

Woodrow Wilson Bridge Project

Shortnose Sturgeon Biological Assessment Supplement

January 2003

A. Introduction

This is a supplemental Biological Assessment (BA) regarding potential effects to the federally endangered shortnose sturgeon (*Acipenser brevirostrum*) from the Woodrow Wilson Bridge project (Project). In the original BA dated April 2000, FHWA determined that the Project was 'not likely to adversely effect' the shortnose sturgeon. NOAA Fisheries Service concurred with this finding in a letter dated February 24, 2000, (Appendix A). As part of the consultation with NOAA Fisheries, pile driving was not considered to pose a threat to the sturgeon. However, during construction of the Project, Project inspectors informed FHWA that fish mortality had resulted from large pile (66-72 inches in diameter) driving near the main channel of the river. No shortnose sturgeon was reported to have been killed. NMFS and other resource agencies were consulted regarding the effects of the pile driving and the Project implemented actions to reduce the potential for fish mortality. Based on this new information that driving these large piles may affect the shortnose sturgeon, this supplement BA was prepared to reevaluate the potential impacts on the shortnose sturgeon from the Project.

B. Project Status

The Woodrow Wilson Bridge Project (Project) is a large multi-jurisdictional public transportation project being jointly undertaken by the Federal Highway Administration (FHWA), the Virginia Department of Transportation (VDOT), the Maryland State Highway Administration (SHA) and the District of Columbia Department of Transportation (DDOT). The Project involves the replacement of the existing Woodrow Wilson Bridge with two side-by-side drawbridges and the reconstruction of four Capital Beltway interchanges (Telegraph Road, US Route 1, I295 and MD Route 210). Additionally, the Project will provide improvements to the recreational facilities in the local communities, substantial environmental mitigation, stormwater management, noise abatement and landscaping.

Since completion of the April 2000 BA, the Project completed the Final Supplemental Environmental Impact Statement on April 14, 2000 and the Record of Decision on June 16, 2000. Project permits were obtained throughout 2000, including the Department of Army on July 27, 2000; Maryland Tidal Wetlands License on June 7, 2000; Maryland Private Wetland Permit on July 26, 2000; Maryland Nontidal Wetlands and Waterways Permit on July 26, 2000; Maryland Water Quality Certification on June 7, 2000; Virginia Marine Resources Commission Permit on June 27, 2000; and the Virginia Department of Environment, Water Protection Permit on June 29, 2000. As required by design changes, the permits have been and continue to be modified to ensure compliance with all construction activities.

Construction on the Project in the River began on October 20, 2000 with initial dredging of the bridge construction channel. This dredging was completed ahead of schedule by January 2001. In the Potomac River and in Jones Point Park, Virginia, the construction of the new bridge foundations began on May 17, 2001 and is 84 percent complete, including all foundation in Jones Point Park and all foundation piles driven. The follow-on superstructure work has been divided into three contracts: bascule, Virginia approach, and Maryland approach. The bascule contract bids have been opened and work should start by March 2003. The approach contracts have both been advertised and both should start later this year. As for Maryland interchange work, three contracts have been awarded and are under construction. The pre-consolidation of soils on Rosalie Island and along Smoots Cove began on August 15, 2001 and is 69 percent complete, the construction of ramps E, F, and E-1 began on November 11, 2001 and is 56 percent complete, and the construction of the new outer loop portion of the I295/I495/I95 interchange providing access to the National Harbor development has just started, as well. In Virginia, the Project completed the demolition of the U.S. Army Reserve Center in Jones Point Park on November 10, 2000. The ground improvements for the US Route 1 Interchange began on December 17, 2001 and are 64 percent complete and the demolition of Hunting Towers began on June 11, 2002 and is 56 percent complete. The Project is actively preparing additional contracts for both bridge and interchange construction in Maryland, Virginia and the District. The next anticipated contract to be awarded in Maryland will include a contract to construct additional roadways in the I295/I495/I95 to replace the existing inner loop. The next Virginia contract anticipated to be awarded will be for the bridge construction of the US Route 1 Interchange. FHWA anticipates that the first of the two replacement bridges will be completed in early 2006 allowing the transfer of traffic to the new bridge. The demolition of the old bridge and the construction of the remaining portions of the second bridge are scheduled to be completed by 2008. FHWA anticipates that the construction of all interchange work will be completed by 2011.

C. Species Status Update

Since the April 2000 BA, the US Fish and Wildlife Service produced a report entitled "A Report of Investigations and Research of Atlantic and Shortnose Sturgeon in Maryland Waters of the Chesapeake Bay (1996-2000)." This document was referenced in the April 2000 BA but was not complete until October of 2000. The two year gill net study did not net a single a shortnose sturgeon in the Potomac River or elsewhere. A cash reward program for commercial fishermen to turn in shortnose sturgeon was also implemented and tracked starting in 1996. This program netted 39 shortnose sturgeon, including three from the Potomac River (two of which were noted in the April 2000 BA coordination letter from NMFS dated February 24, 2000). Over the course of the study, tissue samples of 28 shortnose sturgeon were collected and analyzed. None were significantly different from the Delaware River stock.

In addition, NMFS informed FHWA that two shortnose sturgeon were caught in the Spring of 2002 near Potomac Creek. Tissue samples were obtained for one of the sturgeon and analysis genetically linked the sturgeon to Delaware stock, as well.

