United States Department of the Interior

Fish and Wildlife Service

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January 18, 2017

Mr. Charles M. Simon
Chief, Regulatory Office
Engineering and Technical Services
U.S. Army Corps of Engineers, Detroit District
477 Michigan Avenue
Detroit, Michigan 48226-2550

Attn: Ms. Allison Klement, Project Manager, Michiana Branch Office

Dear Mr. Simon:

This document transmits the U.S. Fish and Wildlife Service's (Service) Final Biological Opinion for the Formal Consultation between Detroit District U.S. Army Corps of Engineers and the Service, pursuant to Section 7 of the Endangered Species Act of 1973, as amended, for the Kosciusko County Bridge No. 18 rehabilitation project at Warsaw, Kosciusko County, Indiana (File Number LRE-2014-00115-143-R14).

The U.S. Army Corps of Engineers is responsible for implementing all requirements of the Biological Opinion and Incidental Take Statement, including work by contractors and consultants. This Biological Opinion authorizes the Detroit District, Corps of Engineers to harm Clubshell mussels within the prescribed limits. A complete administrative record of this consultation is on file at the Service's Northern Indiana Suboffice, Chesterton.

For further discussion, please contact Elizabeth McCloskey at the Northern Indiana Suboffice [(219) 983-9753 or elizabeth_mccloskey@fws.gov].

Sincerely yours,

Scott E. Pruitt
Supervisor

cc: Regional Director, USFWS, Twin Cities, MN (ES-TE Attn: Jennifer Szymanski)
Christie Stanifer, Environmental Coordinator, Division of Water, Indianapolis, IN
Matt Smedley, IDEM, Office of Water Quality, Indianapolis, IN
Brant Fisher, Indiana Division of Fish and Wildlife, Edinburgh, IN

bc: NISO, Chesterton, IN

Endangered Species Act
Section 7 Consultation - Biological Opinion

Action Agency:
U.S. Army Corps of Engineers

Action Considered During Consultation:
Replacement of Kosciusko County Bridge #18 carrying County Road 300 North over Tippecanoe River
Warsaw, Kosciusko County, Indiana

Consultation By:
Region 3, U.S. Fish and Wildlife Service

Date of Issuance:

Consultation History

On March 11, 2014, the U.S. Fish and Wildlife Service's Northern Indiana Suboffice (NISO), Chesterton, Indiana (FWS) routinely checked the Indiana Department of Natural Resources, Division of Water, 30 Day Public Notice Report and found application FW-27443, a proposal to replace and widen Kosciusko County Bridge #18 carrying County Road 300 North over the Tippecanoe River. Early coordination is a normal policy of the Federal Highway Administration (FHWA) and Indiana Department of Transportation (INDOT) for federally funded highway projects; however, since only county funds are to be utilized for this proposed project, no early coordination took place and this Public Notice was the first information FWS received about the project. The following description was provided in the PN:

> The existing 3-span bridge carrying Kosciusko County Road 300 North over Tippecanoe River will be replaced and widened to add a multi-use greenway trail. The existing 28' wide superstructure will be replaced with a prestressed concrete box beam superstructure. The abutments and piers will be extended downstream by 15'-0". The replacement superstructure will be 15'-6" wider than the existing superstructure downstream and 10" wider than the existing superstructure upstream; thereby increasing the out-to-out width to 44'-4". There will be minimal approach roadway work, which will be raised a maximum of 0.6'. The spill through abutment slopes will be armored with revetment riprap over geotextiles. Details of the project are contained in information received electronically at the Division of Water on February 21, 2014 and in plans and information received at the Division of Water on February 25, 2014 and March 10, 2014.

Genus	Species	Common Name	KSC8703	ESI91003	BEF0312	BEF0805	BEF1016
Actinonaias	*ligamentina*	mucket			WD		
Alasmidonta	*marginata*	elktoe	4	WD			
Amblema	*plicata*	threeridge	WD				
Cyclonaias	*tuberculata*	purple wartyback	8	8		WD	WD
Elliptio	*dilatata*	spike		FD			1
Epioblasma	*obliquata perobliqua*	white catspaw		WD			
Epioblasma	*torulosa rangiana*	northern riffleshell	WD				
Fusconaia	*flava*	Wabash pigtoe	8	FD	WD	WD	1
Lampsilis	*cardium*	plain pocketbook	12	1	2	WD	2
Lampsilis	*fasciola*	wavyrayed lampmussel	WD	1	WD	WD	WD
Lampsilis	*siliquoidea*	fatmucket	1		WD		
Lasmigona	*compressa*	creek heelsplitter	FD	FD			
Lasmigona	*costata*	flutedshell	5	FD			
Ligumia	*recta*	black sandshell	WD	WD		WD	
Pleurobema	*clava*	clubshell	9	4	4	WD	WD
Pleurobema	*sintoxia*	round pigtoe	26	20	2	FD	2
Ptychobranchus	*fasciolaris*	kidneyshell	33	11	4	WD	5
Strophitus	*undulatus*	creeper	3	FD			
Toxolasma	*lividus*	purple lilliput	FD			WD	
Villosa	*iris*	rainbow	1	2	WD	WD	WD
Corbicula	*fluminea*	Asian clam			L		L
Dreissena	*polymorpha*	zebra mussel					L

