Landmark
Engineers Inc.

January 16, 2020 Project No. 19-007

City of Windsor Engineering Dept.
350 City Hall Square West
Windsor, Ontario
N9A 6S1

Attention: Mr. Andrew Dowie, P.Eng.
Executive Initiatives Coordinator

Re: East Riverside Shorewall Assessment & Functional Design
Final Report

Dear Mr. Dowie:

In accordance with the terms of our proposal dated 21 May 2019, please be advised that we have completed our investigation and assessment of the City's shorewall structure along Lake St. Clair in East Riverside. The findings of our investigation and our design recommendations for the restoration of the shorewall are presented in the following report.

1.0 Background

It is our understanding that in 1931, the former Town of Riverside acquired approximately 30 acres of waterlots along the Lake St. Clair shoreline from the Province of Ontario and constructed a concrete breakwall on the property in cooperation with the Federal government. We understand that the subject waterlots were subsequently conveyed to the owners of the abutting shoreline properties – with the specific exception of the 1-foot wide strip of property upon which the concrete breakwall was built.

When the City of Windsor annexed the Town of Riverside in 1965, it also inherited the subject breakwall. This situation was brought to the attention of Windsor City Council in response to Council Question 25-2017, which noted the concerns of residents along Riverside Drive East with regard to both the ownership and the condition of the existing breakwall. It is our understanding that abutting property owners have reported the existence of several significant cracks and holes in the 85+ year old concrete

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structure, resulting in active erosion occurring along portions of the privately-owned Lake St. Clair shoreline north of Riverside Drive East.

In response to the above, the City of Windsor retained Landmark Engineers in the summer of 2019 to undertake a condition assessment of the existing concrete breakwall structure located on the Lake St. Clair shoreline between the East Marsh Pumping Station (10864 Riverside Drive East) and the Rendezvous Shores subdivision.

A key plan, depicting the location of the study area, is provided here as Figure 1.

2.0 Purpose and Scope

The principal purpose of this study was to document and assess the condition of the City-owned concrete breakwall along the Lake St. Clair Shoreline between the East Marsh Pumping Station (10864 Riverside Drive East) and the Rendezvous Shores subdivision in East Riverside. The assignment also included the development of a functional design for a scope of shorewall repairs (including the adjacent privately-owned deck slabs), complete with cost estimates for budgeting purposes.

In carrying out this assignment, we executed the following scope of work:

- Visual and tactile inspections (both above and below the waterline) of the existing shoreline structure(s) within the study area;
- Documenting the condition of the existing shoreline structures (both above and below the waterline) via photographs and inspection notes;
- Identifying and quantifying observed deficiencies in the shoreline structure(s); and,
- Preparing functional design recommendations for repairs to the shoreline structures – including order-of-magnitude cost estimates for budgeting purposes.

Our findings are presented below.

3.0 Inspection Methodology

3.1 Underwater Inspections by Watech

For the underwater inspection component of this assignment, Landmark retained Watech Services Inc., a specialized marine engineering and inspection company based out of London, Ontario. We understand that on three separate occasions in October and November 2019, Watech mobilized a workboat to the site and carried out underwater inspections of the subject shorewall using a three-person inspection crew. Their crew included 2 commercial divers equipped with surface-supplied-air diving helmets, complete with inbuilt voice communication and recording devices.

Over the course of their inspections, Watech maintained location control by marking stationing in metres along the shorewall at regular intervals. Watech's stationing began with Station 0+000 at the steel sheet pile section of shorewall along the Rendezvous Shores subdivision, and

ran westerly as far as Station 1+330 at 10870 Riverside Drive East. Watech utilized this stationing to reference regular water depth measurements across the study area – as well as their observations of any deficiencies in the shorewall. We understand that underwater conditions were generally poor over the course of Watech's inspections, with a maximum visibility noted of approximately 0.3m.

A copy of Watech's full report, complete with above- and below-water photographs detailing the findings of their underwater inspections, is attached to this report as Appendix A.