D. Project Description

As part of the Foundations Contract to support the new Potomac River Bridge, approximately 580 piles were driven in the Potomac River providing the support for all 11 foundations or “touchdown” points from the Maryland to the Virginia shoreline. No mortality was associated with the greater majority of these piles (from M3 to M10) though some piles driven for foundations adjacent to or near the navigation channel were associated with fish mortality (Appendix B). Piles for M10, just off the Maryland shoreline south of the existing bridge, were 48” in diameter and 160 feet in length. These piles were driven within cofferdams, which were proven to substantially reduce pressure waves produced by driving, and are located over 2000 feet from the deep navigation channel, where the majority of fish seem to be located. As the pile driving operation moved to the east, the piles progressively increased in size, the driving energies typically were greater, and the effort grew near to the navigation channel. No fish mortality was noted while driving inside cofferdams except for foundation M2, the final foundation location prior to the bascule (or drawbridge) foundations (M1 and V1). In addition to the close proximity to the navigation channel, foundation M2 included some of the largest piles (66” in diameter), providing a logical explanation for the limited mortality.

These foundations are the largest and most complex of all due to the fact that they support the 12-lane drawbridge, all associated machinery and counterweight, and that they are located in 30-40 feet of water, as they straddle the navigation channel. Cofferdams are not practical in this situation, as they require extremely long sheets (over 100 feet in length) as well as internal bracing to counter the extreme hydraulic load exerted by the water column. Beyond complications associated with driving extremely long sheets to form a reasonably watertight cofferdam, the bracing adds complexity and imposes safety risk concerns. Instead, TKC engineered and built a suspended cofferbox (Appendix C) to serve as a temporary form for the construction of the permanent foundation. As opposed to the cofferdams, the driving of the permanent piles was the first order of business for the cofferbox, as the permanent piles supported the box. The cofferbox form system proved to be a safe and efficient means of constructing the M1/V1 foundations though the driving of some of the approximately 40 piles per quadrant resulted in some unanticipated fish mortality. This loss was likely due to a combination of several factors.

For reference, piles being driven for M1 and V1 were some of the largest driven for a bridge project in the country at nearly 200 feet in length, 72 inches in diameter, and 90 tons in weight. In fact, the piles sank nearly 70 feet into the river mud under their own weight. These piles required one of the largest hammers used in the United States for

bridge construction. The IHC S-500 hydraulic hammer exerted as much as 385,000 foot-pounds of force per blow (approximately an order of magnitude greater than a typical hammer) and the hammer alone weighed 62 tons (again, approximately an order of magnitude heavier than a typical hammer). The striking of any pile produces a pressure wave of some magnitude, typically perceived by a human as a sound wave. In a water medium this wave is transmitted to the water column which may exert a force upon fish in the area. Unmitigated, the pressure waves produced by driving of the largest piles in open water at M1/V1 exhibited the potential to negatively affect certain species of fish. This potential increased during spawning season. The Project and agencies immediately recognized this issue and worked diligently in unison to gain knowledge and implement effective minimization techniques.

E. Species Effects- Key Elements

In August of 2001, the Bridge Foundations Contract contractor, TKC, began driving large-bore piles immediately west of the navigation channel. These piles, at 72" in diameter and approximately 200 feet in length, were some of the largest associated with the project and required the highest driving energy.

Careful observation did not reveal fish mortality at the onset of pile driving. However, several days into driving at V1, it was noted that limited fish mortality was occurring and seemed to be associated with the pile driving. Agencies were immediately notified and the contractor worked with the Project to reduce impact. At the onset, fish species included primarily catfish, gizzard shad, carp, and white perch at a mortality rate of approximately 24-36 adult fish per pile. It was quickly learned that "pile tapping" was an effective means of minimizing fish mortality as light tapping prior to heavy driving seemed to "scare" fish away from the zone of mortality, quite similar to the "scare charge" concept often used as part of underwater detonations. This procedure reduced the mortality to five or less fish per pile, most of which were catfish.

The pile-tapping program was implemented for all piles driven adjacent to the navigation channel from August 2001 through the Winter of 2002, including piles for V1 outer loop, M1 outer loop, and M1 inner loop. The agencies were satisfied that the program sufficiently minimized impacts. Once pile driving transitioned into cofferdams at locations closer to the Maryland shoreline (M10), no fish mortality was observed though the Project continued to carefully monitor pile driving operations and committed to contact agencies if the fish counts or species changed.

MDNR Histology Analysis

The Project delivered collected catfish, gizzard shad, and blueback herring to the Maryland DNR Sarbanes Cooperative Oxford Laboratory in Oxford, Maryland, to conduct necropsy and histology analysis. The pathology report results stated that no lesions were apparent, the parasite load was normal, and the mortality was likely the result of pressure waves emitted from pile driving (Appendix A).

Increased Mortality at V1

When the pile driving operation moved back to V1 inner loop, in late March of 2002, mortality was again observed. It became evident that a worst-case scenario had amassed resulting in increased mortality. The contractor was driving the 72-inch diameter piles at energies up to 370,000ft-lb in open water adjacent to the navigation channel during spawning season and additional measures beyond the pile-tapping program would be beneficial in minimizing the mortality. Evidently, the fish population in the area increased due to spawning season, resulting in increased impact.

