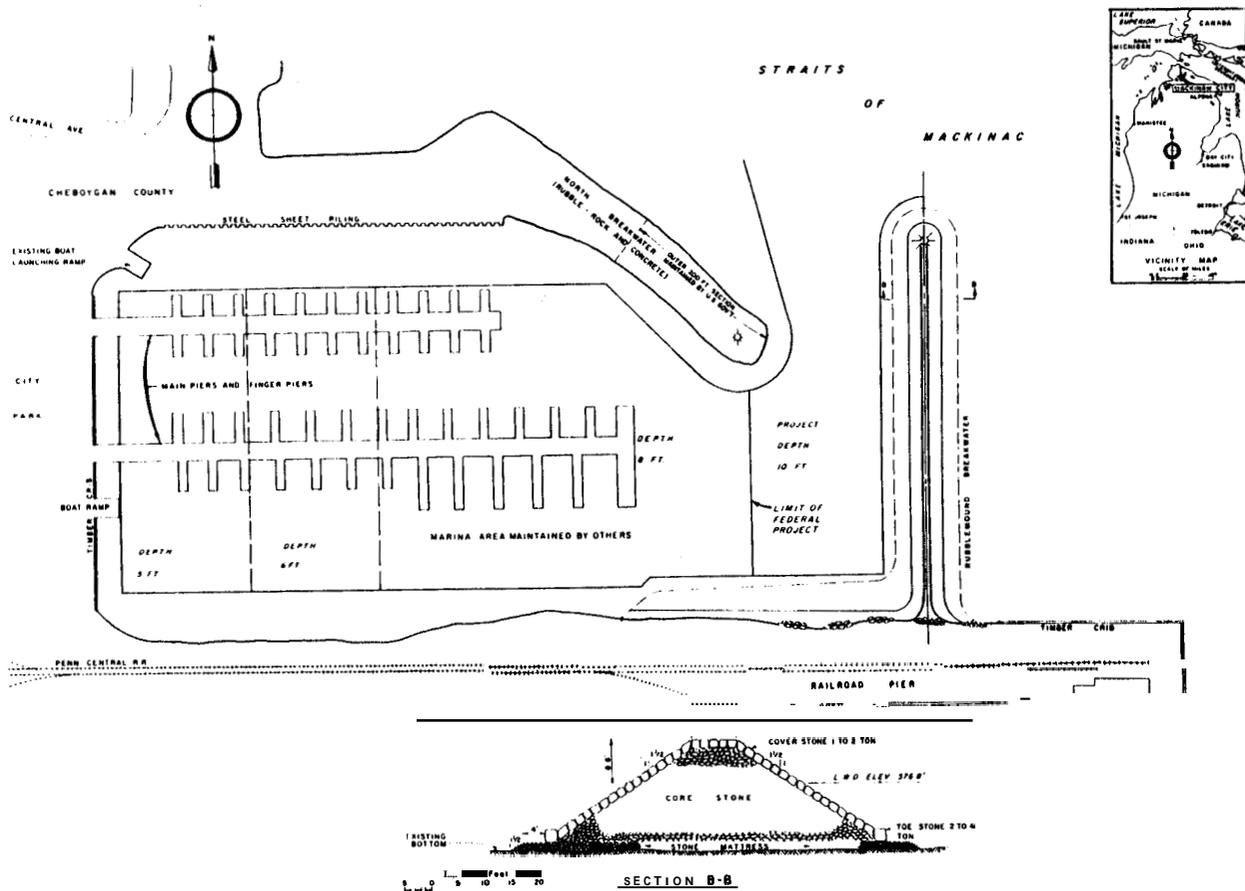


Figure 172. Mackinaw City Harbor, Michigan



Figure 173. Aerial view of Mackinaw City Harbor, Michigan

Table 63

Cheboygan Harbor Breakwater
Cheboygan, Michigan

Date(s)	Construction and Rehabilitation History
1968	Construction of a 775-ft-long rubble-mound breakwater (Figure 174) was completed. The breakwater was constructed with a crest el of +6.0 ft lwd and a crest width of 8 ft. Cover stone was 2 tons (min), toe stone was 4 tons (min), and side slopes of the structure were 1V:1.5H (Figure 174).
1982	Minor repairs to the existing stone breakwater and construction of a concrete walkway on the crest of the structure were completed.
1986	The breakwater is presently considered to be in good condition. An aerial photograph of the Cheboygan Harbor breakwater is shown in Figure 175.

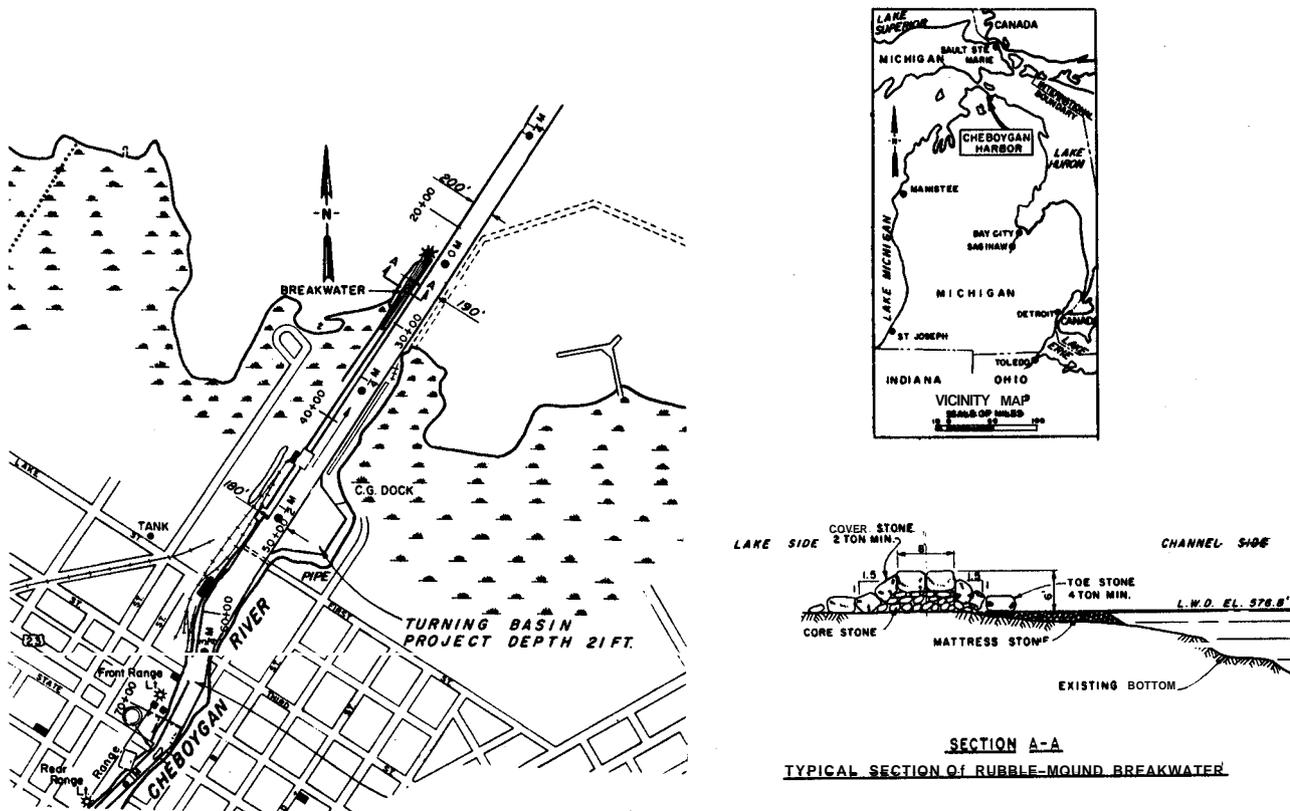


Figure 174. Cheboygan Harbor, Michigan

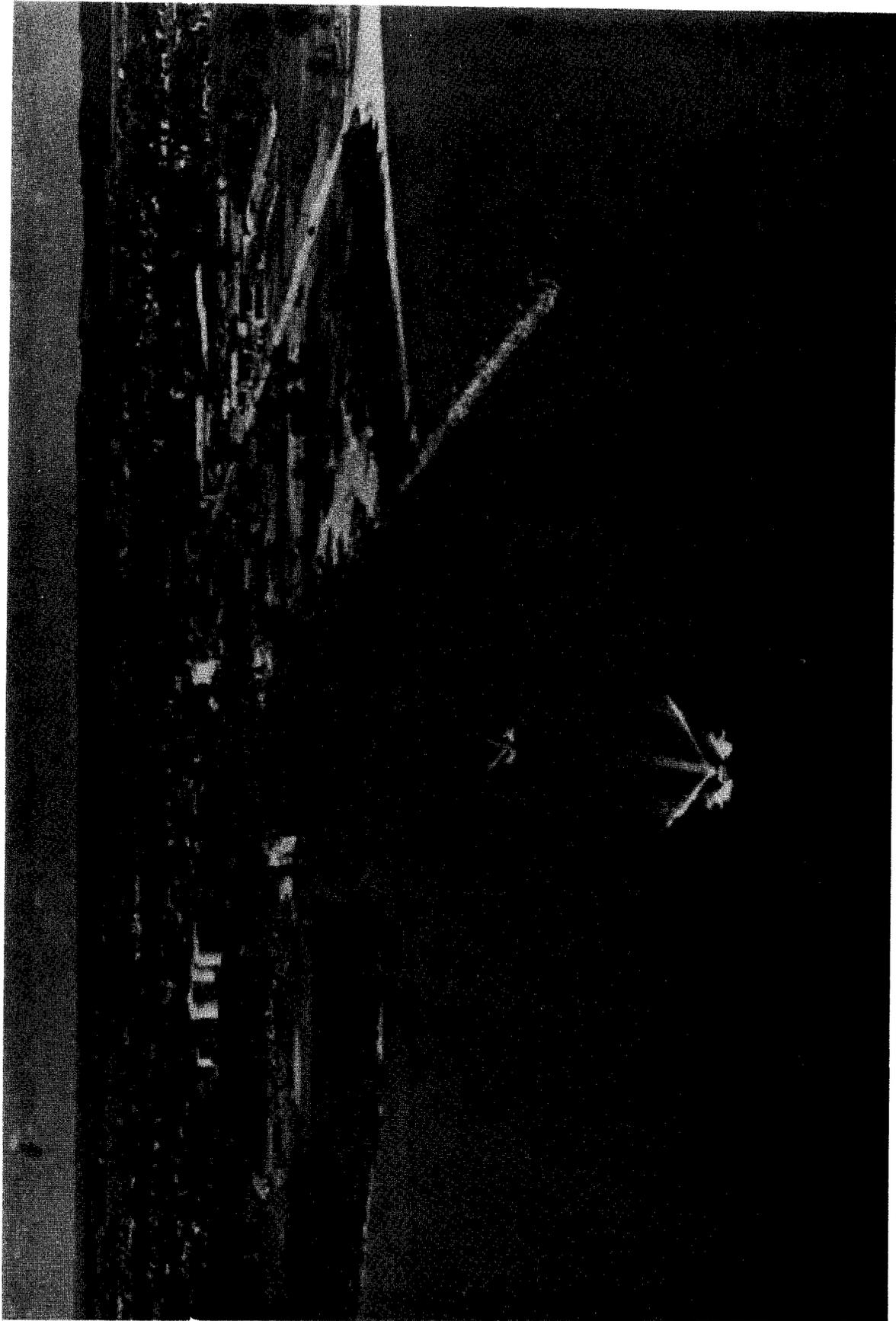


Figure 175. Aerial view of Cheboygan Harbor, Michigan

Table 64

Hammond Bay Breakwaters

Hammond Bay, Michigan

Date(s)	Construction and Rehabilitation History
1965	Construction of a 460-ft-long west breakwater and a 1,445-ft-long east breakwater were completed (Figure 176). The breakwaters were rubble-mound structures with crest widths of 8.0 ft (Figure 176). The crest el of the west breakwater (Section A) and the shoreward arm of the east breakwater (Section D) was +8 ft lwd, while the remaining portions of the east breakwater (Sections B and C) had a crest el of +10 ft lwd. Cover stone for Sections A and D was 1 ton (min), and for Sections B and C cover stone of 3.5 tons (min) was used in construction. Toe stone for Sections A and D was 3 tons and for Sections B and C it was 3.5 tons. Side slopes of 1V:1.5H were also used.
1982	A total of 210 tons of 3- to 5-ton cover stone was added to supplement the existing cover stone. The cost of these repairs was about \$133,000.
1984	An inspection of the breakwaters noted some winter storm damage to the east breakwater. Some cover stone and core stone was missing over about a 70-ft-long area, The west breakwater was in good condition.
1986	The breakwaters presently are considered in fair condition. An aerial view of the Hammond Bay breakwaters is shown in Figure 177.