3.2 Surface Inspections by Landmark

On 20 November 2019, Landmark staff mobilized a small watercraft and carried out a visual and tactile inspection of the subject shoreline from the water surface on Lake St. Clair. Photographs of the shoreline condition were taken at each individual property within the study area, starting with Property #1 at 10870 Riverside Drive East and working easterly as far as Property #69 at 11906 Riverside Drive East. Notes were also compiled to document the conditions observed at each property. A plan depicting the location of each property inspected by Landmark (cross-referenced with Watech's stationing) is attached is Figures 2A and 2B.

A photographic inventory of the shoreline condition at each property within the study area is attached as Appendix B. A summary of Landmark's field notes from the inspection (noting the general configuration and condition of the wall, deck slab, and other onshore features at each property) is attached as Appendix C.

4.0 Summary of Findings

A cross-section depicting the typical configuration of the existing shorewall and shoreline deck slab is attached as Figure 3. This figure was prepared based on the field observations and measurements documented by Watech and Landmark.

4.1 Shorewall Configuration & Condition

As depicted in Figure 3, the existing shorewall structure along the Lake St. Clair shoreline generally consists of a 1.8m-tall vertical concrete wall, cast in-place over timber pilings. The cast-in-place concrete shorewall appears to have been constructed with a slightly concave vertical curvature along its lakeward face, and was constructed with 100mm-diameter drain holes located near mid-height at intermittent locations along its length. The shorewall is generally approximately 0.3m wide along its top edge.

Over the course of Watech's underwater inspections, it was noted that the concrete wall itself is generally in fair to good physical condition, with some spalling and cracking noted at isolated locations – generally at or near the waterline. This is consistent with the observations made in the field by Landmark. Watech also noted that the timber support piles appear to be in fair to good condition at the locations where they were visible. There is no evidence of any significant settlement or misalignment (vertical or horizontal) anywhere along the length of the shorewall within the study area.

The primary concern regarding the condition of the shorewall is that it appears to have been undermined by wave action along a significant proportion of its length, exposing the supporting timber piles and allowing the retained backfill to erode through the gap at the base of the wall. The intermittent drainage holes through the concrete wall could also be providing a pathway for wave action to erode the retained fill materials behind the shorewall.

4.2 Deck Slab Configuration & Condition

For most of the properties within the study area, a concrete deck slab runs along the shoreline, immediately inland of the concrete wall. The configuration of the deck slab varies considerably from property to property, with deck widths ranging between 2.5m and 5.0m, varying deck heights, and varying support configurations for the slab. Generally, it appears that the original deck slabs were supported directly on the backfill materials, while most of the newer-looking slabs rest directly on top of the concrete shorewall.

The condition of the existing deck slab also varies widely from property to property along the length of the subject shoreline, with several properties having what appears to be fairly new and intact slabs (e.g., Appendix B, Property #4 & #5), while others consist of severely broken slabs and/or rubble (e.g., Appendix B, Property #22 & #23). While some of the deterioration of the older deck slabs can be attributed to age and weathering, it appears that most of the damage exhibited in the shoreline deck slabs results from undermining and erosion of the underlying backfill.

Based on our inspection notes (see Appendix C), we estimate that approximately 40 of the 69 properties within the study area exhibit cracking and/or settlement in the deck slab to the extent that would warrant significant repair or replacement in the short- to medium-term.

4.3 Onshore Flood Control Features

As part of Landmark's inspection of the subject shoreline, we noted the presence and condition of any secondary walls and/or berms behind the shoreline deck slabs at each property within the study area (see Appendix C). We understand that many of these features were built in the late 1980s based on the City's 1986 *Shoreline Management Plan* (by N.K. Becker and Associates Ltd.) in an effort to mitigate inland flooding from Lake St. Clair.

The type, condition, and approximate top elevation of these features are listed in Appendix C for the information purposes. No assessment of the integrity and/or effectiveness of these features was carried out at this time, as these features are located on private property and this was beyond the scope of our current assignment.