Agencies were immediately notified and NMFS, MD DNR, ACOE, DEQ, and various groups within MDE became closely involved and coordinated daily through phone calls, email, and site visits. MDE's Fish Kill Investigation Section visited the site on April 3, 2002 to confirm the species and observe the operation. As detailed below, extremely close coordination endured until pile driving moved back to the M6 foundation in late April of 2002 and fish mortality once again ceased.

Pile Driving at M2

As the pile driving operation progressed from M6 to the west, it drew closer to the navigation channel once again. Minor fish mortality was again noted during driving of 66" diameter piles at the M2 foundation (adjacent to M1) in July of 2002 and the Project took the opportunity to demonstrate that the contained ABCS was successful in minimizing fish kill and to conduct additional shock wave monitoring to determine a threshold for fish mortality for this type of pressure wave. This testing was conducted on July 30, the final day of pile driving for the foundation piles. As for the ABCS, the system was implemented and fish kill nearly ceased. In fact, at one point the iron weight on one corner of the air line inadvertently detached, allowing the line to float, twist, and kink and prohibiting adequate air bubble protection on one quadrant. Soon, dead fish were observed outside the cofferdam in that quadrant. The air line was repaired and no additional fish kill was observed during pile driving for the remainder of that day. Additional details on the ABCS can be found below.

No large-bore piles have been driven in-water since this date, although more are proposed at other stages of the project.

Minimization and Documentation Techniques and Procedures

Though neither the contractor, the Project, nor the agencies had observed fish mortality associated with pile driving in the past, an Action Threshold table with required monitoring and collection was immediately established by the agencies (led by MDE and NMFS) and implemented by the Project with full cooperation from the contractor. The structure of this process was as follows,

- ✓ Any number (one or more) of gamefish/commercial fish species taken as a direct result of pile driving was reported and itemized (approximate length and species

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composition) each day. This species category included all anadromous species including striped bass, hickory shad, American shad, white perch, yellow perch, blueback herring, alewives, largemouth bass, small mouth bass, catfish, pickerel, walleye, etc. This category specifically does not include gizzard shad or, in this case, resident panfish (bluegills, pumpkinseed etc.)

- ✓ Any daily total over 10 (all combined species, including non-game species) killed as a direct result of pile driving was reported and itemized each day. Note: less than 10 non-game species constituted a general report.
- ✓ When approaching 50 gamefish lost in one day, some remedial or mitigative action were required to be considered/investigated to rapidly minimize the mortality. Suggestions included cofferdams, timing of work if observations suggest this might help, use of fish finding sonar to avoid work during the presence of large schools, etc.
- ✓ Approaching 100 gamefish lost in one day was considered a serious situation requiring immediate agency coordination and/or immediate action to address the fish kill issue. The agencies requested definitive efforts at this situation to reach one or more primary resource agency personnel to conduct coordination as soon as possible.
- ✓ If a shortnose sturgeon came to the surface wounded or dead within the construction area, for whatever reason and at any time, then Consultation with NMFS would have been re-initiated immediately.

Reports were submitted to the agencies by the Project each morning after a day of pile driving with fish quantities, sizes, and species listed. Incidentally, the contractor voluntarily stopped pile driving on two consecutive days as the mortality approached 100 gamefish. Otherwise, numbers were well below 100 per day. The Project also documented progress regarding minimization techniques discussed and attempted. A number of methods were implemented in April 2002 to protect fish including:

- Expanded pile tapping program
- Time-of-Day Variations
- Implementation of Fish Finder program to locate schools of fish
- Use of Horns underwater
- Use of Turbidity Curtain
- Use of Air Bubble Curtain

Other techniques considered but not utilized:

- Use of scare charges (not a proven technique, potential for additional mortality)
- Use of Sonalyst Fish Startling System (species-specific limitations)
- Use of Strobes (water too turbid to be effective)

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- Use of Electric Sane (water too deep to be effective)
- Driving within a “can” or larger pile (not practical for 72” diameter permanent foundation piles but planned for use with fender piles in 2003 as well as some future permanent piles, as described below)

In retrospect, the various minimization techniques attempted were implemented in an extremely rapid manner and resulted in a wealth of valuable information gained. However, each had limitations, at least initially.

Two schools of thought seemed to prevail: either prevent fish from entering the mortality zone or reduce the pressure wave to an unharmed level. A separate concept was to limit or stop pile driven when fish are present in the potential zone of mortality. This included an attempt to use Fish Finders to locate schools of fish moving through the area. If located, the contractor agreed to temporarily halt driving to allow the school to pass through the zone. Unfortunately, it was evident that large numbers of fish were located all around the V1 area and transient schools were not easily discerned. In fact, fish seemed to be stationary and perhaps using the structural elements of the construction zone, including barges and the existing bridge, for shade and rest areas. Similar masses of stationary fish were not noted while trolling up and down the river with the Fish Finder. Attempts to scare or disperse these fish with pile tapping and use of horns underwater did not seem to be effective, even though tapping was effective for driving until returning to V1 in April 2002. Scare charges were discussed, but not implemented, as they may have resulted in additional mortality and seem to be utilized for “single event” underwater blasting as opposed to rhythmic pile driving which lasts for two to three hours per pile. The contractor also attempted to vary the driving schedule (morning versus afternoon versus evening) in an attempt to discern relationships between time-of-day and/or tidal cycles and presence of fish. As daily mortality numbers varied, sometimes wildly, it was difficult to determine if these exercises provided protection for nearby fish.

