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HARBOR DISTRICT

January 22, 1998

Ms. Lindsay A. Marks, Chief Executive Officer
Board of Harbor Commissioners
Crescent City Harbor District
Crescent City, CA 95531

Subject: Sheet Pile Bulkhead Investigation—Report Submittal
M&N File No.4099

Dear Ms. Marks:

The report for the subject project is enclosed for your use. We greatly appreciate the help that your staff provided during the investigation and field work. If you have any questions concerning our report, please do no hesitate to call me or Rich Dornhelm.

We have enjoyed working on this project with you and look forward to assisting the Crescent City Harbor District staff in the future.

Sincerely,

MOFFATT & NICHOL ENGINEERS

Brad Porter
Project Engineer

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SHEET PILE BULKHEAD INVESTIGATION
Crescent City Harbor District
Crescent City, California

Prepared By:

MOFFATT & NICHOL ENGINEERS
3000 Citrus Circle, Suite 230
Walnut Creek, California
M&N File No. 4099

Date Of Site Investigation:
11 December 1997

Investigating Staff:
Brad Porter, P.E.

1. SUMMARY

The bulkhead wall at Citizen's Dock was built in two phases. The older wall is approximately fifty years old and at the end of its expected useful life. The later wall is 38 years old and shows signs of significant deterioration. Replacement, at an approximate cost of $300,000 is recommended. There are repair options that will extend the life of the wall approximately ten additional years, which range in cost from $29,000 to $93,000. If replacement is not performed, survey points have been placed behind the wall that should be measured on a regular basis to assess ground settlement. This might help to identify any impending failure.

2. HISTORY

The bulkhead is located at the end of Citizens Dock Road and adjacent to Citizen's Dock in Crescent City Harbor. The bulkhead wall was built in two phases; the first phase was built in the 1940's (estimated from undated construction documents) and the second phase (addition) was built in 1962 (Figure 1). Both phases used 30 foot long 3/8-inch thick steel sheet piles driven to a depth of between 4 and 12 feet, and supported by a tie-back system. The top is encased in a concrete cap. The 1940's tie-back system consisted of one waler located 4'-8" below the concrete cap and tied to a system of timber piles. The 1962 addition tie-back system has two walers, one located in line with the 1940's waler, and the other 9'-2" below the cap. These walers as well as the cap are tied back to 8-inch steel H piles. A section through both the 1940's and the 1962 addition are shown in Figure 2.

The first phase was built for a 30,000 sq. ft. parking lot, launching platform and floating docks. It was comprised of a steel sheet pile wall 100 ft. long on the west side extending south from an existing steel sheetpile bulkhead (abutment to Citizens Dock), and a steel sheet pile return wall 50 feet long on the south. There was a 150 ft. long riprap extension on the east end of the south wall. This first phase of the wall is shown in Photograph 1.

The second phase extended the west wall an additional 100 ft. to the south, doubling the available parking area. A new 100 ft. long steel sheet pile wall was built on the south side with a 100 ft. long rip rap extension at the eastern end of the wall. An elevation of the west wall, showing both the 1940's and 1962 wall is shown in Photograph 2.

The steel sheet piles have corroded. Particularly in the 1940's wall, corrosion has created holes in the lower portion of the sheet piles between mean lower low water (MLLW) and mean sea level (MSL). The soil in back of the wall, at the holes, has partially washed out leaving void spaces behind the wall. The surface of the parking lot, behind the wall, is developing localized depressions, apparently due to the soil loss at the lower portion of the wall.

3. INVESTIGATION/EXISTING CONDITIONS

On December 11, 1997 a site visit was made to investigate the condition of the bulkhead wall. Four test pits were excavated behind the wall to observe the condition of the tie back system and to determine whether there were voids in the upper portion of the wall backfill. The pits were dug to an approximate depth of 10 feet to expose the lower tie-backs behind the 1962 wall. No pits were dug behind the 1940's wall because this would have required removal of concrete paving along the wall and interference with underground power lines. Seven nails were placed and the elevations surveyed in the asphalt parking lot behind the wall. The locations of the test pits and nails are shown in Figure 3. Photographs 17, 18 and 19 show test pit locations and the tie-back system. The nails can be surveyed in the future to indicate settlement caused by soil loss behind the wall. The wall was examined from the waterside by boat at low tide (-0.4 MLLW at time of observation). Observations from the visit are summarized below.

3.1 SHEET PILES

1. 1940's Wall (northern 100 ft. of the west wall, see Photographs 8 through 12.).

   - Completely rusted through at mean low water (MLW) for 30-40% of wall length (Figure 4).
   - Voids extend 3-5 ft. back into the wall backfill at MLW elevation.
   - Portion above mean sea level is intact, 40-60% of material remains.
   - Concrete cap has some spalled concrete exposing the rebar (Photograph 4).

2. 1962 Wall (southern 100 ft. of the west wall and south wall, see Photographs 6, 7, 8 and 13 through 16).

   - West Wall (see Photographs 6, 7, and 8) isolated holes are rusted through at low water. The openings equate to about 5-7% of the wall length.
   - Portion above mean sea level is intact, 50-70% of material remains.
   - South wall (see Photographs 13 through 16) two locations which have corroded through, one has water running out continuously at low tide, indicating extensive voids in backfill.

A bow was also noticed in the west wall as shown in Photographs 3 and 5. No detrimental effects from this bowing were observed. It may be that the bow has been there for many years, perhaps since the original construction.

3.2 TIE BACK SYSTEM

1. 1940's wall. The tie-back system for this wall was not examined because of concrete paving and electrical utility interference.

2. 1962 Addition.

   - Buried steel piles in good condition, 90% of material remains.
   - Buried portion of tie rods in good condition, 90% of material remains.
   - Walers are badly corroded, 30-50% of material remains.
   - Nuts on end of tie rods are badly corroded, 20-35% of material remains.

3.2 BACKFILL

- Backfill at four test pit areas was sound - no voids were encountered.
- Backfill was sandy shale, predominantly granular and well drained.

3.4 CONCLUSION

The 1940's bulkhead wall is at the end of its expected life. The exposed steel is badly corroded with holes at the waterline and is therefore in need of replacement. The 1962 addition has fewer holes at the waterline than the 1940's wall. The buried tie back system of the 1962 addition is in relatively good condition and could be reused. The 1940's tie-back system uses timber piles, which may have deteriorated due to the opening in the sheet pile wall. Fortunately, the 1940's wall in the area with extensive corrosion is not as high as the remainder of the west wall. It may be that the single waler has therefore been able to support the wall. This same type of corrosion in the longer portions of the wall might have had much more severe results.

If no corrective action is taken, the steel sheets will continue to corrode, resulting in larger holes and associated growth of the cavities behind the wall at the MLW elevation. There are two likely modes of failure of the wall.

1. Failure Mode 1 - Breach at Wall Base
   The bottom of the wall continues to corrode but the tiebacks hold the top of the wall in place. The top of the wall would remain fixed and the base would "kick out" along with the lower soil. This would cause the soil in back of the wall to settle as much as a few feet. This is the most likely failure mode and could occur in the 1940's wall in the near future; it is unlikely that the 1962 wall would fail in this way for another 5-15 years.

2. Failure Mode 2 - Breach at Top
   If the tie back connections at the walers yield due to their corroded condition, the top of the wall would lean out causing lateral movement, or spreading, of the surface soil in back of the wall. Given the overall age and condition of the wall this could trigger a rupture of a vertical sheet pile seam and a complete breach of the wall. Although it is possible this could happen in a sudden way (within hours) it is more likely that a