5.0 Analysis and Discussion

As noted above and as indicated in the Watech report (see Appendix A), the existing concrete shorewall within the study area appears to be generally stable and in fair condition. Despite the structure's age and its exposure to harsh shoreline conditions, most of the concrete below the observed water level on Lake St. Clair appears to be generally sound, and the supporting timber

piles (where they are exposed) appear to be generally intact. Furthermore, there is no evidence of any significant settlement or misalignment (vertical or horizontal) anywhere along the length of the shorewall within the study area.

Based on the field observations documented by Landmark and Watech, it appears that the primary cause for structural damage and instability along the shoreline within the study area is the undermining of the concrete shorewall and the resulting loss of retained backfill. This ongoing erosion has led to the formation of significant voids below the shoreline deck slabs at several properties, and has resulted in the settlement and/or failure of many of the deck slabs.

Given the above, it is our opinion that any viable strategy for restoration of the shoreline along Lake St. Clair in East Riverside must include measures to fill the existing gaps along the base of the shorewall and protect it from further undermining in the future. Measures to plug and/or fill the existing drainage holes in the shorewall would also be necessary.

6.0 Recommended Works

6.1 Shorewall Repair and Toe Protection Works

To address the undermining and erosion issues noted above, we recommend that an engineered toe protection structure be constructed along the base of the existing shorewall along its entire length. Although toe protection could be achieved by a variety of means (including new steel sheet piling, tremie concrete wall extensions, etc.), we believe that the most practical and economical method would be to install appropriately-sized and bedded rip-rap along the base of the wall, as depicted in Figure 4. This would allow the toe protection to be constructed from a barge with a minimum of disruption to the lake bed and the existing shoreline properties. Based on our initial assessment, any other structural solution would be at least twice as expensive.

In implementing the rip-rap toe protection depicted in Figure 4, it is essential that the clear stone used to infill the gap at the base of the existing shorewall be covered with a heavy-duty non-woven geotextile, as shown. This will serve to prevent the migration of fine backfill materials through the layered rock protection and thus maintain the integrity of the shoreline structures. A similar method (or other non-pervious material) should also be used to plug and/or cap the existing drain holes through the concrete shorewall.

6.2 Slope Stabilization & Deck Restoration Options

With the toe protection installed as described above, the existing voids behind the shorewall and the deficiencies in the deck slab can then be properly addressed. Where the existing deck slab is exhibiting significant cracking and/or settlement, we would recommend that the slab be removed and the underlying eroded backslope covered with a heavy-duty non-woven geotextile. The void can then be filled with an appropriate granular material and a structurally-reinforced deck slab reconstructed over top. In designing the slab, the north edge should rest directly over the shorewall, while the south edge should be supported by a cast-in-place grade beam, founded to frost depth. This scope of slope stabilization and deck restoration works is presented as Option #1 in Figure 5.

Where the existing deck slab is in good condition, it may be possible to stabilize the underlying slope by drilling holes through the deck surface and filling the underlying voids with unshrinkable lean concrete fill. This option (i.e., Option #2 – see Figure 6) would serve to address the eroded backslope while minimizing the disruption to the existing shoreline.

6.3 Cost Estimate

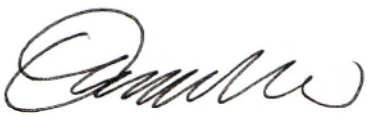
Based on the scope of repairs outlined in Figures 4 through 6 and described above, we estimate that the construction cost to repair and restore the shoreline structures within the study area will be in the order of **$3.5 to $4.5 Million** (excluding HST). A breakdown of this cost estimate is provided in Table 1, based roughly on unit rates that we have observed on similar barge-based construction projects in recent years.

Please note that the breakdown provided in Table 1 represents our most optimistic projections for the scope of work outlined herein. Given the relative inaccessibility of the site (backing entirely on private property) and potential for difficulties to arise during construction due to strong winds, high waves, and inclement weather, we have added a $1 Million estimating contingency to our base estimate to provide the range of costs noted above. Please also note that our cost estimate does not include allowances for engineering, administration, or financing.