Also on March 11, 2014, the FWS emailed the U.S. Army Corps of Engineers (COE) about the IDNR Public Notice, asking if they had also received an application for a Clean Water Act Section 404 permit, and informing them that a number of surveys from 1987 through 2008 (the data then available at NISO) had found living and/or dead Clubshell (*Pleurobema clava*), a federally endangered species, up- and/or downstream of the bridge. Therefore, consultation under Section 7 of the Endangered Species Act, as amended, might be necessary for the Section 404 permit.

On March 12, 2014, COE Project Manager Allison Klement of the Michiana Branch Office responded to FWS by email that she had received the application on March 7, 2014 and forwarded the email between herself and the applicant; the project was assigned File No. LRE-2014-00115-143. The application was scanned and emailed to FWS on March 14, 2014.

On March 17, 2014, FWS emailed IDNR aquatic biologist Brant Fisher about his surveys for mussels in the vicinity of Bridge 18. Fisher responded on March 19th and provided the following chart:

The KSC study was done by Kevin S. Cummings of the Illinois Natural History Survey on July 27, 1987 (Cummings and Berlocher 1990) and the ESI survey was done by Ecological Specialists, Inc. on September 11, 1991 (Ecological Specialists, Inc. 1993). The KSC and ESI reports do not indicate if the surveys were up- or downstream of Bridge 18 or the lengths of the areas surveyed. The KSC report states that sampling at each of the 16 sites they visited totaled 4 collector-hours, and the ESI report states that each of the 20 sites they surveyed was searched for a least 2 person-hours. The 3 BEF surveys were done by Brant Fisher in 2003, 2008, and 2010. He stated that in 2003, he and his assistant only surveyed upstream from Bridge 18, spending 3.5 hours (7 person-hours) and covering approximately 1000 meters. Both the 2008 and 2010 surveys were 2 hours each (4 person-hours) and were conducted downstream from the bridge. During all 3 surveys, Fisher did not find any living mussels directly at the bridge but noted "really good looking sand/gravel substrate throughout". These 5 surveys found living or dead federally endangered Clubshell and weathered dead endangered White catspaw (*Epioblasma obliquatat perobliqua*) and Northern riffleshell (*Epioblasma torulosa rangiana*), plus living or dead Indiana Special Concern Wavyrayed lampmussel (*Lampsilis fasciola*), Kidneyshell (*Ptychobranchus fasciolaris*), and purple Lilliput (*Toxolasma lividus*). Of the federally listed species, only the Clubshell is considered extent in the project area.

During April 21-22, 2014, the COE provided USI Consultants, Inc. (USI) the Preliminary Jurisdictional Determination (PJD) concerning presumed jurisdictional waters and wetlands in the area to be affected by the bridge project, and USI provided a revised permit application incorporating the PJD.

During the period May 23-June 11, 2014, the FWS and COE exchanged email concerning the need for a mussel survey at the site and what additional project information needed to be provided; a list of Federal permit holders for freshwater mussel sampling in Indiana was provided by the FWS, along with IDNR's Guidelines for Sampling Freshwater Mussels in Indiana.

On June 17, 2014, the COE sent a letter to the Kosciusko County Highway Department informing them of the need to have a mussel survey conducted at the site utilizing IDNR's Guidelines, and requesting updated project plans/drawings showing impacts to the river and wetlands.

In July 2014, the Kosciusko County Highway Department, through USI, contracted with John Richardson of Cardno and Dr. Melody Myers-Kinzie at Commonwealth Biomonitoring to conduct a mussel survey at the Bridge 18 project area. Their Statement of Work dated August 7, 2014 was reviewed and approved by the FWS, and site specific authorization to conduct the survey was provided on that date.