As for the concept of preventing fish from entering the potential zone of mortality, the use of a turbidity curtain in conjunction with the existing bridge, fender system, and V1 outer loop cofferbox was an attempt to minimize fish access to the driving area. This theory is inherently sound but difficult in this application due to deep water and strong currents. For example, even if the turbidity curtain was of sufficient length to reach the river bottom, a crosscurrent alignment would be extremely difficult to anchor and maintain due to the excessive load placed on the curtain. However, the Project did deduce that this use of turbidity curtain or similar fish barrier (or fish fence) can and will be used in future contracts in more shallow water to keep fish segregated from a given mortality zone. All future contracts requiring in-water piles less than 48 inches in diameter are required through special provisions to conduct monitoring and implement a “fish fence” system to protect fish, especially shortnose sturgeon, from potentially harmful pressure waves.

The final technique attempted, the air bubble curtain system (ABCS), was borrowed from the underwater blasting industry and is considered an “emerging technology.” The premise is rather simple, water is incompressible but air is compressible. In theory, if a pile to be driven is surrounded by a “curtain” of air bubbles (hence, air), the pressure waves will compress the air, resulting in refraction, reflection, and otherwise dampening of the wave, thus reducing the energy level. TKC quickly fabricated an ABCS using simple and readily available construction equipment and supplies. The source of air was a typical air compressor used for supplying air to a jackhammer or other industrial pneumatic tools. Attached to a compressor was a common flexible air line of sufficient length to drop a loop of air line around the pile and down to the river bottom. Slight incisions were made within the loop of air line to release the air and create the bubble curtain which evenly and completely surrounds the pile, in favorable conditions. Iron weights were tied around 4 points of the loop to keep the line on the river bottom during bubbling. This system was set into motion on April 10 and used during driving thereafter though the fish quantities did not reveal a discernable reduction. Though it was initially suspected that more air and additional lines were needed, it seems that the ABCS, at least as implemented at V1 inner loop, likely lost a substantial percentage of bubbles to the strong current in the relatively deep water accounting for the absence of favorable results for this exercise. As part of the pressure wave testing conducted in June and July of 2002 (detailed below), the Project and TKC later determined, that the ABCS is quite effective in minimizing significant pressure waves when coupled with a containment system in the form of a cofferdam, can (short, large diameter pile), or perhaps a turbidity curtain. This combination will be required to be implemented by future contractors requiring piles greater than 48 inches in diameter to be driven in water and could be applied to similar projects elsewhere.

As noted, pile driving at V1 inner loop was completed on Friday, April 19 and the operation moved to foundation M6, within a cofferdam and away from the navigation channel. No further fish kill was observed, though careful observation continued. An environmental meeting was held on April 23, 2002, with NMFS, MDE, DNR, ACOE, the PCC, MSHA, FHWA and others to discuss the protection methods implemented, as well as the remaining piles on the Project and their potential for impact. The Project agreed to conduct pressure wave testing through a specialized firm and report results. Valuable information was gained through this testing and was informally discussed with the agencies at Joint Evaluation meetings on June 26 and July 31 of 2002.

F. Changes in the Project from Original Biological Assessment

The original (April 2000) biological assessment assumed that pile driving would not affect the shortnose sturgeon or other fish species. Unmitigated, it was realized that driving of larger piles (66” in diameter and greater) near the navigation channel did have the potential to kill certain species of fish. Pressure wave monitoring was used to determine that a pressure wave of 6psi was the threshold for mortality for certain species.

In light of this information, the Project has reviewed the conclusions drawn in the original BA regarding underwater explosive demolition pressure waves.

Also, NMFS has asked the project to review clamshell dredging as incidences of takes have occurred during clamshell dredging elsewhere since the original BA.

G. Effects of the Action

1. Pile Driving Pressure Wave Testing and Analysis

In order to make sound decisions on future pile driving associated with the Project, a pressure wave-testing firm, HiTest Laboratories, was hired. The capture and analysis of a pressure wave is a highly technical process and requires highly specialized equipment with experienced professions to operate the equipment and analyze the data. The event is composed of a complex waveform that occurs within a fraction of a second with numerous background waves and other data present. The Project met with the expert firm in June, briefed them on the issue, and developed a plan to capture as much relevant data as possible. Goals established for the testing included:

- ✓ Determine appropriate unit of measure for the waves;
- ✓ Measure amplitude of the waves;
- ✓ Determine waveform or signature of the wave;
- ✓ Determine threshold for fish mortality;
- ✓ Measure performance of minimization techniques performed in comparison to our baseline data.

Between two monitoring sessions, HiTest provided the Project with this required data. On June 28, 2002, two senior technicians were on site to monitor a 66-inch diameter pipe piles being driven at Foundation M3 outer loop north, just west of the center of the Potomac River (see Appendix B for Detail). The monitoring was completed on a pile at location "A3" within a 45'x40' steel sheet pile cofferdam. This was the first of 12 piles to be driven in the cofferdam with A3 located in the southwest corner of the cofferdam to best mimic a "can." Again, a "can" is a short, large diameter temporary pile dropped and placed over a permanently pile to be driven to offer wave reduction and bubble curtain containment benefits.