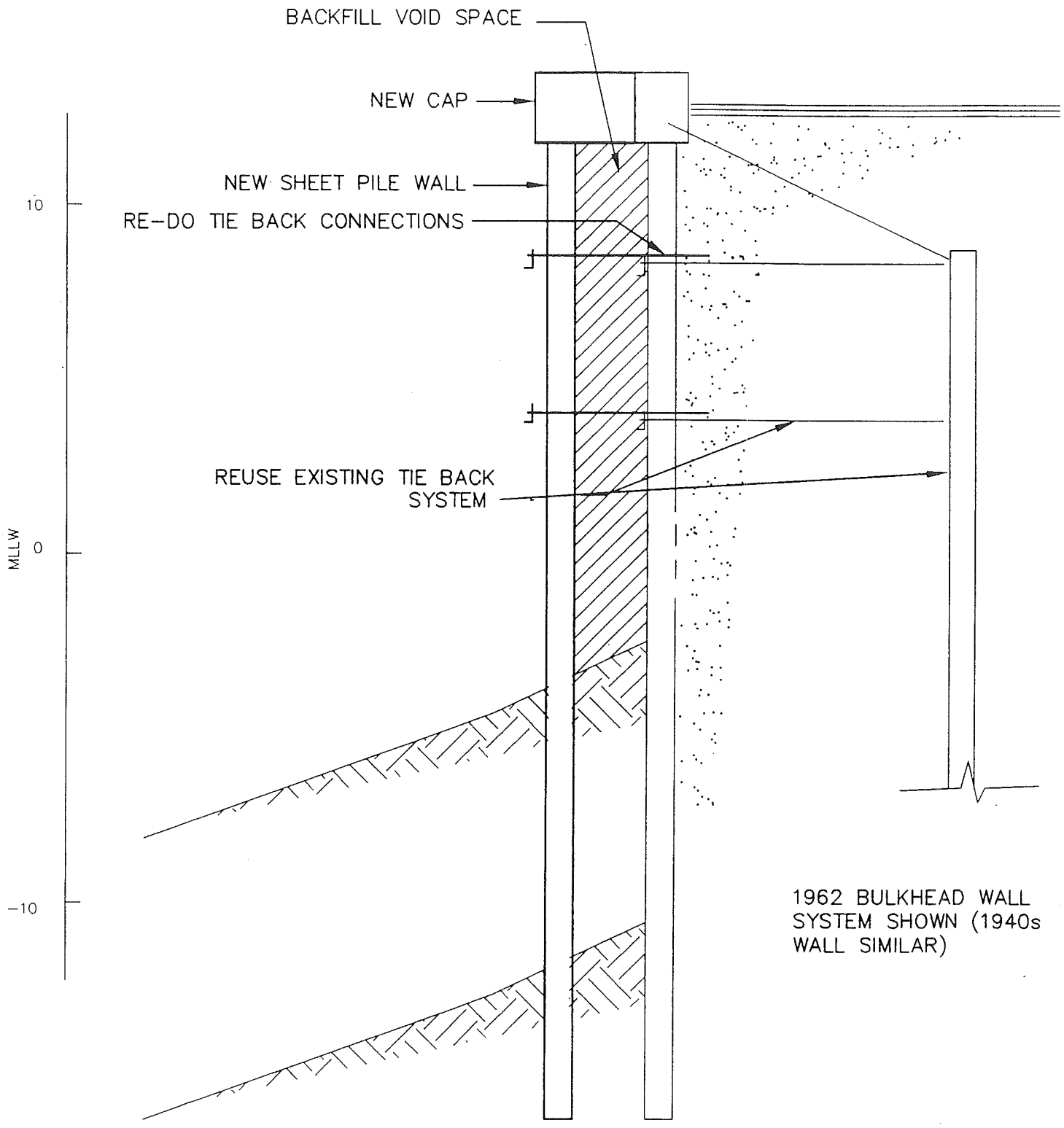

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FIGURE 5 – REPLACEMENT WALL

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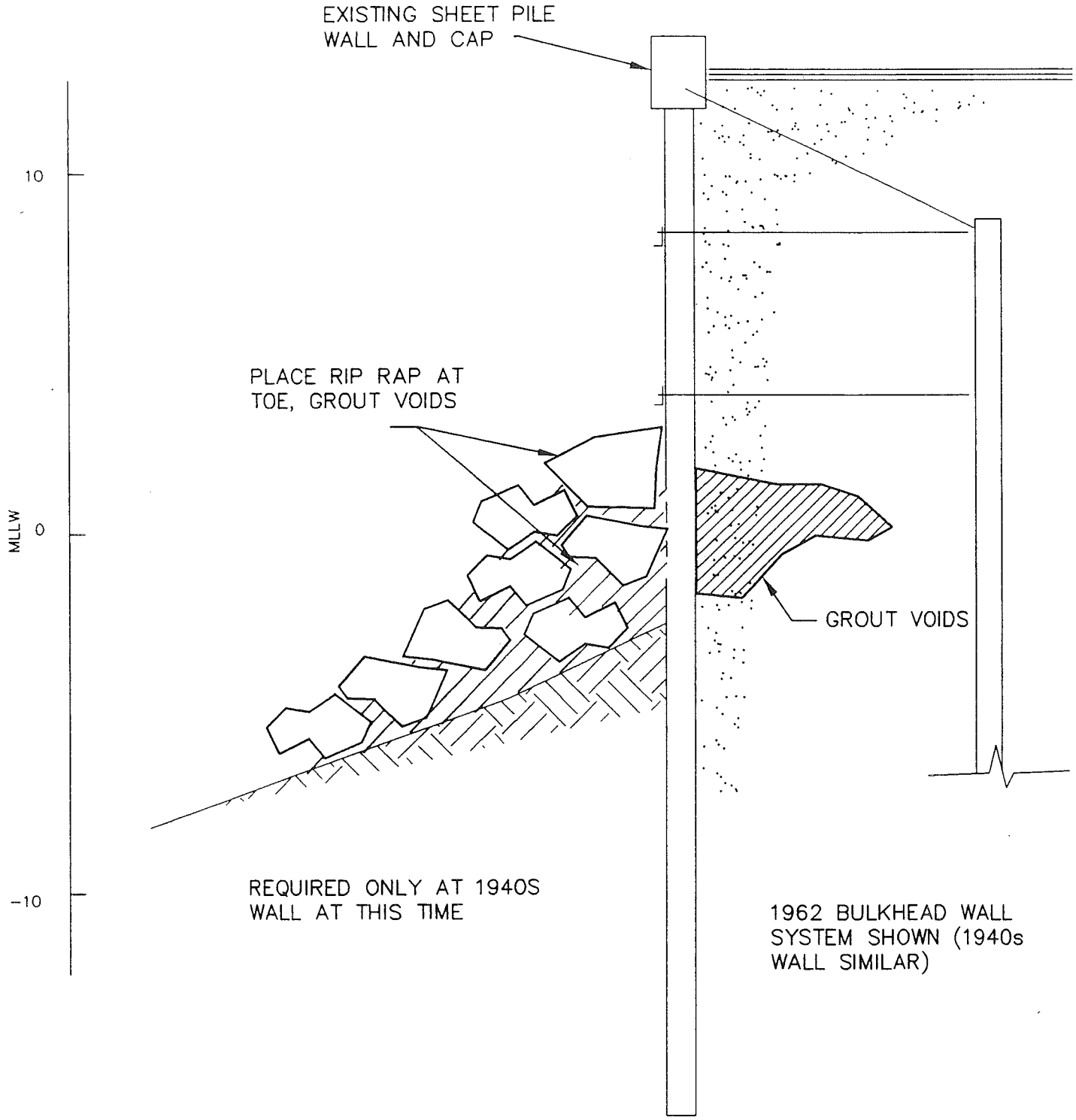

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FIGURE 6 – REPAIR ALTERNATIVE 1, RIP RAP AT TOE

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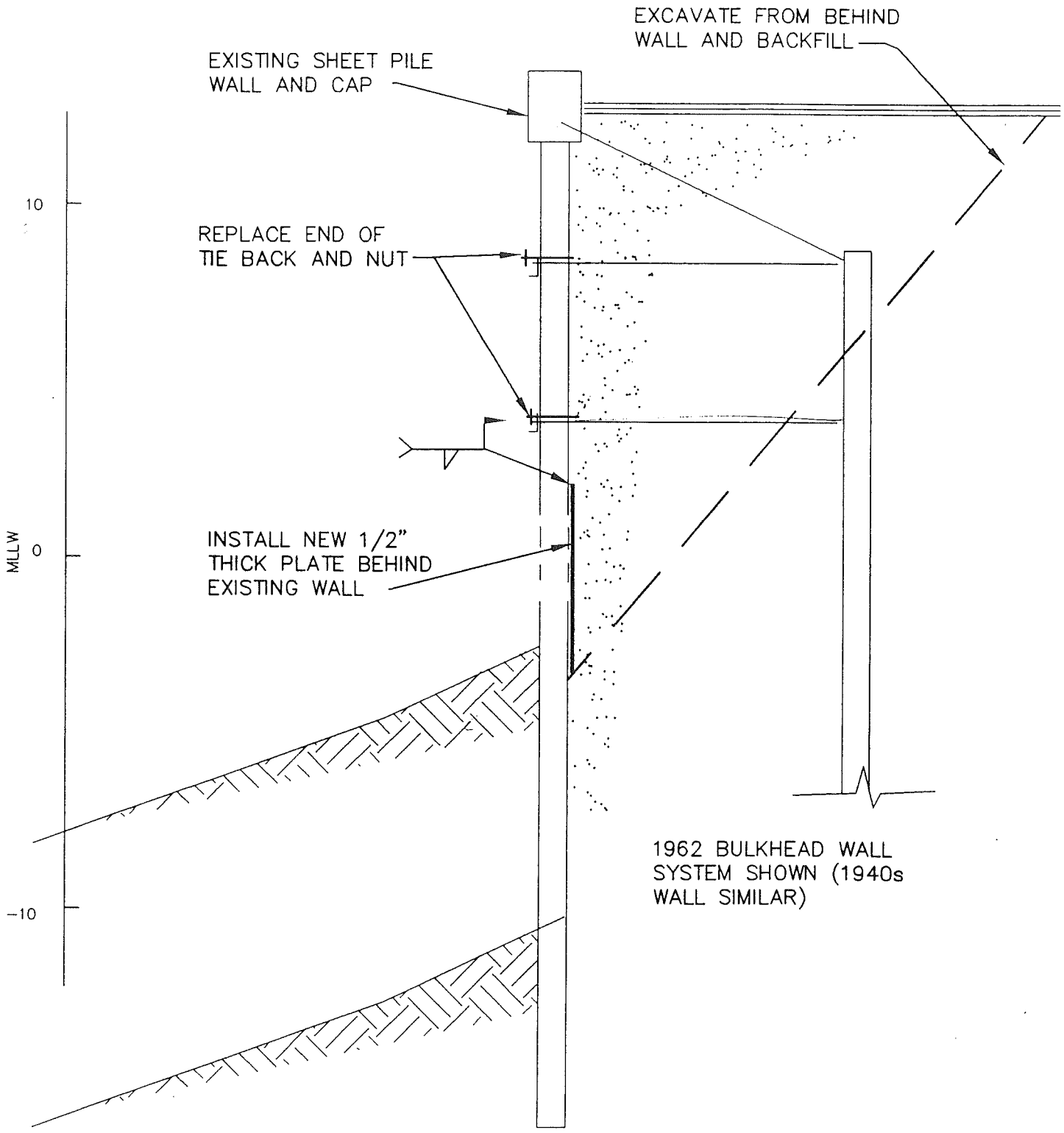

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FIGURE 7 – REPAIR ALTERNATIVE 2, BRIDGE PLATE BEHIND

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leaning of the wall would show localized bowing at the location of the failing tie-rod connection. This would be expected to occur over a period of days or months.

4. ALTERNATIVES AND COSTS

4.1 REPLACEMENT WALL

A new steel or concrete sheet pile wall could be driven a few feet outside of the old wall, and tied into the existing tie-back system (see Figure 5). Although the 1940's wall is in need of replacement sooner then the 1962 wall, there would be a premium to pay for additional mobilization if replacement was done at separate times.

Estimated Construction Cost: $300,000

4.2 REPAIR

Three repair alternatives are discussed below. The purpose of each of these alternatives is to address the weakness in the wall caused by corrosion in the steel plate near the waterline. As noted during the field investigation, the connection of the tie-back system to the steel plate is severely corroded and also needs repair. It is therefore recommended, if the walls are to be repaired, that the attachment of the tie-back system to the wall be repaired regardless of the repair alternative selected.

Replace Corroded Tie-back Nuts. Replace the corroded nuts that are exposed on the ends of the tie rods, this would require cutting off approximately 2 feet from the ends of the tie rods and threading on a new rod, or welding a new rod onto the end of the existing rods.

Estimated Construction Cost:	1940's	$4,000
	1962	$18,000

1. Riprap at Toe/Grout Holes.
   Place riprap at the toe of the 1940's portion of the existing wall (Figure 6) and grout between the stones to halt soil migration from behind the wall. This would require that the floating docks be removed from in front of the wall and that the boat hoist could not be used at this location. Riprap is not required at the 1962 wall at this time, but the holes should be grouted and the condition of the wall monitored regularly.

   Estimated Construction Cost: $32,000

2. Bridge Plate Behind.
   Excavate from behind the wall and place a metal plate to bridge the holes in the existing sheet pile (Figure 7). This should be done on the 1940's wall immediately and could be done as needed on the 1962 wall although as the wall continues to

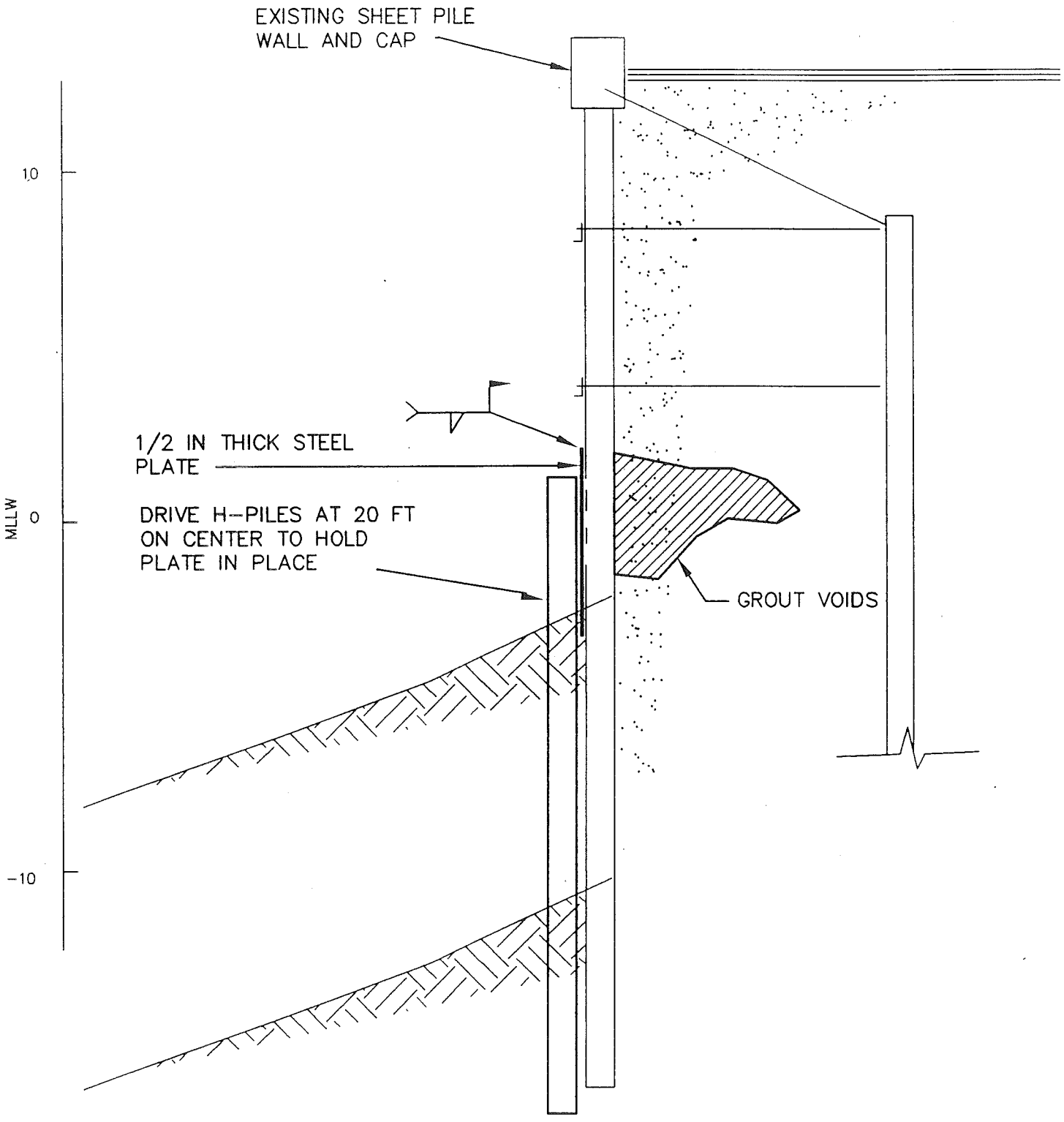

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FIGURE 8 – REPAIR ALTERNATIVE 3, STEEL PLATE IN FRONT

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corrode less material will be available to attach to in the future. If the 1962 wall is not done, the holes should be grouted as in Alternative 1.