On August 26 and 27, 2014, an area 500 feet upstream and 1500 feet downstream of the existing bridge was surveyed for mussels. Mussel collection was conducted along 22 transects 100 feet apart perpendicular to the river, with 5 upstream and 15 downstream of the bridge, plus 1 each at the upstream and downstream edges of the bridge. The sampling included five 0.25 square meter quadrats evenly spaced across the width of the river along the transect lines, giving a total of 110 quadrat samples. Each quadrat was excavated to a depth of 6 inches or more to locate smaller mussels and those species buried in the substrate. The excavated material was put through a wire mesh basket to sift out mussels not immediately located. After quadrat sampling was completed, a combination of snorkeling, viewing buckets, and general visual surveys were conducted bank to bank between each 100-foot transect line.

Federally endangered species found by either method were immediately processed, including taking a GPS reading of location, and returned to where they were found. Other mussels were held in submerged mesh bags until completion of each transect reach survey, when they were processed and returned to the reach where found. Processing involved measurements and species determination. A total of 180 mussels were collected representing 13 species, including the Indiana Special Concern Kidneyshell (33 individuals) and Wavyrayed lampmussel (4 individuals) and the federally endangered Clubshell (13 individuals). The majority of the mussels (107) were found 800 to 1,300 feet downstream of the bridge; only 13 mussels were collected within 300 feet of the bridge. The closest Clubshells were 380 feet upstream and 480 feet downstream of the bridge.

The mussel survey report was provided to the FWS by Cardno on September 19, 2014. The report determined that the bridge project was likely to affect the endangered Clubshell and recommended preparation of a Biological Assessment.

On November 20, 2014, the COE emailed information to FWS about the relocation of a power line along the south side CR 300 North, made necessary by the widening of the bridge. The COE estimated that slightly over 0.1 acre of forested wetland would be cleared and converted to emergent wetland, which would require mitigation. The poles would need to be relocated a minimum of 27 feet south from the current edge of pavement to provide enough room for the equipment needed to dismantle and rebuild the bridge deck and pound in the pile bents; this means clearing in 3 wetland areas 10 feet wide and various lengths.

On December 3, 2014, the COE announced that an on-site meeting will be held at the bridge site on December 19th. This meeting took place with FWS, COE, IDEM, IDNR, KREMC, Kosciusko County Highway Department, USI, and Cardno in attendance. The KREMC power line relocation was discussed, along with the need to move a natural gas line, which would largely be bored under the wetlands and river. The roadway embankment will be widened, as will the new bridge, to accommodate the trail. It is proposed to clean the existing pile bents and recoat them with an epoxy substance; the same epoxy will be painted onto the new pile bents. FWS expressed concern about the cleaning of the old material and recoating with new epoxy because of the toxicity of such materials to aquatic life, and requesting product information sheets for review. The draft Biological Assessment, dated December 11, 2014, was hand delivered to FWS, who indicated that the cleaning and epoxy issues as discussed at this meeting will need to be addressed in the BA.

USI provided an email to all the agencies on December 23, 2014, indicating that they had determined that the project impacts, including the bridge reconstruction and power line and gas line relocations, would be 0.15 acre of permanent wetland loss, 0.32 acre of conversion from forested to emergent wetland, and 0.01 acre of instream impacts from new pile bents and riprap. This was not based upon an actual wetland delineation, which will need to be done after the winter during the growing season. Updated aerial photographs were provided showing the expected locations of wetland impacts and the locations of possible mitigation areas.

During the next several months, Kosciusko County and USI discussed whether or not to proceed with the project, given that there will be enough impacts to wetlands to require mitigation and that a formal wetland delineation will be necessary. On March 9, 2015, USI emailed the COE, FWS, and IDEM to inform them that the County plans to move the project forward and that they are waiting for warm weather to do the wetland delineation.

On March 16, 2015, FWS emailed Cardno and COE about the status of the BA and the additional information requested at the December 19, 2014 meeting, including how the existing material would be removed and how it would be kept out of the river. Also needed are updated project drawings showing the impacts on the river and the wetlands. Cardno responded that the draft BA will be updated and they are still waiting to conduct the wetland delineation.

Between April and August 2015, Kosciusko County and the City of Warsaw discussed coordination of funding for the wetland delineation, so further work on the project was delayed during that time period. An email exchange with the agencies on August 17, 2015 indicated that the wetland delineation should be completed within the next month, with a mitigation plan and the update to the BA to follow. The wetland delineation was prepared on September 22, 2015 and was provided to the agencies by USI on October 6, 2015. The delineation showed that 0.15 acre of wetlands will be permanently impacted and 0.12 acre will be temporarily impacted among 4 wetland sites, including emergent, scrub-shrub, and forested types. However, this delineation needed to be verified by the COE.