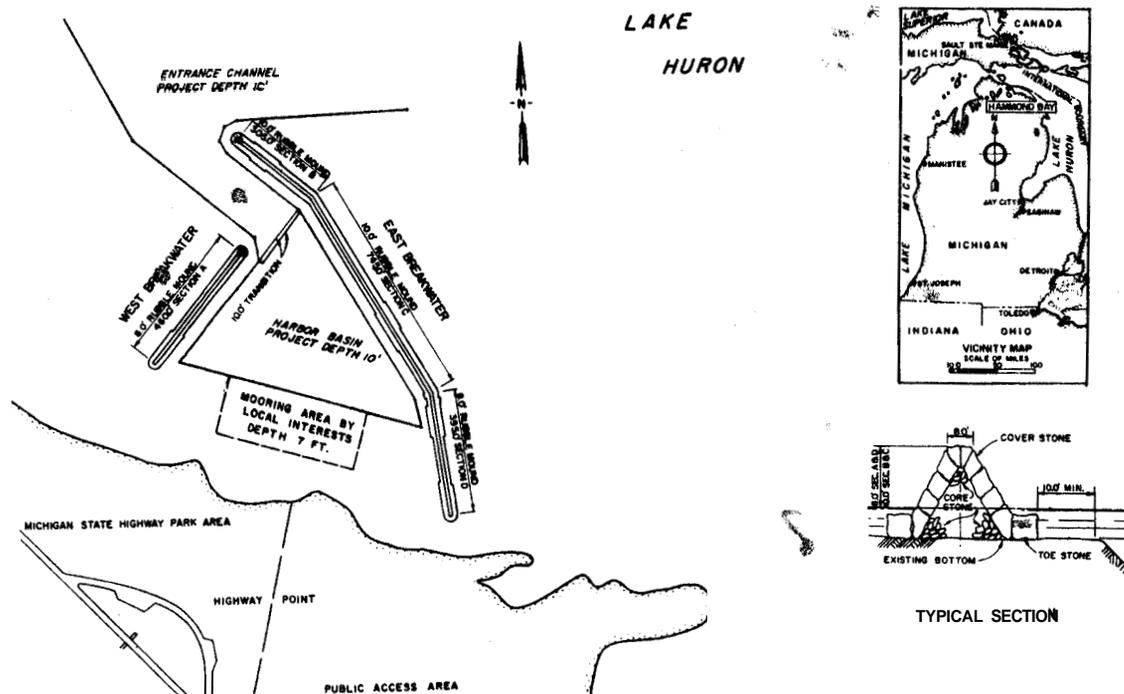


Figure 176. Hammond Bay Harbor, Michigan

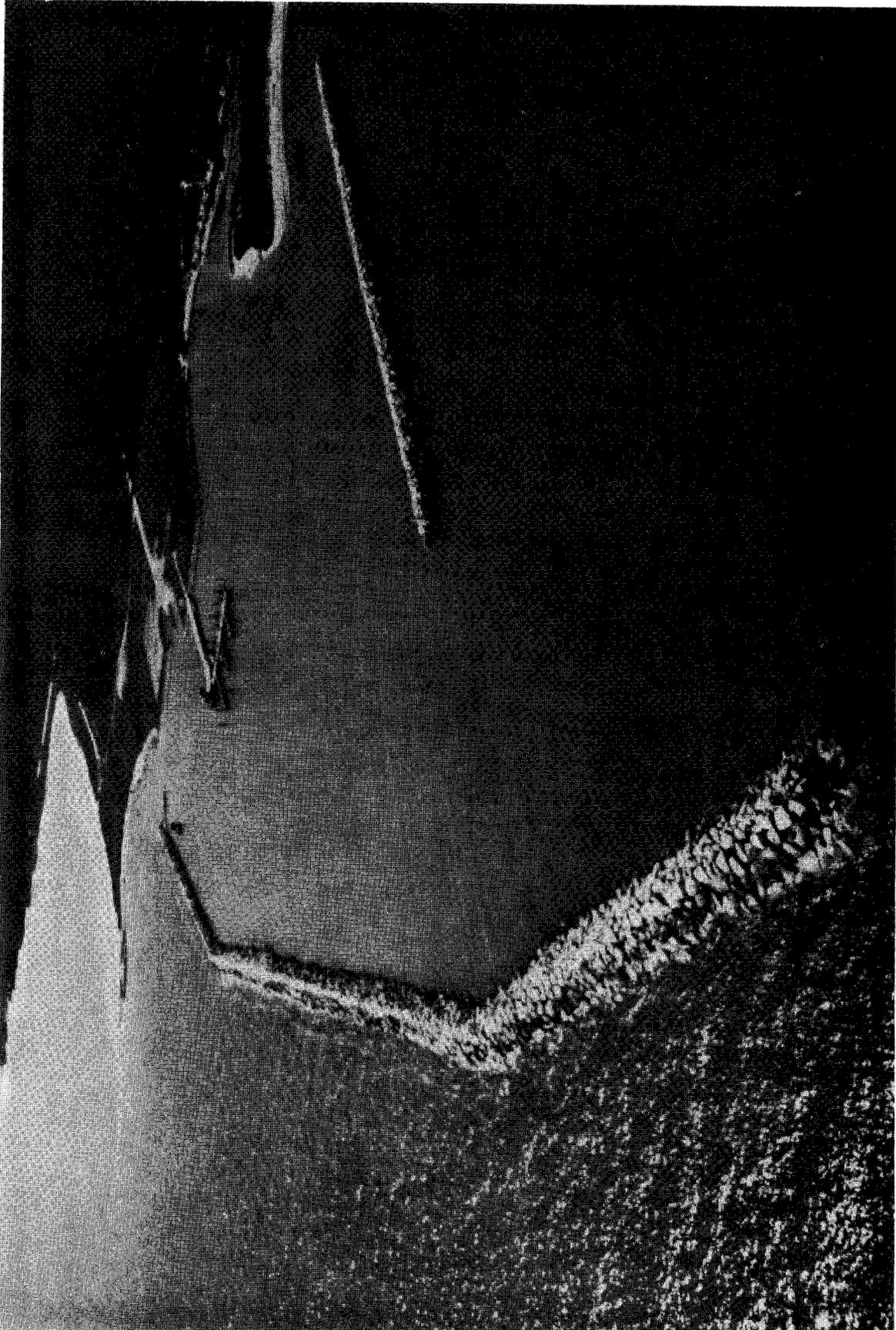


Figure 1JJ Aerial view of X amon^o Bay Harbor Michigan

Table 65

Alpena Harbor Breakwater
Alpena Harbor, Michigan

Date(s)	Construction and Rehabilitation History
1939	A 750-ft-long rubble-mound breakwater (Figure 178) was constructed from the shore extending parallel to the entrance channel.
1965	The project was modified, which entailed removal of the existing breakwater and construction of a new 550-ft-long offshore rubble breakwater. The new structure would include an 8-ft crest width, 4-ton cover stone, a crest el of +8 ft lwd, and 1-V:1.5-H side slopes on the harbor side with 1-V:1.75-H side slopes on the lakeside (Figure 178).
1969	The 1965 modification to the project was reclassified into an inactive status based on an unfavorable benefit-to-cost ratio.
1986	The existing breakwater has never undergone maintenance during its lifetime and is considered presently to be in good condition.