Two pressure transducers were placed in the water, each 12.5 feet from the edge of the pile. One was located inside the cofferdam to mimic "open water" driving and one was placed 3.5 feet outside of the cofferdam, to the south, to measure the attenuation of the cofferdam/can. The water was approximately 14 feet deep and the transducers were suspended at mid-water column (5.5 feet from the water surface in approximately 15 feet of water). The shock waves were read by a digital oscilloscope which records approximately 500,000 readings per second of monitoring. Data was collected and processed with custom software using a high performance computer station, on location.

Readings were taken in milivolts and then converted to pounds per square inch (psi) for conformance with other results from other projects, as well as future monitoring with this project. Incidentally, psi threshold values were prescribed and are contained in the original BA regarding underwater detonations. This unit was the logical choice and would be compatible with other values (see Section 2. Review of Underwater Explosive Demolition).

Energy delivery to the pile via the hammer was also a consideration and was varied to represent different types of driving. The first data set represented pressure waves produced to mimic pressure waves produced by driving the future 52-inch fender piles in early 2003. Two sets of data were taken, one set while driving at 110,000 foot pounds per blow, the other at 210,000 foot pounds per blow, referencing the potential range of energy used by the appropriate hammer to drive the fender pile. At 110,000 ftlbs, the pressure wave inside and outside of the cofferdam measured 12.3 psi and 6.1psi, respectively. Driving at 210,000 ftlbs yielded 15.2 psi inside the cofferdam and 8.7 psi outside the cofferdam (Appendix B).

Next, the hammer was run at full strength. The S500 is an extremely efficient hammer rated at 365,000 ftlbs maximum driving force. This force was achieved and exceeded at the larger M1 and V1 piles, but the maximum force exerted on the 66-inch test pile at M3 was 300,000 ftlbs due to pile diameter, soil substrate, and other variables. Regardless, this value was significantly higher, perhaps an order of magnitude, than typical pile driving for a bridge project. Recorded values at this energy included 15.3 psi inside the cofferdam and 10.4 psi outside the cofferdam.

Driving continues even after the hammer travels beneath the water surface in order to obtain the specified pile tip elevation. The hydraulic hammer is cable of accomplishing this task, one of the main reasons for specifying this type of hammer. Monitoring of driving at 300,000ftlbs was also completed after the hammer fully submerged, towards the end of the drive. Recorded values include 20.3 psi inside the cofferdam and 16.7 psi outside the cofferdam.

In general, there is a linear relationship, as expected, between energy delivered and resulting pressure wave in the water column (Appendix D). The results also indicated that the sheet pile cofferdam reduced the pressure wave by approximately 15-50% with the greatest attenuation at lower energies. As the energy increased, the attenuation decreased as indicated on Table 1. While the cofferdams provided substantial attenuation, the ABCS used in conjunction with the cofferdam/can performed exceptionally well and reduced the pressure wave to a minimal level regardless of driving energy or hammer elevation (above or below water). This is discussed further below.

Hammer Energy	Test Location	ABCS On?	PSI
120,000 ft-lb	Inside coffer	No	12.3
120,000 ft-lb	Outside coffer	No	6.1 (50% reduct)

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120,000 ft-lb	Inside coffer	Yes	1.7 (86% reduct)
120,000 ft-lb	Outside coffer	Yes	1.2 (90% reduct)
210,000 ft-lb	Inside coffer	No	15.2
210,000 ft-lb	Outside coffer	No	8.7 (42% reduct)
210,000 ft-lb	Inside coffer	Yes	1.7 (89% reduct)
210,000 ft-lb	Outside coffer	Yes	1.2 (92% reduct)
300,000 ft-lb	Inside coffer	No	15.3
300,000 ft-lb	Outside coffer	No	10.4 (32% reduct)
300,000 ft-lb	Inside coffer*	No	20.3
300,000 ft-lb	Outside coffer*	No	16.7 (17% reduct)
300,000 ft-lb	Inside coffer*	Yes	1.8 (91% reduct)
300,000 ft-lb	Outside coffer*	Yes	1.1 (95% reduct)

*Reading were taken with the hammer 1-2 feet underwater

On July 30, 2002, the last day of driving for permanent river piles for this contract, HiTest once again conducted pressure wave monitoring. While no fish mortality occurred while driving during the last monitoring session at M3, minor fish mortality was noted for some piles at M2 outer loop south. This was likely due to the proximity to the navigation channel (M2 is in 24 feet of water) and, potentially, increased driving energies. The goals established for this monitoring session included:

- ✓ Gaining knowledge on the mortality threshold in relation to driving energies and pressure wave (psi);
- ✓ Gaining knowledge on wave attenuation over distance both inside (mimicking open water driving) and outside of the cofferdam;
- ✓ Verifying that the contained ABCS was effective.

The same equipment was utilized, though additional transducers were set for additional monitoring points, as noted below.

- ✓ Transducer 1 was set just 3.25 feet from the pile to be driven;
- ✓ Transducer 2 was set 28 feet from T-1, outside of the cofferdam to the south;
- ✓ Transducer 3 was set 64.5 feet from T-1, in line with T-2, outside of the cofferdam;
- ✓ Transducer 4 was set 90 feet from T-1 but inside the cofferdam, along the north wall.