On December 17, 2015, Cardno provided a revised draft BA for review, which discussed FWS concerns about cleaning the existing piles and coating both the old and new piles without dropping any material into the river. Two methods of dealing with these concerns were described, with no indication which one might be used. Material Safety Data Sheets on the various epoxies and other materials were included. On December 23, 2015, USI provided a revised permit application to the COE and IDEM, which incorporated project plans as of that date.

Through February and March 2016, emails were exchanged among the applicant and the regulatory agencies regarding the status of the project review and any additional information that might be necessary. The applicant wondered if they could go ahead with utility relocation as a separate permit approval while waiting for the BA and BO for the actual bridge reconstruction. IDEM responded on March 2nd with a Letter of Deficiency indicating that the wetland delineation had not yet been verified and that detailed information on the relocation of a natural gas line was not provided. The COE responded on March 21st the she had been to the site to verify the wetland delineation, and although the wetland boundaries appear to be appropriate, there are discrepancies with the wetland types: Additional locations are or were forested wetlands but were or will be cleared for the relocated utilities and converted to emergent types. Drawings of the delineation were marked up to show the necessary changes. During April and May 2016, emails continued to be exchanged regarding needed changes in project drawings related to wetland and waters impacts; project drawings were updated as necessary.

By letter of June 1, 2016, FWS provided comments to Cardno concerning the revised draft BA of December 17, 2015 and the revised permit application (with changes as of April 2016). The original and revised draft BAs had indicated that the bridge would simply be widened to the south (downstream) so that the trail could be added, but the permit application stated that the entire superstructure of the bridge would be replaced with a wider structure of a difference type/design. The revised draft BA did not address removal and replacement of the bridge superstructure and what precautions need to be undertaken to avoid any material falling into the river. The application also stated that the existing piles would be cleaned and recoated with epoxy, and the 6 new piles would also be coated with epoxy; the revised draft BA described two possible methods of treating the piles but no preferred method was provided. FWS indicated that Method 1 (cleaning and coating the existing piles) must include an analysis of the impacts of the products entering the river, including estimated mussel take levels. Method 2 (not cleaning the existing piles but wrapping them in a fiber reinforced composite system) would likely avoid many if not all of the adverse impacts of Method 1; therefore FWS recommended that Method. Detailed maps of the work areas and erosion control plans were requested, along with additional information about the utility relocations.

Cardno responded with another revised draft BA on June 18, 2016 and addressed the concerns expressed in the FWS June 1st letter. It acknowledged that the bridge superstructure will be replaced and indicated that a tarp will be hung under the structure prior to its removal in order to catch any falling debris; any debris that inadvertently falls into the river will be removed by hand. It stated that 6 new epoxy coated piles will be driven into the riverbed to support the wider superstructure, and the existing steel piles will be wrapped with fiber and filled with epoxy to an elevation 1-foot above the normal flow elevation. Additional information was provided about the utility relocations and erosion control plans.

On June 27, 2016, the COE forwarded an email to FWS and IDEM which provided a revised permit application from the applicant which reflects the project as currently proposed, including a revised Project Description to remove the reference to cleaning the existing piles and replace it with the wrapping and epoxy coating. Updated project drawing and erosion control plans were also included.

By email of July 21, 2016 to Cardno concerning the June 18th BA revisions, FWS requested further clarification about the treatment of the existing piles since it was not clear how the fiber wrap would be placed and then filled with epoxy. Cardno responded on July 22, 2016 and provided a clearer explanation of how the piles would be treated.

On July 28, 2016, the FWS provided a letter to Cardno indicating that the current draft of the Biological Assessment, as revised on July 22nd, is adequate for the FWS to accurately determine the degree of impact to the federally endangered Clubshell mussel caused by the proposed project, and therefore the COE may request formal consultation under Section 7 at their convenience.

On August 10, 2016, the COE provided FWS with a final BA and a request to initiate formal Section 7 consultation with FWS. On August 15th, FWS acknowledged receipt of the BA and request for initiation of formal consultation and agreed that the Clubshell is the only Federally listed species that may be affected by the proposed action.

Species Considered in This Biological Opinion

The Clubshell (*Pleurobema clava*) was listed as an endangered species on February 22, 1993 (50 CFR 17) under the Endangered Species Act of 1973, as amended, without critical habitat (USFWS 1993). However, on January 22, 2015, the Center for Biological Diversity petitioned the FWS to designate critical habitat for the Clubshell and 8 additional listed species (CBD 2015); no designation has been finalized. The Recovery Plan was approved on September 21, 1994 (Watters 1994). Federal listing was deemed necessary due to drastic declines in its range and abundance. As discussed in the recovery plan, its decline is attributed to a number of factors, including river damming, point-source pollution, instream sand and gravel mining, and agricultural and urban runoff of sediment and other non-point source pollutants. However, the specific reasons for the drastic decline in this species remain unknown.