Estimated Construction Cost:	1940's only	$35,000
	1940's and 1962	$75,000

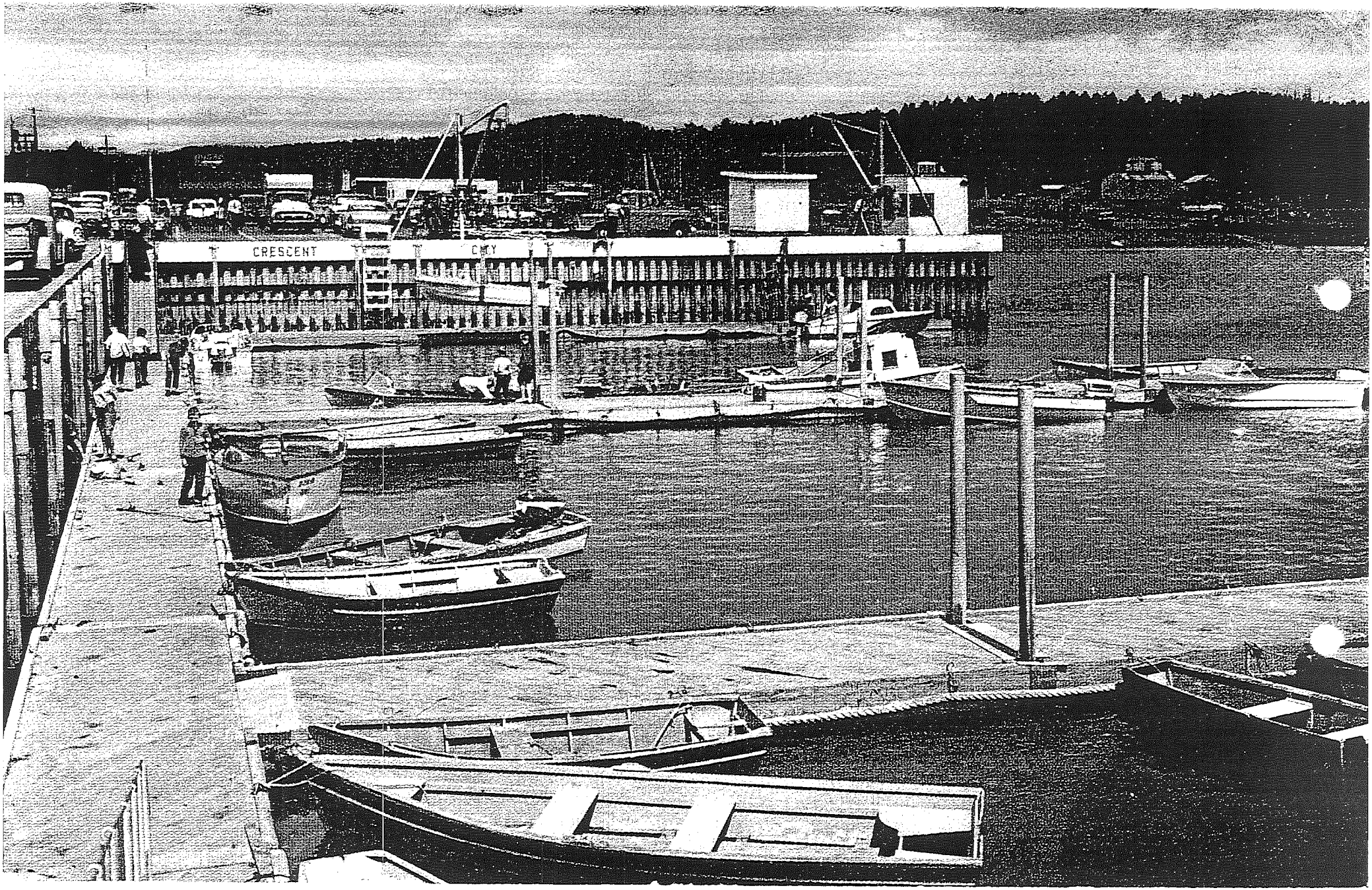
3. Piles and Plate in Front.
   Place a new steel plate on the front of the wall (Figure 8), attached by welding to the wall on the top of the plate. The bottom of the plate will be held in place by new steel piles driven in front of the plates. The existing void spaces behind the sheet piles will be pressure grouted to fill the voids. Because of the cost of mobilization for a pile driver, the entire wall should be done at one time.

Estimated Construction Cost:	1940's and 1962	$68,000

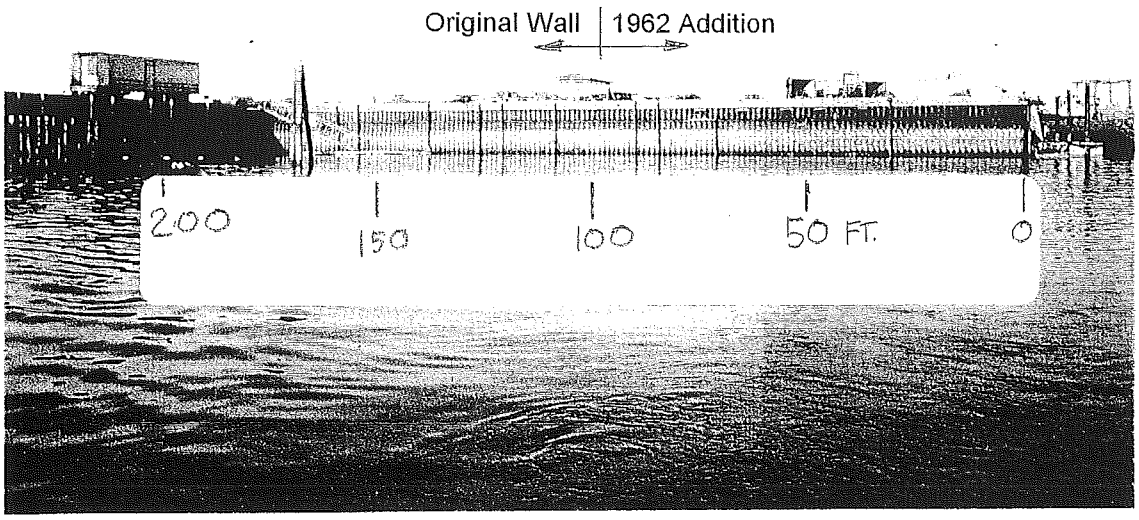
5. RECOMMENDATIONS

The wall is in a deteriorated condition and should be replaced or repaired. If the parking lot and other uses adjacent to the wall are to continue, it is recommended that the wall be replaced. Fifty years is about the maximum life span of a steel sheet pile wall. Any of the repair alternatives considered will add 10-15 years to the life of the existing wall but will not halt the continuing deterioration of other parts of the wall that do not yet show distress or impending failure. Repair will also require increased maintenance costs, although some of the work may possibly be performed by Harbor District Staff. Complete replacement is the least cost option over the expected life of the wall.

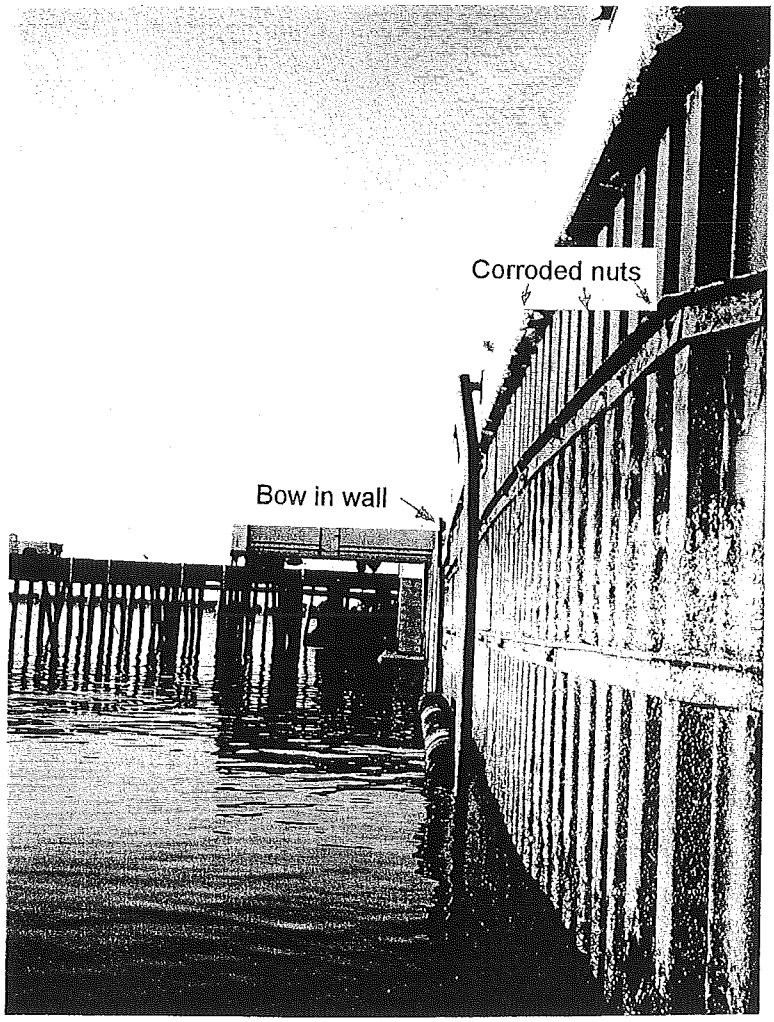
If replacement is not performed in the near future, the Harbor District should monitor the settlement that is occurring behind the wall. Nails were set behind the wall and their elevations were recorded during the field investigation (Figure 3). These should be measured for settlement every 3 months in order to help detect if failure of the wall is impending. The wall face should be examined on a regular basis to observe both the extent of the corrosion and loss of material from behind the wall through the corroded openings.