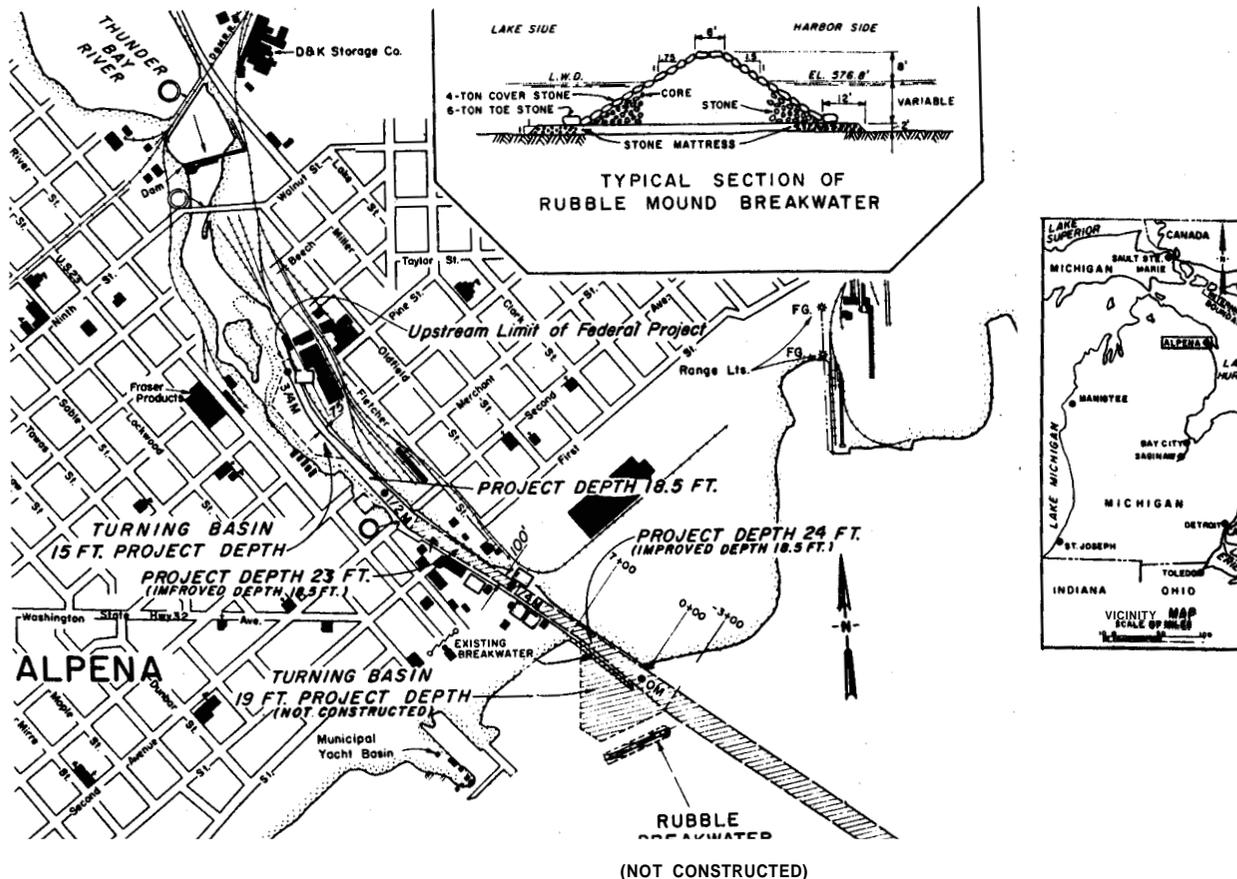
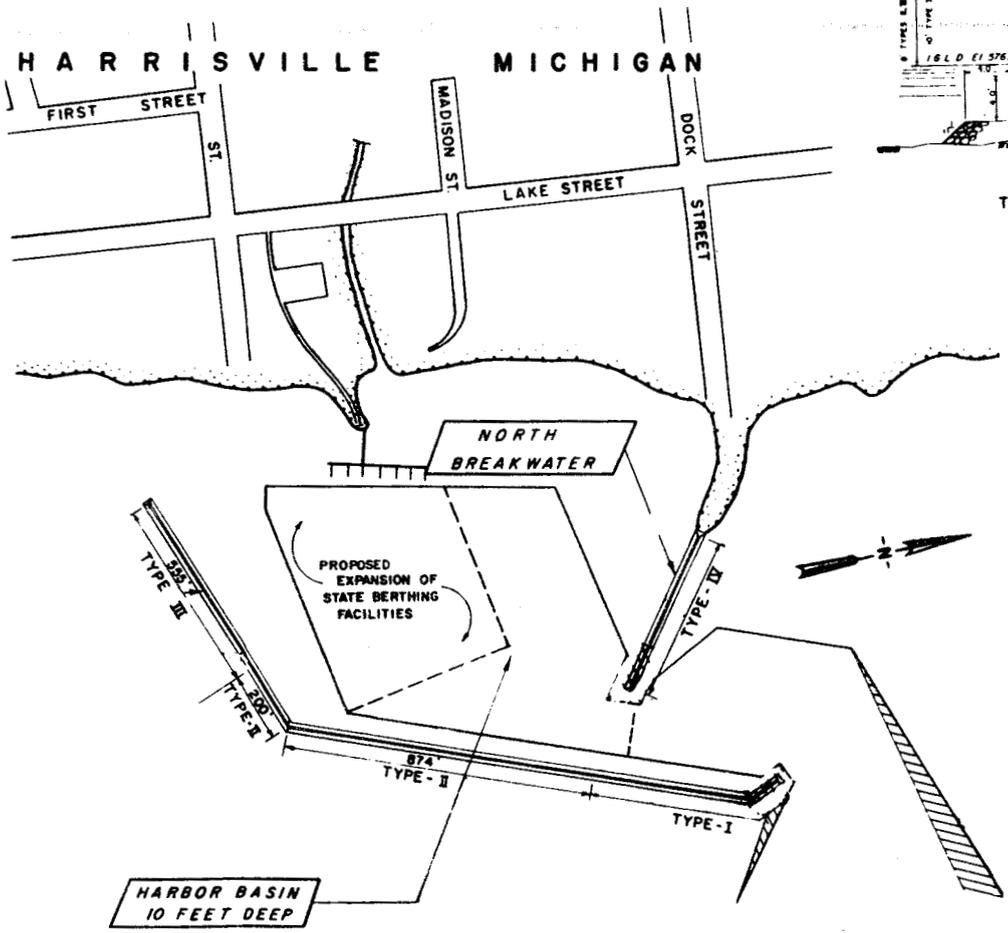


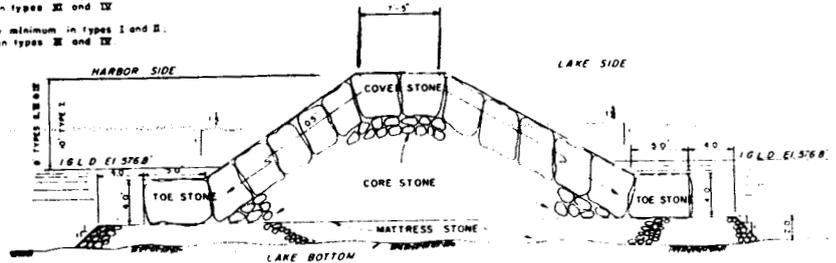
Figure 178. Alpena Harbor, Michigan

Table 66
Harrisville Harbor Breakwaters
Harrisville, Michigan

<u>Date(s)</u>	<u>Construction and Rehabilitation History</u>
1959	Construction of a 360-ft-long north breakwater and a 2,170-ft-long south breakwater was completed (Figure 179). The breakwater was constructed of rubble-mound materials with cover stones ranging to 3 (min) and 5 tons (min) for Types III and IV and Types I and II structures, respectively (Figure 179). The lakeward end of the south breakwater (Type I) had a crest el of +10 ft lwd, and the remaining portions of the structure (Types II, III, and IV) had a crest el of +8.0 ft lwd. The crest width was about 7.5 ft; and side slopes on the lakeside of the breakwaters were 1V:1.75H, while side slopes on the harbor side were 1V:1.5H. Toe stone ranged from 5 tons (min) in Types III and IV to 7 tons (min) in Types I and II.
1971	Replenishment of cover stone on the breakwaters was accomplished.
1984	An inspection of the breakwaters revealed some winter storm damage since several cover stones were missing. An estimated 80 tons of stone would be required to repair the breakwaters.
1985	Extensions of the north and south breakwaters of approximately 140 and 110 ft, respectively, were completed (Figure 179, hatched ends) for a cost of over \$433,000. Cover stones up to 9.5 tons were used.
1986	The breakwaters, presently, are considered in fair condition. An aerial photo of the Harrisville Harbor breakwaters (prior to breakwater extensions) is shown in Figure 180.



NOTE
 Cover stone 5 ton minimum in types I and II
 3 ton minimum in types III and IV
 Toe stone 7 ton minimum in types I and II
 5 ton minimum in types III and IV



TYPICAL CROSS SECTION OF BREAKWATERS
 COMPLETED 1939

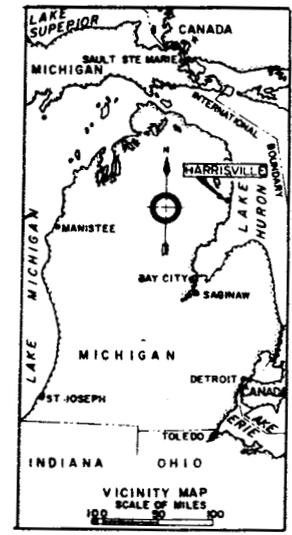


Figure 179. Harrisville Harbor, Michigan

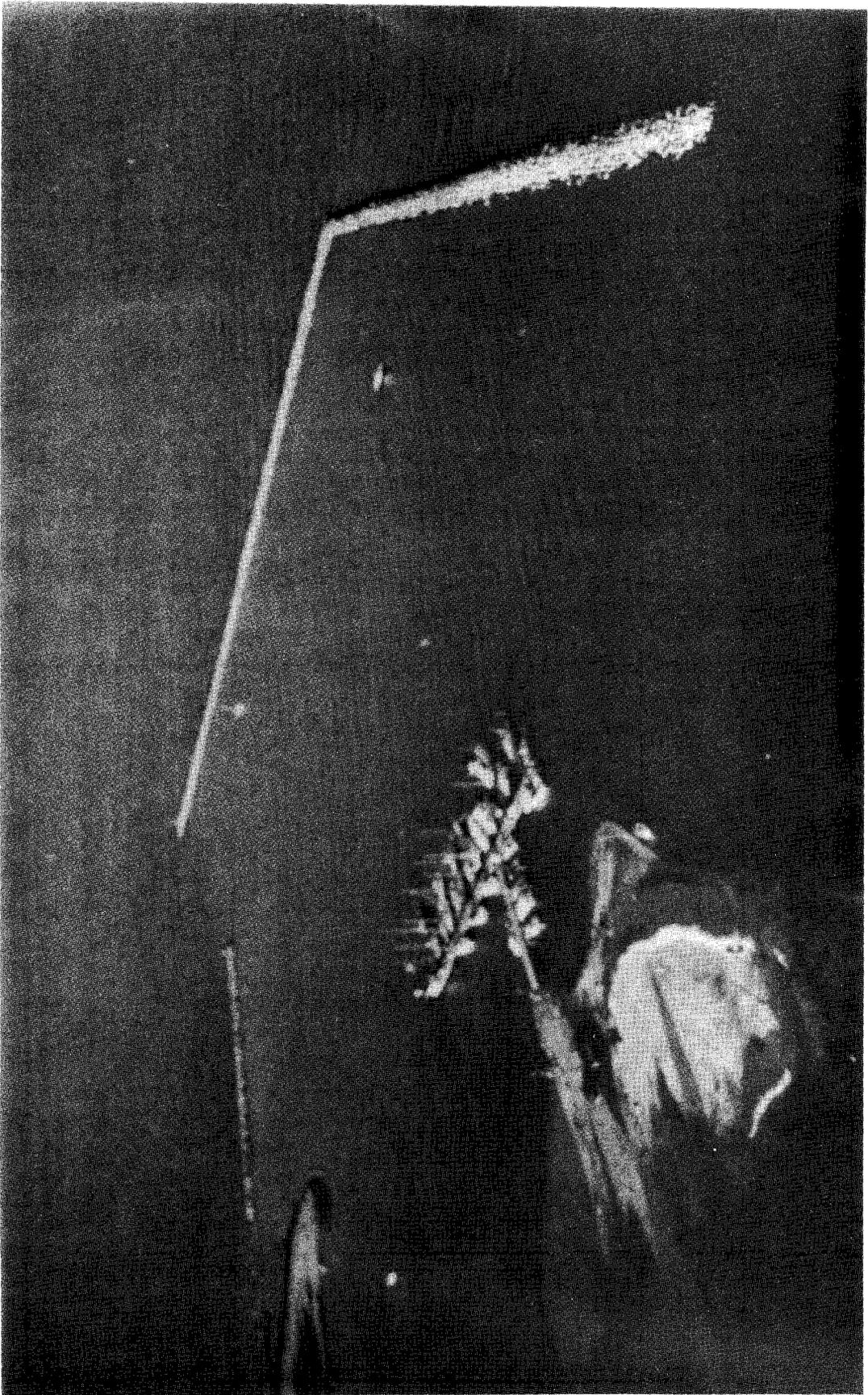


Figure 180. Aerial view of Harrisville Harbor, Michigan

Table 67

Au Sable Harbor Jetties

Au Sable, Michigan

Date(s)	Construction and Rehabilitation History
1962	Construction of north and south jetties (Figure 181) was completed. The shoreward 980 ft of the north jetty and 1,000 ft of the south jetty were constructed with steel sheetpiling at a crest el of +8.0 ft lwd (Figure 182). The lakeward 227 ft of the north jetty and 200 ft of the south jetty were constructed with 27.2-ft diameter steel sheet-pile cells. The cells were stone filled and capped with concrete to an el of +8.0 ft lwd (Figure 182). Riprap was placed on each side of the cellular portions of the breakwater (Figure 182) and along some portions of the steel sheet-pile structures (Figure 181).
1975	Rehabilitation of the north and south jetties was completed for a cost of about \$392,000. This work included repairs for broken and sunken cell caps and replenishment of riprap in various areas.
1984	An inspection of the jetties revealed them to be in very good condition. An aerial view of the Au Sable Harbor jetties is shown in Figure 183.