P. clava is considered a small mussel, reaching up to 3 inches in length, and is triangular in shape (Figure No. 1 Grabarkiewicz and Crail 2006). For comparison, the smallest North American mussels, such as the Lilliput (*Toxolasma lividus*), are up to 1.5 inches in length, while the largest, such as the Black sandshell (*Ligumia recta),* are up to 10 inches in length. Clubshell is not sexually dimorphic, meaning that male and female shells look the same.

There are 2 Families of the Order *Unioniformes/Unionoida* in North America: *Margaritiferidae*, with 5 North American species, and *Unionidae*, with approximately 295 species. *Unionidae* included 2 Sub-families, the *Unioninea* (with its Tribe *Anodontini*), and *Ambleminae* (with its Tribes *Lampsilini, Amblemini, Pleurobemini, Quadrulini, and Gonideini*) (Graf and Cummings 2007). *Ambleminae* includes the vast majority of North American species, about 250 (Campbell *et al.* 2005). *Pleurobema clava* and the other *Pleurobema* spp. are within the Tribe *Pleurobemini*, along with *Elliptio* spp., *Fusconaia* spp., *Plethobasus*, spp., and others (Campbell *et al.* 2005, Campbell and Lydeard 2012, Lydeard *et al.* 1996). However, earlier workers utilized other classification systems; for example Call (1900) listed about 70 species within Indiana which were distributed among only 3 genera. Modern biologists have also used different nomenclature, as discussed in Bogan and Roe (2008) Campbell *et al.* (2005, 2008), Graf and Cummings (2007), and Lydeard *et al.* (1996). For example, Clubshell was originally named *Unio clava* by Lamarck, likely because *Unio* was a known Old World genus and was used extensively in early North American descriptions (Campbell *et al.* 2005, Graf and Cummings 2007); Rafinesque (1820) called it *Unio mytiloides* "by subsequent designation (Herrmannsen 1847) (a subjective synonym of *Pleurobema clava* [Lamarck 1819])" (Campbell and Lydeard 2012). The species has also been called *Pleurobema clavum* (Goodrich and van der Schalie 1944).

Freshwater mussels have a complex life cycle in which modified larvae (glochidia) are obligate parasites on the gills or fins of fishes. Eggs are deposited in the interlamellar spaces (water tubes) of the gills of the female mussel where they are fertilized by sperm filtered from the water column. The glochidia are brooded in the gills (marsupia) until mature, then released through the siphons, after which they can survive only a few days before they must find a suitable fish host (Zimmerman and Neves 2002). A cyst is quickly formed around the glochidia, and they stay on the fish for several weeks or months before they fall off as juvenile mussels, which then bury themselves in the sediment. The degree of host specificity varies among species from specialists, able to successfully parasitize only one or a few closely related fish species, to generalists which can complete development on a taxonomically wide range of fish species (Haag and Warren 2003). There are 2 primary reproductive strategies that have been described for unionoidean mussels: Some species exhibit prolonged incubation periods (long-term or bradytictic brooders) and are gravid throughout most of the year, while others exhibit short incubation periods (tachytictic or short-term brooders), with spawning and glochidial release occurring in the same season (Gordon and Layzer 1989, Graf and Foifhil 2000, Haag and Staton 2003). The juveniles of most freshwater mussel live buried in stream sediments for months to years, depending upon the species (Cope *et al.* 2008, Geist and Auerswald 2007, Morales *et al.* 2006, Strayer and Malcom 2012).

The identification of freshwater mussel species requires use of morphological characters such as shell shape, periostracum (the thin organic coating or "skin" which is the outermost layer of the shell) texture and color, ray patterns, foot color, nacre (inner shell layer) color, number of gills charged when gravid (females carrying larvae), and alignment and structure of the pseudocardinal teeth (triangular, often serrated, teeth located on the anterior-dorsal part of the shell) and lateral teeth (elongated teeth along the hinge line of the shell) (Figure No. 2 Grabarkiewicz and Crail 2006) (Campbell *et al.* 2005, 2008, Parmalee and Bogan, 1998, Jones and Neves 2010, Tankersley 1996, Williams *et al.* 2008). Some soft-part and internal shell characters cannot be readily utilized in identification without sacrificing the animal, thus field identification of live mussels mainly uses external shell characters that can be difficult to distinguish between similar looking species. Geometric morphometrics can analyze and resolve differences in external shell shape between and among species using digitized high quality photographs (similar to LIDAR determining topography or 3-D printers making a 3-dementional object) (Bogan and Roe 2008, Schilling 2015) rather than the various physical (morphological) measurements traditionally used. However, a sufficient number of shell landmarks need to be mapped and analyzed in order to differentiate subtle differences, which is why "problem" species are hard to tell apart (morphological overlap) and why this method is not usable in the field (Schilling 2015).