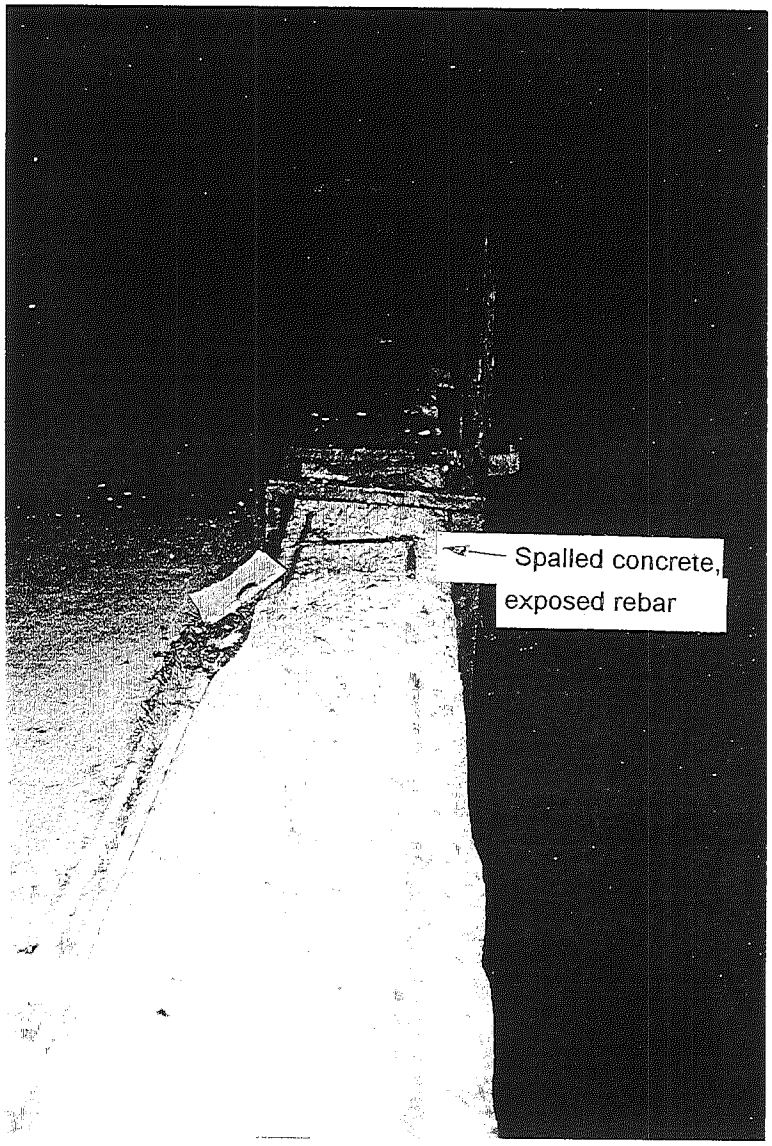
Photograph 1 -- West wall looking east, circa late 1950s



Photograph 2 -- West wall looking east

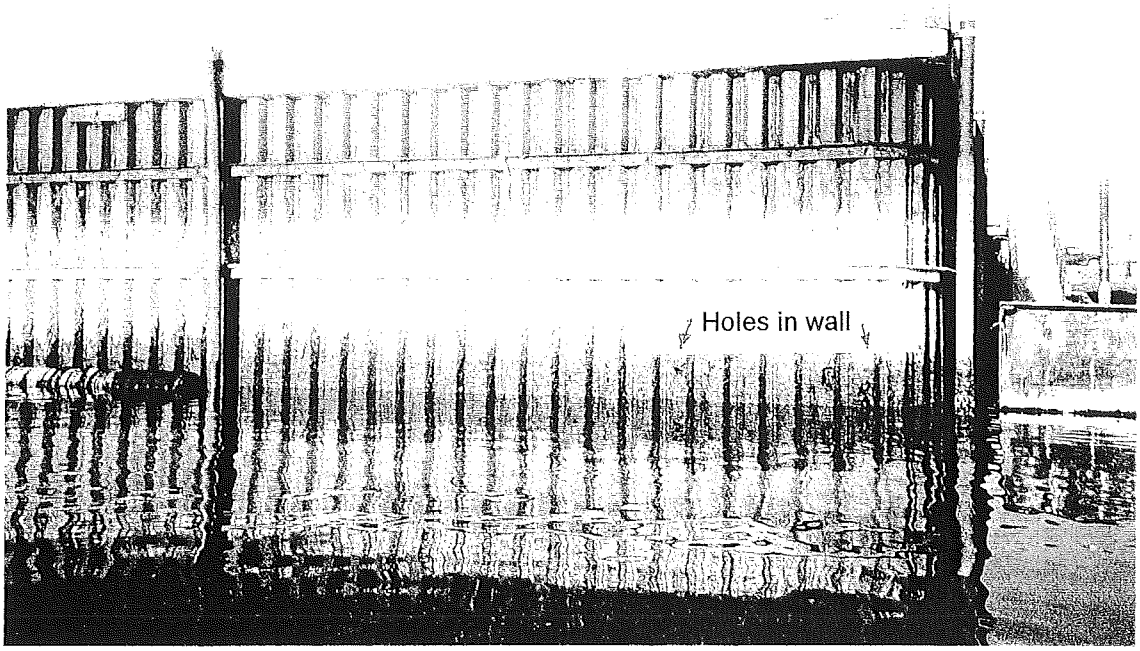


Photograph 3 -- West wall at south end, looking north

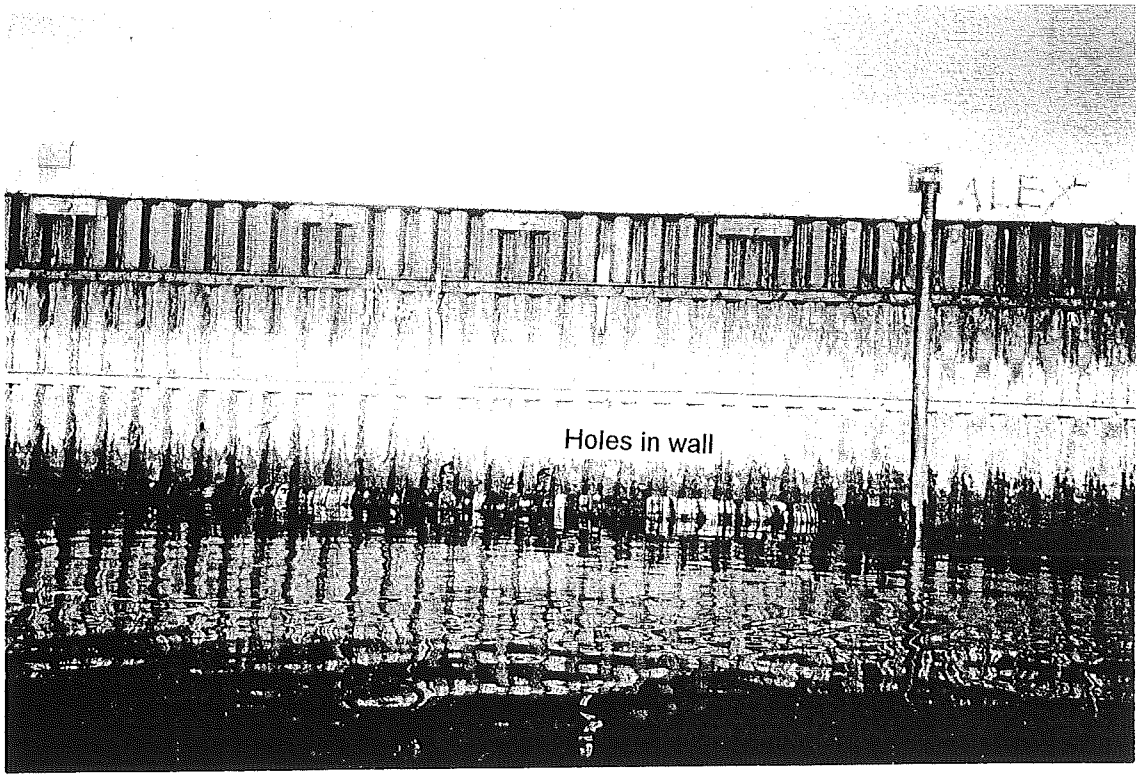


Photograph 4 -- Pile cap west wall, looking south

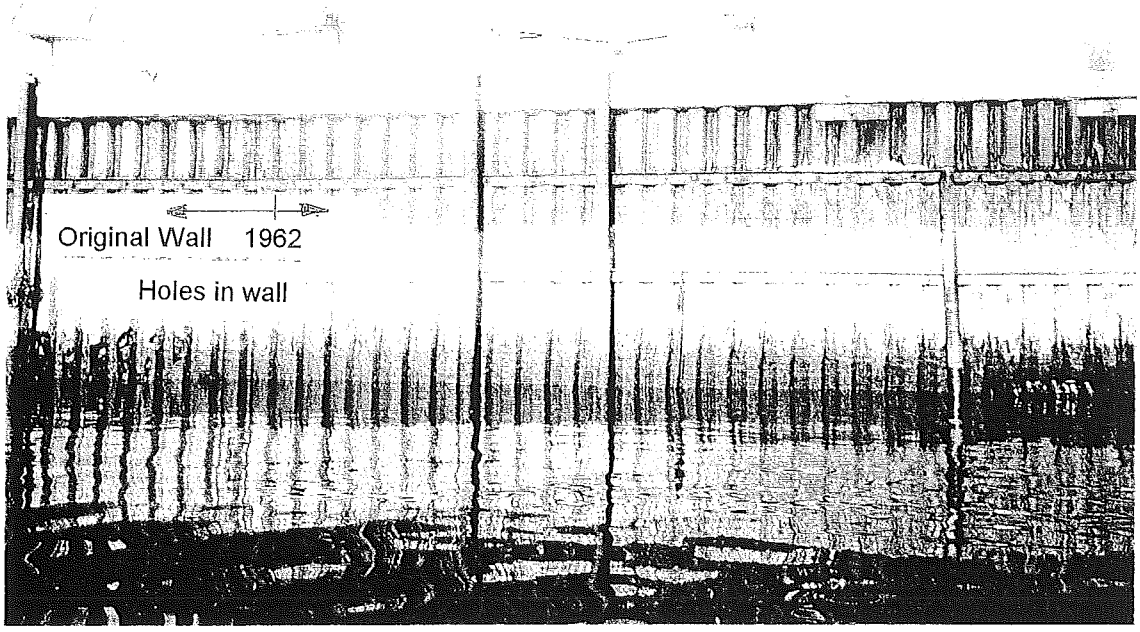
Photograph 5 -- Pile cap west wall, looking north



