GOWANUS CANAL PRELIMINARY BULKHEAD STUDY
BROOKLYN, KINGS COUNTY, NEW YORK

prepared for

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and

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1.0 TYPOLOGY OF BULKHEAD CONSTRUCTION

The purposes of this document are to identify the types of bulkheads that line the Gowanus Canal in Brooklyn, New York (Figure 1), to evaluate the historic significance and integrity of each of these types of bulkheads, and to recommend possible treatment strategies for historically significant bulkheads. The study was carried out in compliance with Section 106 of the National Register Preservation Act in conjunction with this EPA directed CERCLA (Superfund) action. In the case that repair of deteriorated bulkheads appears infeasible, mitigation recommendations have been made. As specified in the scope of work for this investigation, little original research was conducted. Instead, most of the information in this document was gathered from information in two previous studies: Hunter Research, Inc. (HRI)'s *National Register of Historic Places Eligibility Evaluation and Cultural Resources Assessment for the Gowanus Canal* (HRI 2004) and Adam Brown's *Gowanus Canal: Bulkhead Inventory Survey* (Brown 2000).

1.1 DEFINITION OF A BULKHEAD

In general terms, a bulkhead is a structure erected to prevent the bank of a waterway from collapsing into the waterway. As indicated in the *Design of Coastal Revetments, Seawalls and Bulkheads*, issued by the U.S. Army Corps of Engineers:

> The terms *bulkhead* and *seawall* are often used interchangeably. However, a bulkhead is primarily intended to retain or prevent sliding of the land, while protecting the upland area against wave action is of secondary importance. Seawalls, on the other hand, are more massive structures whose primary purpose is interception of waves. Bulkheads may be either cantilevered or anchored (like sheetpiling) or gravity structures (such as rock-filled timber cribs). Their use is limited to those areas where wave action can be resisted by such materials (USACE 1995:1-1).

Over time, a variety of materials and construction techniques have been employed for river and canal bulkheads including timber cribs, timber piles, wood sheet piling, and steel sheet piling.

1.2 HISTORY OF BULKHEAD CONSTRUCTION ON THE GOWANUS CANAL

Although precise information about bulkhead planning and installation on the Gowanus Canal is minimal, HRI was able to assemble significant amounts of information concerning the sequence of bulkhead construction in their 2004 report.

The Gowanus Canal, as initially planned in the 1840s, was viewed as a possible solution to the lack of adequate drainage for sewage and stormwater of the rapidly growing city. In addition, the filling of the Gowanus marshes would provide additional available land for development. The initial plans for the canal were developed by Major David B. Douglass, a West Point-trained engineer who had earlier worked on New Jersey's Morris Canal.

A year after Douglass made his proposals, Daniel Richards, one of the city's most prominent landowners and real estate developers, presented a plan to City Council which would drain the Gowanus meadows and allow them to be filled. Developed in collaboration with the City Surveyor, Willard Dey, Richards's plan called for a 5,400-foot-long, 100-foot-canal, approximately 14 feet deep excavated to five feet below mean water with walls at four feet above mean high water.

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Figure 1. Project location. Detail of *Jersey City, N.J.-N.Y.* and *Brooklyn, N.Y.* 7.5-minute quadrangles (USGS 1981 and 1995).

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In order to avoid the expense of cribwork, Richards apparently proposed timber sheet piling to retain the vertical canal banks. When initial construction had been completed in 1854, the waterway lacked finished walls in most places or was lined with timber sheet piling unable to withstand stormwater washing mud into the canal (HRI 2004:40).

The initial major improvements for the canal took place between 1866 and 1870 under the auspices of the Gowanus Canal Improvement Commission. HRI described the types of bulkhead construction employed:

> At least inshore of Hamilton Avenue, the commission built canal walls where none existed previously or were not being built by private interests. Some landowners such as Edwin Litchfield built cribwork walls along their own frontages, often using these walls to fill extensive areas away from the canal....Existing conditions strongly suggest that the commission walls built 1866-1870 were also cribwork, based in part on the poor performance of sheet pile structure in the marsh environment (HRI 2004:42).

1.3 TYPES OF BULKHEADS ON THE GOWANUS CANAL

Three major types of bulkheads are present along the Gowanus Canal:

- Timber cribwork. In many areas the upper section is deteriorated, replaced with concrete and/or covered with rip-rap.

- Concrete bulkheads or relieving platforms, including five bridge abutments.

- Sheet piling of timber or steel.

1.3.1 Timber Crib Bulkheads

The earliest examples of this type consisted of a few rough logs laid along the water's edge with earth and sand filling behind them. Later cribs were constructed of rough logs, notched at the junction to form a rectangular framing, weighted with stones to sink it to the bottom, the filling being rock, earth and sand. As the crib sank in the subsoil additional logs were placed, building it up to the proper height.

HRI described a standardized mid-nineteenth century timber crib bulkhead:

> Cribwork construction of the mid-nineteenth century and later involved spiking together logs in alternating perpendicular rows forming square or rectangular cells. Arranged in lines or grids, these cells commonly measured five to eight feet on a side, and from about seven to eight feet in height. Empty cribwork units could be floated into place and sunk as fill was added. Some cells, probably at the bottom of cell units, had plank flooring to hold enough material to sink the structure; builders added more fill once the cells were in place to form a solid bulkhead. Cribwork often reached to between 20 and 25 feet below mean low water, and extended to about 10 feet above this elevation. In section, cribs below mean low water typically extended to widths of 20 to 25 feet, sometimes tapering in the exterior or both faces as they rose. Above mean low water, crib widths in section narrowed to about fifteen feet....Square timbers, spiked or bolted together in a smooth, continuous face and fitted into notch cribwork logs, formed the outer face of the bulkhead above mean low water in most cases….The upper horizontal surface of the bulkhead varied from packed earth to timber to stone (HRI 2004:72).

The turn-of-the-twentieth century crib was made of squared timbers, halved together at the corners and splices, the successive corners held together with drift bolts. Mooring piles and string pieces were provided and a deck of six-inch planks was usually added.

The timber crib bulkhead was recommended where timber was cheap and a hard clay or gravel bottom could be found at a reasonable depth. The estimated lifespan of crib bulkheads was 50 to 75 years (Orrock 1910:161). According to a 1905 report, the Department of Docks of the City of New York had constructed about 17,550 linear feet of crib bulkhead (Hoag 1905:107).

By the early twentieth century, opinion at the New York Dock Department had turned against the timber crib:

> Of all the structures with which the Department has had to deal, the most uncertain and unsatisfactory are crib bulkheads. No one can afford to predict their behavior; they may bulge on the face; they may retain a constant profile but bulge for line; they may even show an inshore movement at times; they may settle and they may not (Hoag 1905:105).

Based upon his field investigations, marine diver Adam Brown subdivided the types of timber crib bulkheads found on the Gowanus Canal: general timber crib (Type 1; Figure 2); crib with mass concrete for the upper three to five feet (Type 2; Figure 3); crib with concrete blocks for the upper three to five feet (Type 3; Figure 4); crib with vertical timber facing (Type 4; Figure 5); crib with fender piles along face (Type 5; Figure 6); crib with steel strap tiebacks (Type 6; Figure 7); and crib with concrete bulkhead wall (Type 7; Figure 8).

By far the most common of these types observed by Adam Brown was the general timber crib which, in 2000, represented 44.5 percent of the total bulkhead length. Second most common was the crib with mass concrete for the upper three to five feet (Type 2) which accounted for 18.2 percent of the total bulkhead length. The remaining types represented from 0.6 to 5.6 percent of the total bulkhead length. Many of the types of timber crib bulkheads may represent attempts to maintain deteriorating bulkheads. For example, the mass concrete or concrete blocks may have been employed to either cover or replace the original, then deteriorated timber superstructure, as may be the use of vertical timber facing or fender piles. Steel strap tiebacks may have been used, as they are with sheetpile walls, to anchor the wall to the adjacent bank to prevent shifting.

HRI indicated that in the early twentieth century, concrete bulkheads were appended to older cribwork and that the new work generally extended beyond the old a distance of about 20 feet (HRI 2004:74).

1.3.2 Timber Pile Bulkheads

Timber crib bulkheads were appropriate where there was a firm surface upon which the crib could be set. Where, as in many locations in the former Gowanus marshes, the waterway bottom was sandy or silty or bedrock or clay were located more than 25 feet below mean low water, timber pile-driven bulkheads were the norm.

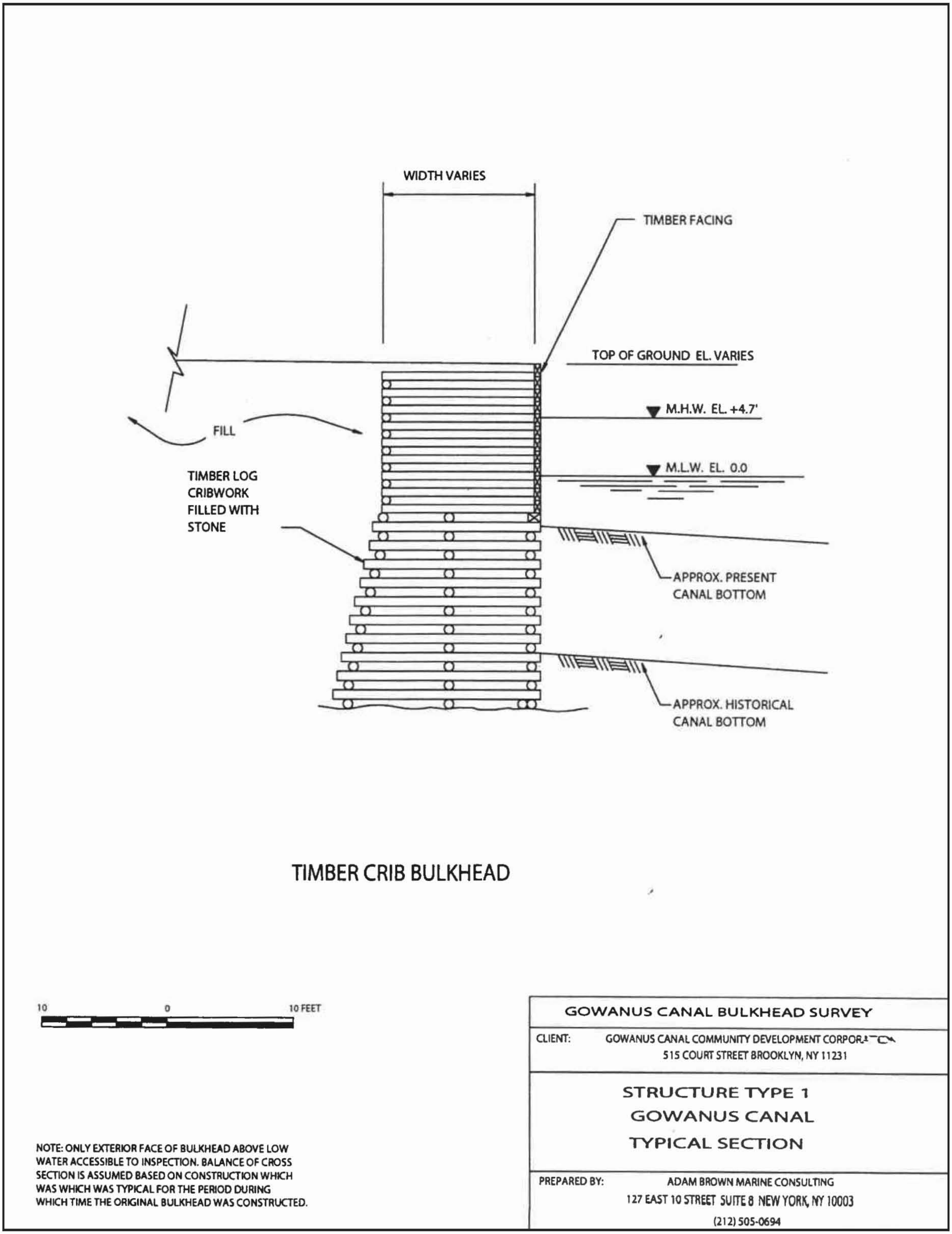


Figure 2. Typical section of timber crib bulkhead, Gowanus Canal (Brown 2000). Used by permission.