Driving was initiated on the pile and recordation started when fish mortality was first observed (at T-2 with 120,000 ft-lb driving energy). The psi at T-1 was 28psi, T-2 was 6.3psi, T-2 was 3.2 psi, and T-4 was 3.2 psi. Since the zone of mortality was at T-2, it is reasonable to deduce that the psi threshold for fish mortality of the most susceptible species is approximately 6psi. Note: The contract specifications use 4psi as a threshold

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in an effort to be conservative and account for any variations due to different piles, hammers, water depths, substrate, driving energies, etc. We are confident that the pressure waves generated are of a worst-case scenario when comparable to the remaining piles to be driven.

Continuing with the testing, driving energy was increased, as did the pressure wave values, as noted on the table below. The driving energy peaked at 360,000 ft-lb per blow, substantially higher than the maximum energy of 300,000 ft-lb per blow during June 28. Multiple variables could account for this but it is likely that the soil resistance is the primary reason for the higher energy on the July 30 testing. A maximum pressure wave of 55psi was recorded at T-1 during mid-pile driving at 360,000ft-lb with the hammer above the water surface. Fish mortality continued but within a 50 foot radius of the pile.

As far as wave energy dissipation over distance (a function of time, as well), it is apparent that the waves rapidly lose energy both inside and outside of the cofferdam over distance. In fact, the readings at T-3 and T-4 are similar; T-3 being outside of the cofferdam but 25.5 feet closer than T-4, located inside the cofferdam. These results are depicted on Table 2. As with the June 28 monitoring, the ABCS was implemented near the end of the pile driving for a reading at T-1 and T-4. Again, the results show excellent performance reducing 55 psi pressure waves to 1 psi, and 4 psi pressure waves (at 90') to non-detect levels. More information on the ABCS can be found below.

Hammer Energy	Test Location	ABCS On?	PSI
120,000 ft-lb	T-1	No	28
120,000 ft-lb	T-2	No	6.3
120,000 ft-lb	T-3	No	3.2
120,000 ft-lb	T-4	No	3.2
300,000 ft-lb	T-1	No	N/A
300,000 ft-lb	T-2	No	6.6
300,000 ft-lb	T-3	No	4.2
300,000 ft-lb	T-4	No	4.2
360,000 ft-lb	T-1	No	55
360,000 ft-lb	T-2	No	9.5
360,000 ft-lb	T-3	No	5.5
360,000 ft-lb	T-4	No	4.2
360,000 ft-lb	T-1	Yes	1
360,000 ft-lb	T-4	Yes	Non-Detect

Air Bubble Curtains

As previously mentioned, the concept of ABCS was documented in the original BA in reference to underwater explosive detonations. The theory also worked for pile driving, even though the pressure waveform, duration, and source of wave were quite different. The Project, contractor, and the agencies discussed the use of the ABCS and we gained information from a similarly large project: the San Francisco-Oakland Bay Bridge Project sponsored by the California Department of Transportation on the west coast of the U.S. This project had conducted a pile test program for large diameter piles (up to 96" in diameter) in which a large freestanding template was utilized. The contractor designed and implemented an ABCS using the template as a frame. Large volumes of air from multiple air compressors supplied air to three parallel PVC pipes around the bottom perimeter of the template, with small holes drilled through to create bubbles. Results were largely empirical due to technical difficulties associated with testing equipment, though visual observation concluded that fish mortality was notably reduced. Thus, the Project anticipated that the concept of an ABCS had the potential to reduce mortality for our pile driving, as well. As described above, TKC and the PCC designed a fairly rudimentary system with easily acceptable, durable, and practically maintainable equipment and supplies. When our ABCS system was implemented while driving at V1 inner loop, no discernable reduction in fish mortality was evident, though bubbles were evident at the water surface. This is likely due to the strong currents in the full depth of the river (30-40 feet) carrying a substantial portion of the bubble curtain away from the subject pile. When testing was completed on June 28 and again on July 30, the ABCS was tested and performed well in attenuating the pressure wave. As depicted in Table 1, the wave was attenuated not only at a distance from the pile but also immediately outside of the bubble curtain. It seems that the crucial component, at least in attenuating this particular waveform with this particular system, is containing the bubble stack. Testing at both M3 and M2 was conducted within a cofferdam which contained the bubble stack. A can and a full-depth turbidity curtain would provide the same continuity effect. As discussed with Hi-Test Laboratories, a larger ABCS with multiple air lines and a larger volume of air may well successfully attenuate pressure waves in an open water environment, though this has not been tested by the Project.

In summary, the monitoring provided data indicating that the driving of large-bore pipe piles in the Potomac River with a large hydraulic hammer produced pressure waves that reflected the driving energy. These waves ranged in amplitude from non-detect to 55 psi. The pressure waves dissipate rapidly over distance and a sheet pile cofferdam substantially assists attenuation though some varying portion of wave energy typically passes through the cofferdam. The data indicates that the threshold for fish mortality under this scenario is approximately 6 psi. Perhaps the most important data gained is that of the performance of the ABCS. During multiple tests, the ABCS reduced even the highest pressure wave to minimal levels, well below the 6psi threshold.

With this, the Project proceeded with reviewing all future piles, determining potential for impact to aquatic species, and utilizing the knowledge gained to require future

contractors to provide adequate protection under the Project's management, especially utilizing the threshold value for use with "fish fence," use of ABCS, and additional monitoring.

