5. CONCLUSIONS, RECOMMENDATIONS, COST ESTIMATES

5.1 CONCLUSIONS

In general, Pier 40 is in overall **Poor** condition. The allowable uniform live load rating for the pier has been significantly reduced from its original design live load capacity. Based on its current usage, the overall operational condition of Pier 40 should be maintained to support a minimum allowable live load rating of 100 psf for general assembly, for fire truck loads in all public areas, and to be able to resist all of the aforementioned lateral loads.

The current vertical live load capacity of the pier is summarized in Table 5-1.

Table 5-1 Summary of Load Ratings for Pier 40

Structure	Governing Structural Element	Allowable Uniform Live Load	Fire Truck Access
Pier Shed	Steel H-piles rated Severe	100 psf (with a 2% overstress)	No Restrictions
Court Yard	Concrete pile cap beam with exposed steel reinforcing and Severe piles	150 psf	No Restrictions
Finger Pier Extension	Deteriorated beams and deck	0 psf (with the possibility of ice loading)	Not Applicable
		100 psf (with no possibility of ice loading)	

The Pier Shed is capable of supporting a uniform live load of 100 psf in its existing condition and it is also capable of supporting a fire truck with a 24 kip wheel load and a Rescue Truck with a 26 kip wheel load. The results of the analysis indicate that the design ice load, which is based on an 8 inch thick layer of ice, is very demanding on the pier structure and is the controlling load within Load Combination 8, as well as Load Combination 9.

Earlier inspection reports had discounted ice loading conditions as being low probability. With the continued deterioration of the pier substructure and the severe winter of 2013/2014, the ice loads specified in the HRPT Design Guide have now been included in the load combinations, greatly reducing the allowable live loads.

While the steel H-piles with a pile grade of Severe under the Pier Shed and are currently sufficient to support the current usage on the pier, the level of corrosion on the piles has reached a critical level. Any notable amount of additional section loss, especially at the tops of the piles, could possibly result in load restrictions on the pier.

The allowable uniform live load rating for the Court Yard is 150 psf, and is governed by the structural capacity of the concrete pile cap beams with exposed reinforcing. Although the extent of deterioration on the concrete beams varies throughout the entire Court Yard, the structure was conservatively rated based on the lowest load rating determined for the analyzed structural elements.

At the Finger Pier Extension, the steel H-piles are capable of supporting a uniform live load of 0 psf in their current condition, based upon the loading combinations outlined in the HRPT Design Guide. It is important to note that the allowable uniform live load rating of 0 psf is governed by the Ice Load outlined in Load Combination 8 and Load Combination 9. Since the controlling load is an ice load, it is recommended that access to the Finger Pier Extension be restricted anytime that the possibility for an ice load exists. When there is no possibility of ice load on the Finger Pier the allowable live load is 100 psf.

The Finger Pier Extension was not analyzed for fire truck loads due to its size, and limited access to large vehicular traffic. It should be noted that fire truck access on the apron around the Pier Shed is somewhat restricted due to gated entrances and limited apron deck space.

With the installation of a proper fender system, vessels similar in size to the Hornblower Infinity could also moor along the south and west sides of the pier, in addition to the currently occupied north side. Vessels significantly larger than the Hornblower Infinity would require additional mooring analyses to determine whether the piles are capable of resisting the associated lateral loads. Existing mooring line and

mooring hardware capacities associated with the Hornblower Infinity were not evaluated.

5.2 RECOMMENDED REPAIR

A cost effective repair plan that addresses all areas of deterioration without the need for future phased repair efforts (aside from routine inspections and regular maintenance) was developed.

The controlling defect on the steel H-Piles is the corrosion at the tops of the piles, above the MHW line. An epoxy coating often obscures this corrosion, however, selective removal of the epoxy coating at Level II/III locations has confirmed that corrosion of the underlying steel H-Piles exists. As this corrosion extends to the very tops of the piles, to just below the concrete pile cap, the integrity of the load transfer/bearing between the piles and the pile caps can become compromised, and the associated repair must reestablish these connections, as well as strengthen the deteriorated areas of the piles.

