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Britt Murray
State of Delaware
Division of Parks & Recreation
89 Kings Highway
Dover, DE 19901

RE: WO# D4237.00
Cape Henlopen Fishing Pier:
Structural Condition Assessment & Reconstruction Recommendations
Cape Henlopen State Park
Lewes, Delaware

Dear Britt:

In accordance with our proposal dated October 20, 2006, we are submitting this engineering letter report. Our review was prompted by your observations of deteriorated piling during the summer of 2006, and the subsequent partial closure of the pier.

Our work to-date has included an initial cursory review of the piling, followed by a more in-depth visual review of the piling in the portion of the pier which remains open at this time, design of emergency (short-term) repairs for the piling in the same location, preparation of a preliminary report dated August 2006, an engineering analysis of the existing pier superstructure, and preparation of this report. Some of this work was performed under a separate agreement dated August 2006. Our field work consisted of visual observations and minor selective probing of the visible structural elements of the pier, along with the identification of those piling currently in need of repair on the inner portion of the pier.

The purpose of this report is to explore options of permanent repairs and reconstruction of the existing pier. We note that the pier is currently partially open to the public on a short-term basis, with the understanding that the condition of the existing piling must be frequently monitored. Furthermore, we note that the current live load capacity of the pier is 50 pounds per square foot (psf).

Given the current use of the pier (fishing), we do not think this load will be exceeded on widespread areas of the pier; however, we recommend that any long-term repairs or new construction be designed for a minimum live load of 100 psf.

Furthermore, we recommend that repairs required to bring the pier up to a live load capacity of 100 psf be performed at your earliest possible convenience. In the interim, the live load on the pier should be limited to 50 psf, and special events that may exceed this must be prohibited. The use of a crane on the pier by SPI-Pharma is permitted per the conditions of our letter dated October 2006. We note that the condition of the piling should be monitored prior to, and during the use of the crane.

FINDINGS

General

We understand that the pier was originally constructed ca 1942, and is of timber construction, with all original materials treated with an unknown level of creosote. The inner portion has undergone some repairs to the original decking, and has been completely overlaid with a new deck. The middle section and East T-head have none of the original superstructure and are currently closed to the public. The West T-head is similar in construction to the inner section and is also currently closed to the public.

For the purposes of this report we have divided the pier into 4 distinct sections as described below. We have grouped our findings according to the sections of the pier.

Inner (wide) section: Extends from the shoreline outwards into the bay approximately 1236 feet. This portion of the pier is approximately 24 feet wide, and consists entirely of original construction, with the exception of a new overlay of decking. Approximately 10 piling have new epoxy jackets as part of a 2007 repair.

Middle (narrow) section: Extends from the offshore end of the inner section out to the T-head. The middle section is approximately 550 feet long and 10 feet wide, and is comprised of the original deteriorated piling, with a relatively new system of girders, stringers, and decking constructed ca 1995. The middle section is approximately 1.83 feet lower than the inner section.

East T-head: Extends from approximately 55 feet west of the middle section to the east end of the t-head. This area is similar in construction and elevation to the middle section, having a 1995 superstructure supported by the original deteriorated pilings. The total length is approximately 255 feet.

West T-head: Similar in construction and elevation to the inner portion, with all of the original construction and a new deck overlay. The total length is approximately 145 feet.

Inner Section

Following our observations of August 2006, we identified 131 piling which were deteriorated to the extent that they no longer had any load carrying capacity. (Refer to photograph #1.) Of those 131 piling, 10 were identified as requiring immediate repair to allow certain portions of the pier to remain open under a temporarily reduced capacity of 50 psf. We understand that the 10 piling have been repaired and the small sections of the pier previously closed are now open to the public.

As part of this report, we have analyzed the pier for the purpose of identifying those piling requiring repairs in order to achieve a minimum live load capacity of 100 psf. We have considered these repairs to be "long-term" in the sense that they will provide for a live load capacity of at least 100 psf and provide an additional 8-12 years of useful life for the pier; however, we note that the remaining superstructure is of the original ca 1942 construction. According to our review, we believe the pier was originally designed for a live load capacity of 200-250 psf.

At this time, the girders, stringers, and decking appear to be in fair condition, although the likely areas of deterioration are not visible for our review. These are the areas of horizontal contact between the decking/stringer connection, and the horizontal surface between the stringer/girder connection. Given the high original design load and redundant nature of the construction, we believe the superstructure components will maintain a 100 psf live load capacity after a moderate amount of deterioration. Of importance is the age of the existing creosote treatment on the superstructure- currently approximately 65 years. Our experience with similar structures has shown a maximum useful life of 50-70 years. We anticipate that deterioration will advance quickly as the creosote continues to fail.