Thank you for the opportunity to work on this assignment. We trust that the above will be sufficient for your purposes. If you have any questions or concerns, please do not hesitate to call.

Yours truly,

Landmark Engineers Inc.



Daniel M. Krutsch, P.Eng.

David T. Killen, P.Eng.

Landmark Engineers Inc.

Title: KEY PLAN – STUDY AREA	Date: 14 JAN. 2020	FIGURE 1
	Scale: NTS	
Project: EAST RIVERSIDE SHOREWALL ASSESSMENT	Project No.: 19-007	

LEGEND

(1)	PROPERTY IDENTIFICATION #
	PROPERTY LIMITS
0+500	STATIONING (AS PER WATECH REPORT)

Landmark Engineers Inc.

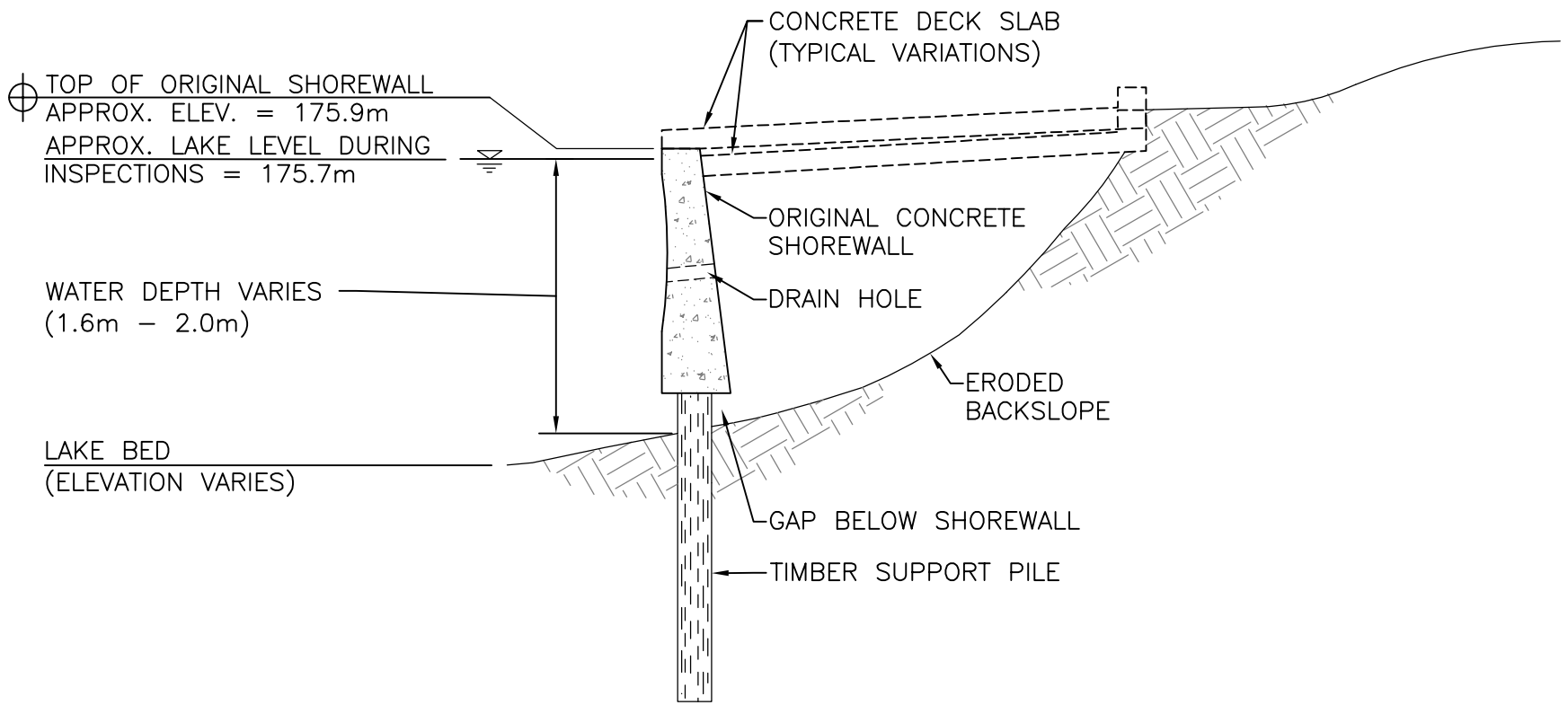
Title: PROPERTIES INSPECTED (10870 TO 11382 RIVERSIDE DR. E.)	Date: 15 DEC 19	FIGURE 2A
Project: EAST RIVERSIDE SHOREWALL ASSESSMENT	Scale: NTS	
	Project No.: 19-007	