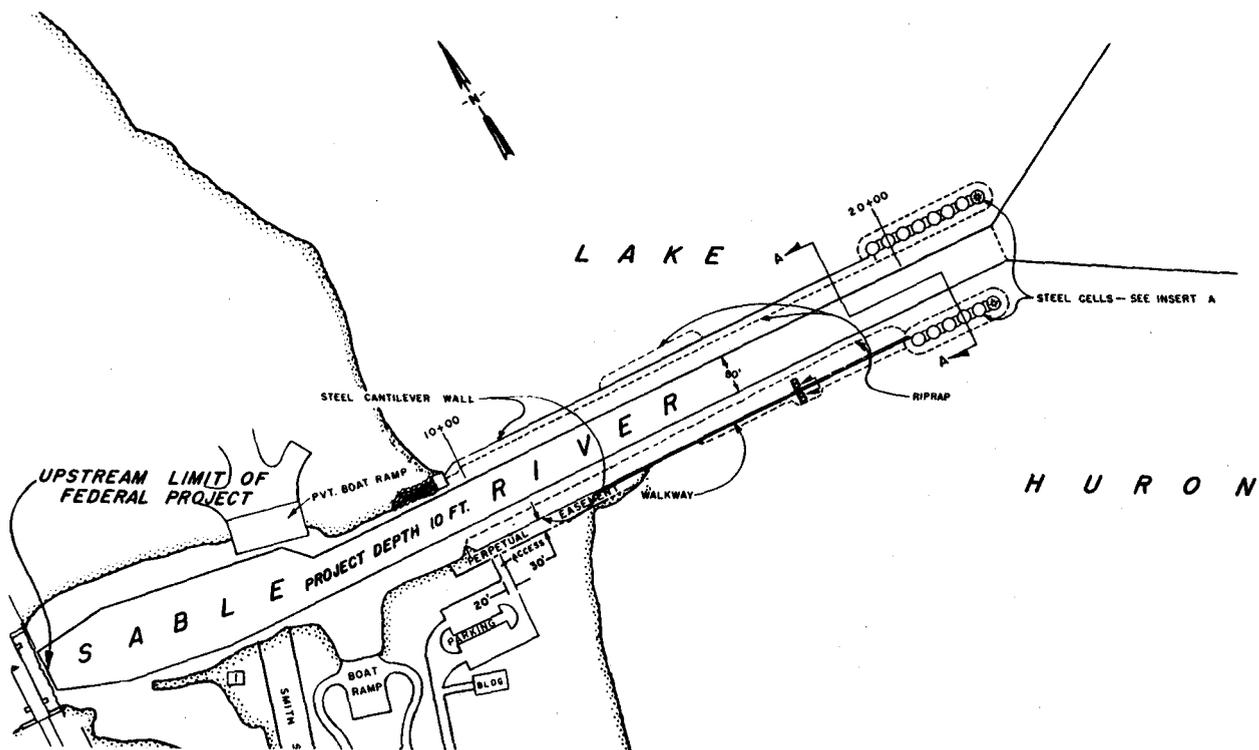
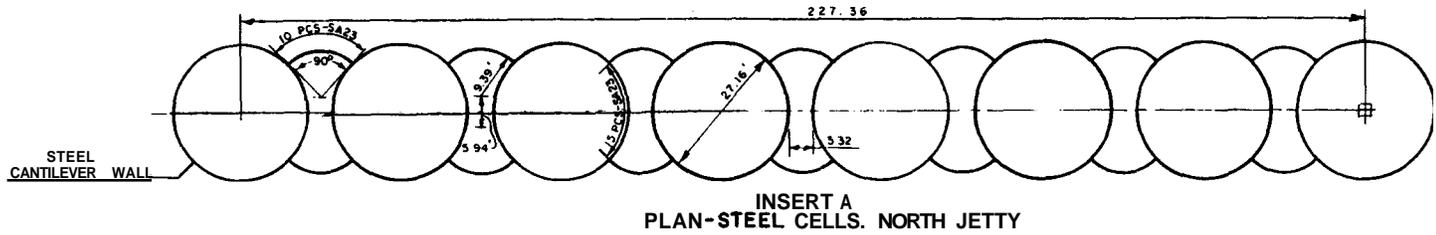
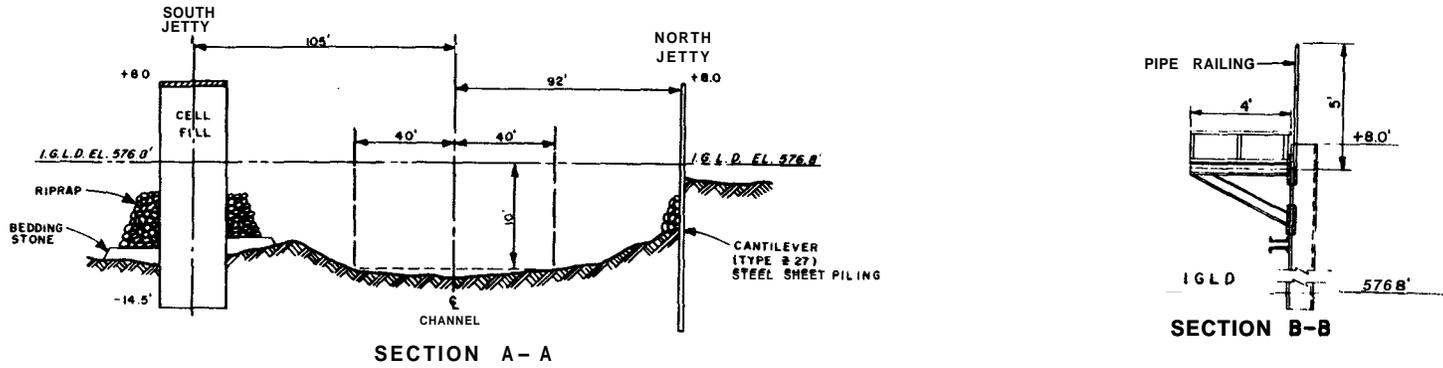


Figure 181. Au Sable Harbor, Michigan



NOTE SOUTH JETTY SIMILAR

Figure 182. Typical structure section and plan views, Au Sable Harbor, Michigan

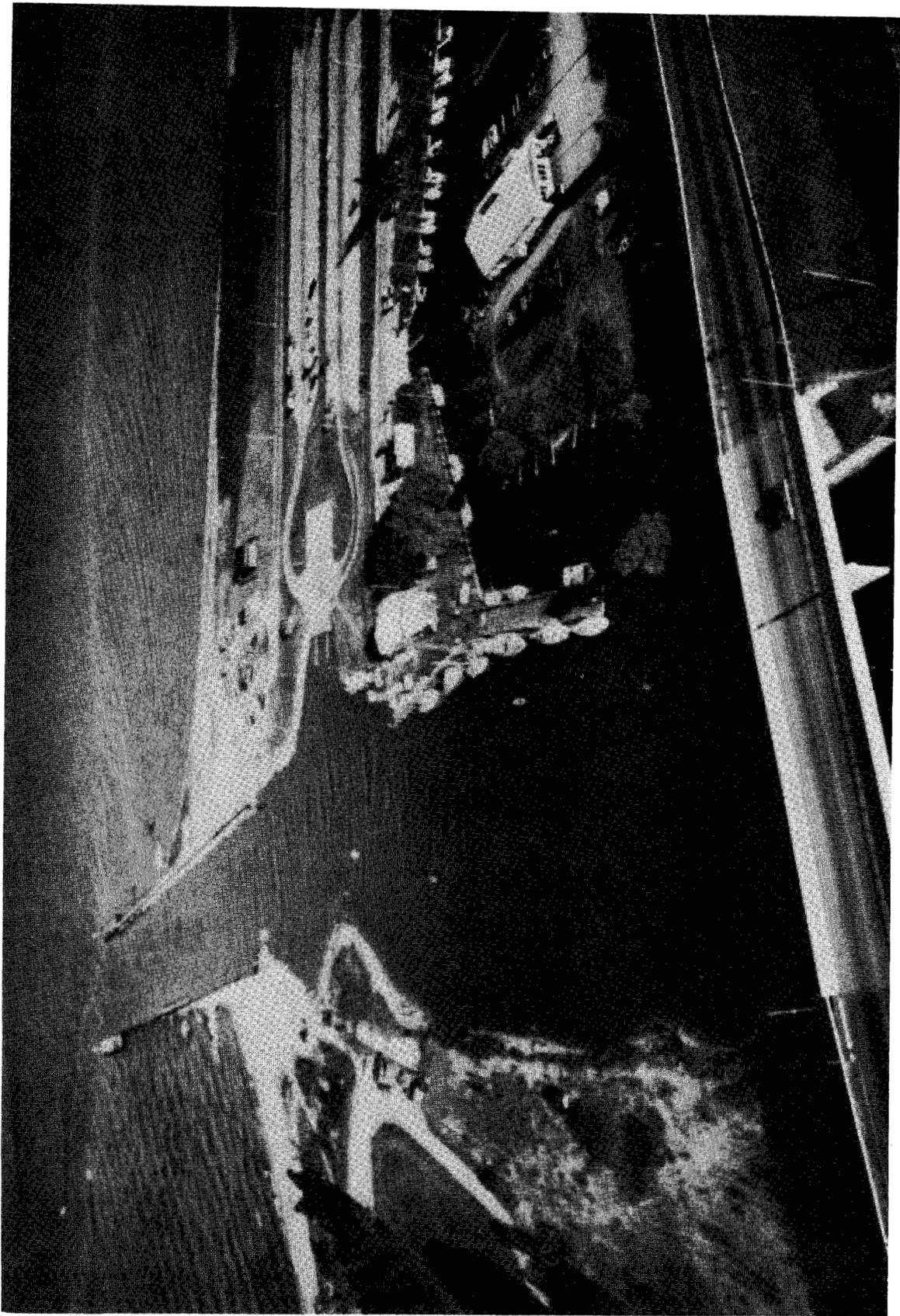


Figure 183. Aerial view of Au Sable Harbor, Michigan

Table 68

Tawas Bay Harbor BreakwaterTawas Bay, Michigan

t (s)	Constructi	and	itati	ry
7	Construction of four cast sections of an existing length of 4 ft (Figure 184) extending from an existing timber pile- owned breakwater. The breakwater was extended to form a structure 2 ft in width. The structure was filled and capped with precast concrete at a crest level of +7.25 ft. The sheetpiling was extended to an elevation of +10.5 ft on the bay side. Riprap from 400 lb was placed on the bay side (Figure 184).			
1985	An inspection of the site indicated the breakwater to be in very good condition. No maintenance has been performed on the breakwater since its construction. An aerial photograph of the Tawas Harbor breakwater is shown in Figure 185.			