Middle Section

The superstructure of the middle section was partially reconstructed ca 1997, reducing the pier width to 10 feet. (Refer to photograph #2.) The new superstructure was designed for a live load of 100 psf, and at this time is in fair to good condition. Given the non-redundant nature of the construction and the original design load of 100 psf, each of the piling in the 4-pile bents are required to support the superstructure. We note that approximately ½ of the 45 bents in the middle section contain a batter piling on the west side of the bent, presumably for use in resisting ice loads. The batter piling do not contribute to the resistance of gravity loads, but aid in resisting ice, wave, and wind loads. We do not recommend repair of the batter piling as their effectiveness is questionable; however, you should be aware that not repairing these piling increases the vulnerability of the pier to lateral loads- ice in particular.

Although a pile-by-pile review of the middle section was not performed as part of this project, the overall condition of the piling appears to be generally worse than the inner section. We attribute this to deeper water, increased wave action, and a more favorable environment for the growth of marine borers.

East T-head

Similar in construction to the middle section, although with varying widths, the superstructure was rebuilt ca 1997, is in good to fair condition, and has a live load capacity of 100 psf. (Refer to photograph #3) As with the middle section, the piling are in generally worse condition than the inner section, and each piling in each bent must be repaired for this area of the pier to have a 100 psf live load capacity.

West T-head

This area of the pier is similar in construction to the inner section, although the piling generally appear to be in worse condition than the inner section. (Refer to photograph #4) We understand that this section of the pier will be demolished, and therefore spent no appreciable time reviewing this area. Given the widespread deterioration of the piling observed during our initial cursory review in August 2006 we concur with the decision to demolish this area of the pier.

Should collapse of the West T-head occur, the possibility exists that collapse of this area could affect nearby portions of the east T-head and the middle section due to the connection of the superstructure.

RECOMMENDATIONS

Summary of Recommendations Prior to Permanent Repairs

1. Maintain current closures on unsafe sections of pier.

2. Close the pier to the public during significant coastal storms.

3. Close the pier to the public during periods of ice in the bay.

4. Limit the live load to 50 psf. Events or circumstances that may exceed 50 psf should not be permitted.

5. Until such time that final repairs are made, monitor the condition of the piling, as the deterioration will continue.

6. Collapse of the West T-head is possible. We suggest you make plans for removal of this area.

7. Remove abandoned piling that may fail and become a hazard to navigation.

8. Continue to monitor the condition of the railing, decking, and superstructure, making repairs as necessary.

9. Operate the SPI-Pharma crane in accordance with our recommendations of October 2006.

General

See attached sketches S1, S2, and S3 for a summary of the following recommendations.

In accordance with your request, we have considered the option of repairing the pier with the goal of obtaining an additional 8-12 years of use. Currently the inner section of the pier is open to the public with a reduced live load capacity of 50 psf. The recommendations of this report have been prepared with a scope of work required to obtain a more appropriate live load capacity of 100 psf. For the purposes of this report, piling repairs are considered to be a fiberglass jacket with reinforcing steel and epoxy grout in the annular void between the piling and the jacket. This is a similar repair to the repairs performed in March of 2007.

Other repair schemes considered for this report are: driving additional piling outboard of the existing piling and adding a new girder, and a bolted repair utilizing a new pile section at the deteriorated area. These repairs were not considered practical or economical.

It is important to note that prior to committing to any long term repairs of the piling, the condition of the superstructure and the piling below mean low water must be verified. Therefore, prior to performing long-term repairs we recommend that an underwater condition survey of the piling be performed by qualified diving contractor experienced in the underwater surveying of piers and wharves. The purpose of this survey would be to verify the condition of the piling between the mud line and mean low water. Based on our experience, we have no reason to suspect the condition of the piling below the mud line elevation. For long term planning, we have assumed that all of the existing piling will eventually completely deteriorate in the splash zone.

Furthermore, we suggest that a qualified testing firm be engaged for the purpose of testing the existing levels of creosote in the piling and superstructure. Additionally, we recommend that several small areas of the existing superstructure be removed to allow review of the horizontal contact surfaces of the stringers and girders. The

results of the testing and field review of the existing superstructure may affect your decision to proceed with long-term repairs.

The recommended piling repairs may be performed in phases if a complete repair of the pier is not economically feasible at this time; however, if a phased repair is chosen we suggest that the condition of the piling be closely monitored as the existing piling will continue to deteriorate. Additional areas of closure may be warranted and should be anticipated as the deterioration advances. We do not suggest that the pier remain open to the public with a rated capacity of 50 psf any longer than absolutely necessary. If the phased repair scheme is utilized, additional field reviews of the existing piling are recommended.

We have considered a 3 year phased repair as one of the many options available for a phased repair scheme. (Reference S2, Sht. 2 of 4) Under this option, we have estimated that the worst 150 piling in the inner section and 95 piling in the middle section will be repaired in year 1. This will allow public access to all of the middle section and the inner half of the middle section. During year 2, an additional 150 piling are repaired in the inner section, and the remaining 90 piling in the middle section are repaired, allowing public access out to the end of the middle section. The final 116 piling in the inner section and 184 piling in the East T-head are repaired during year 3, allowing public access out to the end of the East T-head.

Numerous variations to a 3 year repair plan are possible, according to available funds and the total length of pier required to remain open.