LEGEND

(1)	PROPERTY IDENTIFICATION #
	PROPERTY LIMITS
0+500	STATIONING (AS PER WATECH REPORT)

Landmark Engineers Inc.

Title: PROPERTIES INSPECTED (11382 TO 11906 RIVERSIDE DR. E.)	Date: 15 DEC 19	FIGURE 2B
Project: EAST RIVERSIDE SHOREWALL ASSESSMENT	Scale: NTS	
	Project No.: 15-007	



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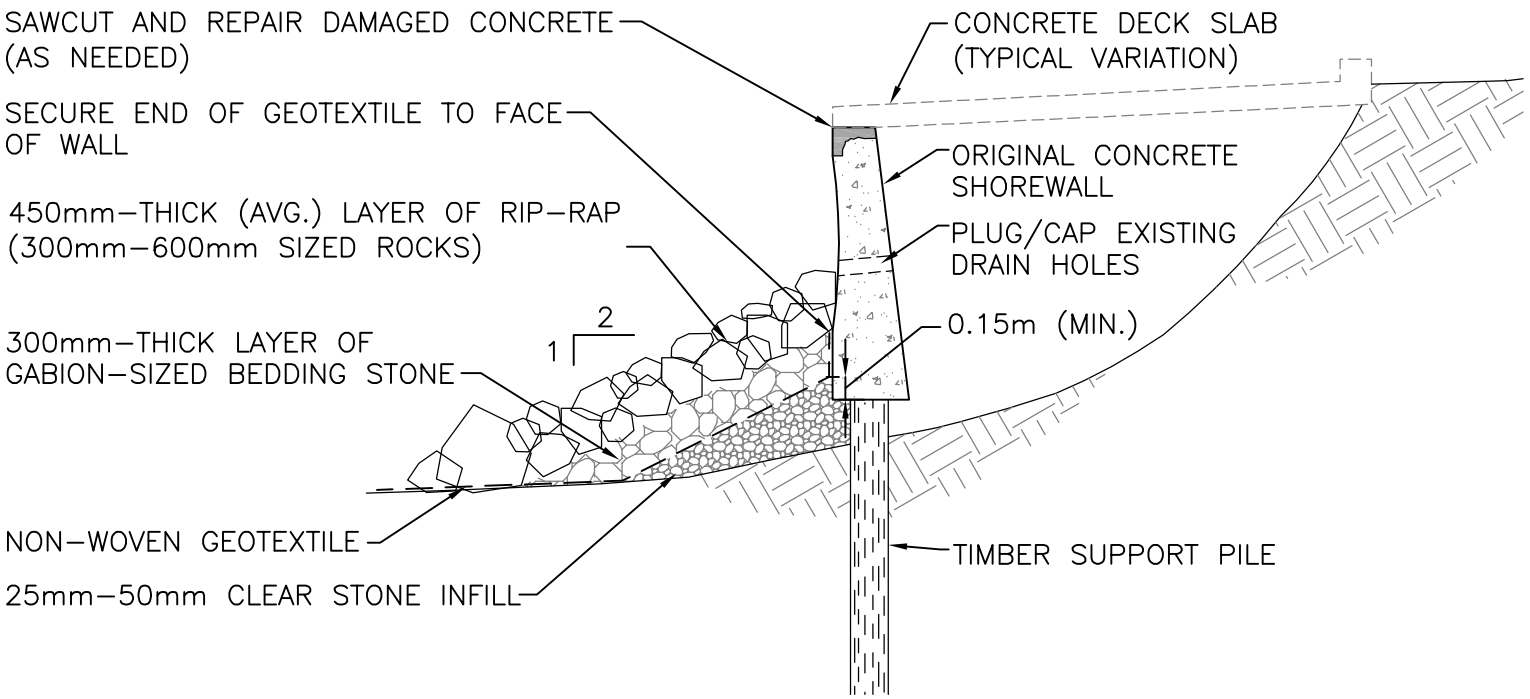
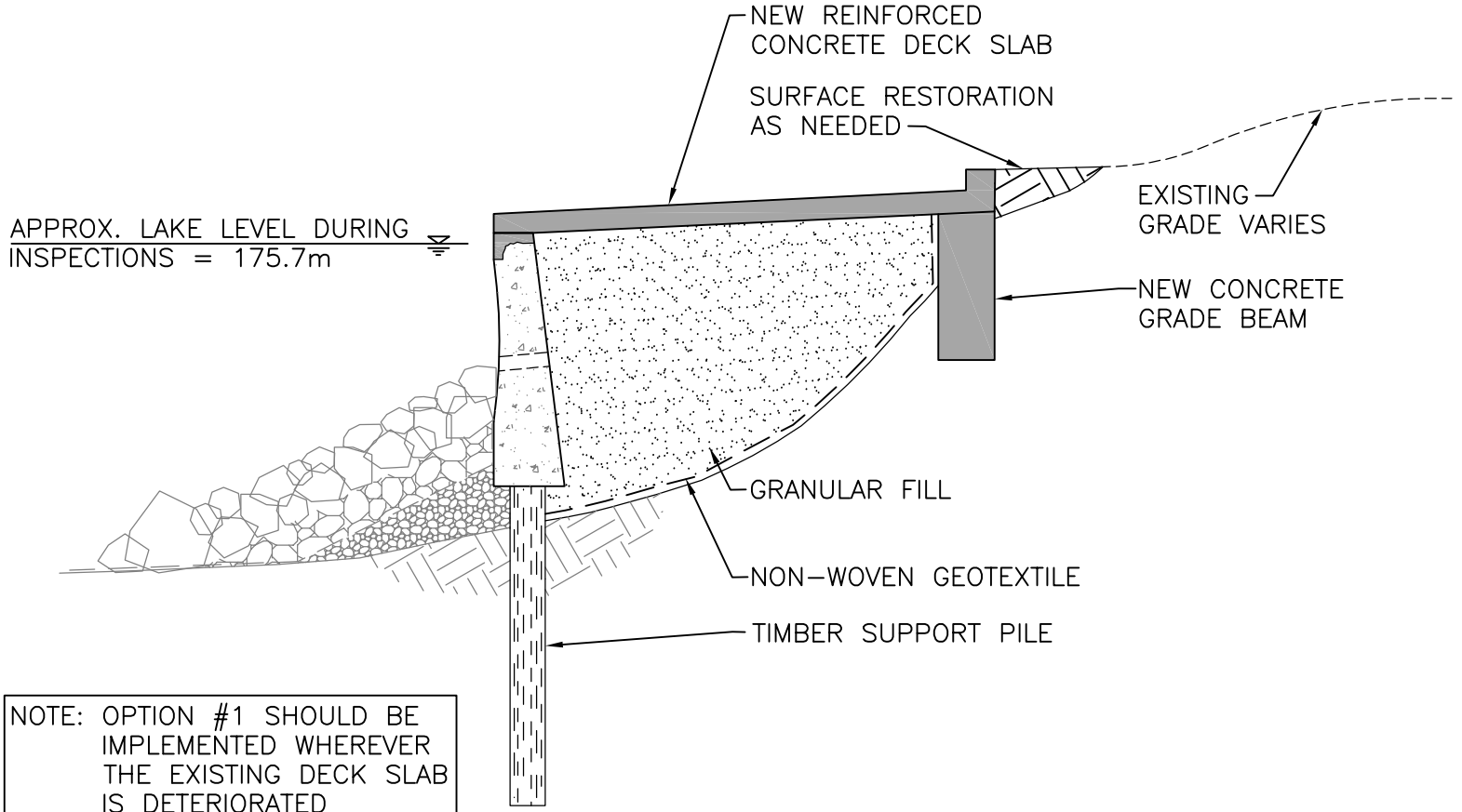
Title: EXISTING CONDITIONS (TYPICAL)	Date: 14 JAN. 2020	FIGURE 3
Project: EAST RIVERSIDE SHOREWALL ASSESSMENT & FUNCTIONAL DESIGN	Scale: 1:50	
	Project No.: 19-007	