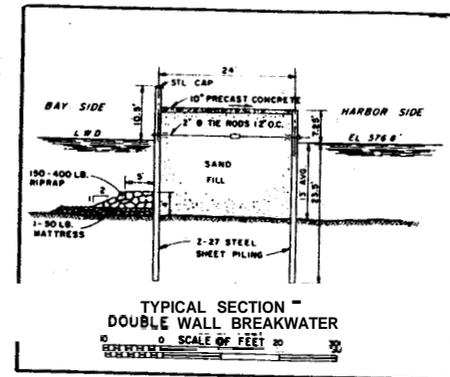
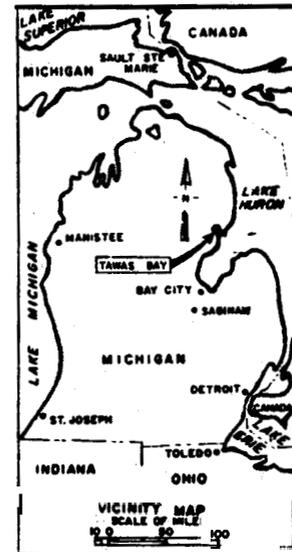
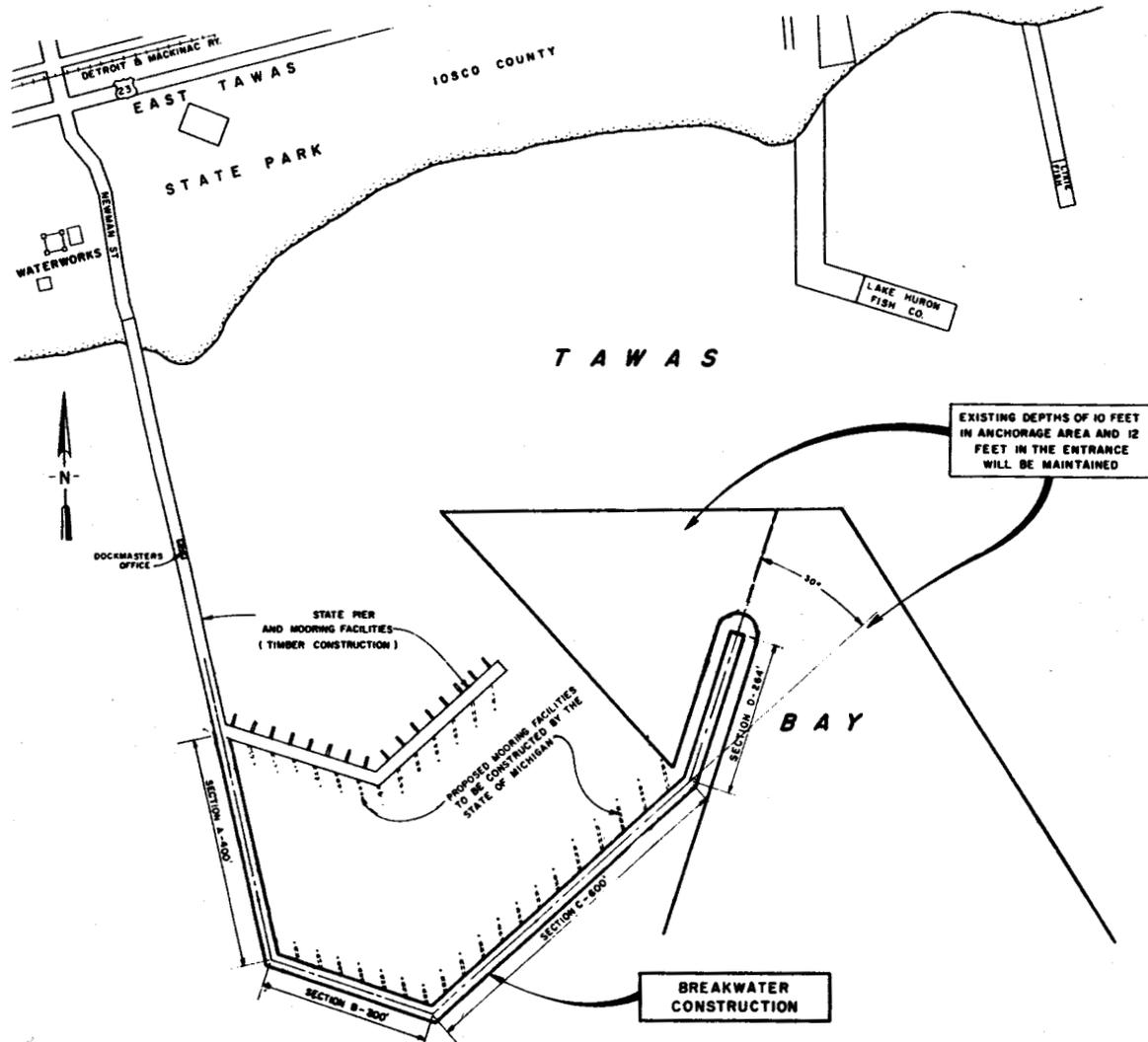


Figure 184. Tawas Bay Harbor, Michigan

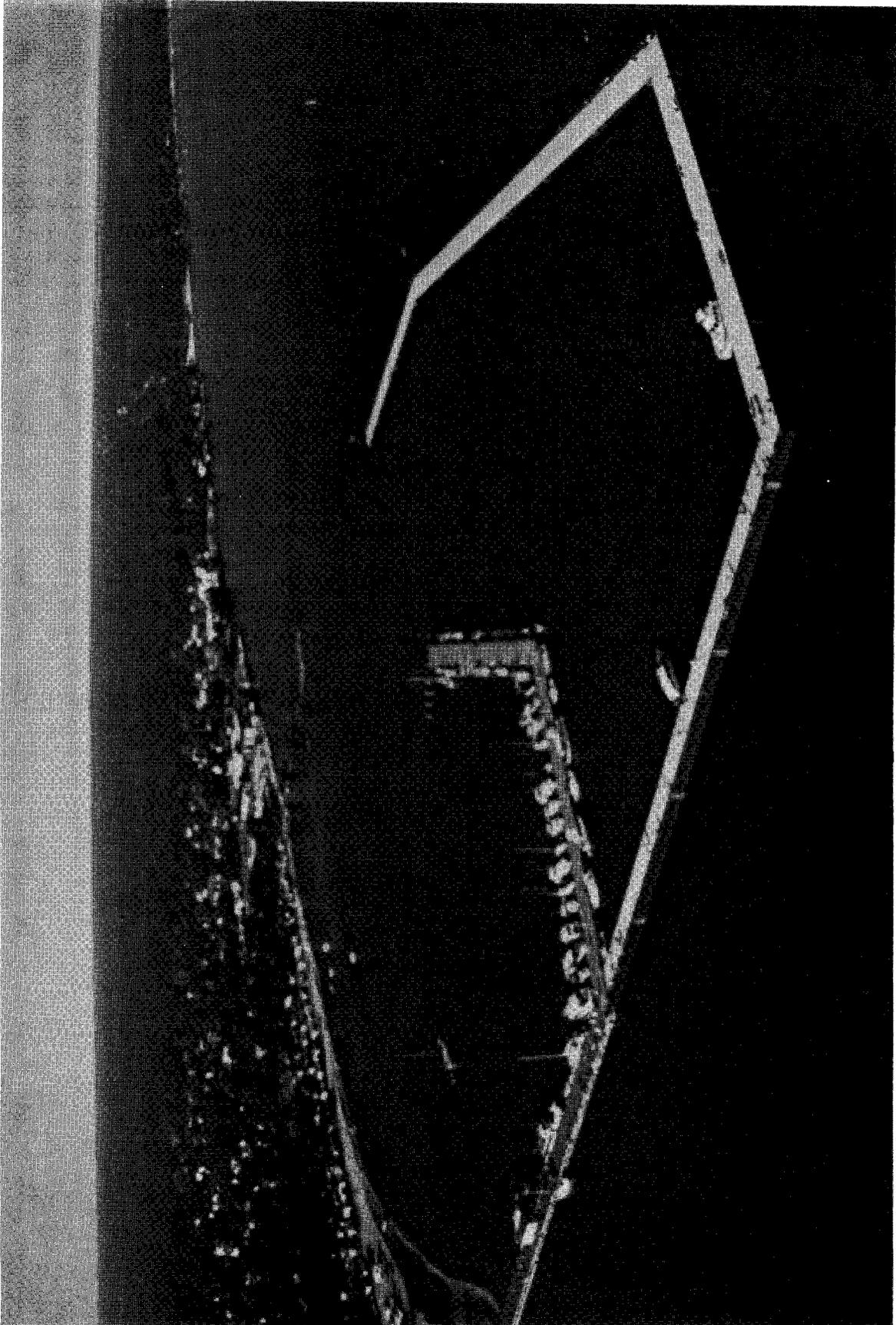


Figure 185. Aerial view of Tawas Bay Harbor, Michigan

Table 69

Point Lookout Harbor BreakwatersAu Gres, Michigan

Date(s)	Construction and Rehabilitation History
1972	Construction of a 4,000-ft-long east and a 3,800-ft-long west breakwater was completed. The breakwaters were rubble-mound structures extending parallel into Saginaw Bay (Figure 186). They consisted of cover stone laid on excavated material. Cover stone on the channel sides consisted of 1/4-ton (min) material, and cover stone on the bay sides of the breakwaters consisted of 3/4-ton (min) material. The breakwaters had 10-ft crest widths and side slopes of 1V:3H for the east breakwater and 1V:2.5H for the west structure. The crest el of the east breakwater ranged from +9 to +12 ft lwd, and the west breakwater had a crest el ranging from +6 to +9 ft lwd (Figure 186).
1976	Approximately 1,300 tons of cover stone (1,500-300 lb) was placed along the bay side of the east breakwater in critical areas to prevent failure of the structure.
1978	Approximately 500 tons of cover stone (3/4 to 1 ton) was placed along the bay side of the west breakwater in areas to maintain stability and prevent failure.
1986	Stone was placed at the harbor, and the structures are currently in good condition. An aerial photograph (photo taken in 1981) of the Point Lookout Harbor breakwaters is shown in Figure 187.

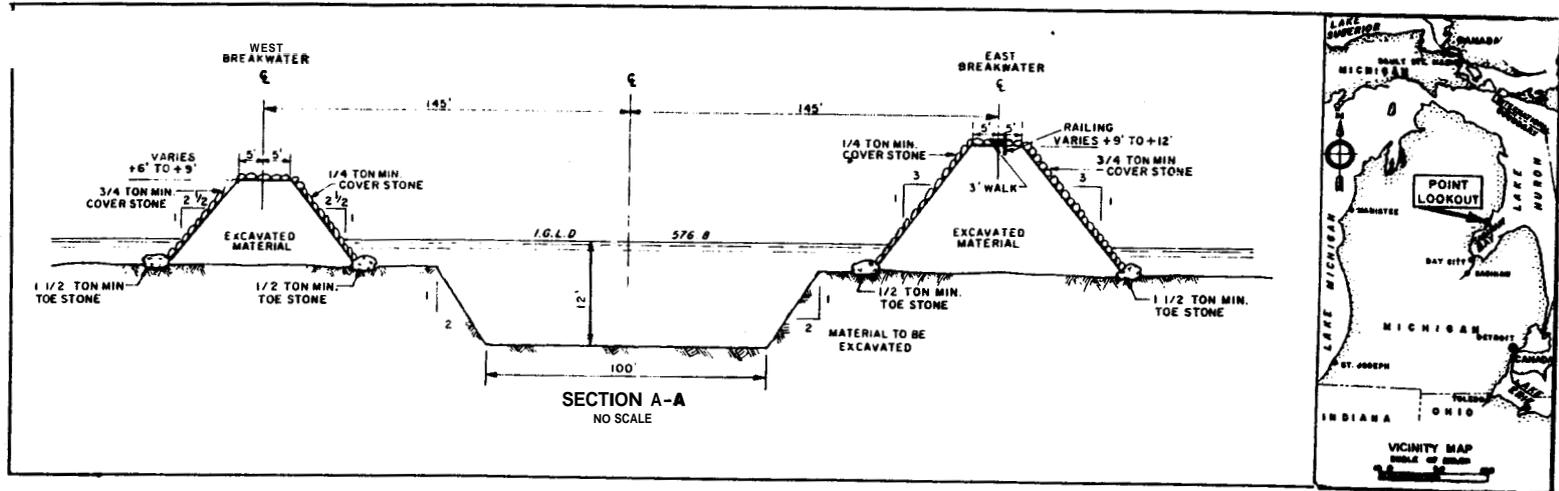
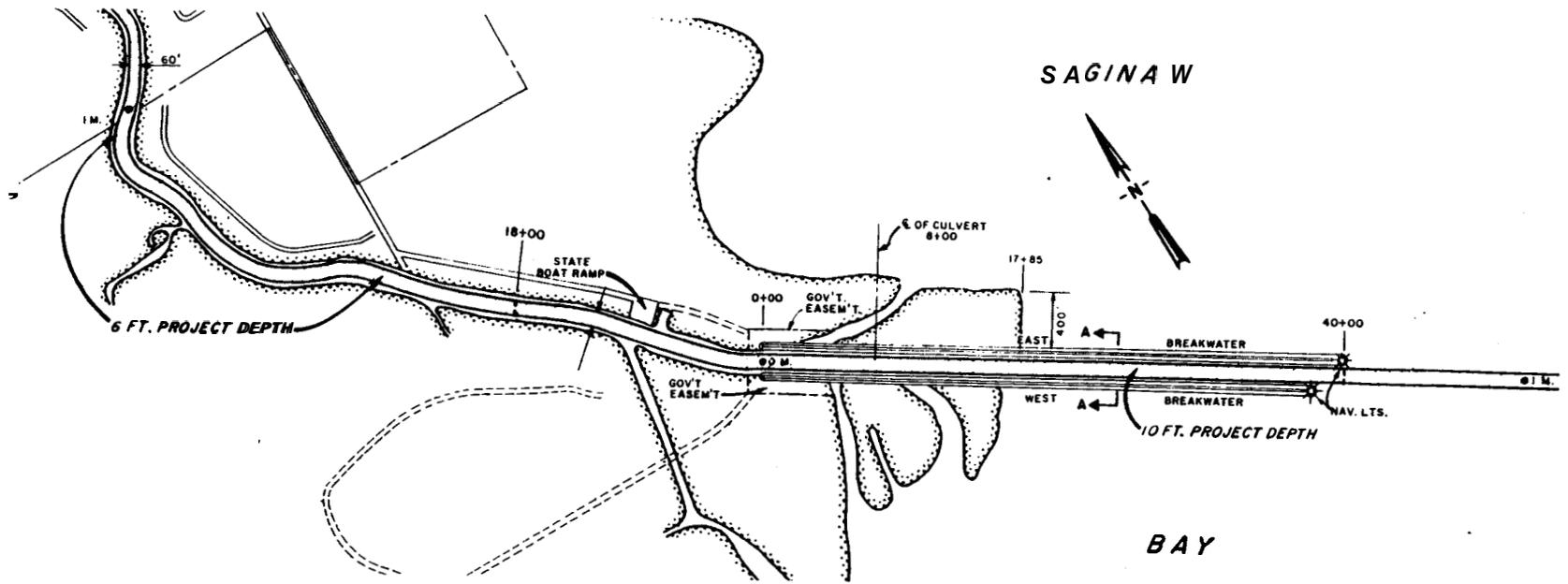