Although the pile flanges were previously repaired/strengthened with C-Channels within the mid-pile zone, at approximately MLW, the H-piles webs were not repaired within this zone and are very thin. The H-pile webs should be strengthened as well. Therefore, it is recommended that reinforced concrete encasements, with structural connections to the pile caps, be installed. These encasements should extend down into the mudline.

At pile locations that do not require structural repairs to maintain the aforementioned minimum operational capacity, it is recommended that non-structural encasements be installed as a preventative measure to inhibit corrosion and preserve the pile in its existing condition. These non-structural repairs should extend from the tops of the piles and into the mudline. They would effectively replace the function of a cathodic protection system. It is recommended that these be epoxy grout encasements.

Since the recommended repairs are widespread, there are several obstacles to the swift and efficient rehabilitation of the pier. These obstacles include pier size, environmental obstacles, and lack of head room. Pier 40 is a large pier and repairs specified at the interior/middle piles will be significantly more labor intensive than repairs

specified along the pier perimeter. Environmental obstacles include pouring encasements in the winter months, which is not possible/recommended. Finally, large areas of the pier, especially the Court Yard, have little to no headroom during some or all of the tide cycle. All of these factors contribute to the difficulty associated with a widespread and comprehensive repair effort and cause repair costs to increase.

5.3 RECOMMENDATIONS

Recommendations made in this report are grouped into the following three levels of importance. The definition of each level of importance is taken from the New York City Economic Development Corporation's (NYCEDC) Waterfront Facilities Maintenance Management System Inspection Guidelines Manual.

- **"Immediate"** actions are taken to prevent unsafe conditions and are intended to return structural capacity.

- **"Priority"** repairs do not require immediate action, are intended to maintain the structure in a safe operating condition and/or prevent deterioration from continuing to a point where the future repairs will be significantly more costly. Based on general assumptions of production rates and construction crew size, it is expected that Priority repairs will take approximately 6 years to complete.

- **"Routine"** actions are those to be undertaken as part of a scheduled maintenance program. Postponing recommended Routine Level actions will not compromise the structural integrity of the facility or significantly increase the cost to repair the structure. Based on general assumptions of production rates and construction crew size, it is expected that Routine repairs will take approximately 1.5 years to complete.

5.3.1 Repair Description

(A) IMMEDIATE ACTIONS

At the Finger Pier Extension, the steel H-piles are capable of supporting a uniform live load of 0 psf in their current condition, based upon the loading combinations outlined in the HRPT Design Guide. It is important to note that the allowable uniform

live load rating of 0 psf is governed by the Ice Load outlined in Load Combination 8 and Load Combination 9. Since the controlling load is an ice load, it is recommended that access to the Finger Pier Extension be restricted anytime that the possibility for an ice load exists and that repairs to restore its structural capacity be implemented on an Immediate basis.

(B) PRIORITY ACTIONS

While the steel H-piles with a pile grade of Severe under the Pier Shed are currently sufficient to support the current usage on the pier, the level of corrosion on the piles has reached a critical level. Any notable amount of additional section loss, especially at the tops of the piles, could possibly result in load restrictions on the pier. Since the most severe corrosion is located at the tops of the piles, where nearly 25 percent of the H-piles (830 piles) have an epoxy coating that conceals this corrosion from view, it is difficult to determine when each pile would reach its critical load capacity. For this reason, and to better ensure uninterrupted use of the facility, it is recommended that all steel H-piles graded Severe and Major be repaired with structural concrete encasements on a Priority basis.

While Pier Shed piles graded Severe and Major are currently sufficient to support the current usage, non-structural encasement, which will "freeze" the pile in its existing condition, are not recommended. Structural encasements are recommended instead because these piles have little allowance for additional deterioration if the current load rating is required. Further, this load rating analysis is based on a Routine inspection, which is a general inspection intended to assess the general overall condition of the structure. If, in the future, a Repair Design Inspection is conducted, which is intended to record relevant attributes of each defect to be repaired, this additional information could be used to possible reduce the number of recommended structural encasements.

The existing cathodic protection system appears to be at the end of its useful life. Considering the data collected, and the high cost/risk of leaving an uncoated steel structure in an aggressive saltwater environment, it is recommended that any pile not recommended for encasement on an Immediate or Priority basis and with anodes having 5 years or less of estimated remaining life, be encased with a non-structural encasement on a Priority basis.