Landmark Engineers Inc.

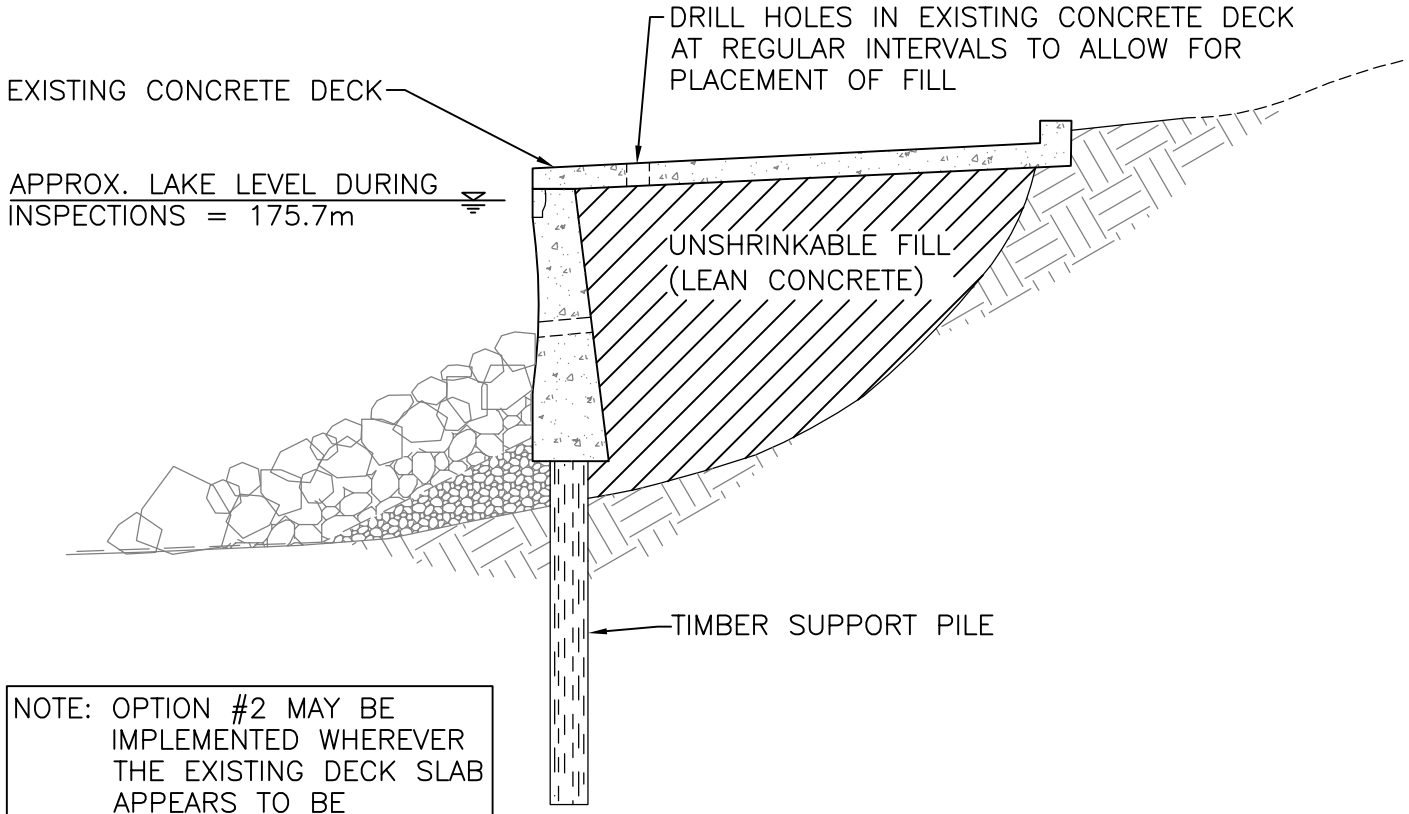
Title: PROPOSED WORKS: SHOREWALL REPAIR AND TOE PROTECTION	Date: 14 JAN. 2020	FIGURE 4
Project: EAST RIVERSIDE SHOREWALL ASSESSMENT & FUNCTIONAL DESIGN	Scale: 1:50	
	Project No.: 19-007	