Figure 186. Point Lookout Harbor, Au Gres, Michigan

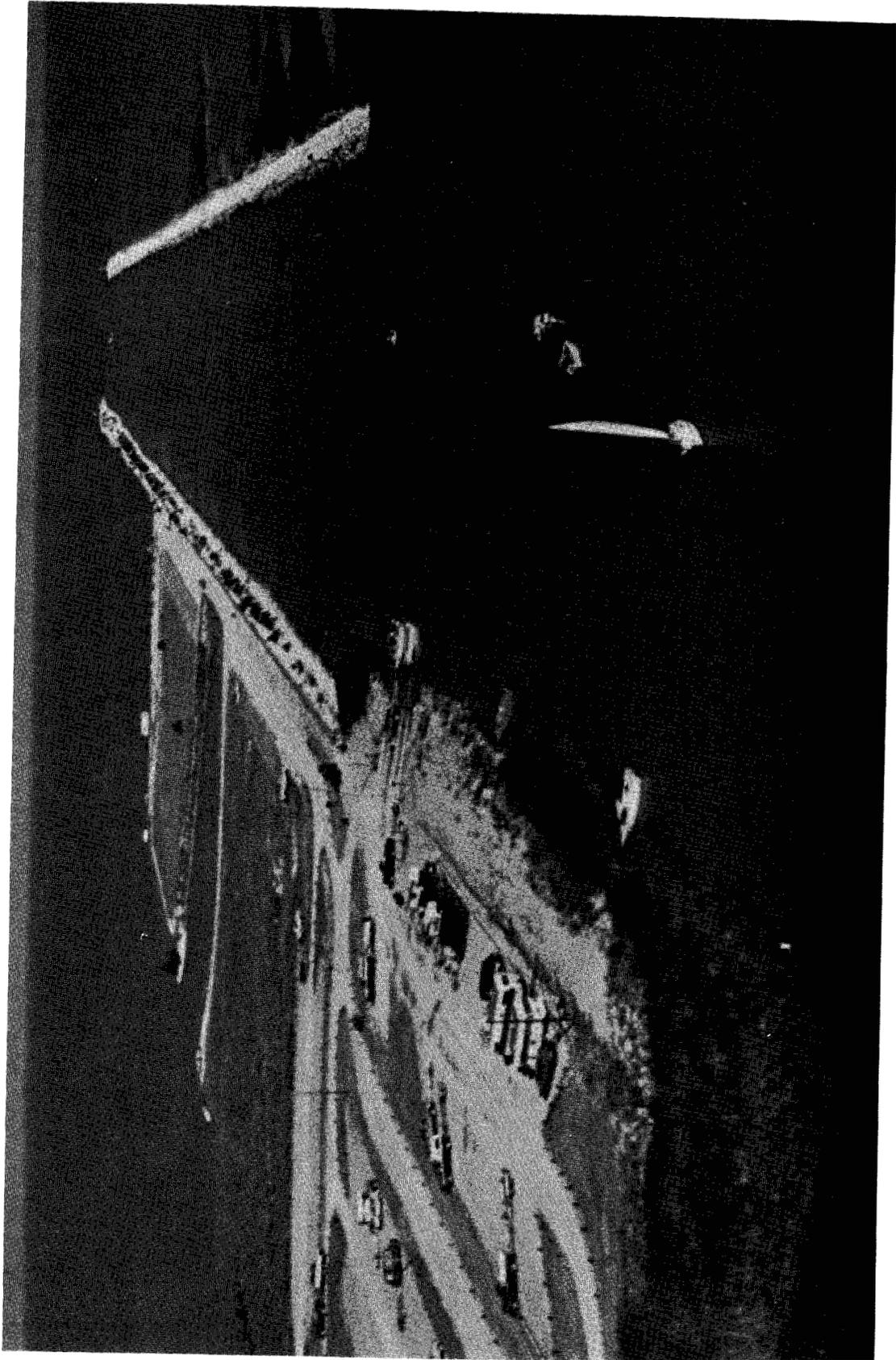


Figure 187. Aerial view of Point Lookout Harbor, Au Gres, Michigan

Table 70

Caseville Harbor Breakwater

Caseville, Michigan

Date(s)	Construction and Rehabilitation History
1964	Construction of a 1,780-ft-long rubble-mound breakwater (Figure 188) was completed. The structure had an 8-ft crest width, 1-V:1.5-H side slopes on the channel side, and 1-V:1.75-H side slopes on the lake-side (Figure 188). The lakeward 1,000-ft length (Section I) had a crest el of +8.0 ft lwd and 2-ton (min) cover stone, while the shoreward 780-ft section (Section II) included a crest el of +6.0 ft lwd and cover stone that was 1 ton (min).
1980	Repair of the rubble-mound breakwater was performed.
1986	The structure presently is considered to be in good condition. An aerial view of the Caseville Harbor breakwater is shown in Figure 189.