Variations in shell morphology in freshwater mussels have caused confusion in species identification for centuries, especially when early biologists started reviewing North American fauna and tried to determine how they fit with known European mussels. The various shell traits include presence/absence of sulcus (a shallow depression or furrow on the outside surface of the shell), shape and position of posterior ridge (ridge on back half of the valve running from beak to posterior ventral edge), shape and position of posterior margin, variations of periostracum color, distance between external annuli (rings), minor striations, and position, size, and color of rays on the shell. These can vary with the size and age of the shell and in males and females (Bogan and Roe 2008, Campbell *et al.* 2008, Kat 1993, Parmalee and Bogan 1998, Williams *et al.* 1993). Incorporating soft-anatomy into species descriptions assisted with developing more accurate taxonomy, as was developing information on reproduction, such as which and how many gills are modified in gravid females (Tankersley 1996).

Various described species were sometimes believed to be the same with synonymous names, as in the case of the Ohio riffleshell (*Epioblasma cincinnatiensis*), Tennessee riffleshell (*E. propinqua*), and Wabash riffleshell (*E. sampsonii*) possibly being distinct species or possibly being forms of Northern riffleshell (*E. torulosa rangiana*) or Tubercled blossom (*E. torulosa torulosa*) (Haag and Cicerello 2016). Since the Ohio, Tennessee, and Wabash riffleshell are presumed extinct and no tissue samples are available for genetic evaluation, their true identity will likely never be known. As previously stated, *Pleurobema clava* also had several different names (Campbell and Lydeard 2012, Goodrich and van der Schalie 1944).

Molecular genetic approaches have improved the understanding of taxonomy and phylogeny of freshwater mussels (Bogan and Roe 2008, Campbell *et al.* 2005 and 2008, Campbell and Lydeard 2012, Lydeard *et al.* 1996). When *P. clava* was listed as endangered in 1991, there was concern about the correct identification of this species versus the Tennessee clubshell (*P. oviforme*) within the southern portion of the species range in Kentucky, Tennessee, and Alabama because these species are morphologically very similar (Haag and Cicerello 2016, Schilling 2005, USFWS 1994, 2008). Campbell *et al.* (2008) discuss the genera *Pleurobema* and its genetics and describe it as a "taxonomically challenging taxa …whose shells often differ only by subtle characteristics" so that "identifying and delimiting species within *Pleurobema* based on shell morphology is especially problematic." Therefore, Campbell *et al.* (2008) (as well as Campbell and Lydeard 2012) investigated the genetics of *Pleurobema* and determined that *P. clava* and *P. oviforme* are distinct species, although very closely related, separated by only a few genetic markers (species pairs/clades). In addition, they (and Schilling 2005) believe that the genetic markers indicate that there are 2 forms of *P. oviforme*. *P. oviforme* is considered a Cumberlandian species endemic to the upper Tennessee and Cumberland River drainages and *P. clava* is considered an Ohio River Basin (also called Interior Basin) species that did not extend further up the Tennessee River than Muscle (Mussel) Shoals, Alabama (Campbell *et al.* 2008, Ortmann 1925, Sickel *et al.* 2007).