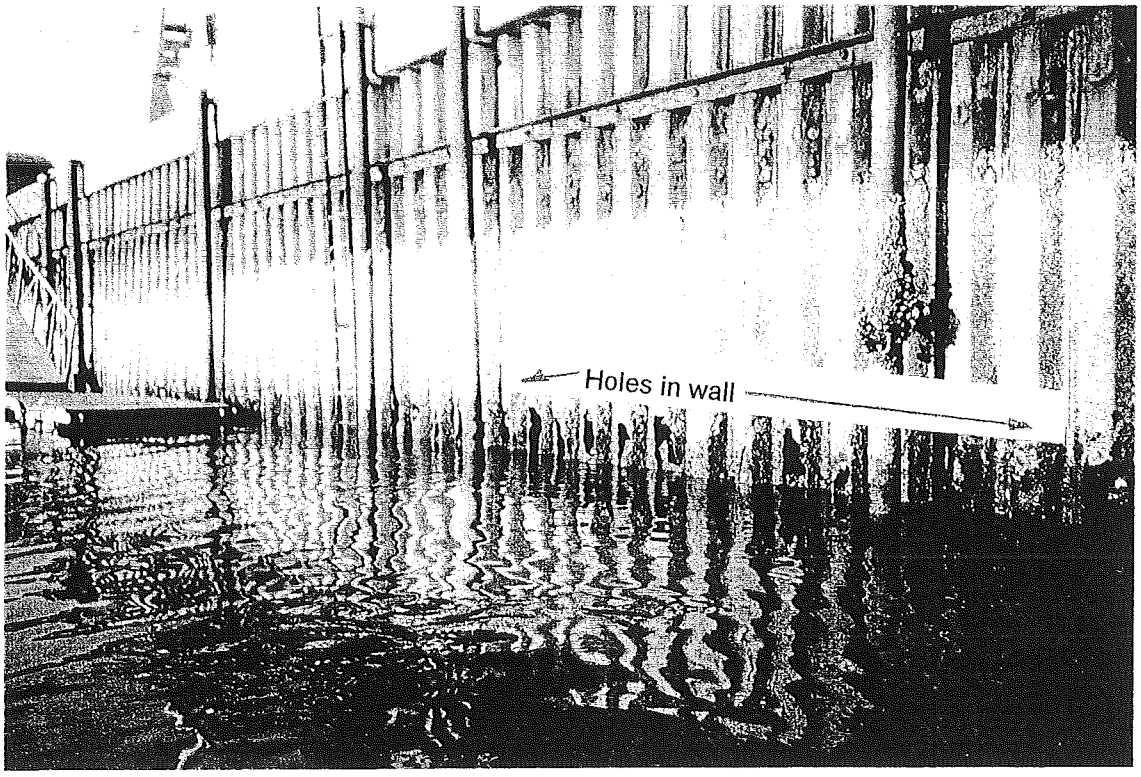
Photograph 6 -- West wall sta. 0-30



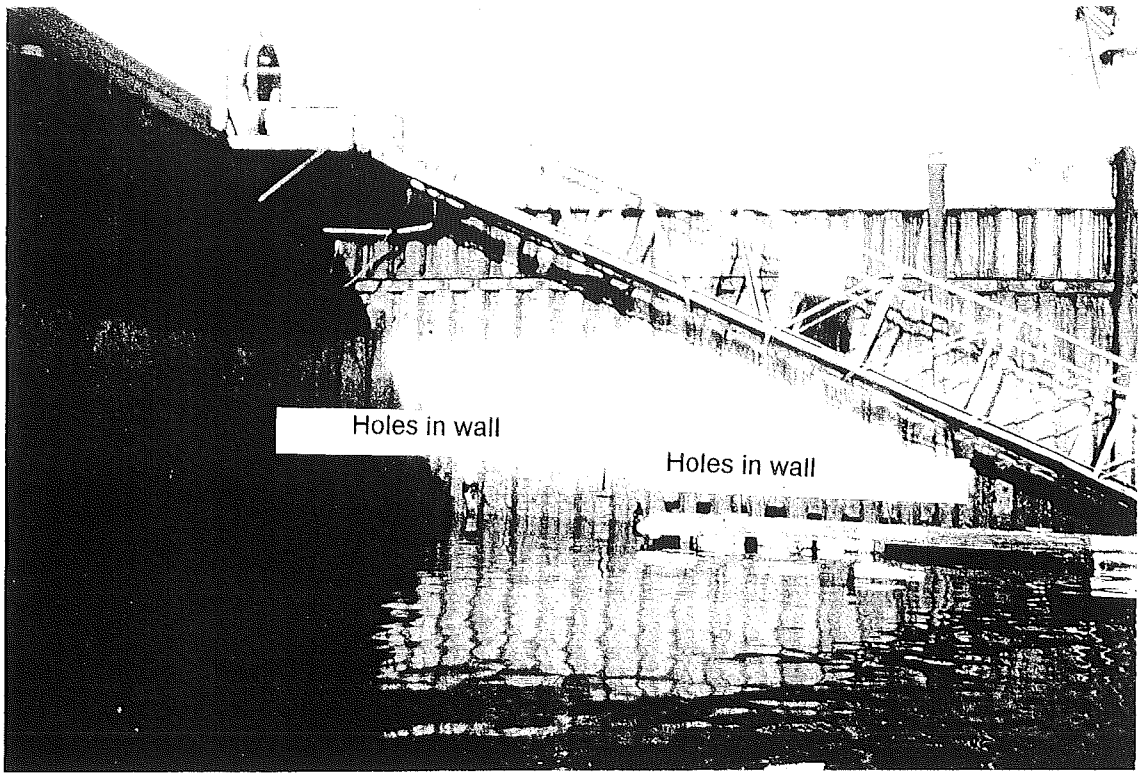
Photograph 7 -- West wall sta. 30-60



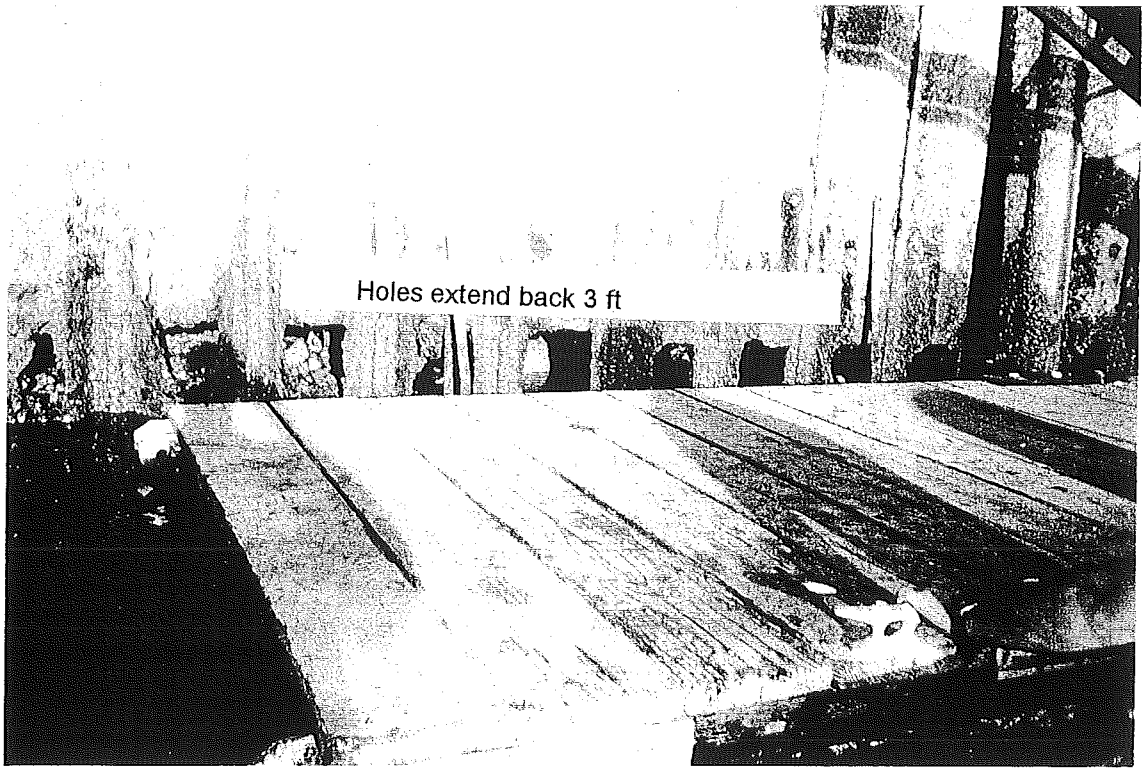
Photograph 8 -- West wall sta. 65 to 110



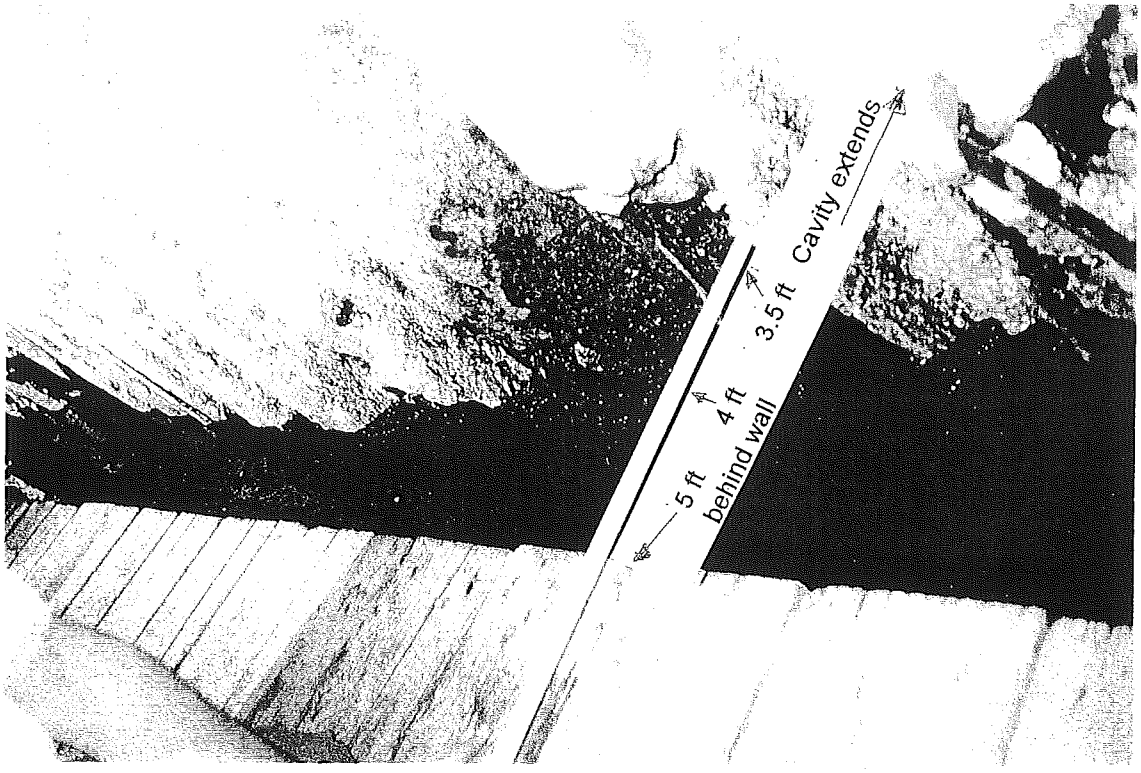
Photograph 9 -- West wall sta. 110-150



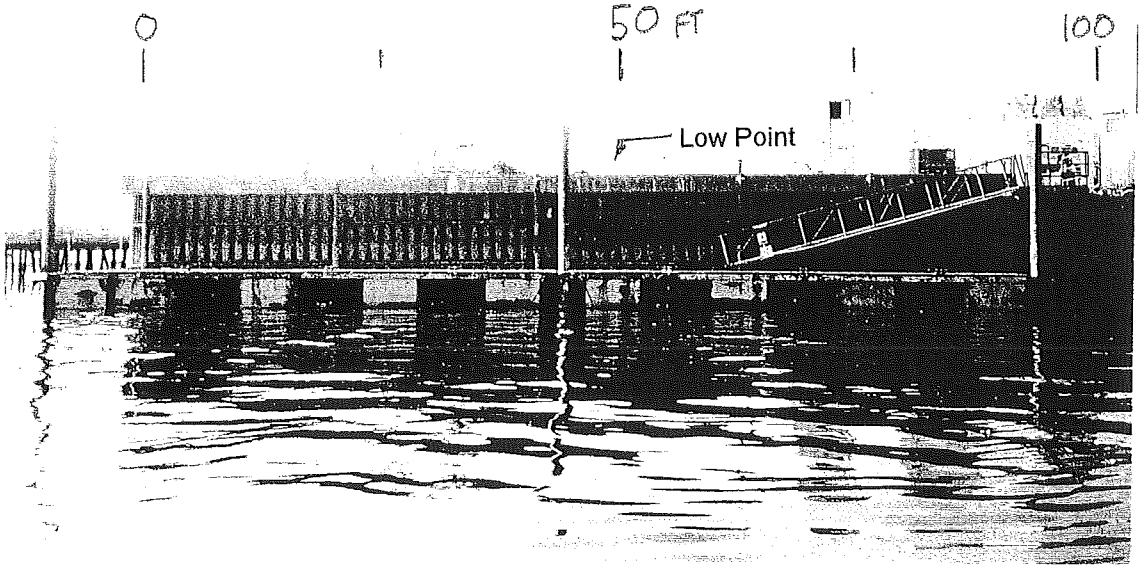
Photograph 10 -- West wall sta. 150 to195