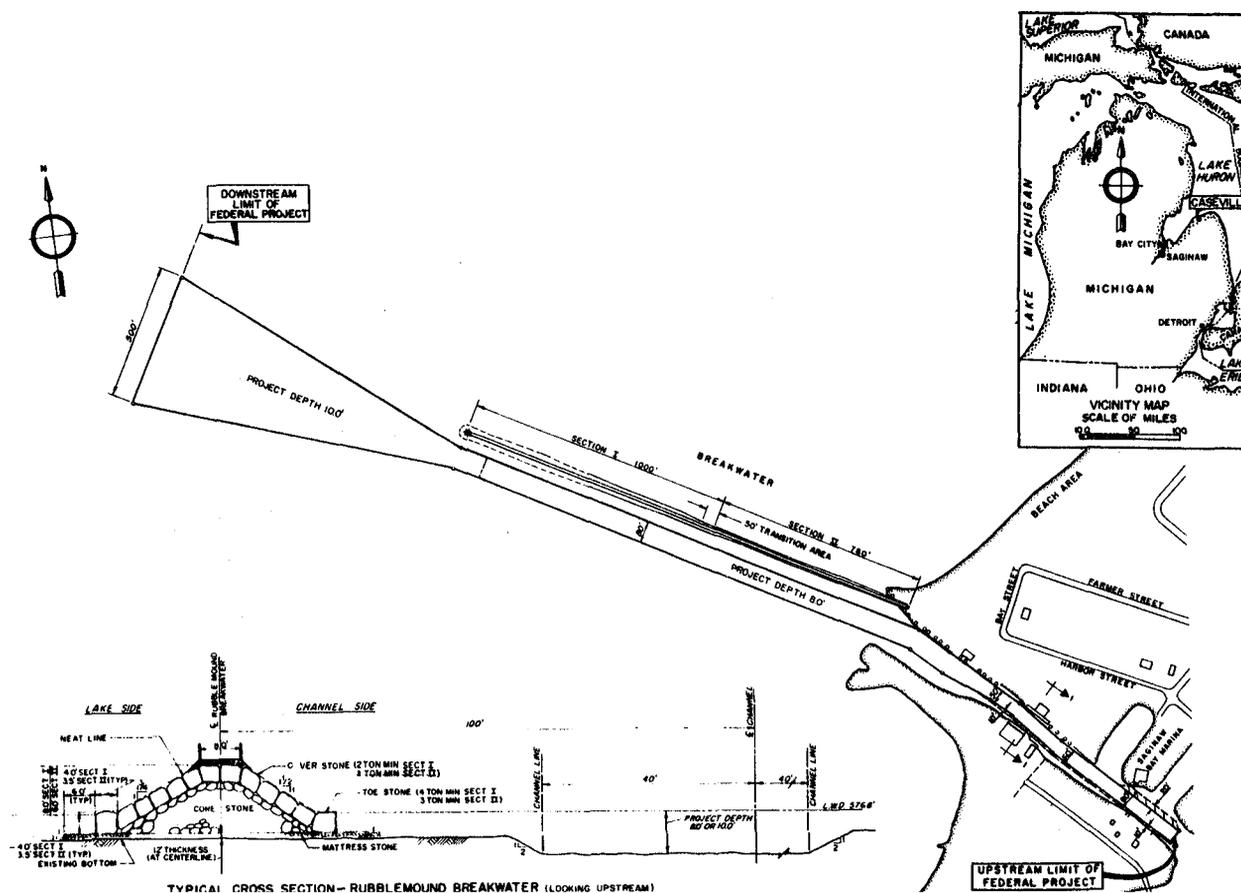


Figure 188. Caseville Harbor, Michigan

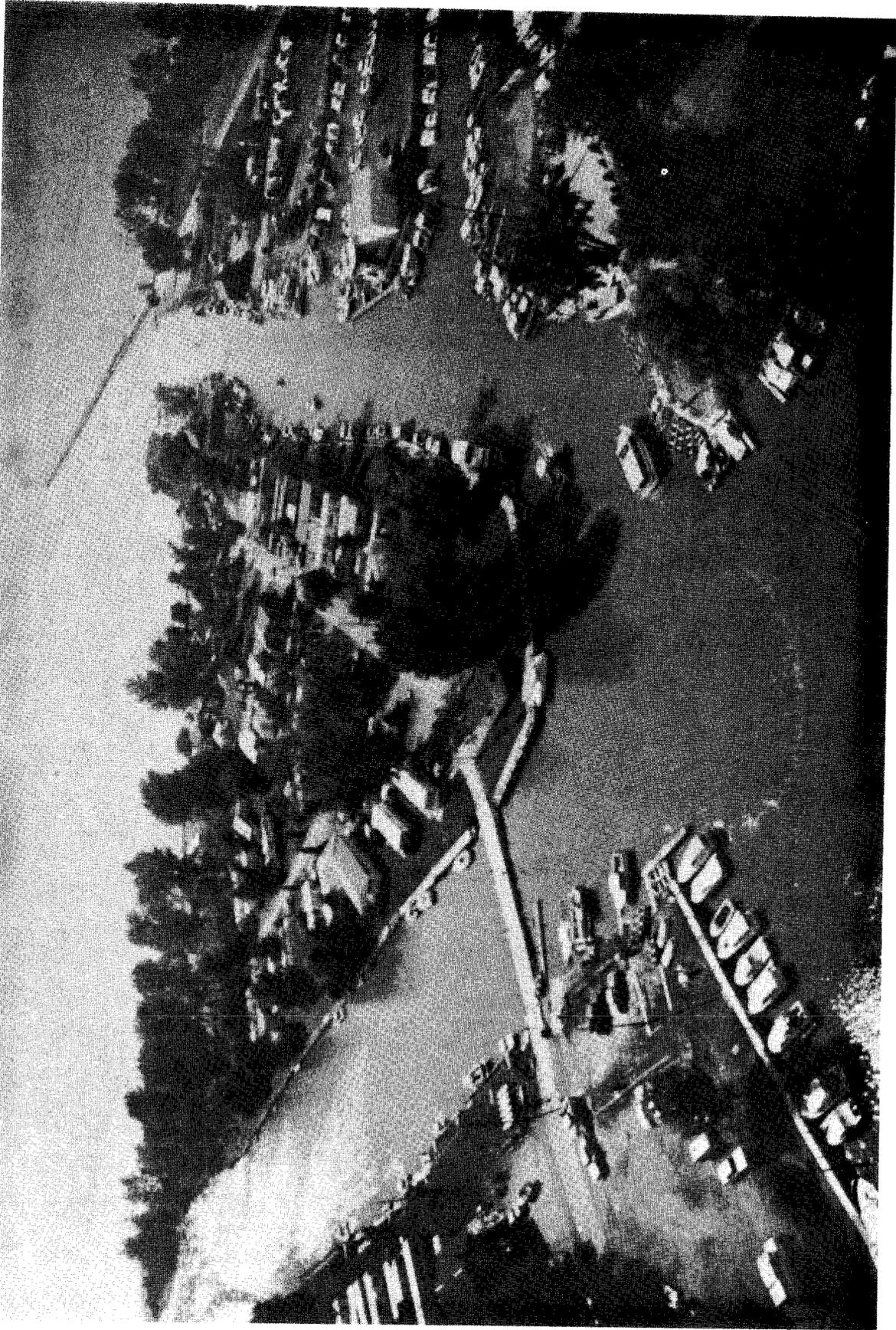
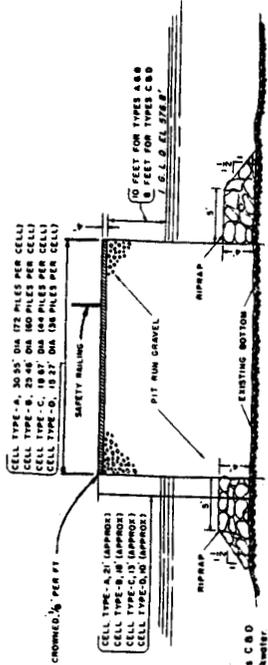
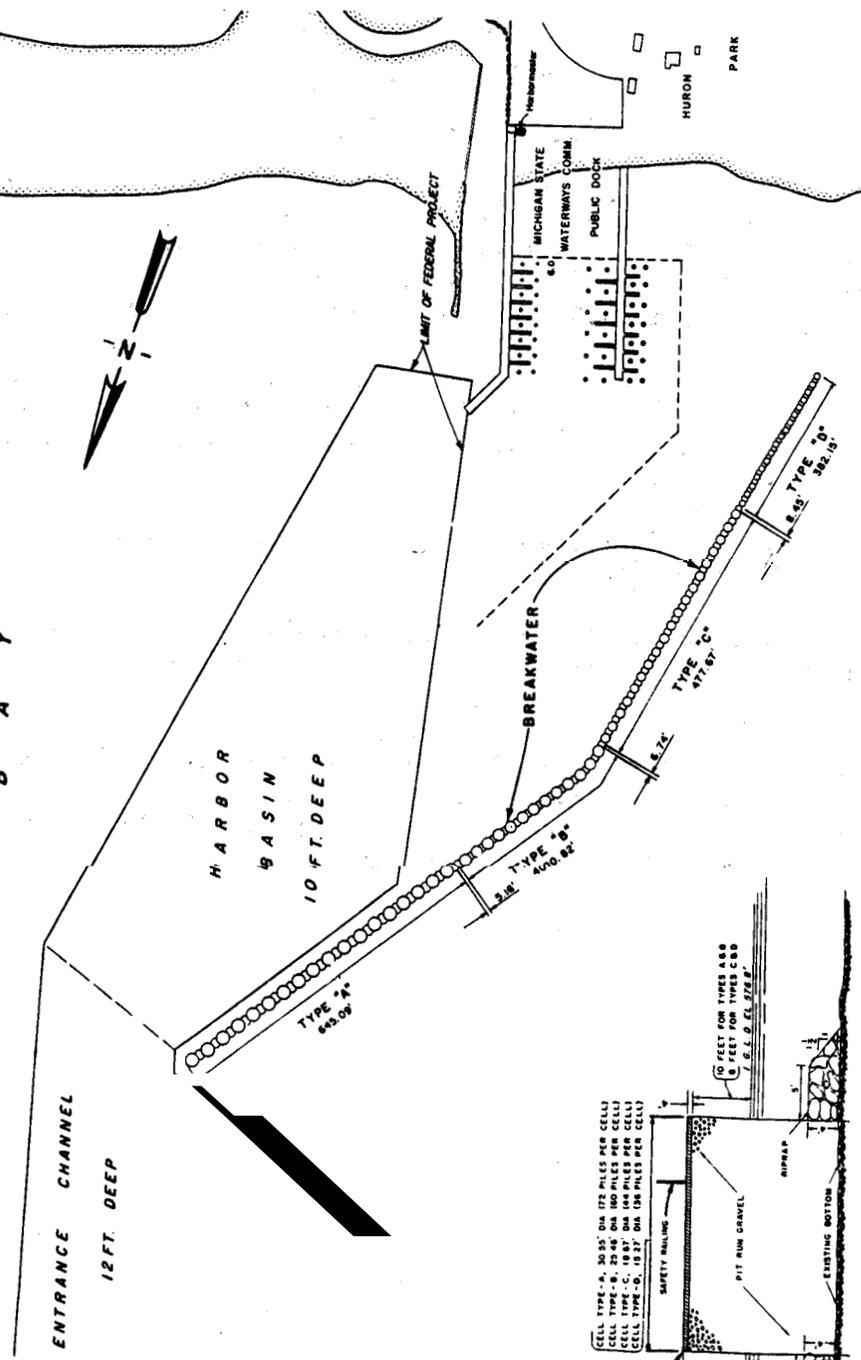
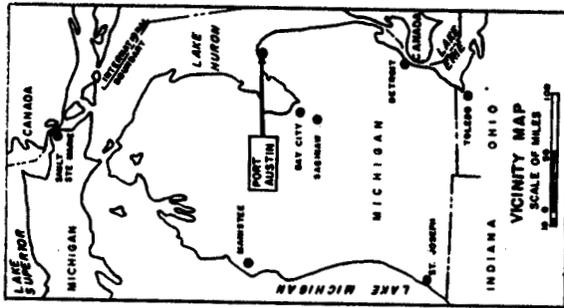


Figure 189. Aerial view of Caseville Harbor, Michigan

Table 71
Port Austin Harbor Breakwater
Port Austin, Michigan

Date(s)	Construction and Rehabilitation History
1959	Construction of a 1,926-ft-long offshore breakwater (Figure 190) was completed. The breakwater was built with cellular steel sheetpiling which ranged from 15.3 (Type D) to 30.4 ft (Type A) in diameter (Figure 190). The cells were filled with sand and gravel and crowned with a bituminous cap. The crest el of the breakwater was +10 ft lwd for Types A and B and +8 ft lwd for Types C and D. Riprap was placed along the sides of the cellular breakwater except on the harbor side of Types C and D.
1979	The lakeward cells (Types A and B) were replenished with stone and capped with concrete.
1983	The shoreward cells (Types C and D) revealed hairline cracks in the asphalt which were sealed. Caulking of construction joints in the breakwater also was performed.
1986	A safety railing was installed on the structure. The breakwater is considered to be in good condition; however, some construction joints are separating and require repairs. An aerial view of the Port Austin breakwater is shown in Figure 191.

S A G I N A W
B A Y



TYPICAL CROSS SECTION OF BREAKWATER

Figure 190. Port Austin Harbor, Michigan

E Sheet Piling is Type SA-28
o Riprap Required in Sections C & D
1 the Harbor Side of the Breakwater.