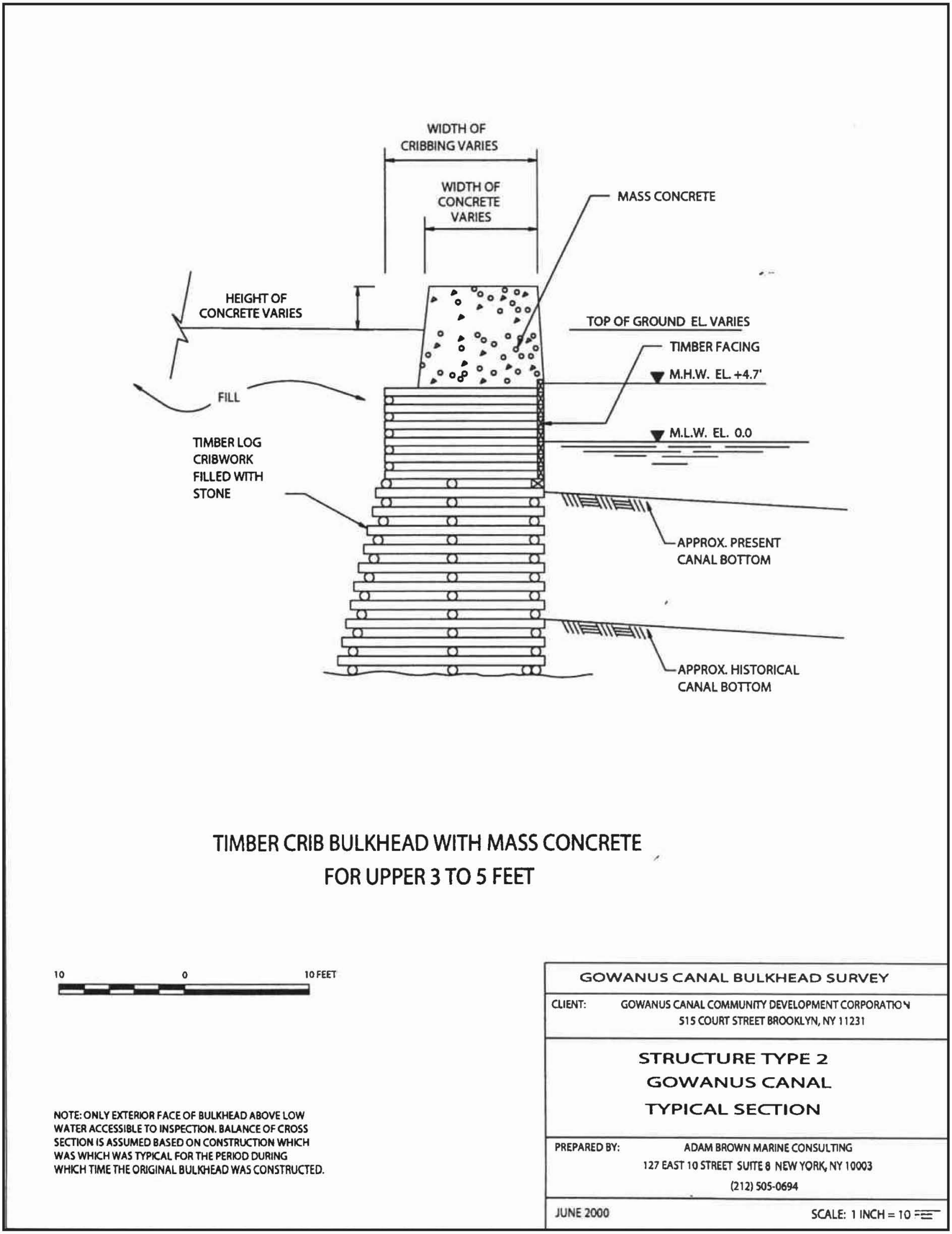


Figure 3. Typical section of timber crib bulkhead with mass concrete for upper 3 to 5 feet (Brown 2000). Used by permission.

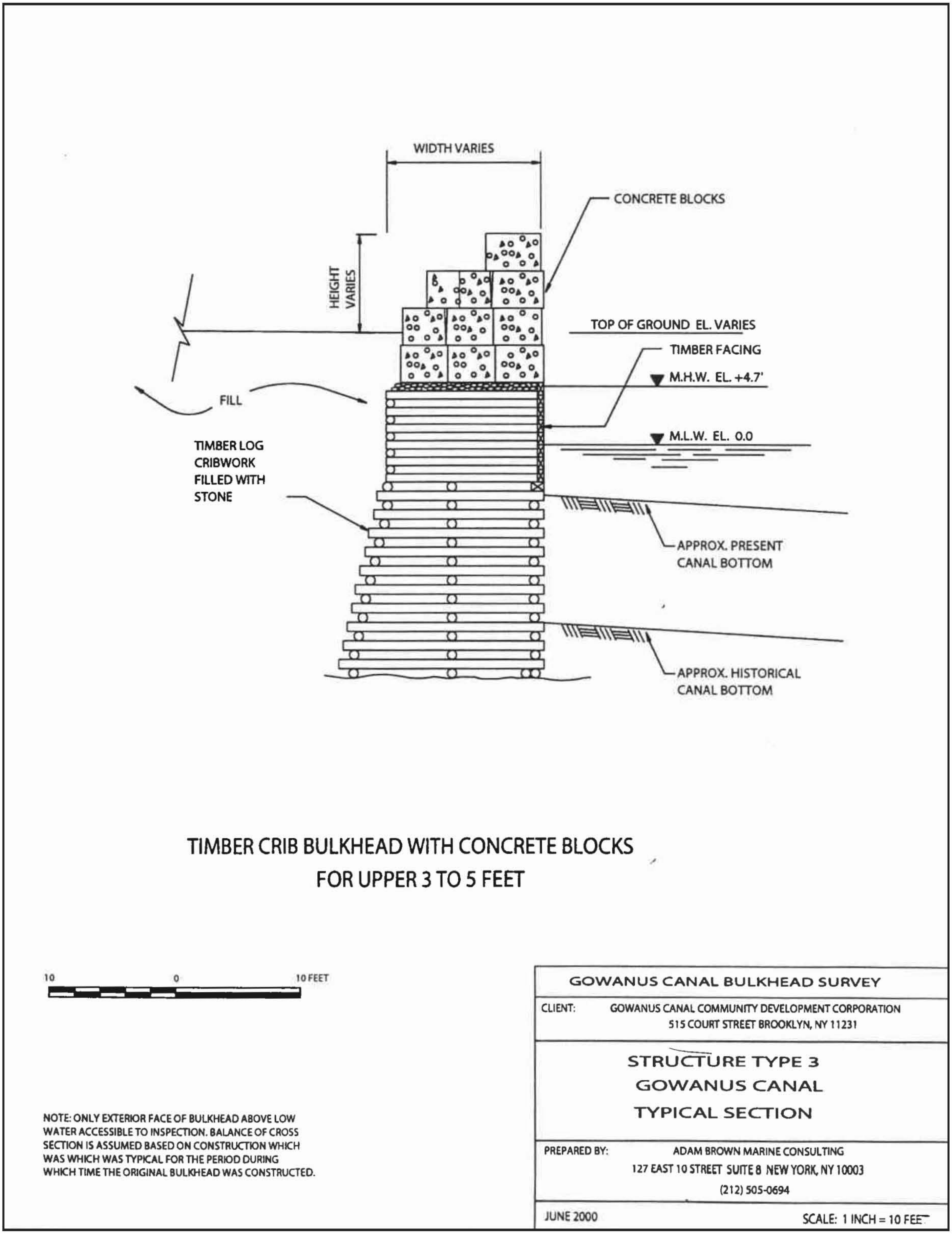


Figure 4. Typical section of timber crib bulkhead with concrete blocks for upper 3 to 5 feet (Brown 2000). Used by permission.

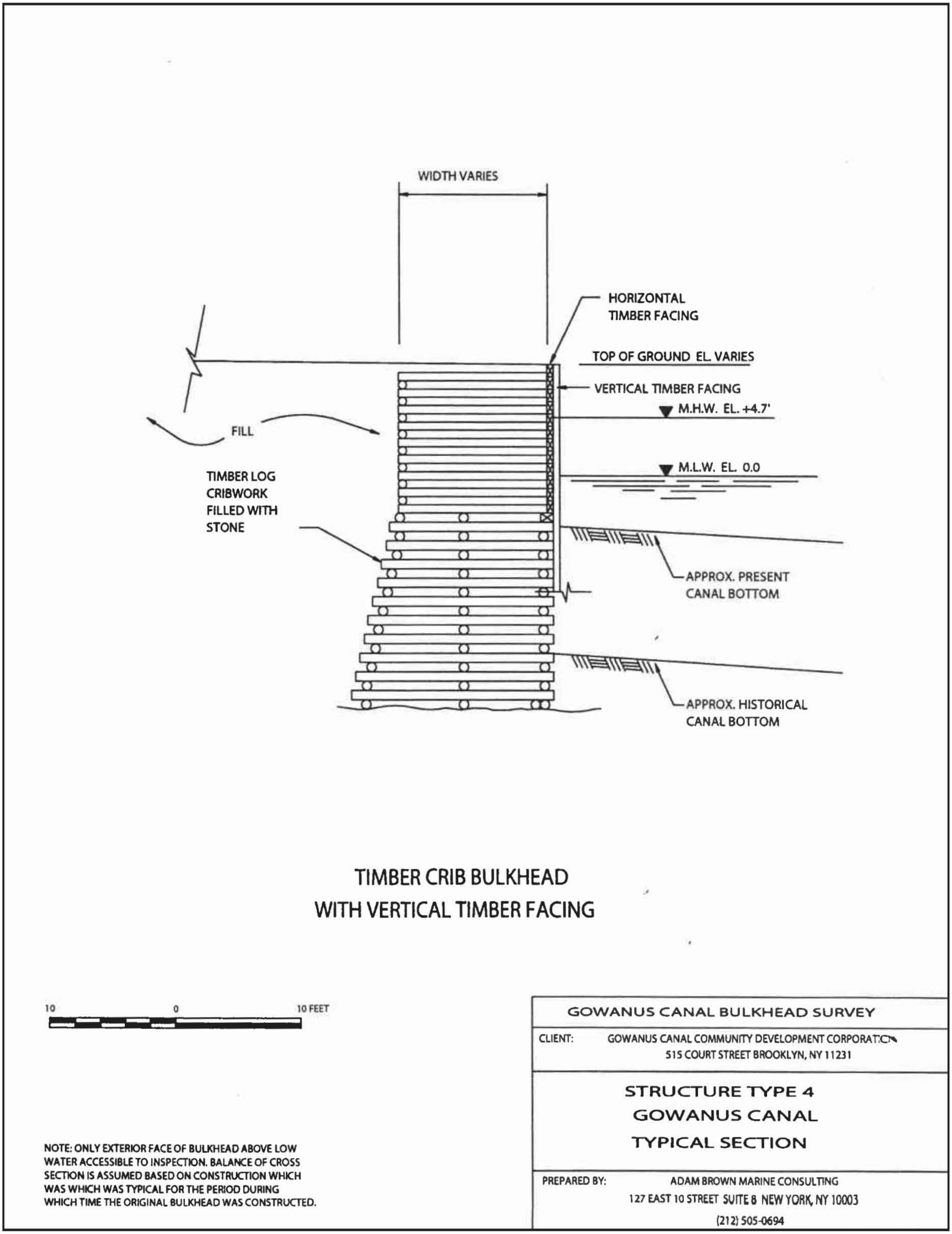


Figure 5. Typical section of timber crib bulkhead with vertical timber facing (Brown 2000). Used by permission.