(C) ROUTINE ACTIONS

All steel H-Piles are in an active state of corrosion and are currently protected by a cathodic protection system that is likely at the end of its useful life. Further, this cathodic protection system does not protect the most aggressive zone of corrosion, the splash zone, located just above MHW. To keep future maintenance efforts to a minimum, it is recommended that all piles currently graded Moderate or Minor be repaired with a full-height protective encasement on a Routine basis.

The concrete pile cap beams with exposed steel reinforcing should be repaired by replacing the deteriorated steel reinforcing bars, including the stirrups, which are typically more heavily corroded than the longitudinal reinforcing bars. After the existing reinforcing is cleaned and replaced, with all unsound concrete removed a minimum of 1 in. behind the reinforcing, the beam cross section should be restored by a form and pour/pump concrete repair technique. It is recommended that all spalls with exposed reinforcement, all structural cracks, and all large cracks be repaired on a Routine basis.

It should be noted that concrete pile cap beams with fine cracks and delaminated soffits are currently not recommended for repair.

The precast prestressed deck planks with exposed prestressing strands should be repaired by cleaning the exposed strands and forming and pouring/pumping a concrete patch to protect the remaining strands. Analysis results of the precast planks indicate that a plank can support a uniform live load of 300 psf, and a fire truck wheel load assuming 60% section loss in the bottom layer of prestressing strands.

The exposed steel reinforcing on the deck soffit at the Finger Pier Extension should be repaired by replacing any broken reinforcing bars and forming and pouring/pumping a concrete patch.

It should be noted that delaminated concrete on the deck soffit is currently not recommended for repair.

Table 5-2 Cost Estimate for Pier 40 Recommended Repair

Repair Type	Structure	Number of Piles to Repair		Timber Fender System Replacement (LF)	Area of Beam and Deck to Repair (SF)	Cost Estimate	
		Structural Encasements	Non-Structural Encasements			Subtotal	TOTAL
Immediate	Pier Shed	--	--	--	--	--	$80.6M
	Court Yard	--	--	--	--	--	
	Finger Pier Ext.	110	--	--	--	$3.96M	
Priority	Pier Shed	1,671	676	--	--	54.41M	
	Court Yard	--	444	--	--	$6.63M	
	Finger Pier Ext.	--	4	--	--	$104,307	
Routine	Pier Shed	168	330	2,405	950	$13.49M	
	Court Yard	--	39	--	500	$1.12M	
	Finger Pier Ext.	--	21	--	280	$848k	
Escalation to Mid-Point of Construction – 7.5 Year Construction Period							
Escalation to 2016 (2 Year Design Period)		6.09%		$4.9M		$14.9M	
Escalation to 2020 (Mid-Point of Construction)		11.72%		$10M			
Total Project Construction Cost With Escalation				**$95.5M**			

Note: Owner's costs, not included in the base pricing, totals $9.1M. For detailed breakdown of costs please refer to Appendix C.

The strengths of this repair recommendation are that it is comprehensive and addresses all notable defects. The resulting repaired structure should be relatively low maintenance, sufficient to support the current use requirements for the foreseeable

future, and any unknown deficiencies that exist now will likely be discovered and remedied during such a widespread rehabilitation effort.

5.3.2 Miscellaneous Repairs

Although these repairs will not affect the structural capacity of the pier, it is recommended that these repairs be completed to ensure public safety.

The concrete closure wall, between the deck planks of the Court Yard and the Pier Shed, has several areas of severe deterioration with through spalls/voids and large width cracks. It is recommended that these severe defects be repaired on a Routine basis to prevent access to the pier substructure from the Court Yard.

5.3.3 Additional Investigation

As per the American Society of Civil Engineers Underwater Inspections Guidelines Manual, steel pile supported structures in **Poor** condition that are located in aggressive environments should be inspected every 4 years.

5.4 COST ESTIMATE

The estimated cost for the recommended repair is presented in Appendix C. Included in the cost estimate, but not shown in Table 5-2, are typical owner costs estimated at approximately $9.1 million which would be expended during both the design and engineering phase and during construction. Owner costs include items such as design services, construction administration, diving and controlled inspections. The order-of-magnitude total for both contractor and owner costs is therefore estimated at approximately $104.6 million.