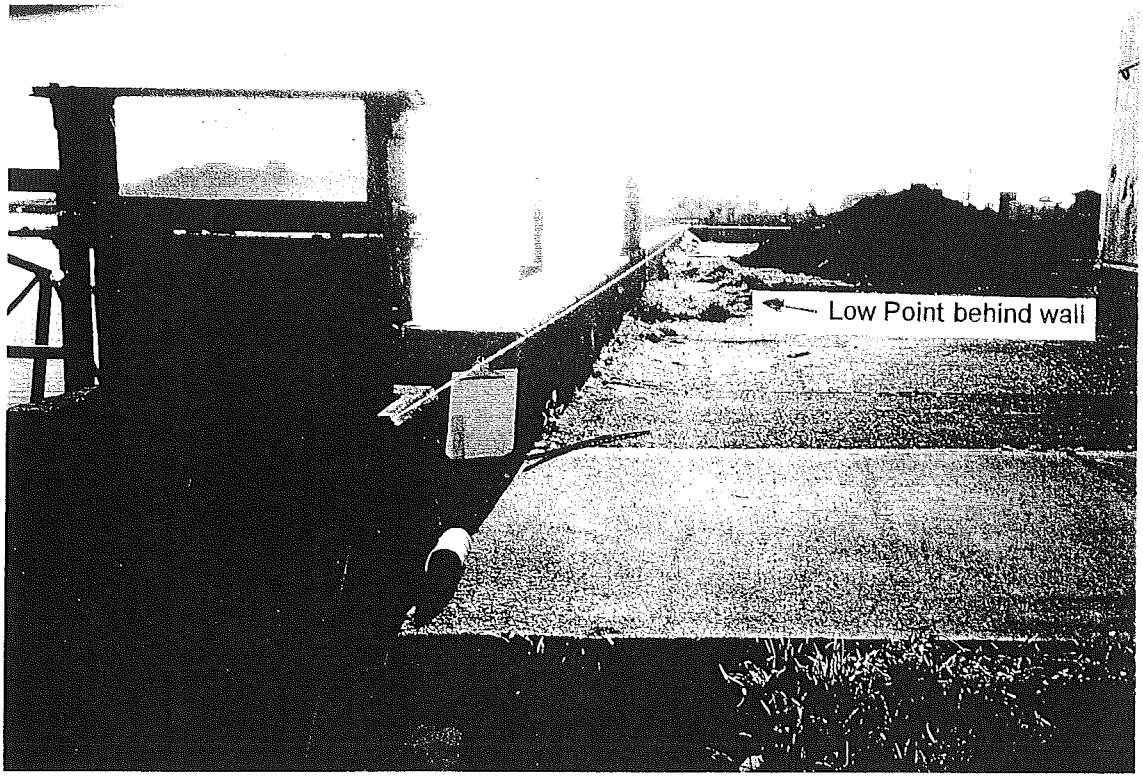
Photograph 11 -- West wall close up at sta. 160



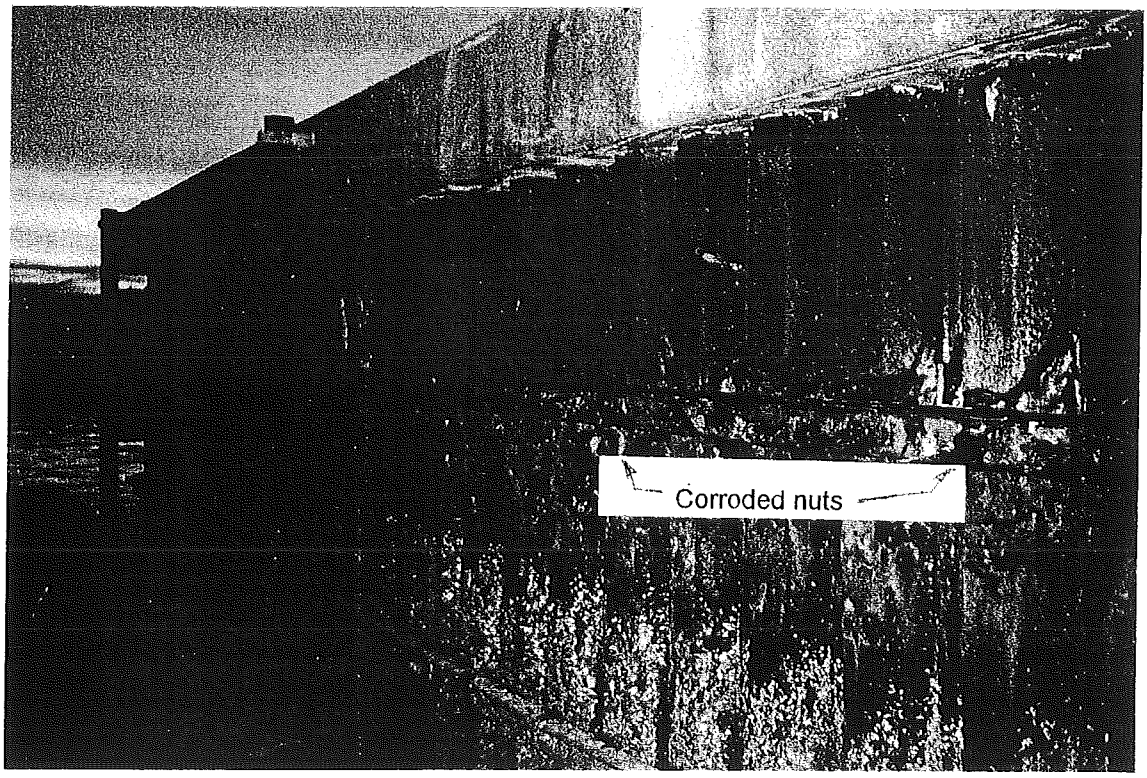
Photograph 12 -- West wall close up at sta. 150



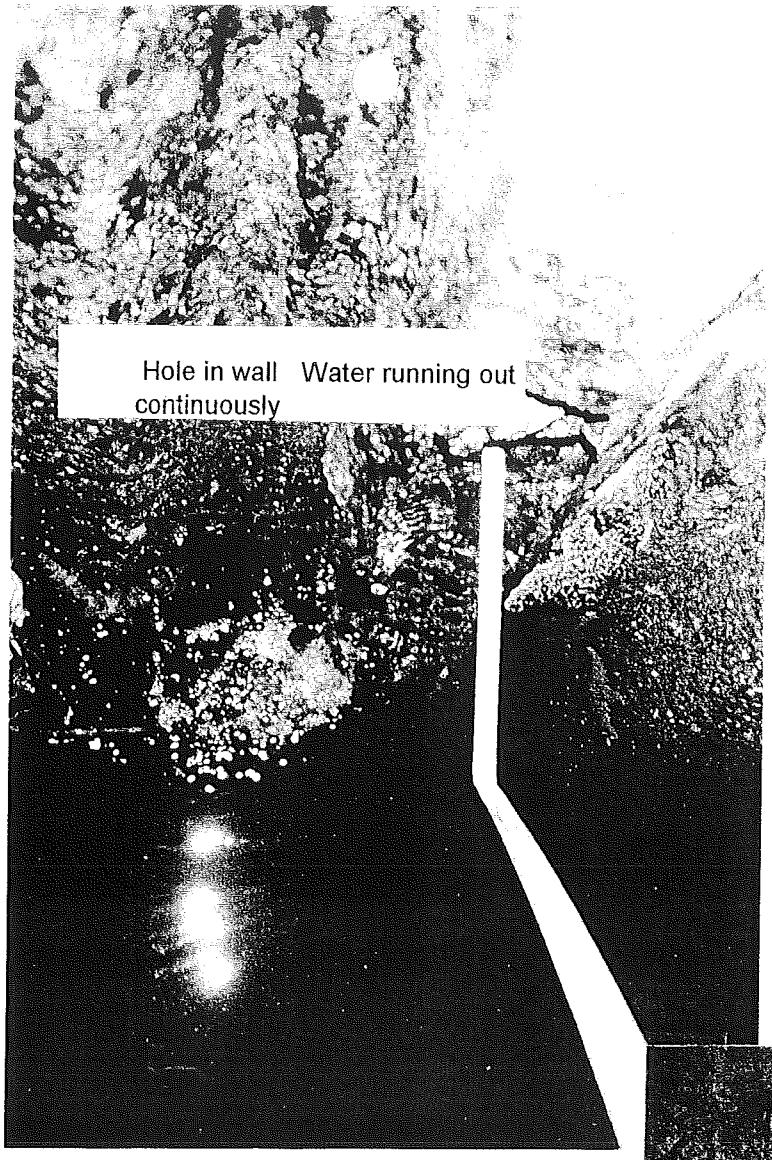
Photograph 13 -- South wall



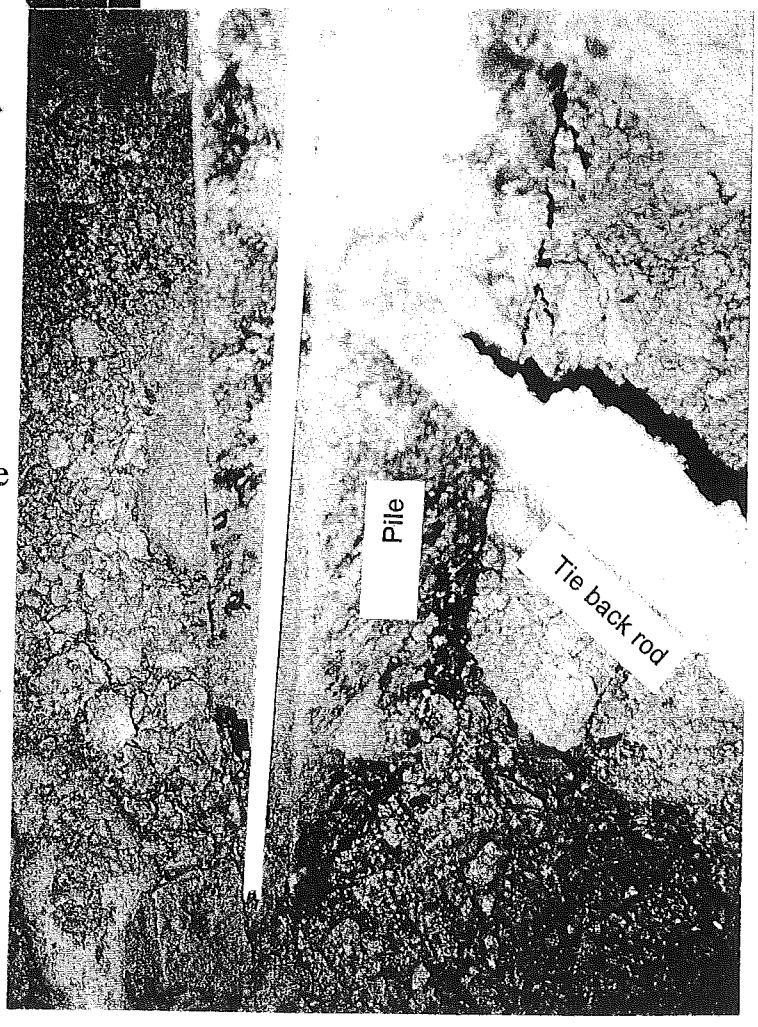
Photograph 14 -- South wall pile cap, looking west