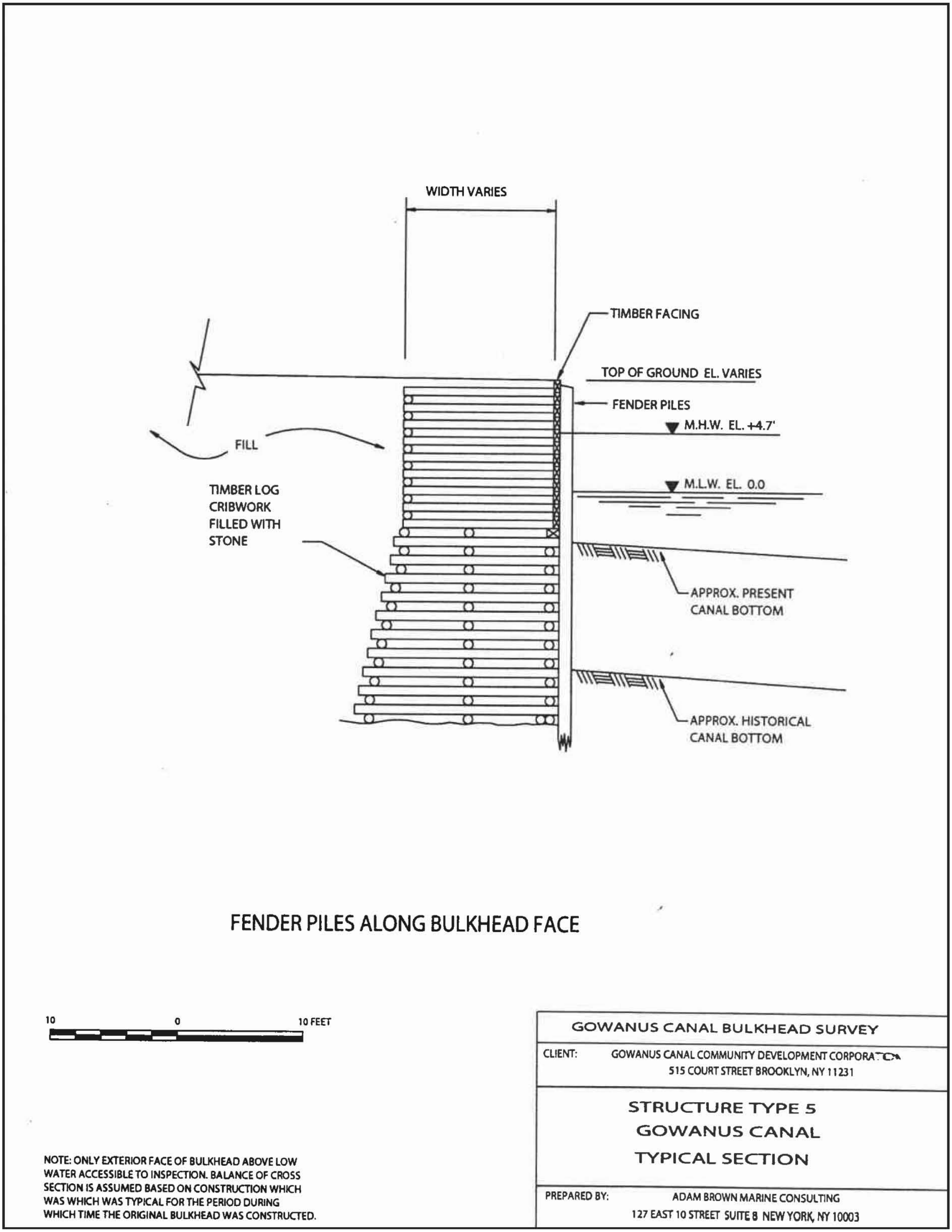


Figure 6. Typical section of timber crib bulkhead with fender piles along bulkhead face (Brown 2000). Used by permission.

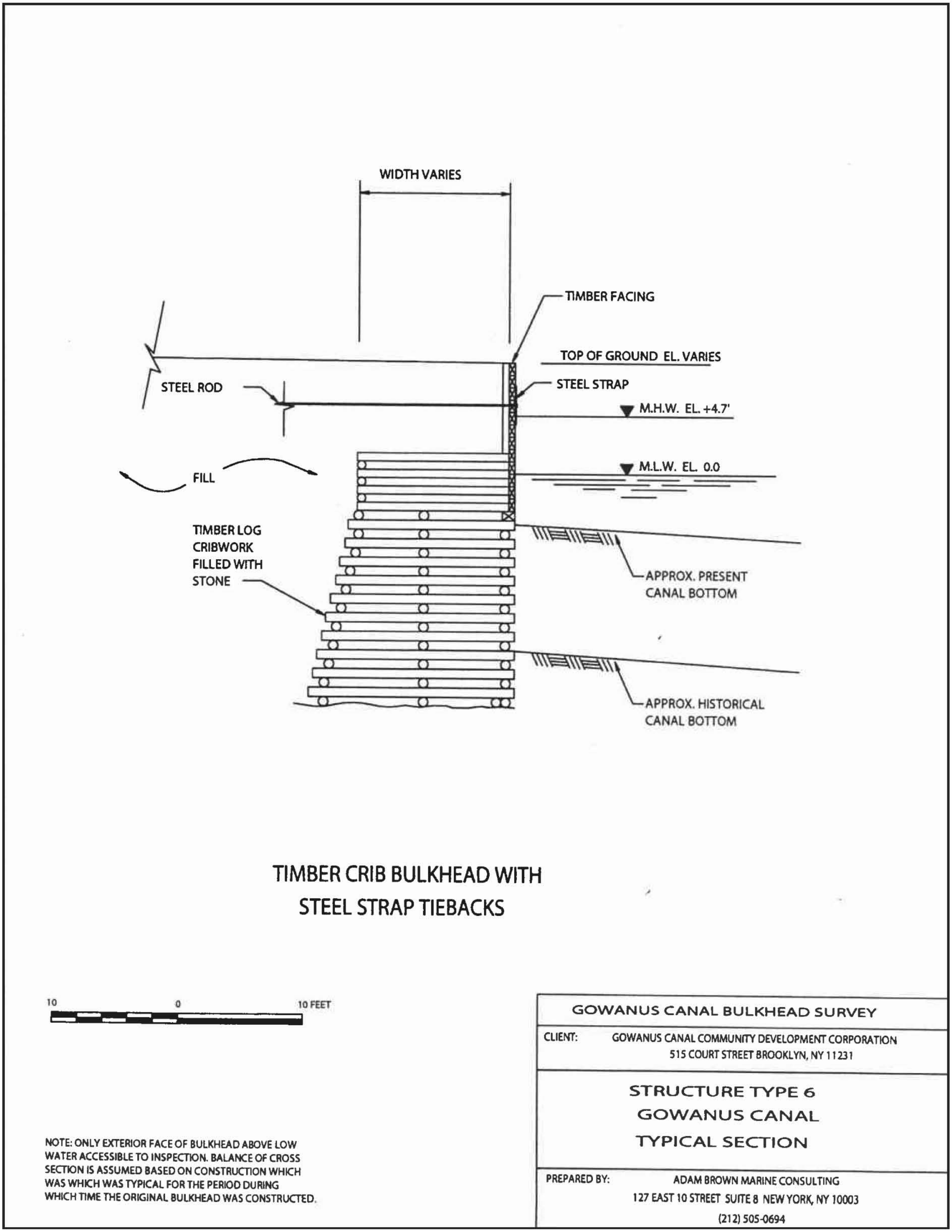


Figure 7. Typical section of timber crib bulkhead with steel strap tiebacks (Brown 2000). Used by permission.

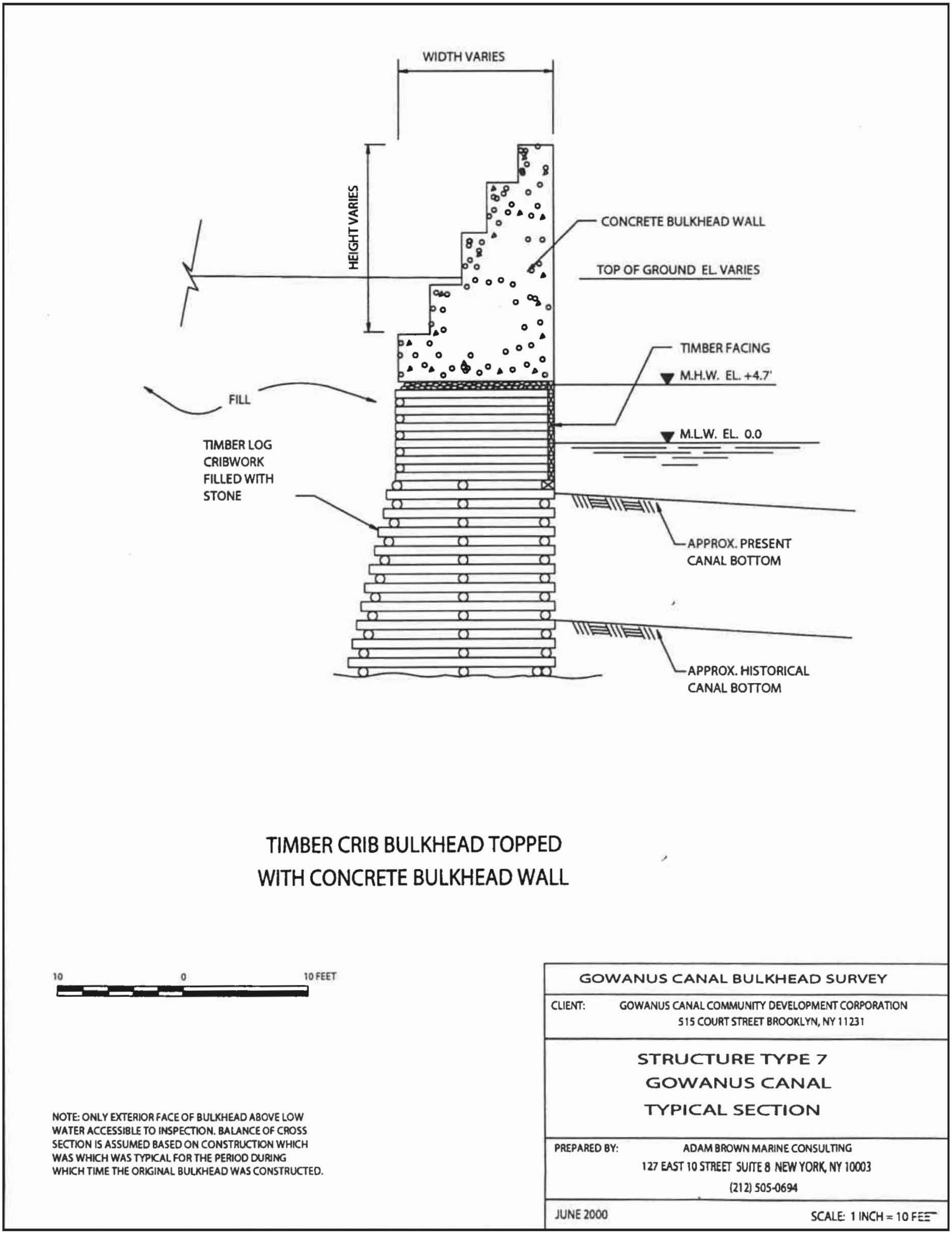


Figure 8. Typical section of timber crib bulkhead topped with concrete bulkhead wall (Brown 2000). Used by permission.