Causes of Mussel Endangerment

Freshwater mussels have been decimated throughout the eastern United States and are considered the most imperiled group of animals in North America. Of the approximate 300 recognized unionoid species known from the U.S. and Canada, about 70 percent have been listed by the Natural Heritage Network as presumed extinct, possibly extinct, critically imperiled, imperiled, or vulnerable (Haag 2009, Lydeard *et al.* 2004, Neves *et al.* 1997, Pringle *et al.* 2000, Smith and Meyer 2010, Shannon *et al.* 1993, Strayer *et al.* 2004, Vaughn and Taylor 1999, Williams *et al.* 1993). Extinction rates for freshwater taxa, including mussels, fishes, and gastropods, are 5 times greater than those for terrestrial fauna and are similar to the rates estimated for tropical rainforest communities (Ricciardi and Rasmussen 1999). Changes in aquatic habitats due to impoundments, dredging, snagging, channelization, urbanization, and sedimentation have adversely affected mussels directly through smothering, lack of oxygen, changes in food abundance, and other factors, and indirectly through loss of host fish species (Bogan 1993, Brim Box and Mossa 1999, Galbraith and Vaughn 2011, Gangloff *et al.* 2009, Haag 2009, Landis *et al.* 2013, Landis and Stoeckel 2016, Lydeard *et al.* 2004, Lyons *et al.* 2007, Shea *et al.* 2013, Sickel *et al.* 2007, Smith and Meyer 2010, Stansbury 1971, Strayer and Dudgeon 2010, Strayer 2014, Taylor 1989, Vaughn and Taylor 1999, Warrington *et al.* 2016, Watters 2000). Also, invasions by non-native organisms such as zebra mussels (*Dreissena polymorpha*) have further imperiled native freshwater mussels (Baker and Levinton 2003, Burlakova *et al.* 2014, Haag *et al.* 1993, Higgins and Vander Zanden 2010, Parker *et al.* 1998, Ricciardi *et al.* 1998, Schloesser *et al.* 2006, Strayer 1999a, Strayer *et al.* 1999, Watters and Flaute 2010). In addition, discharges of toxic and/or endocrine-disrupting chemicals (EDCs) and nutrient-enriched effluents from waste water treatment plants and non-point runoff have adversely affected native mussel populations (Augspurger *et al.* 2003, Bartsch *et al.* 2003, Bringolf *et al.* 2007, 2010, Cope *et al.* 2008, Fong and Molnar 2008, Frank and Gerstmann 2007, Gagné *et al.* 2001, 2004, 2005, 2010, 2011, Gillis 2012, Hazelton *et al.* 2014, Hickey *et al* 1997, Keller 1993, Mummert *et al.* 2003, Newton 2003, Newton *et al.* 2003, Sovic 2016, Wang *et al.* 2016). With global warming affecting the hydrological cycle, the affects of water warming, extended drought, heavy rains, and various weather extremes on freshwater mussels have become of greater concern (Galbraith *et al.* 2012, Ganser *et al.* 2013, 2015, Golladay *et al.* 2004, Gough *et al.* 2012, Haag and Warren 2008, Hastie *et al.* 2003, Johnson *et al.* 2001, Pandolfo *et al.* 2010, Spooner *et al.* 2011, Vaughn *et al.* 2015, Waller *et al.* 1999).

Dams in particular have been implicated in major losses of freshwater mussels, such as those in the Tennessee, Cumberland, Mobile, Ohio, and other major river systems in the southeastern United States where mussel populations were once the most numerous and diverse in the world (Hughes and Parmalee 1999, Lydread 2004, Neves *et al.* 1997, Pringle *et al.* 2000, Watters 2000, Williams *et al.* 1992, 1993). The United States has more than 5,500 large dams, defined as those higher than 15 meters (50 feet), and 17 percent of larger rivers have been dammed in the last 100 years (Pringle *et al.* 2000).

The period of major dam construction in North America occurred in the 60 years between 1924 and 1984, with Wilson Dam on the Tennessee River at Muscle (Mussel) Shoals going into operation in 1924, although an earlier dam far upstream had been constructed in 1913 (Haag 2009, Hughes and Parmalee 1999). The Tennessee Valley Authority (TVA) later took over these existing dams in the 1930's and built additional dams in the system throughout the 1930's and 40's, with the 1913 dam being replaced with a larger dam in 1967 (Hughes and Parmalee 1999). There are now 9 mainstream navigational dams controlling over 600 miles of the Tennessee River, with additional navigational and flood control dams on tributaries like the Cumberland (11 dams). Just south of the Tennessee River Basin in the Mobile River Basin, which includes the Mobile, Coosa, Tombigbee, Etowah, Black Warrior, and Alabama Rivers, there are 19 navigational locks and dams (6 of which control the Tennessee-Tombigbee Waterway and connect these 2 originally separate river systems) and 15 hydropower dams (Pringle *et al.* 2000).