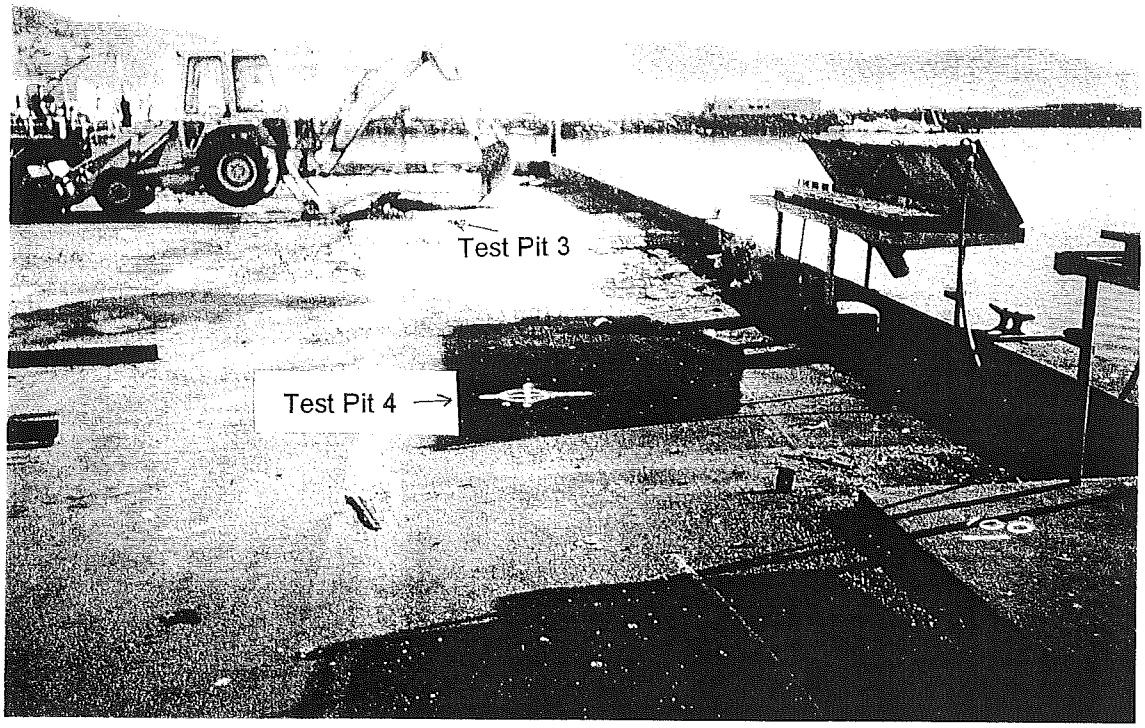
Photograph 15 -- South wall, sta 0 to 30



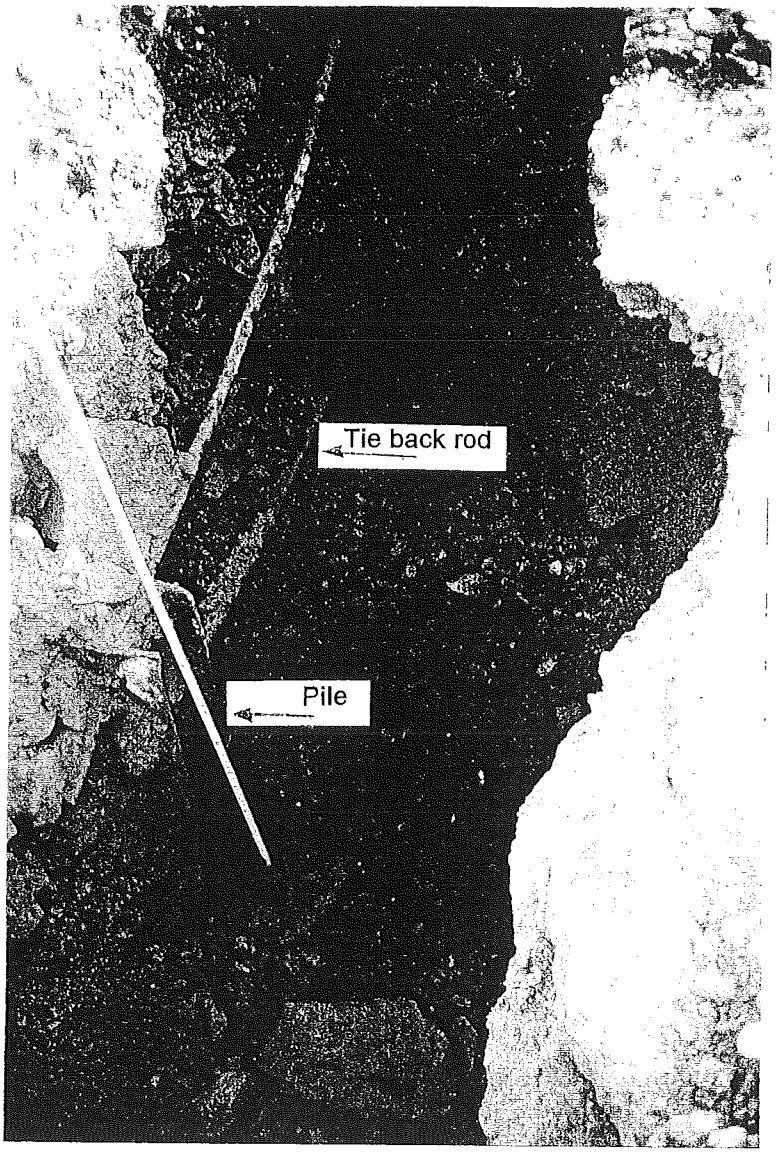
Photograph 16 -- South wall, sta 66



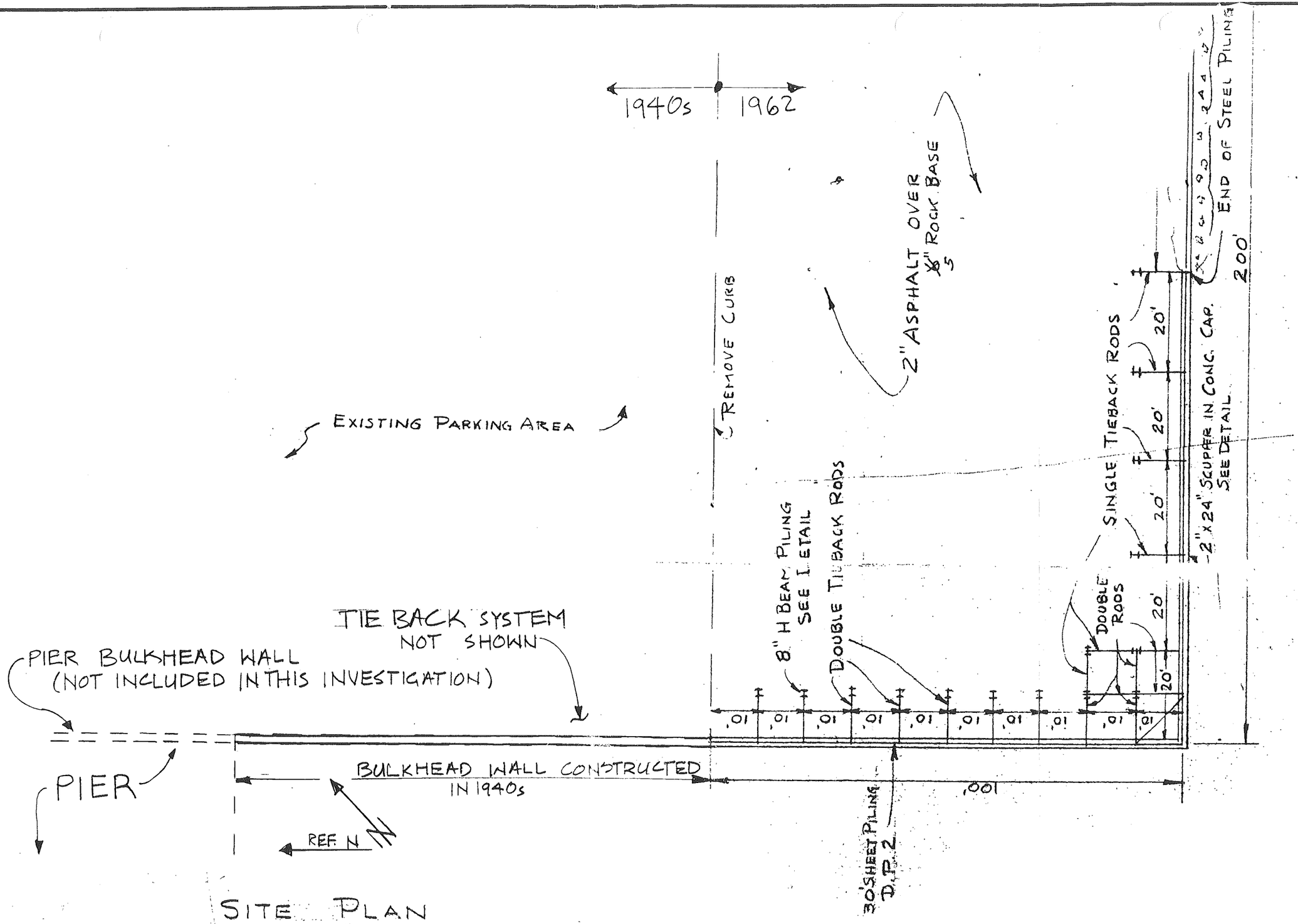
Photograph 17 -- Test Pit 1, tie back and pile



Photograph 18 -- Parking Lot, looking south at Test Pits 4 and 3



Photograph 19 -- Test Pit 1, tie back and pile



SITE PLAN
SCALE 1"=20'

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FIGURE 1 -- SITE PLAN (1962 ADDITION DWG.)