As J.F. Springer indicated in his history of steel sheet piling prepared for *Cassier's Magazine*, the earliest sheet-pile was an unhewn timber. This raw timber was succeeded by squared timber and tongue-and-groove timber. Springer viewed the culmination of the development of wood sheet piling as the Wakefield sheeting developed in the latter portion of the nineteenth century which he described, as follows:

> Each consists of three planks identical in width and thickness. These are bolted and nailed together to form a unit-pile, having a face equal to that of a single plank and a tongue and groove of the depth of one-half the width of a plank.

Springer indicated that this type of piling was often quite successful (Springer 1910:160). However, there could also be difficulties with this material. One was its limited ability to withstand lateral pressure. A second is the inevitable deterioration of the interlock points, while a third was the difficulty of driving sheeting through hard soils (Springer 1910:162).

Adam Brown indicated that the following types of closely spaced timber pile bulkheads are present on the Gowanus Canal: closely spaced timber piles (Type 8; Figure 9), representing 0.9 percent of the total bulkhead length; piles topper with concrete base and concrete blocks (Type 9; Figure 10), representing 0.2 percent of the total bulkhead length; piles with timber waler (Type 10; Figure 11), representing 0.7 percent of the total bulkhead length; piles with horizontal timber facing (Type 11; Figure 12), representing 0.2 percent of the total bulkhead length; and piles with vertical facing over horizontal facing (Type 12; Figure 13).

1.3.3 Wood Sheet Pile Bulkheads

Although steel sheet pile bulkheads began being used in the late nineteenth century in some areas of the country, available evidence suggests that they were first used on the Gowanus Canal in the second quarter of the twentieth century. Initially the sheet pile was employed behind new timber piles to add stability to the construction but after World War II, steel piling tended to replace the timber pile supports and subdecks completely (HRI 2004:74).

Adam Brown described the construction of the steel sheet pile bulkhead (Figures 14 and 15):

> A steel sheet pile bulkhead consists of a flexible wall formed of steel sheets with interlocking joints and cap of concrete construction. The bulkhead is restrained from outward movement by an anchorage system placed above the low water level. The anchorage system is made up of tie rods and anchors (deadmen), of either concrete blocks, sheet piles, or A-frames of batter piles (Brown 2000).

According to Adam Brown, approximately 16.6 percent of the total bulkhead length was, as of 2000, constructed of sheet pile.

1.3.4. Steel Sheet Pile Bulkheads

According to HRI, most concrete bulkheads in the New York City area were relieving platform designs (Figure 16), introduced shortly after 1900 by some of the region's railroads. In his bulkhead study, Adam Brown defines a "relieving platform":

> A relieving platform is a deck of timber or concrete supported on piles, generally of timber, at an elevation sufficiently above mean low water to eliminate underwater

> construction and low enough to keep timber piles permanently wet. A masonry gravity wall is located at the outshore face of the platform to retain the fill which extends from the deck up to finished grade. Upland or onshore fill is retained by an embankment of rip rap, or rip rap protected earth, beneath the deck, and a curtain wall located at the inshore end of the deck. Batter piles are provided to resist the lateral thrust from live load surcharges, from the earth placed above the deck and from the fill acting on the unsupported length of the curtain wall. The objective of this type of structure is to relieve or reduce the lateral thrust which would act on a wall with a vertical face extending from canal bottom to finished grade (Brown 2000).

According to Adam Brown, as of 2000, approximately 2.9 percent of the total bulkhead length consisted of relieving platforms.

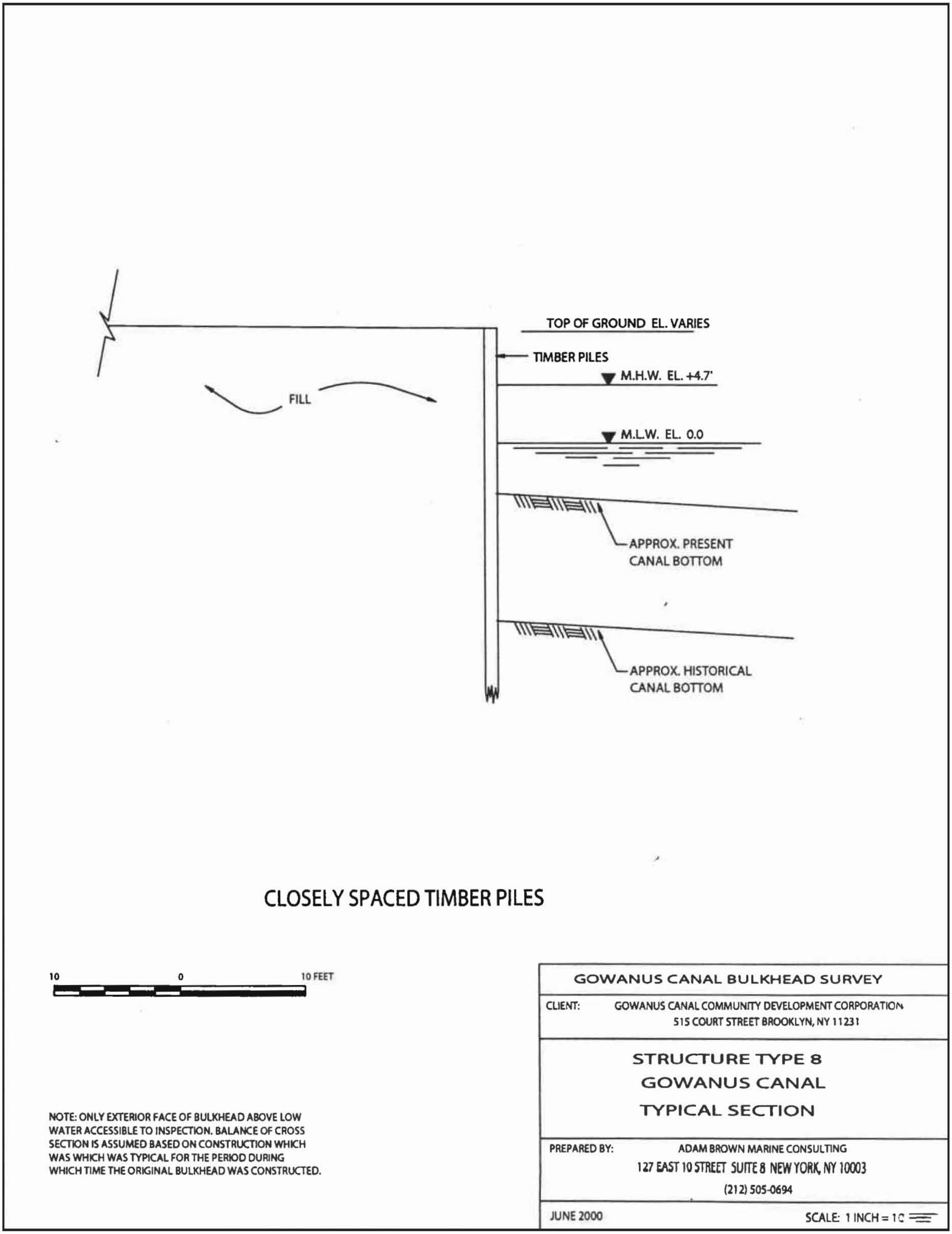


Figure 9. Typical section of closely spaced timber piles (Brown 2000). Used by permission.

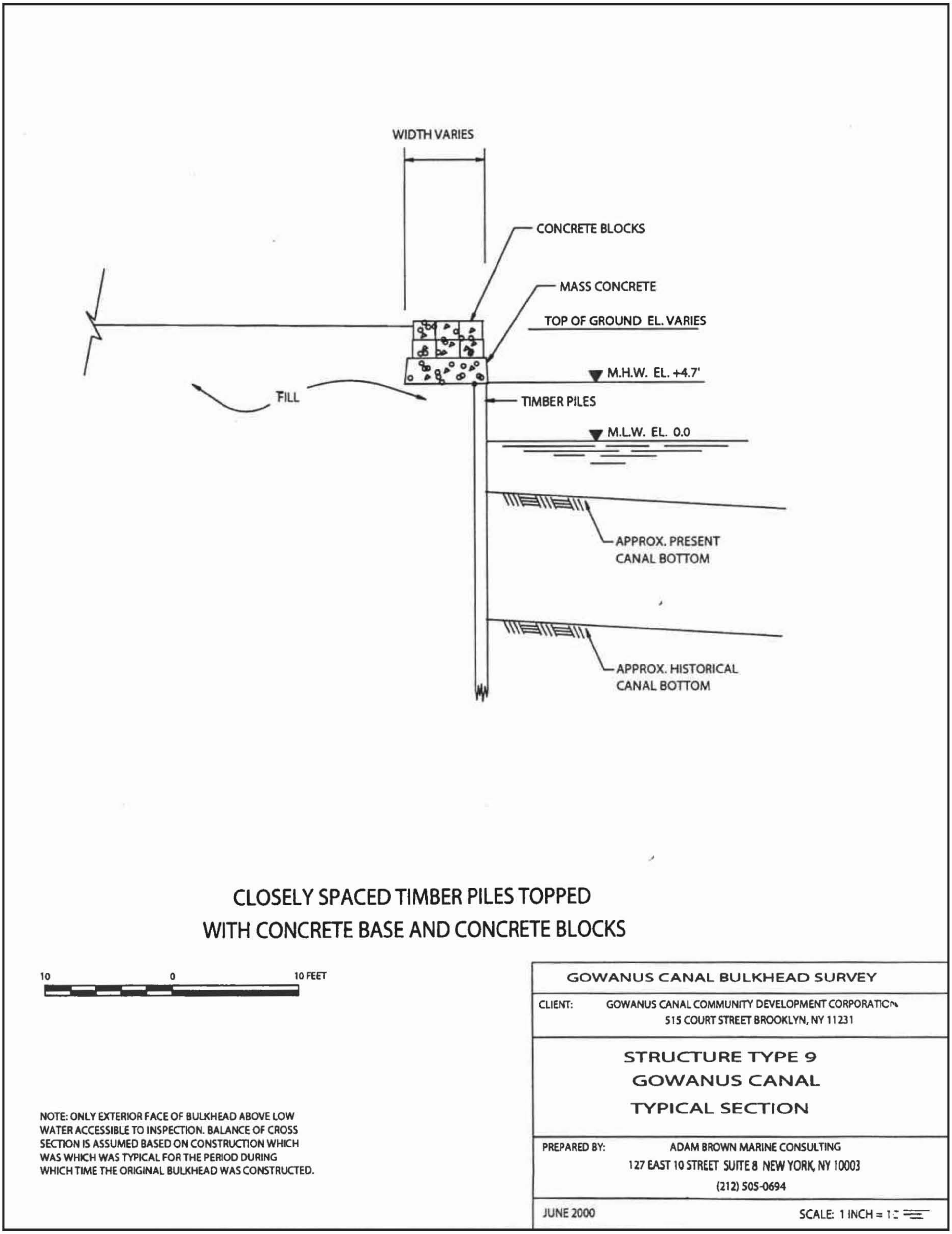


Figure 10. Typical section of closely spaced timber piles topped with concrete base and concrete blocks (Brown 2000). Used by permission.