Future Pile Driving

As noted above, on July 30th, 2002, the Foundations Contract "drove out," completing almost all of the large-bore pipe piles to be driven in water for the entire project (approximately 568 piles out of 670 or 85% of the in-water permanent piles for the twin-span mainline bridge). While this marks excellent progress for the main bridge, fender piles and one section of large bore piles remain as do many piles on the Virginia side for ramps and bridges over Cameron Run for US Route 1 and Telegraph Road interchanges. Additional piles will also be needed for the Pedestrian/bike Bridge over Smoot Cove on the Maryland side.

The remaining large-bore pipe piles on the project are considered a priority and include:

- Ninety 54"-dia pipe piles to be driven for the fender rings around the bascules (M1 and V1);
- Twenty-four 60"-dia pipe piles to be driven for the I-95NB to US-1SB ramp over Cameron Run;
- Twelve 48"-dia pipe piles to be driven for the mainline bridge (M 10- Inner Loop North).

The 90 fender ring piles will be driven around M1 and V1 to protect the new bridge from ship collisions in conjunction with an integral interlocking concrete barrier attached to the piles. These piles are of a substantial diameter and are located adjacent to the navigation channel. A cofferdam is impractical due to water depth, water current, and the linear nature of the piles, as opposed to the typical grid of piles. Over half of these piles will be driven in the Winter of 2003. The piles will be driven by TKC and every attempt is being made to drive these piles prior to March 1 though the schedule relies upon the completion of the most technically challenging work associated with the existing contract. The contractor has committed to drive these piles using an integrated system including a can and the air bubble curtain. Again, a can is a short, large diameter temporary pile that is vertically placed over the permanent pile to be driven. The can rests on the river bottom (so that it may be removed after the permanent pile is driven) and protrudes above the water surface. The can will contain the air bubble curtain in situations in which cofferdam or turbidity curtains are not practical. This system is feasible for the fender piles because the top of the driven pile will be above the water surface when complete. Therefore, the hammer will not have to drive through the can, thus substantially reducing the diameter of the can to a practical size. This was a severe limitation for the can option for driving at M1 and V1, as the top of the M1/V1 piles were underwater at final elevation. For the fender pile system, the ABCS will likely be welded to the bottom of the can and quick-connected to the air supply once the can is dropped into place and driving is set to commence. In addition, a much smaller hammer and significantly reduced driving energy as the piles are not required to support near the weight of the

foundation piles. This should result in greatly reduced pressure waves generated and an effective system implemented to attenuate what waves are emitted. Incidentally, pressure wave testing will be conducted and the pile driving will be carefully monitored by environmental professionals to ensure fish are protected. Approximately 52 of the 90 piles will be driven this winter and the remaining 38 piles (currently in conflict with the existing bridge) will be driven by a future contractor after the existing bridge is demolished (2006-2007 timeframe). A contained ABCS will be required through special provisions in the contract for the remaining 38 fender piles (see Appendix E).

The 60" piles are to support the I-95 NB to US 1 SB ramp over Cameron Run. The specifications for this have been written, approved, and incorporated into the bid documents for VDOT contract VA-5 Advanced Bridge for US 1 Interchange. The contracts' special provisions are attached (Appendix E) and basically requires an ABCS and monitoring to ensure that the system is functioning properly to protect fish for these particular piles. These provisions were developed as part of this fish protection exercise.

The twelve 48" diameter piles are made up of the final bent of piles for the Foundation M10 inner loop north. By design, these piles were unable to be driven by TKC, as they were too close to the existing bridge. These piles will be driven after the existing bridge is demolished and as part of the inner loop construction (2007-2008 timeframe). The contractor will be required, through the contract specifications, to protect fish using a cofferdam and ABCS. Given that no fish kill was observed for driving of the other 36 piles at M10 within a cofferdam, nor at the 48 piles driven at M9 to the west, the Project is confident that no fish mortality will occur with an enhanced protection system, as required through special provisions (Appendix E).

There are a number of additional piles to be driven in-water, however, the remaining piles are of a magnitude more typical and comparable to other bridge projects in the region and nation. These include a number of 24" square (and smaller) reinforced pre-cast concrete piles, smaller pipe piles for the US 1/Telegraph Road interchanges and a number of similar piles for the biker/pedestrian bridge over Smoot Cove (still under design). These piles are smaller, shorter, driven with a much smaller hammer at a greatly reduced energy level (an order of magnitude smaller). In addition, concrete piles absorb energy more efficiently than pipe piles emitting less energy to the water column. All of these factors equate to low to no potential for potentially harmful pressure waves. Regardless, the Project wishes to proceed in a conservative manner and is proposing to provide monitoring and adequate protection for in-water piles which prove to exert potential harm to fish. Attached are the contract specifications included in all upcoming VDOT contracts with permanent in water piles. The specifications require pressure wave monitoring to determine pressure wave energies (Appendix E). If above the conservative threshold for harm (4 psi), the contractor must determine the zone of mortality (generally the 4 psi pressure gradient) and erect a fish fence to prevent fish from entering the zone or implement an ABCS and provide monitoring results proving the adequate performance of the system.

The pedestrian bridge over Smoot Cove is a small bridge capable of supporting only light loads. Piles anticipated for the bridge are anticipated to be comparable or smaller than any typical bridge project, thus, no impact is anticipated. The environmental inspection team will be monitoring the installation of these piles, as well, to ensure no fish are harmed and the contractor will be required to follow the special provisions created to protect aquatic species (Appendix E).