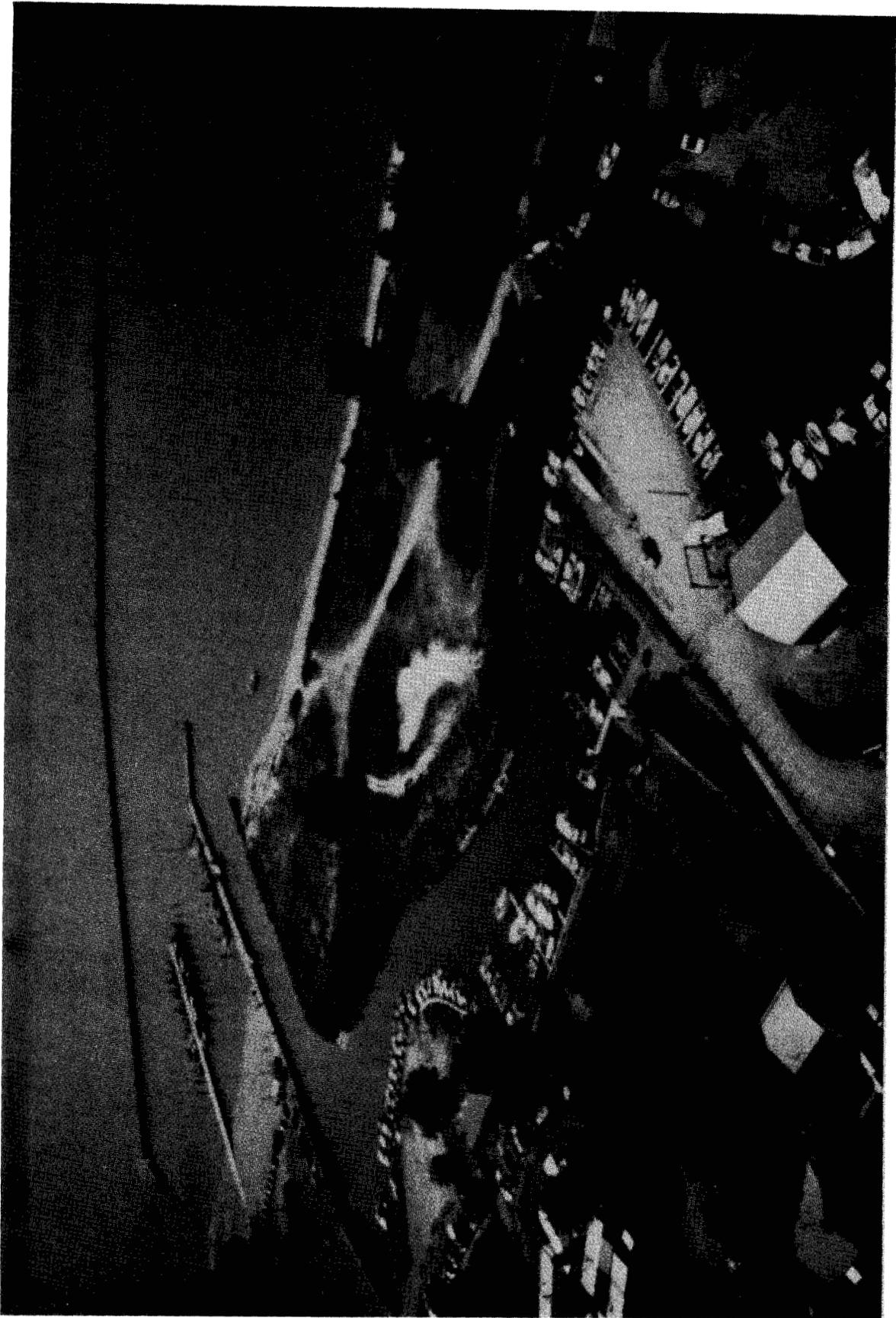


Figure 191. Aerial view of Port Austin Harbor, Michigan

Table 72
Harbor Beach Breakwaters
Harbor Beach, Michigan

Date(s)	Construction and Rehabilitation History
1874- 1885	Construction of a 1,204-ft-long north breakwater, a 4,716-ft-long main breakwater, and a 1,956-ft-long south breakwater (Figure 192) was completed during this period. The breakwaters were constructed with stone-filled timber cribs which ranged from 16 to 38 ft in width (Figure 193).
1905- 1909	The main breakwater was capped with a stone and concrete superstructure (Figure 193, Cross Sections D-D and E-E). The superstructure included a parapet that had a crest el of +16.5 ft lwd.
1911- 1912	The north breakwater was capped with a concrete superstructure (Figure 193, Cross Sections A-A and B-B). The breakwater crest el was established at +8.0 ft lwd.
1916- 1917	The south breakwater was capped with a concrete superstructure (Figure 193, Cross Sections F-F through I-I). The crest el of most of the structure was +8.0 ft lwd, but the northern end of the breakwater (Cross-Section F-F) included a parapet with an el of +14 ft lwd.
1916- 1919	Riprap was placed on the lakeside of the main breakwater (Figure 193, Cross Sections D-D and E-E). It was placed on a 1-V:1.5-H slope with a crest ranging from about +3 ft lwd (Cross Section D-D) to +6.5 ft lwd (Cross Section E-E).
1921	Riprap was placed on each side of the south breakwater (Figure 193, Cross Sections F-F through I-I). The crest of the riprap on the lakeside was +8.0 ft lwd, and on the harbor side it was at an el of +3.5 ft lwd.
1925- 1926	Riprap was placed on the lakeside of a portion of the north breakwater (Figure 193, Cross Section B-B) to an el of about +3.5 ft lwd.
1966	Rehabilitation of the south end of the main breakwater (Figure 192, Cross Section E-E) was performed. Work consisted of replenishing stone fill and repairing cracks in the substructures. Cost of the repairs was about \$172,000.
1971	Rehabilitation of portions of the south breakwater (Figure 192, Cross Sections F-F through H-H) was completed. Riprap protection which included a total of approximately 38,500 tons of stone (ranging from 6 to 15 tons each) was performed for about \$676,000.
1975	Riprap was replenished along portions of the main breakwater.

(Continued)

Table 72 (Concluded)

Date(s)	Construction and Rehabilitation History
1981	Riprap was replenished along portions of the north breakwater, and cracks in the superstructure were repaired.
1985	An inspection of the site indicated the structures are in need of major rehabilitation. The timber cribbing of the substructures is collapsing under the weight of the concrete superstructures resulting in shifting and cracking of the superstructure. The breakwaters are considered to be in poor condition, and major rehabilitation has been recommended for the harbor to maintain its protective status. An aerial view of the Harbor Beach breakwaters is shown in Figure 194.

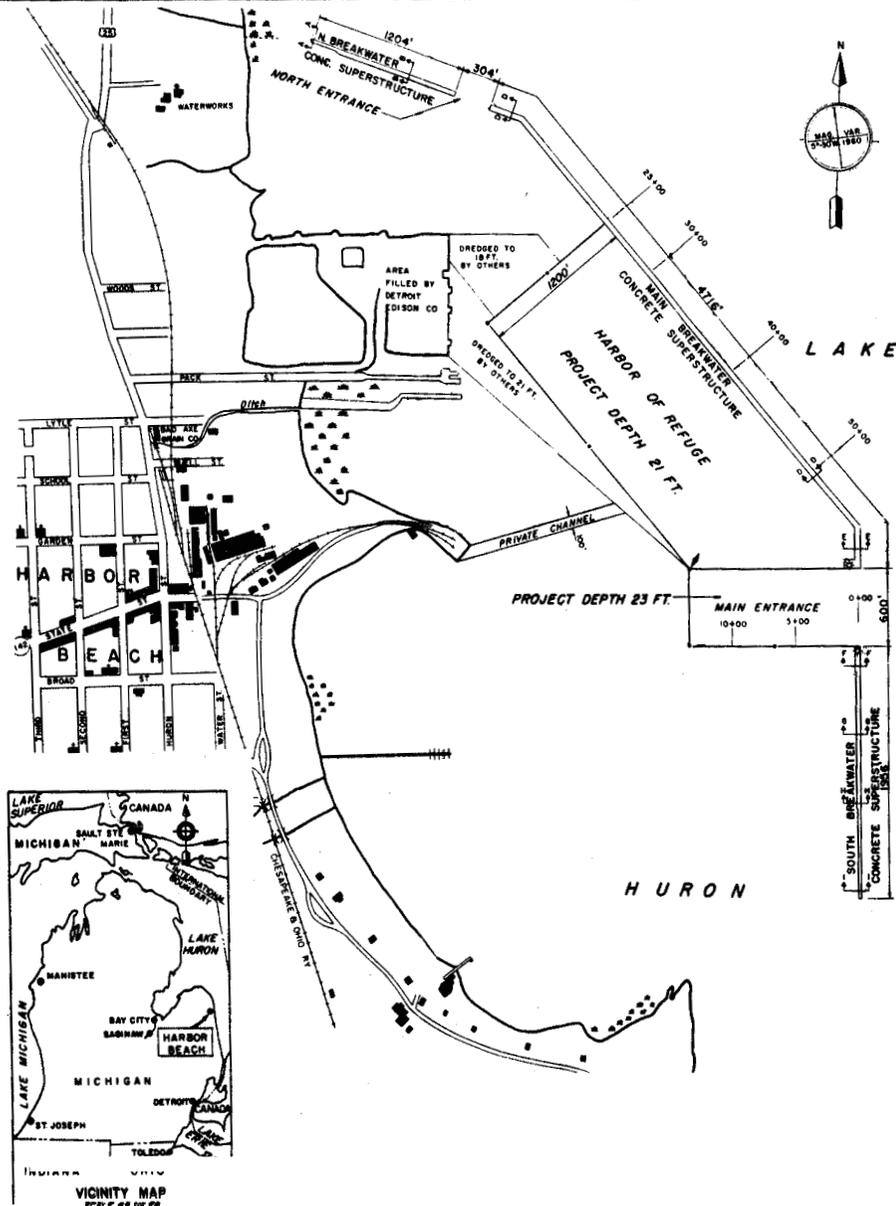


Figure 192. Harbor Beach, Michigan

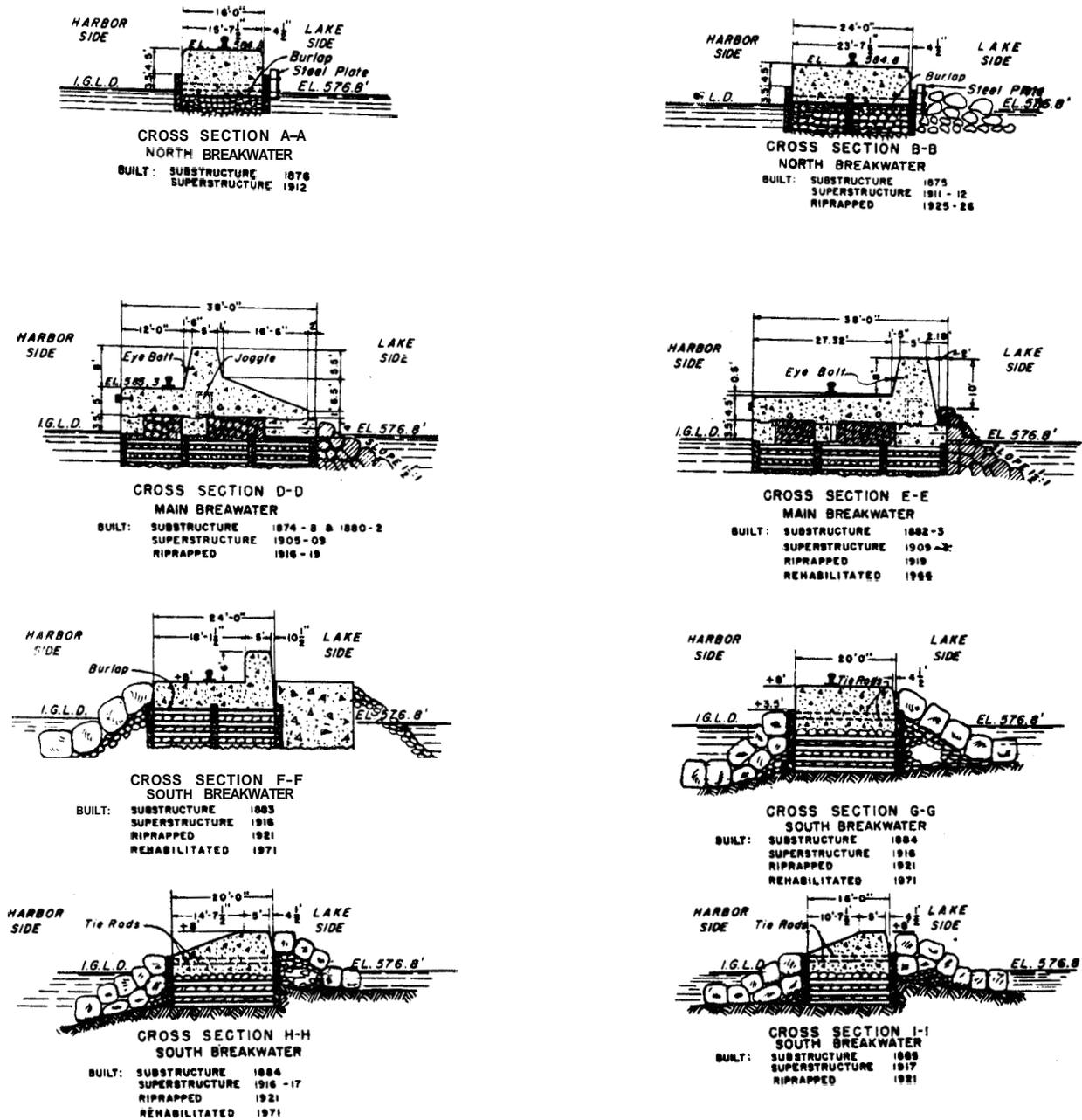


Figure 193. Typical breakwater cross sections, Harbor Beach, Michigan