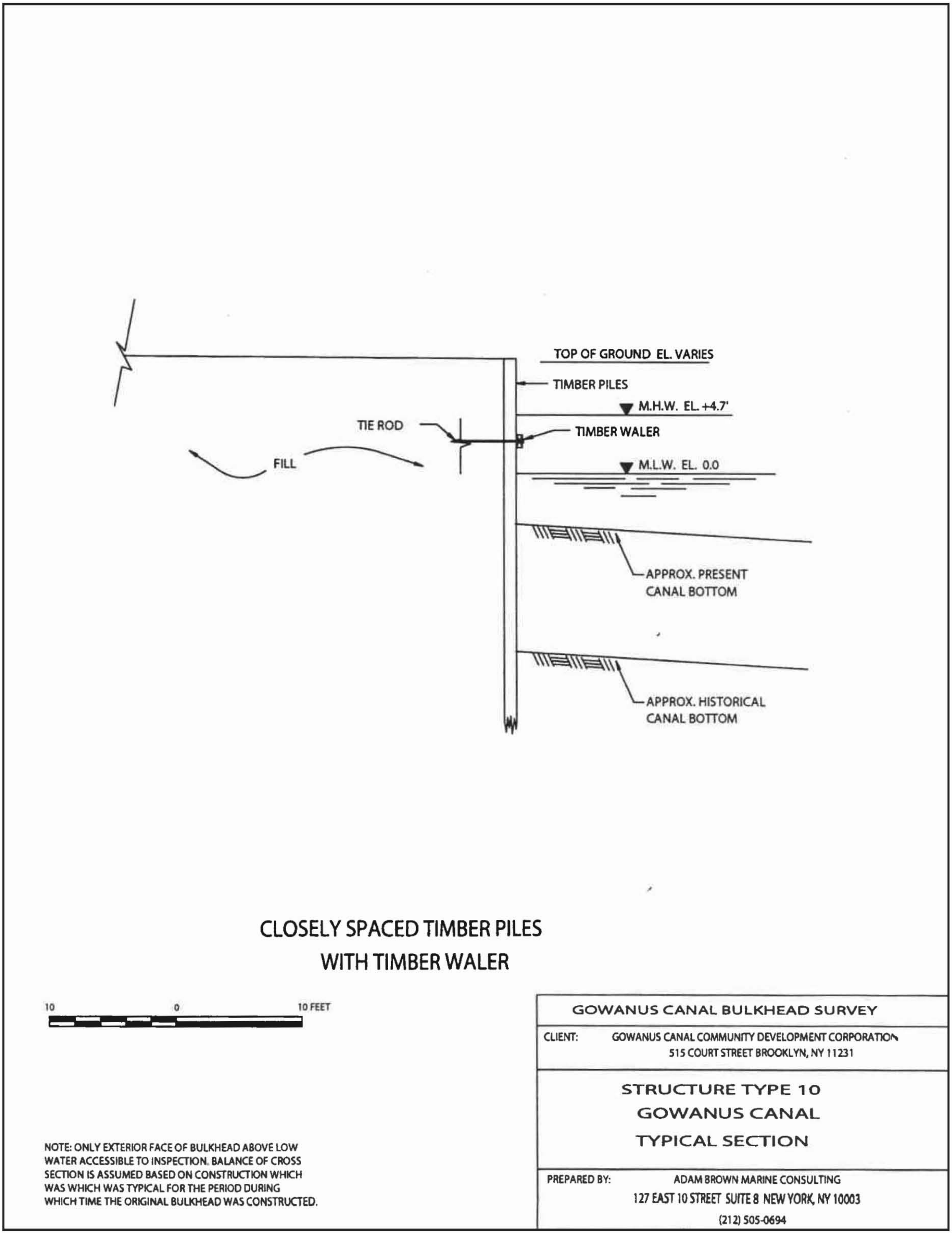


Figure 11. Typical section of closely spaced timber piles with timber waler (Brown 2000). Used by permission.

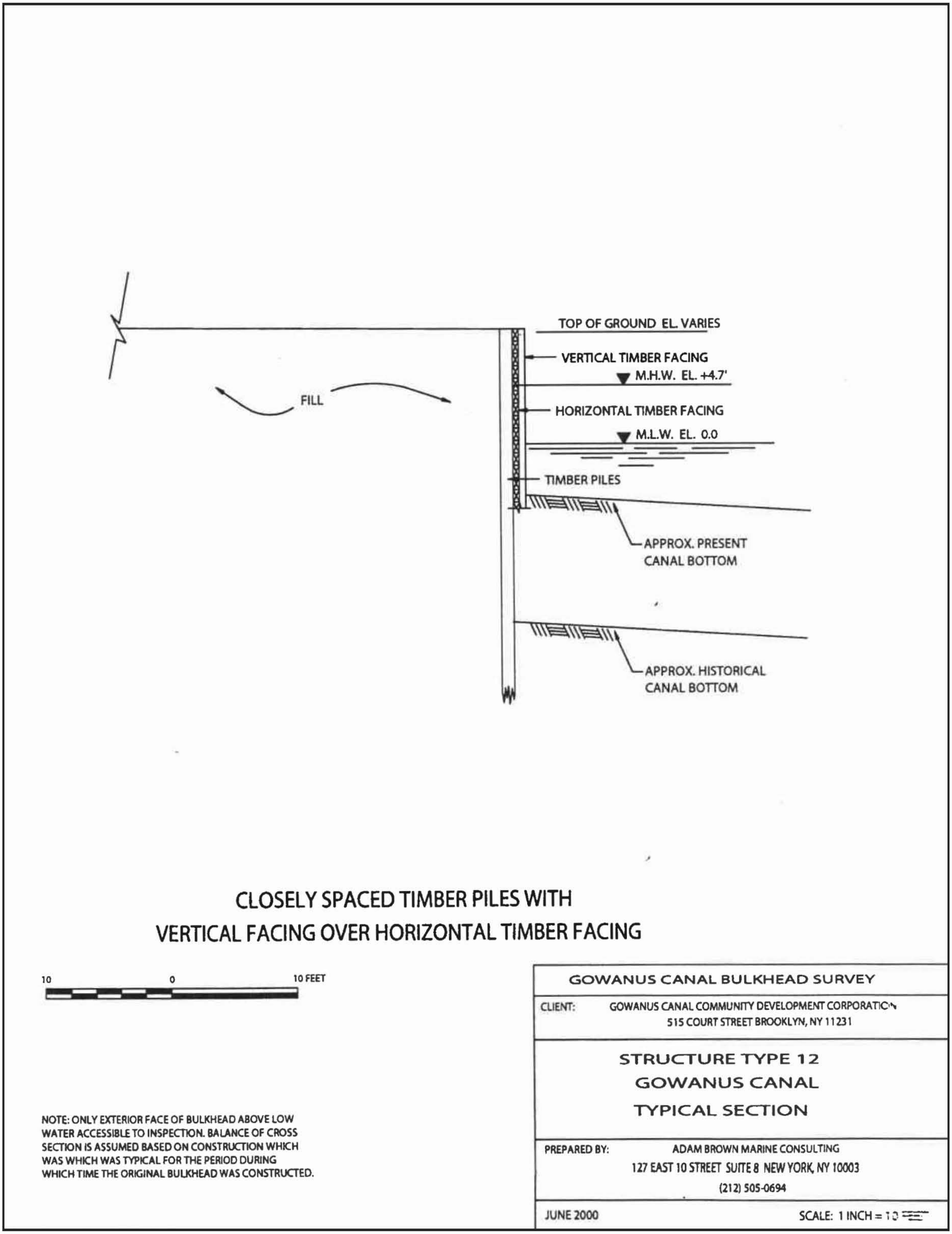


Figure 12. Typical section of closely spaced timber piles with horizontal timber facing (Brown 2000). Used by permission.

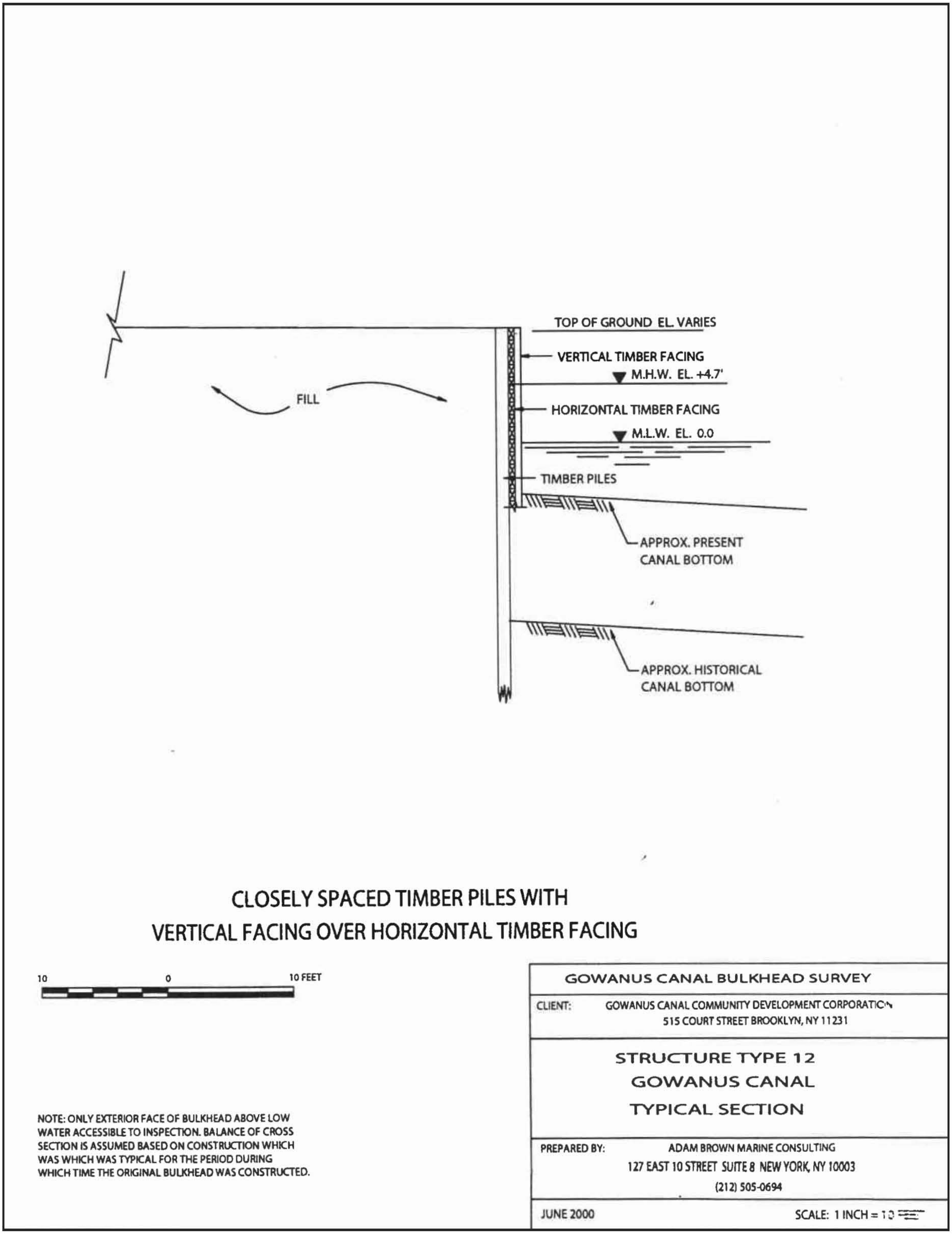


Figure 13. Typical section of closely spaced timber piles with vertical facing over horizontal timber facing (Brown 2000). Used by permission.