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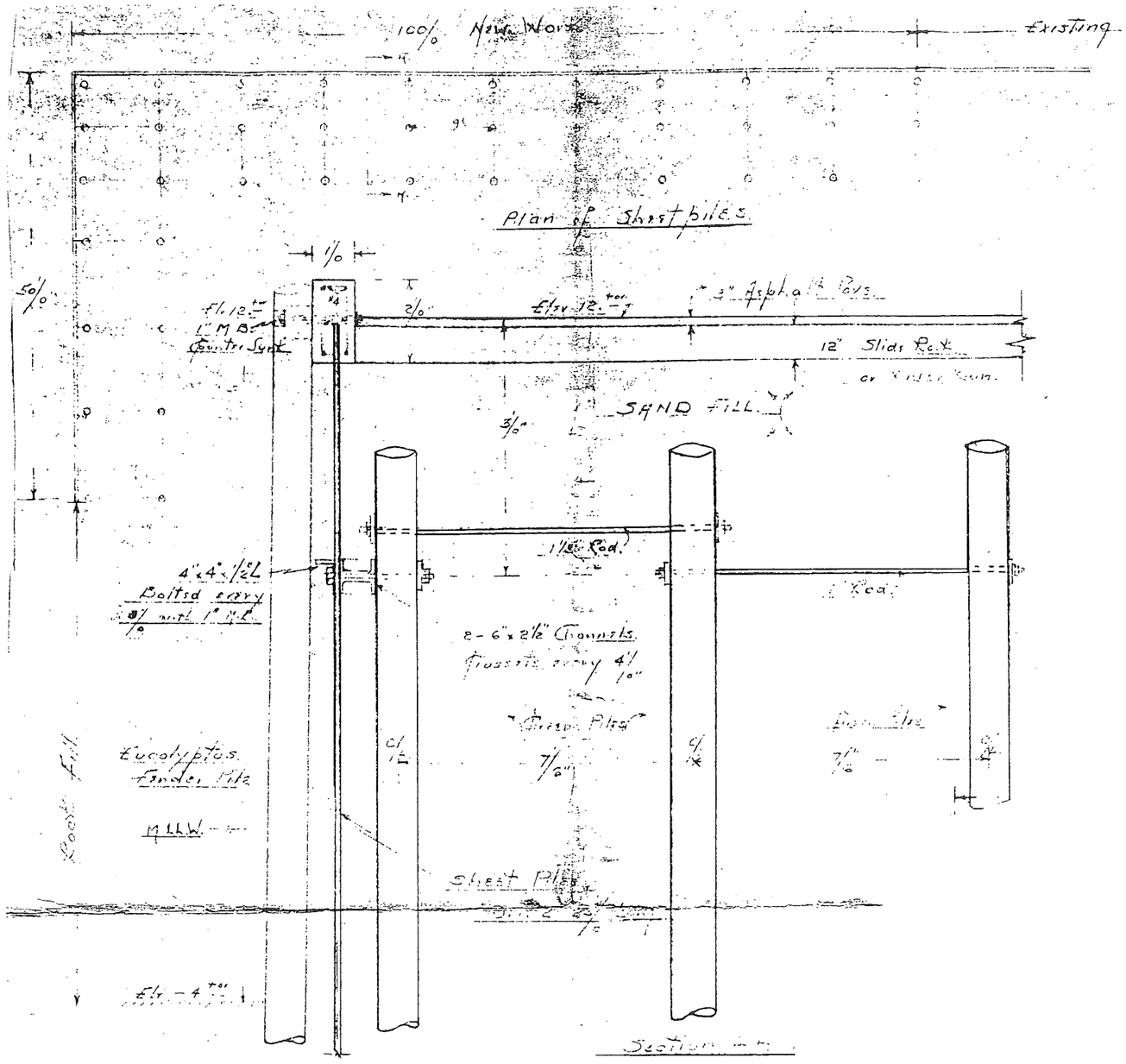
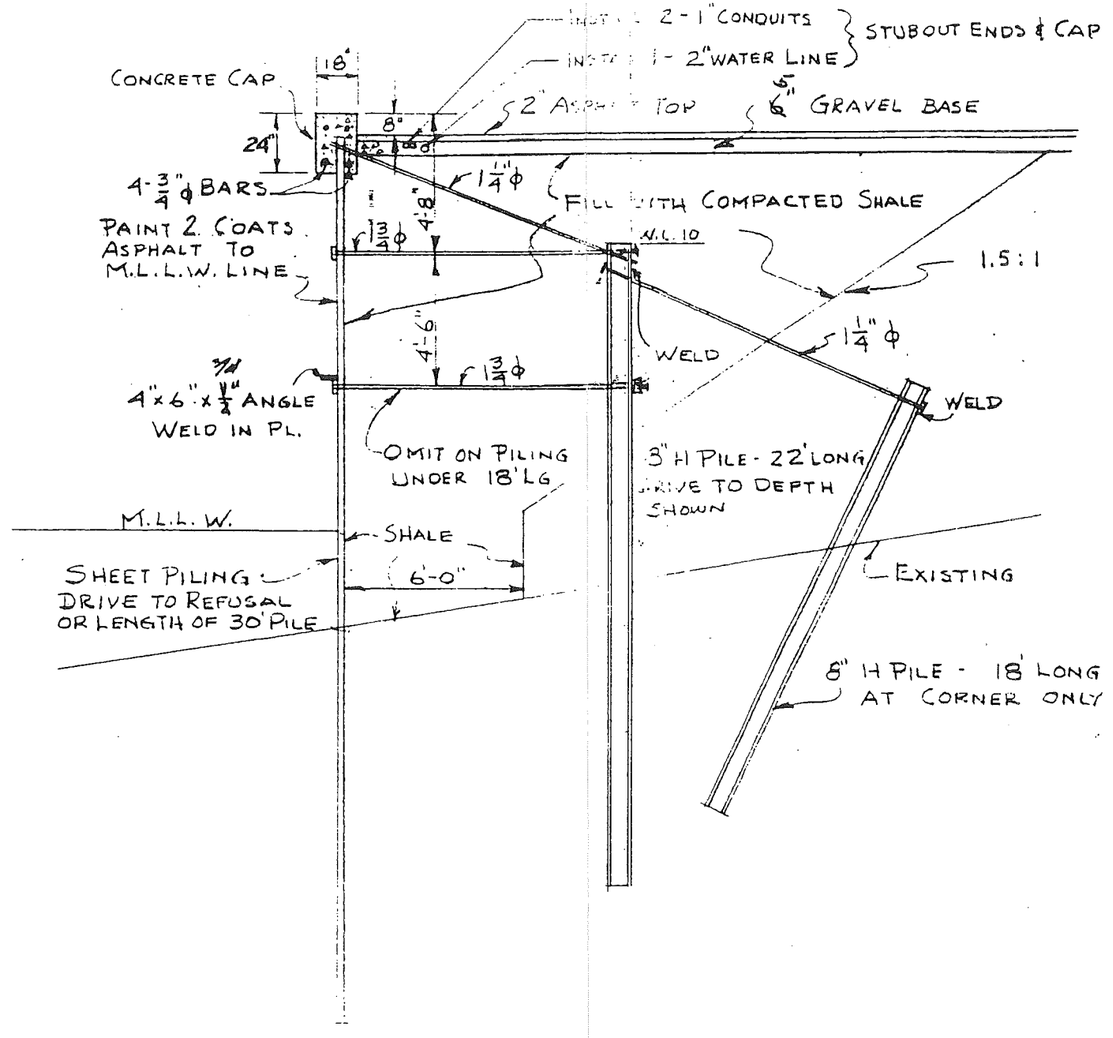


1940'S WALL -- SECTION AND PLAN



1962 WALL -- SECTION

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FIGURE 2 -- TYPICAL BULKHEAD WALL -- 1940'S AND 1962

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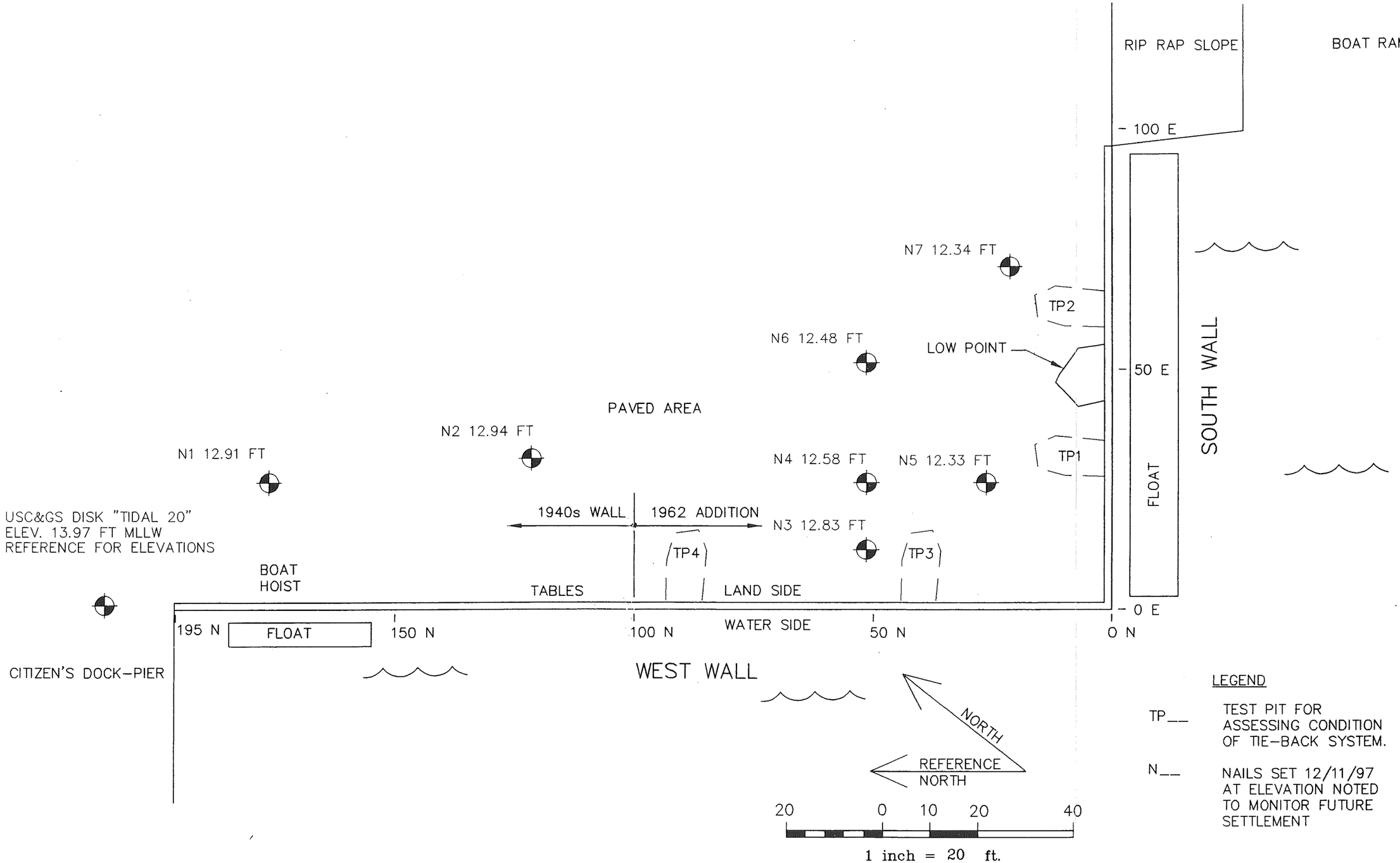

LEGEND

TP___ TEST PIT FOR ASSESSING CONDITION OF TIE–BACK SYSTEM.

N___ NAILS SET 12/11/97 AT ELEVATION NOTED TO MONITOR FUTURE SETTLEMENT

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FIGURE 3 --SITE PLAN

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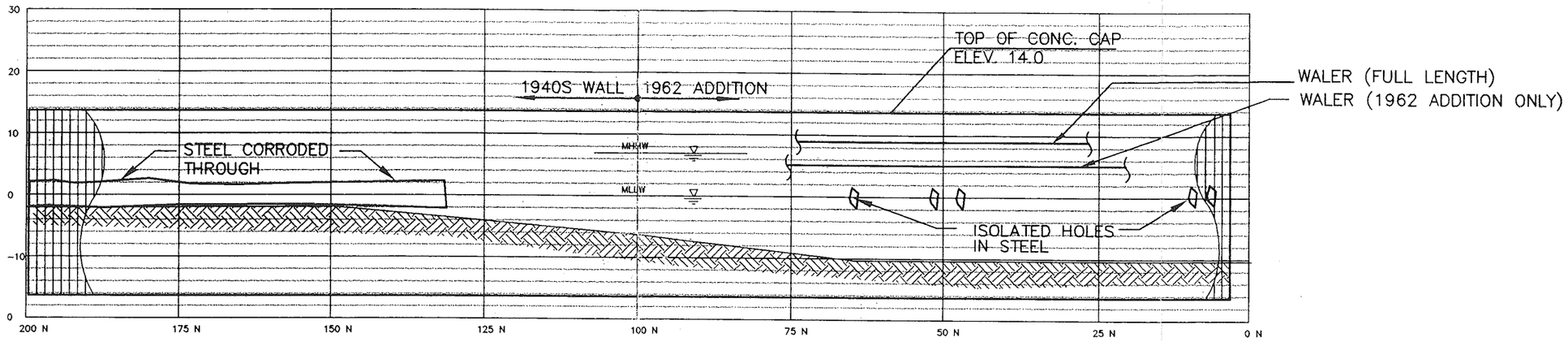
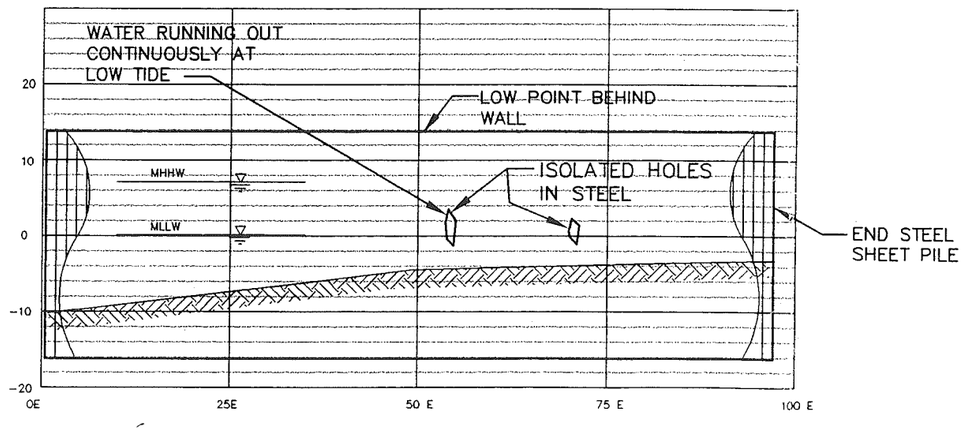


WEST WALL – ELEVATION



SOUTH WALL – ELEVATION

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FIGURE 4 -- EXISTING ELEVATIONS

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