2. Review of Underwater Explosive Demolition

In light of the information and knowledge gained through the pile driving process, the Project has reviewed and considered the psi thresholds contained in the original Shortnose Sturgeon BA. The threshold values for underwater explosive demolition are higher than those values recorded during pile driving, however, pressure wave experts immediately noted a significant difference between the waveform generated by the pile driving and a typical underwater detonation. The two waveforms do not exhibit a comparable relationship. A typical underwater explosive demolition waveform denotes a sharp positive wave followed by a shallow negative wave and little else. In contrast, the large bore pile driving exhibited a complex waveform depicting reverberations of positive and negative waves, which continue for a duration at least 10 times that of a single detonation event. In fact, the total wave event for the 55 psi reading on July 30 was 60 times the duration of the detonation event. Though many factors influence wave duration, for the sake of comparison, HiTest Laboratory created a comparative graphic depicting three pressure wave charts (Appendix F):

1. The waveform captured during the July 30th monitoring of a pile strike at 120,000 ft-lb;
2. The waveform of an underwater detonation of a 60-pound charge, measured at 28 feet from the epicenter. This is a relatively large charge detonated in open water emitting a pressure wave peak of nearly 2,000 psi;
3. The waveform of an underwater detonation of a 5-pound charge, measured at 150 feet from the epicenter. The wave sharply peaked at 130psi and is quite similar to what is envisioned as part of the potential explosive demolition of the existing Woodrow Wilson Bridge.

As shown, each of the numerous positive waves are counteracted by a negative wave of nearly the same amplitude (on some occasions the negative wave was greater than the corresponding positive wave) for the pile driving pressure wave. This effect is similar to a “push/tug” force repeated many times for each pile strike on a fish within the zone of influence. This effect can also be related to the analogy of being struck numerous times in a split second as opposed to being struck once.

In light of this information indicating the significant difference in pile driving and detonation waveforms, the Project is confident that the threshold values required by

NMFS as referenced from the Wilmington Harbor Project remain appropriate for any future underwater explosives used as part of the bridge demolition.

3. Review of Clamshell Dredging

As requested by NMFS, the Project has also reviewed our procedures for clamshell dredging. In spite of scrutiny from the PCC environmental inspection, the PCC construction inspection team on site, and the independent environmental compliance monitor, only a minor number of fish (less than 10) have been observed in the dredged scows, including dredging, offloading, and placement observations. No shortnose sturgeons were noted, only catfish. The project has dredged approximately 400,000 cubic yards thus far over the course of two full years and anticipates approximately 100,000-150,000 additional cubic yards of production dredging in the future with an unknown quantity of maintenance dredging, if required at all. In essence, over two thirds of the dredging is complete. We are strictly adhering to the October 16-February 14 open-water dredging window with dredging in the off-season conducted within cofferdams and cans, only. It is our opinion that this method of clamshell dredging within the confines of these rigorous time-of-year restrictions offers maximum protection to all aquatic species, especially the shortnose sturgeon.

Conclusion

From July 2001 to July 2002, the Project experienced intermittent fish mortality as a result of pressure waves from large bore pile driving (66" in diameter and greater) near the navigation channel of the Potomac River. Pressure wave testing indicated that fish mortality occurred at levels of 6psi and greater for certain fish species. The fish species predominantly affected by the elevated pressure wave were shad (gizzard), perch, and alewife. As noted by NMFS in coordination during the original BA process, shad and alewife are more susceptible to pressure wave due to their laterally compressed body shape, in comparison to the shortnose sturgeon's fusiform shape.

The testing combined with visual observation also demonstrated that the use of a contained ABCS effectively reduced even high energy pile driving (360,000 ft-lb) of large diameter piles (66" piles) to minimal levels (below 6 psi), thus minimizing potential impacts to fish species, especially the more resilient shortnose sturgeon. These largest piles requiring the highest energies are complete for the Project. The largest piles to be driven are 60", 54", and 48" with only the 54" piles being driven near the navigation channel. Driving energies for these remaining piles will be at a maximum of 150,000 ft-lb, less than half of the energy of the larger piles. To be sure to protect the shortnose sturgeon, these piles will be driven with a contained ABCS and monitored to ensure proper performance. Smaller piles will be driven in Cameron Run and Smoots Cove. Permanent in-water piles under 48" in diameter will require either a contained ABCS or fish fence which is a barrier which prevents fish from entering the zone of mortality.

With these measures in place, the potential to harm fish has been minimized, especially all life forms of the shortnose sturgeon.

This issue also prompted the review of the threshold levels assigned to the underwater explosive demolition requirements as depicted in the original BA. Though the pressure wave levels differ, it was readily apparent that the waveform is also significantly different, indicating that the two are not directly comparable and that the demolition information, as cited in the Wilmington Harbor Study, remains relevant.

Thirdly, at the request of NMFS, we reviewed our dredging procedures and determined that the time-of-year restrictions, environmental monitoring, and use of the clamshell bucket only (no hydraulic dredging permitted) minimizes the potential for conflict with fish.

Determination of Effect

FHWA has determined that the Woodrow Wilson Bridge project is not likely to adversely affect the shortnose sturgeon (*Acipenser brevirostrum*), a federally endangered species based on insignificant effects. The Project will implement specialized protection measures to further minimize the low potential for a shortnose sturgeon take. FHWA has formulated this determination based on the best scientific and commercial data available outlined in this supplemental BA and the original BA (April 2000).

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