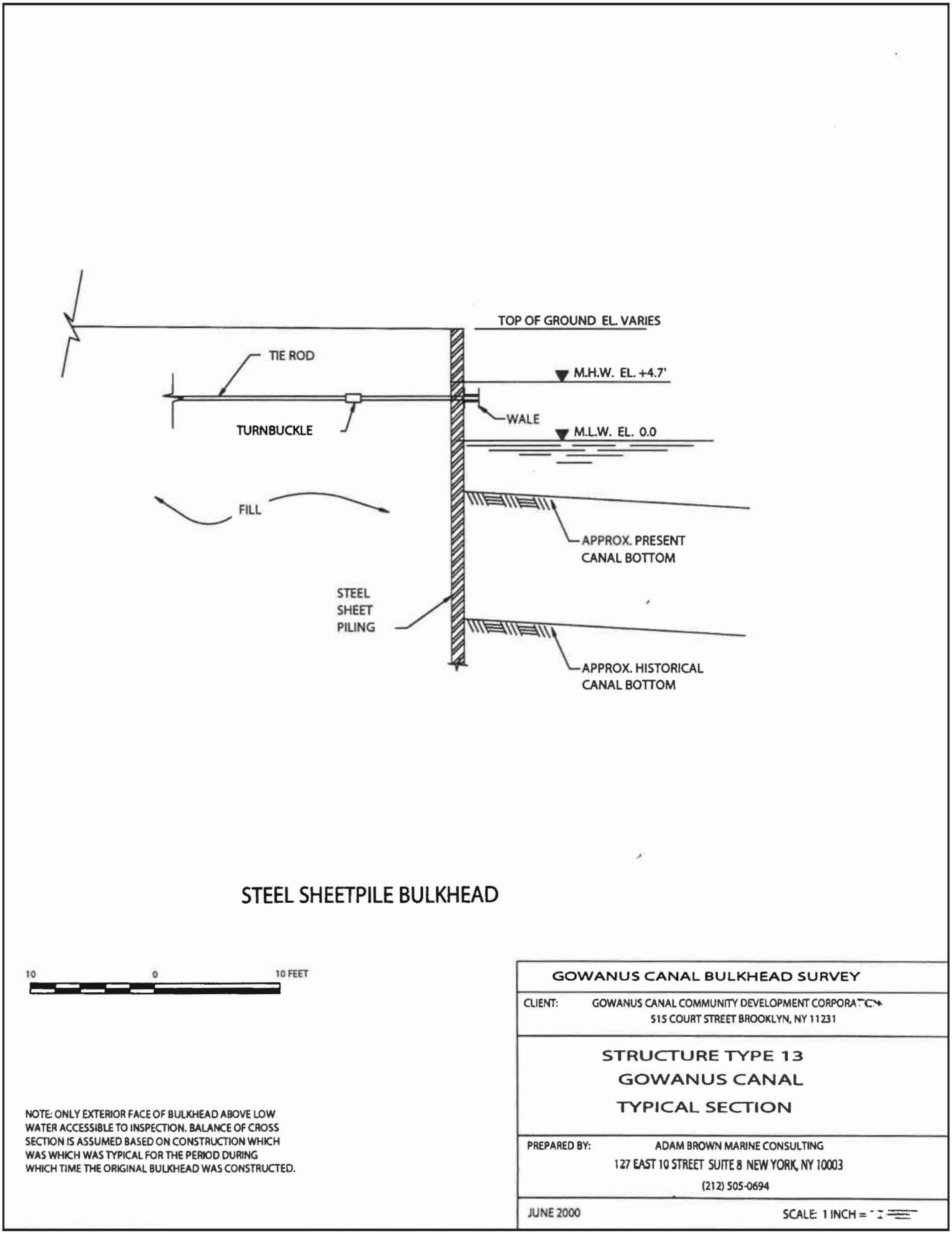


Figure 14. Typical section of sheet pile bulkhead (Brown 2000). Used by permission.

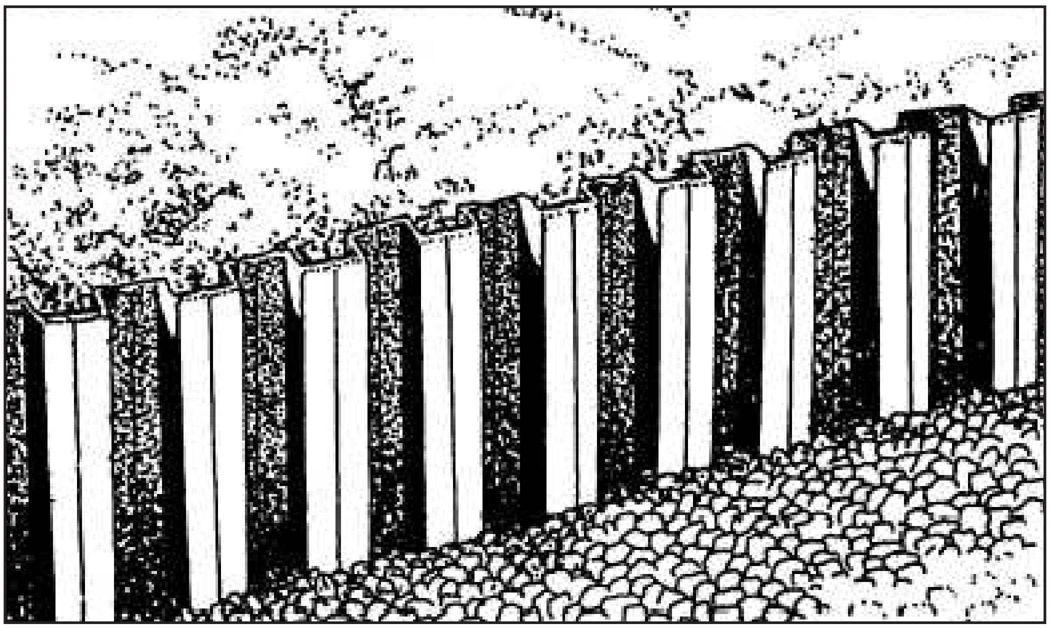


Figure 15. Elevation drawing of steel sheet pile bulkhead (from http://www.tpub.com/content/engineering/14071/css/14071_22.htm).

junction with the platform, where the thickness of riprap, through which the filling passed, was a minimum. This could have been prevented by careful grading of the riprap to make it sufficiently tight to hold the filling, by depositing a bed of selected dry filling over the riprap, or by placing a vertical sheeting at the rear edge of the platform.

It is important to make the dredged trench of sufficient

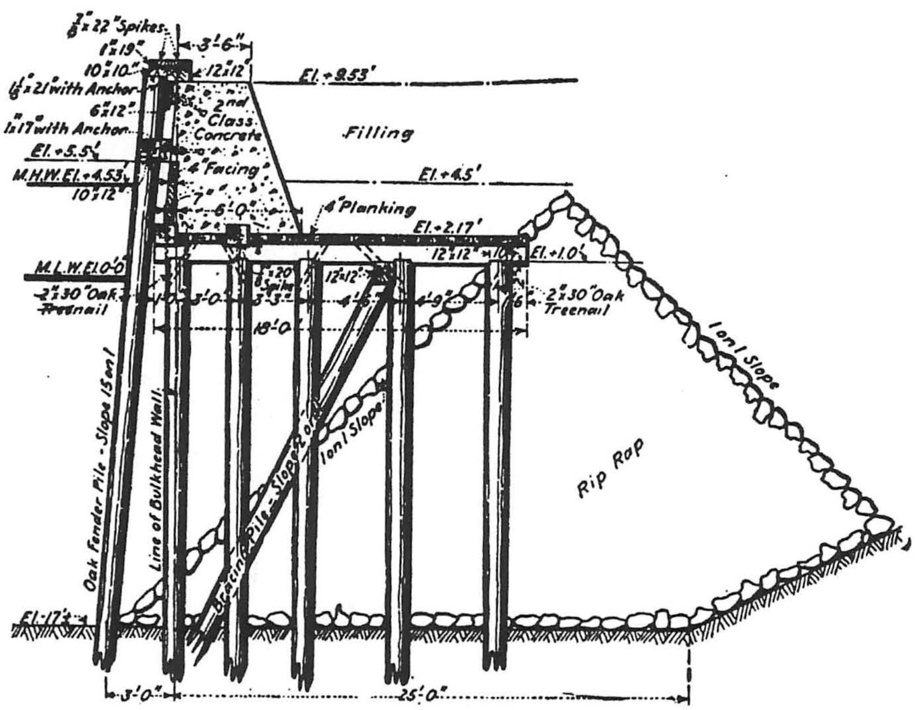


Fig. 31. Platform Wall, Gowanus Bay, Brooklyn, N. Y.

width, in the rear of such a wall, to prevent the riprap from sliding and pushing the piles out of plumb. Where such a wall encloses a large tidal area to be filled by pumping, special attention must be paid to the management of the filling and to the openings for controlling the effluent of the pumps and the flow of the tide through the wall, in order to prevent the washing of the dredged material through the riprap.

This wall was designed for a live load of 500 pounds per square foot and required piles to be placed 4 feet longi-

Figure 16. Example of platform wall construction (Greene 1917).

2.0 NATIONAL REGISTER SIGNIFICANCE AND INTEGRITY REQUIREMENTS FOR BULKHEADS

Considered in its entirety, the Gowanus Canal bulkhead system, as other surveyed bulkhead systems in New York (for example, the Hudson River Bulkhead), is representative of the evolution of bulkhead technology in the region. As noted, the earliest portions of the bulkhead may date from the 1850s or 1860s, while the dates of the most recent sections are not known, but probably post-date 1960.