The scope of repairs described for the inner portion of the pier includes the repair of 4 out of every 6 piling per bent. The fiberglass/epoxy jacket type repair will increase the diameter of the piles by approximately 6 inches, thereby providing additional surface area for the effects of moving ice loads. We note that the pier is currently under risk of collapse during a significant ice event, and that the proposed repairs will improve the current resistance to ice loads, but will not return the pier to original as-built capacity. Should the option of a long-term repair be chosen, the potential for significant damage by ice should be noted, particularly if the repairs are phased.

Additional items for consideration if the long term repair option is chosen include: routine deck repair and maintenance, fence maintenance, and access of the pier by SPI-Pharma for equipment maintenance. Removal of the existing abandoned piling in the middle and East T-head should also be considered, due to the possibility of becoming a hazard to navigation as deterioration progress.

Specific recommendations for each section of the pier may be found below.

<u>Inner section</u>

The long-term repairs and actions recommended for the inner section are as follows:

1. Perform laboratory testing on the superstructure framing for the purpose of identifying the remaining levels of creosote preservative in the wood*.

2. Remove a portion of the decking and stringer system to allow review of the horizontal contact surfaces*.

3. Perform an underwater condition survey of a representative number of the existing piling*.

4. Repair the exterior piling in each bent. (2 per bent)

5. Repair (2) interior non-adjacent piling in each bent. Stagger interior repairs from bent to bent.

* Perform these additional evaluations prior to committing to a long-term repair option.

Notes:
A. A total of 4 piling per bent in the inner section are recommended for repair.
B. Phasing the repairs over time is possible; however, additional reviews and partial closures may be required, depending on the delay of repairs and rate of deterioration.
C. Some bents may initially require less than 4 piling repairs if phased repairs are implemented. Additional field review of the piling will be required.

Middle Section & East T-head

1. Perform laboratory testing on the superstructure framing for the purpose of identifying the remaining levels of creosote preservative in the wood*.

2. Perform an underwater condition survey of a representative number of the existing piling*.

3. Repair each piling in every bent. (4 piling per bent in middle section; approximately 6 piling per bent in East T-head)

4. Give consideration to the removal of the existing abandoned piling in these areas to reduce the possibility of these piling becoming a hazard to navigation.

5. Partial collapse of the middle section and the East T-head cannot be ruled out in the interim period before pile repairs are completed. These areas of the pier are particularly vulnerable to ice and coastal storm events.

* Perform these additional evaluations prior to committing to a long-term repair option.

Notes:
A. Pile repairs as described above are recommended prior to opening any portion of the middle section.
B. If repairs are performed as funds become available, repairs could begin at the landward end of the middle section and progress outward as funds permit.
C. Phased repairs may initially require fewer immediate piling repairs pending additional field review of the existing piling.

West T-head

Due to the significant number of damaged piling and the difficulty of obtaining clear access to the piling we do not believe repairs to this area of the pier are feasible. For the same reasons we believe that the West T-head area of the pier is currently under risk of collapse, particularly during coastal storms and/or ice events. Accordingly, we recommend that the West T-head portion of the pier remain closed and be removed at your earliest convenience.

New Pier Construction

For the purposes of this report we have considered the construction of a new pier of the same size and footprint as the existing pier. As requested, the proposed structural system consists of 18" square pre-cast concrete piling, a cast-in-place concrete pile cap, and a deck of pre-cast, pre-stressed concrete tee beams with a cast-in-place concrete topping. We have attached to this report a schematic cross section of the proposed pier and an Engineer's Estimate of Probable Construction Cost.

The all-concrete design would likely provide the greatest life-span, durability, and aesthetic qualities of any pier system. Other structural systems that could be considered for this site are: concrete piling, concrete caps, and aluminum deck sections (similar to the Woodland Beach pier); timber piling and superstructure (similar to existing pier). These alternate systems may prove to be lower in initial cost, but may not be as durable or desirable for maintenance or aesthetic reasons.

Cost saving items that should be considered for the construction of a new pier include: reduced width from shore out to deep water, reduced overall length, and a reduced length of the t-head.

We anticipate that ice loads will govern the piling design, particularly in light of the unique geography of the site. The thickness of ice to be considered can greatly influence the pile and cap design, and therefore must be discussed and established during design. Also of interest is the "funneling" effect of the inner breakwater and easterly trend of the shoreline toward Cape Henlopen. Ebb current coupled with the prevailing westerly winds tends to cause ice floes moving down the bay to

become condensed into the area of the pier, creating concentrations of ice higher than in nearby areas of the bay.

Should the option of a new pier be chosen, we recommend that a subsurface investigation and geotechnical engineering report be performed early in the design phase.

We trust this letter report fulfills your needs at this time. Please call if you have any questions, of if additional discussion is required.
Respectfully submitted,

BAKER, INGRAM & ASSOCIATES

Frank M. Young, P.E.

A. Paynter Ingram, P.E.

FMY/API: aml

Attachments:
1. Repair Sketch S1
2. Repair Sketch S2
3. New Pier Plan S3
4. New Pier Section S4
5. Engineer's Estimate of Probable Construction Cost
6. Photographs