NOTE: OPTION #1 SHOULD BE IMPLEMENTED WHEREVER THE EXISTING DECK SLAB IS DETERIORATED

Landmark Engineers Inc.

Title: PROPOSED WORKS: SLOPE STABILIZATION & DECK RESTORATION (OPTION #1)	Date: 14 JAN. 2020	FIGURE 5
Project: EAST RIVERSIDE SHOREWALL ASSESSMENT & FUNCTIONAL DESIGN	Scale: 1:50	
	Project No.: 19-007	



NOTE: OPTION #2 MAY BE IMPLEMENTED WHEREVER THE EXISTING DECK SLAB APPEARS TO BE DETERIORATED

Landmark Engineers Inc.

Title: PROPOSED WORKS: SLOPE STABILIZATION (OPTION #2)	Date: 14 JAN. 2020	FIGURE 6
Project: EAST RIVERSIDE SHOREWALL ASSESSMENT & FUNCTIONAL DESIGN	Scale: 1:50	
	Project No.: 19-007	

Table 1 - East Riverside Shoreline Restoration Works

Budget Estimate

ITEM NO.	DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT PRICE	TOTAL PRICE
SECTION A - SHOREWALL REPAIR & TOE PROTECTION WORKS					
1	Patch repairs to existing concrete shorewall	Cu. M.	5	$20,000.00	$100,000.00
2	Supply and place clear stone infill	Tonnes	1,200	$90.00	$108,000.00
3	Supply and install geotextile	Sq. M.	5,000	$5.00	$25,000.00
4	Supply and place gabion-sized bedding stone	Tonnes	1,400	$90.00	$126,000.00
5	Supply and place rip-rap	Tonnes	2,800	$110.00	$308,000.00
		TOTAL SECTION A			**$667,000.00**
SECTION B - SLOPE STABILIZATION & DECK RESTORATION WORKS (Option #1)					
1	Break up, remove, and dispose of existing concrete deck slab and underlying debris	Sq. M.	3000	$25.00	$75,000.00
2	Rough grade backslope	Sq. M.	3000	$10.00	$30,000.00
3	Supply and install geotextile	Sq. M.	3000	$5.00	$15,000.00
4	Supply, place, and consolidate granular fill	Tonnes	7500	$80.00	$600,000.00
5	Construct new reinforced concrete grade beam	Lin. M.	760	$500.00	$380,000.00
6	Construct new reinforced concrete deck slab	Sq. M.	3000	$200.00	$600,000.00
		TOTAL SECTION B			**$1,700,000.00**
SECTION C - SLOPE STABILIZATION WORKS (Option #2)					
1	Drill holes in existing concrete deck and infill void with unshrinkable lean concrete fill	Cu. M.	2000	$500.00	$1,000,000.00
		TOTAL SECTION C			**$1,000,000.00**
SECTION D - MISCELLANEOUS COSTS					
1	Mobilization & Demobilization	Lump Sum			$80,000.00
2	Yard Restoration Works	Allowance			$28,000.00
3	Contract Costs	Allowance			$25,000.00
		TOTAL SECTION D			**$133,000.00**
		TOTAL ESTIMATED COST			**$3,500,000.00**