The earliest portions of the bulkheads are of timber crib construction. Historian Michael Raber, in his evaluation of the Hudson River bulkheads, discusses significance and integrity issues related to timber crib bulkheads:

> When timber was relatively inexpensive, cribwork was a cheap form of bulkhead requiring only hand tools after any dredging phases. Disappearance of marine borers from the harbor beginning about 1850 made most bulkhead components permanent. Periodic replacement of all components subject to decay above mean low water complicates any identification of extant cribwork bulkheads with particular decades, and minimizes the significance of these upper elements. Cribwork bottoms are the least documented and probably most varied elements in timber bulkheads throughout the port, however, and tend to remain well preserved under water. The bottoms…could include important information on once-widespread vernacular engineering practice (Raber 2000:5).

As noted, the condition of portions of the bulkhead varies as does its date of construction or alteration. While concrete may usually be indicative of twentieth century construction, it may represent alterations to a nineteenth century bulkhead whose timber crib substructure remains intact. Steel sheet pile bulkheads may have replaced original bulkhead construction but may contribute to the significance of the resource as evidence of the evolution of bulkhead construction. Additional research should be focused on, among other topics, the dates of construction of the later portions of the bulkhead.

JMA recommends that all portions of the bulkhead that can be dated to before 1960 be considered eligible for the National Register under Criterion A. In addition, it is recommended that the timber crib portions of the bulkhead also be considered eligible under Criterion C as exemplifying the characteristics of nineteenth century timber crib construction and under Criterion D as having the potential to yield information about mid-to-late nineteenth century, timber crib construction practice.

3.0 PRESERVATION TREATMENT AND MITIGATION STRATEGIES FOR BULKHEADS

3.1 CASE STUDIES OF OTHER FEDERALLY-FUNDED OR PERMITTED UNDERTAKINGS INVOLVING BULKHEADS

The following represent easily accessible information on federal undertakings in which historic bulkheads are affected. This information may not be representative, and it is recommended that further information be sought in one or more state historic preservation office research collections.

Hudson River Park

Character of the Bulkhead

The Hudson River Park, planned to extend along the west shore of Manhattan from its tip to the Clinton neighborhood, includes within its APE the Hudson River Bulkhead. The bulkhead and its associated structural systems were constructed between 1871 and 1936 by the New York City Department of Docks. The EIS for the undertaking described the bulkhead as follows:

> The majority of the construction consisted of masonry walls on a variety of foundation systems, with quarry-faced ashlar granite block forming the visible face along nearly 80 percent of the armored frontage. The carefully built granite walls created a consistent monumental surface to waterfront sections seen by many thousands of transatlantic passengers, reinforcing an image of New York's commercial prominence. The bulkhead also incorporates two sections of older timber design. Approximately 18 percent of the bulkhead has concrete facing on a low-water relieving platform, a type which began to be used ca. 1920 and became the standard for new or replacement pile-supported bulkheads (AKRF 1998:7.5).

Proposed Treatment Recommendation and Mitigation

The EIS described the proposed treatment recommendation as follows:

> As presently proposed, repair work in sections of the bulkhead that are faced with granite would be done using either granite that has been salvaged from other sections of the bulkhead to replace its coping (or top layer). The proposed plan, which has been approved by SHPO, would involve rehabilitation of large sections/length of the granite bulkhead in relatively good/intact condition using granite salvaged from areas of the wall where the wall is either in poor conditions or where only a small length of the wall remains. In areas where the granite wall is either in deteriorated condition or of a short length, repairs would be made in concrete…. (AKRF 1998).

East River Waterfront Esplanade and Piers

Character of the Bulkhead

Typically, the visible bulkhead above the water line consisted of rough-cut granite ashlar with a capping course of larger granite blocks, with beveled upper edges surmounted by a simple squared timber "backing-log." The granite walls were backed by mass concrete and originally included four courses of granite blocks laid as alternating headers and stretchers to an elevation of about 9.4 feet above mean low water.

All sections of the East River bulkhead within the project area have been altered to various degrees since their construction. On sections retaining the highest degree of integrity, such as the area between Broad Street and Coenties Slip, the visible alteration has been the replacement of the "backing-log" with a new piece of timber that, rather than being laid atop the granite cap stone, has been bolted into the face of the cap stone. Furthermore, a substantial metal railing has been added atop the bulkhead for much of its length, the majority of which likely dates to the construction of the FDR Drive along the waterfront (AKRF 2006:6-17).

Proposed Treatment Recommendation and Mitigation

The EIS for the proposed project indicates that the following changes would be made:

> From Broad Street to Old Slip, the esplanade would be developed with a new, approximately 20-foot-wide structure built out over the water, beyond the existing bulkhead. The new archipelago area is expected to be an independent structure on pilings.
>
> The proposed reconstruction of Pier 15 would require new piles, as well as presumably, minor alterations for attachments to the bulkhead.
>
> …the original granite bulkhead remains in good condition from Broad Street to Coenties Slip. The area would be visible from the new independent structure carrying the archipelago. The bulkhead structure itself would not be altered. In addition, the original granite bulkhead would remain visible at other locations within the project area. From Coenties Slip to Old Slip, the bulkhead may be in very poor condition behind the concrete wall which was built in the mid-20th century (AKRF 2006:6-24-25).

New Whatcom Redevelopment Project (Washington State)

Character of the Project and Bulkhead

Among the potentially eligible historic resources include the bulkhead/wharf defining the Whatcom Waterway in Bellingham, which is reflective of historic maritime use.

Proposed Treatment Recommendation and Mitigation

The proposed mitigation of the action would include HABS/HAER documentation for eligible structures that are scheduled for demolition, an interpretation plan for the Whatcom Waterway area and potentially eligible buildings and structures onsite that are scheduled for demolition or major modification, and salvage and reuse developed for potentially eligible for buildings and structures scheduled for demolition (Port of Bellingham 2008:3-11-12).

World Trade Center Transportation Hub, Route 9A Pedestrian Underpass

Character of the Project and Bulkhead

The project involves construction of a pedestrian concourse to provide access between the former World Trade Center site, Battery Park City, and the World Financial Center. The portion of the pedestrian concourse that crosses Route 9A will be constructed as an underpass, and this proposed construction intersects the expected location of a portion of the Hudson River Bulkhead (HRB).

Based on Michael Raber’s 2000 study, it was expected that the bulkhead design would employ wide concrete blocks supporting a granite wall with wood log backing, receiving platform, inclined bracing and vertical posts. This design was used between 1899 and 1915 (Louis Berger Group, Inc. 2006:3).

Proposed Treatment and Mitigation

Based upon drawings in the Port Authority of New York and New Jersey (PANYNJP) it is thought that the upper portion of the bulkhead may have already been disturbed by installation of a flume/outfall for the World Trade Center. To confirm the condition of the HRB in the project area, Louis Berger suggested archeological monitoring during the Underpass construction.

Berger indicated a planned strategy if the configuration of the HRB was as expected:

> It is anticipated that the HRB will extend to a depth of 50 feet from the top of the granite wall. At a depth of approximately 15 feet from the top of the granite wall, it is anticipate that the material will change to concrete….The archaeologist will record the exposed granite/stone wall supported by stone and logs as the excavation contractor exposes this wall along the length of the trench…The archeologist will record evidence of the exposed HRB by drawing a plan view of it’s [sic] extent across the archaeological trench, photograph the exposed portions, collect any archaeological material in association with the HRB, and draw the nearest soil profile (Louis Berger Group, Inc. 2006:9).

363-365 Bond Street, Brooklyn, New York

Character of the Project and the Bulkhead

The applicant, Toll Brothers, Inc., proposed to redevelop two blocks along the west waterfront of the Gowanus Canal. The proposed development would include a mixture of residential, commercial, community facility, and open space uses.

The portion of the canal bulkhead within the proposed project area is of wood crib construction.

Proposed Treatment and Mitigation

The proposed treatment of the portion of the bulkhead within the project area was the subject of a July 2008 memorandum from Joseph Silva, an engineer with Halcrow HPA. The initial plan called for the installing of a new steel sheet pile wall outboard of the existing timber crib bulkhead as close as constructability would allow. However, this plan was rejected by the New York State Department of Environmental Protection (Halcrow HPA 2009).

The memorandum evaluated four strategies: no action; repair the existing rock filled timber crib bulkhead; install a new steel sheet pile bulkhead behind the existing timber bulkhead; or complete demolition, excavation, removal, and replacement of the existing bulkhead.

The no action alternative would permit the bulkhead to continue to deteriorate and eventually collapse. Repairs to the bulkhead were viewed as providing only a short-term solution to the ongoing deterioration and eventual failure of the bulkhead. Repairs would consist of patching and possibility fortifying it in selected locations. However, since the deterioration was so widespread, these types of repairs would only be partially effective.

The third alternative, installation of a new sheet pile bulkhead behind the existing timber bulkhead was determined impractical because it would disrupt the framework of timbers causing the risk of failure of the bulkhead. The final alternative, demolition and rebuilding, was deemed too extreme, disruptive to the environment, and cost prohibitive.

As a solution, Halcrow HPA suggested the construction of a new steel sheet pile wall placed up against the existing bulkhead. The sheet pile wall would mimic the existing timber crib wall through use of timber facing consistent with the existing crib wall pattern (see Figure 17) (Halcrow HPA 2009).

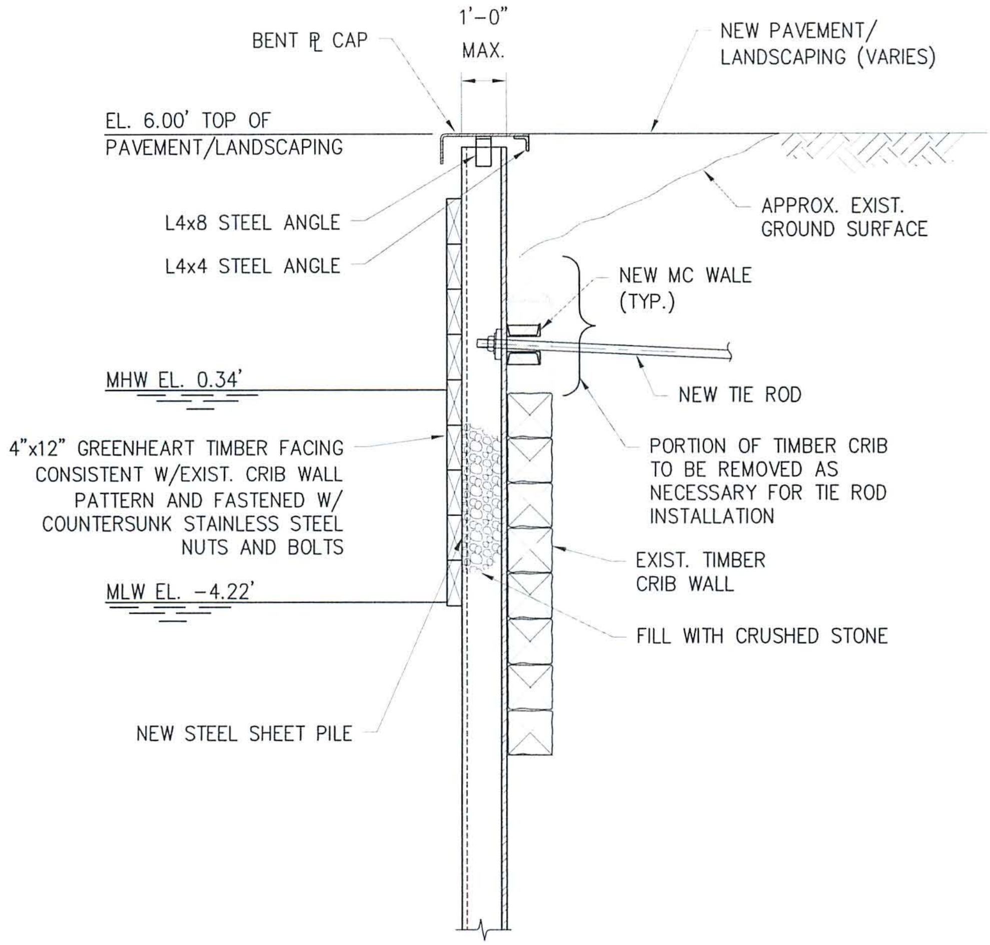
3.2 TREATMENT RECOMMENDATIONS FOR DEWATERED BULKHEADS

As part of the proposed remedy, dewatering of the canal may be applicable. An initial literature search failed to identify references specifically related to dewatering bulkheads. Sources were identified that discuss the effects of dewatering timber pile building foundations. As Russo, Brainerd, and Vatovec indicate in an article in *Structure*, dewatering poses substantial risk to structural members which remain continually immersed:

> Dewatering has the potential to cause ground settlement, settlement of pile foundations due to drawdown (negative skin friction), or rotting of untreated wood pile foundation systems.
>
> Removing water from weaker, compressible soil strata such as soft clay, peat and silt [as is apparently present in portions of the Gowanus Canal], effectively increases the stress on the soil, which can cause consolidation. Depending on the extent of compressible soils and the profile of the water-elevation drawdown, settlement can either be uniform or differential….Consolidation of soil around piles can create negative friction resulting in a downward force on the piles and subsequent settlement.
>
> When sections of previously immersed, untreated wood piles become exposed to air, conditions such as moisture and abundant oxygen, necessary for fungal growth, are created and initiate an accelerated decay process. The rate of deterioration of piles is highly sensitive to even minor variations in the environment around the piles: wood species, soil chemistry and makeup, etc. Consequently, the duration of exposure necessary to significantly impair the structural integrity of piles is unpredictable, but is usually longer than the length of most construction-related dewatering operations (Russo, Brainerd, and Vatovec 2008).

A similar caution is raised concerning pilings in a National Park Service Preservation Tech Note in which the author cautions that previously submerged timber piles that are exposed to air can quickly undergo dryout. Strategies suggested to mitigate this effect include using watertight excavation support systems such as slurry walls (NPS n.d.:3).

Because of the risk of structural deterioration during dewatering, it would be prudent to have a structural engineer or other professional familiar with timber deterioration on site or on call during the dewatering.



A / 3 SECTION
SCALE 1/4"=1'–0"

PURPOSE: PROPOSED NEW BULKHEAD PREPARED BY HPA ENGINEERS, P.C.	363–365 BOND STREET SHEETPILE BULKHEAD SECTION A	PROPOSED: STEEL SHEET PILE BULKHEAD CITY: BROOKLYN COUNTY: KINGS APPLICANT: TOLL BROTHERS, INC. SHEET 4 OF 7 DATE: 6/19/2008

Figure 17. Proposed alterations to timber crib bulkheads on portion of Gowanus Canal near 363-365 Bond Street (HPA Engineers, PC 2008).

The appropriate treatment strategy for deteriorated bulkheads will depend, of course, on its materials and method of construction. A discussion of treatment options is included in the Naval Engineering Facilities Command's (NEFC) *Maintenance of Waterfront Facilities* (UFC 4-150-07) available on the Internet (http://www.wbdg.org/ccb/DOD/UFC/ufc_4_150_07.pdf.) Some of the recommendations included in this publication are summarized below.

Repair of Timber Piles

Marine borers are the cause of extensive damage to wood piles, and due to the carcinogenic character of the leading marine wood preserver, creosote, some states have banned its use in marine waters. The United Facilities Criteria handbook for maintenance and operation of waterfront facilities discusses six repair methods for damaged wood piles:

1) Wrapping them with polyvinyl chloride or polyethylene wraps;

2) Partial posting of a damaged wood pile by joining a new pile but with bolted prestressed timber fish plates;

3) Encasement of the pile in concrete;

4) Repair or retrofit of timber piles with an underwater-curing epoxy and fiber-reinforced wraps;

5) Replacement with a new wood pile; and

6) Replacement of the wood pile with a new concrete pile.

Clearly, several of these methods would not adhere to the provisions of the Secretary of Interior's Standard due to either removal or covering of historic fabric. Suggestions 5 and 6 would permit the removal of the historic fabric with no attempt to retain the historic character of the structure. Suggestions 1 and 3 would involve obscuring the historic fabric of the bulkhead. Clearly, the remaining two alternatives: sistering a portion of the old pile to the new pile, and use of epoxy consolidates, represent approaches in keeping with accepted preservation practice with the exception of the application of a fiber-reinforced wrap to the column's exterior (Lopez-Anido et al. 2005:78-79).

Repair of Timber Sheet Piling Walls

The NEFC indicates that three repair strategies may be used on timber sheet piling walls. First, in the case of light to moderate movement of the upper portion of the wall, the existing tie-back system should be reinforced. If a tie-back system is not present, movement may be reduced by installing a tie-back system at the top of the wall. In the case of deterioration of pilings, a repair strategy includes installing a concrete cap or face on the timber sheet piling wall (NEFC 2001:6-4).

Clearly, the first two alternatives would be in keeping with the Secretary of the Interior's Standards for Rehabilitation, while the third would not. It must, however, be recognized, that the third alternative has already been used in sections of the Gowanus Canal.

Repair of Steel Sheet Pile Wall Bulkheads

The NEFC cites six repair techniques for sheet piling walls:

1. Coating and cathodic protection to slow corrosion;
2. Patching of missing portions of the wall;
3. Reinforcing the tie-back systems;
4. Replacement of the existing wall;
5. Installation of a concrete cap or face;
6. Scour protection.

Clearly, the first three repair techniques will not greatly alter the appearance of the existing wall so would be in accordance with the Secretary of the Interior's Standards. Coating and cathodic protection involves the installation of wiring and a power source to insure the cathodic protection and covering of the existing surface with a protective coating, as discussed on pages 3.21 and 3.22 of the UFC manual. Patching of the wall generally consists of either the use of epoxy or steel plate or both. Reinforcement of the tie back system can stabilize a wall that suffers from light to moderate movement. This repair (shown in Figure 17) would include installing a new wale above the existing wales, trenching for tie rods and deadman anchors, and installation of zinc or magnesium anodes to prevent future corrosion of the rods. A final strategy is to change the soil loading acting on the wall. For example, stone riprap dumped against its exterior toe will add resistance to movement (NEFC 2001:8-4-5).

Repair of Earth-Filled Structures

In the case of bulkheads used to retain the surrounding shoreline, the NEFC recommends using riprap to shore up the structure or reduce seepage and loss of backfill rather than performing expensive repairs to the structure. Specific recommendations include:

> Where there is evidence of erosion or loss of soil, protective coverings, such as rock fill or armor units, should be removed and the internal fill inspected. Any necessary repairs in the form of replacement of properly compacted soil should be made…A series of soil layers of varying coarseness may be used to insure that the finer, central materials cannot be washed out through the coarser shell materials (NEFC 2001:10-2).

A potentially useful material for retention of soil is geotextiles, porous, flexible polymeric fabrics used for separating soil types, soil retention, and strength reinforcement. Geotextiles may also be used to seal structures to prevent further loss of material (NEFC 2001:10-1-4).

3.3 MITIGATION OPTIONS FOR ADVERSE EFFECTS ON BULKHEADS

At the time of Brown's 2000 survey, an estimated 41.7 percent of the bulkhead length was in fair condition or worse. Fair condition was noted as characterized by timber deterioration sufficient to let fill escape. Because of lack of preventive maintenance in the intervening years, it is likely that the proportion of timber deterioration may have increased. Clearly, a portion of this length will not be able to be repaired.

For that portion of the bulkhead, several mitigation activities are recommended:

1) thorough archeological investigation of the timber cribs including photography and measured drawings to document the varieties in crib construction;

2) additional historical documentation including an intensive-level context development for both canal bulkheads and bulkheads of the New York area, as well as to obtain as much information as possible concerning the evolution of the Gowanus Canal bulkheads; and

3) a public history component consisting of an illustrated popular history of the Gowanus Canal; a website on the Gowanus Canal's history and cleanup; a video history of the canal and cleanup activities; and/or one or more interpretative panels concerning the canal placed at locations of public gathering near the canal.

4.0 SUGGESTIONS FOR ADDITIONAL AREAS OF RESEARCH AND REPOSITORIES

This preliminary investigation has yielded some information useful to the preparation of environmental compliance documentation for the Gowanus Canal, but it has also pointed to areas where additional information would be very useful. These areas of recommended further research include the following:

- Background information on timber crib construction using sources from the mid-nineteenth century and more recent research.

Such information would provide insight into the varieties of timber crib construction and how the Gowanus Canal cribs are typical or atypical of construction practices. Such sources may include digitized documents available on a variety of on-line public databases (such as Google Books and Internet Archives), and subscription databases (including JSTOR, American History and Life, etc.).

In addition, further information may be available in a variety of research collections, such as the American Philosophical Society, the Library Company of Philadelphia, and the Hagley Library (Wilmington, Delaware).

- Chronological information concerning construction of and alterations to the Gowanus Canal bulkhead.

A potentially critical source may be the archival records of the New York Department of Docks, an agency established in 1870. According to Raber, most surviving plans and drawings related to New York City's municipal waterfront construction are deposited at the Municipal Archives in Lower Manhattan.

Another useful Department of Docks source is likely to be the annual reports of the Department. Scattered earlier years are available on-line through Google Books, and an initial perusal yielded some references to bulkhead construction on the Gowanus Canal. These reports are available in the collection of the Main Research Library, New York Public Library, or at the Municipal Records and Research Center, New York Department of Records and Information Services.

Other sources may include newspaper articles and historic photographs. The *Brooklyn Daily Eagle* newspaper has been digitized from the 1840s into the early 1900s and will be a useful source of information for earlier changes to the canal, while articles on later canal alterations may be available in the Brooklyn Collection vertical files of the Brooklyn Public Library. The Brooklyn Collection also contains many historic photographs of the Gowanus Canal, as does the New York Public Library Research Library, and the Municipal Archives.

One other potential source of information on the construction and the evolution of the canal and its bulkheads is the New York Canal Records available at the New York State Archives in Albany. It is recommended that an initial reference inquiry be made to ascertain whether the collection does indeed contain information on the Gowanus Canal.

- Additional information concerning treatment recommendations for bulkhead components.

Up-to-date information on material conservation for bulkhead components may be available in a variety of sources including Naval and Army Corps of Engineers technical manuals, publications of the American Institute for Conservation and the Association for Preservation Technology, and the Texas A&M University Underwater Archeology program and Institute for Nautical Archeology. In addition, the

Maritime Conservation Program of East Carolina University may be able to provide guidance on materials conservation issues.

One specific study that may contain useful guidance is the 1965 *Bulkhead Stabilization Survey, Study and Report at Various Locations*, prepared by Christopher J. Foster Consulting Engineers. This report incorporates data from field survey of bulkhead failure areas and provides practical methods to stabilize existing steel sheet pile bulkheads and timber bulkheads with tie-rod anchorages. This report is available through the Defense Technical Information Center.

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