Arnold Ortmann did his work on freshwater mussels between 1900 and 1926, including reports on the Tennessee River in 1918 and 1925; he reported 64 species in the general Knoxville area, whereas in 1970 Isom (1971) found only 4 mussel species. Downstream of Knoxville in the area of Chickamauga Reservoir near Chattanooga, the Tennessee River supported 46 species of freshwater mussels prior to the impoundment (Parmalee *et al.* 1982); after impoundment 28 species were extirpated and several are now extinct, with most of the losses being endemic Cumberlandian species. Although there is confusion about the actual numbers of freshwater mussel species in these river systems at the time of European settlement because of misidentification by various naturalists, as previously explained (there may have been more or fewer species because genetic testing was unknown at the time), it is estimated that approximately 78 species were identified from the Tennessee River prior to 1918, although 28 of these species (including *Pleurobema clava*) were not collected after 1910 (Hughes and Parmalee 1999, Sickel *et al.* 2007); 63 species, including a number of endemics, are extinct, extirpated, or imperiled (*i.e.* Federal or State listed as endangered or threatened) (Pringle *et al.*2000). It is believed that 94 species of freshwater mussels were historically present in the Cumberland River (Gordon and Layzer 1989); currently there are 36 extinct or imperiled species. Of the known 75 Mobile River Basin mussel species (33 of which are endemic), 16 endemics are presumed extinct and 17 species are Federally listed (Pringle *et al.* 2000).

Most of the large river dams were constructed for purposes of flood control, hydroelectric power generation, navigation, water storage for potable use, and recreation. The result of this massive dam building was to eliminate most free-flowing large rivers and many medium-sized and even small rivers in the United States (Haag 2009, Pringle *et al.* 2000). The shallow, shoal habitat required by most riverine mussel species was therefore eliminated in most of the large rivers where the greatest mussel diversity originally occurred. For example, during this period the Tennessee, Cumberland, Ohio, and Coosa Rivers were transformed into a series of reservoirs and regulated reaches with little or no free-flowing main-channel shallow habitat remaining; many of the large tributaries were also impounded or affected by the mainstem impoundments, such as having the confluences drowned within the mainstem reservoirs. A wave of mussel species extinctions occurred as a result of these dams (Bogan 1993, Haag 2009, Haag and Williams 2014, Pringle *et al.* 2000, Watters and Flaute 2010). Mussels were eliminated due to the abrupt and permanent transformation of shallow, flowing riverine (lotic) habitat into deep, often oxygen-poor, non-flowing (lentic) habitat. Downstream of the dams, the tailwaters are often adversely affected by cold water releases and/or fluctuating releases due to hydropower generation or drought conditions, which impairs reproduction (*e.g.* cold water, loss of host fishes) (Galbraith and Vaughn 2011, Haag 2009, Watters 2000), or strands mussels (Cushman 1985, Gough *et al.* 2012, USFWS 2014, Vaughn *et al.* 2015).

Watters and Flaute (2010) present a compelling description of the decline of the freshwater mussel fauna of the Ohio River mainstem in relation to the construction of navigation locks and dams, the development of urban centers along the river, and the arrival of the non-native zebra mussel. There are currently 18 navigation locks and dams between Pittsburgh and the confluence with the Mississippi River at Cairo, Illinois, where a 19th large lock and dam is under construction to replace 2 small ones. The entire river is now pooled, with the navigation channel maintained at 9 feet deep. These 19 large locks and dams replaced 53 small dams first authorized in 1910 along the almost 1,000 miles of the Ohio River, but the earlier dams had little impact upon the mussel population. The authors utilized data from historic collections and recent surveys, including those from the Ohio River Islands National Wildlife Refuge, to indicate changes in mussel populations in 9 of the 19 pools created by the high dams, highlighting changes after the construction of the locks and dams and after zebra mussel invasion (only these 9 pool reaches have adequate historic mussel data).

The Markland river reach which includes Cincinnati shows mussel declines for over 120 years prior to the construction of the Markland Lock and Dam between Indiana and Kentucky in the early 1960's, which thus likely reflects the impacts of pollution from industries in both Ohio and Kentucky in the Cincinnati area. What is now the Markland pool was a well-studied reach of the river due to proximity to Cincinnati and 68 freshwater mussel species have been recorded, including Federally endangered Clubshell, Winged mapleleaf (*Quadrula fragosa*), Rough pigtoe (*Pleurobema plenum*), Sheepnose (*Plethobasus cyphyus*), Orangefoot pimpleback (*Plethobasus cooperianus*), White wartyback (*Plethobasus cicatricosus*), Ring pink (*Obovaria retusa*), Scaleshell (*Leptodea leptodon*), Pink mucket (*Lampsilis abrupta*), Cracking pearlymussel (*Hemistena lata*), Snuffbox (*Epioblasma triquetra*), Tubercled blossom (*Epioblasma torulosa torulosa*), Northern riffleshell (*Epioblasma torulosa rangiana*), Catspaw (*Epioblasma obliquata obliquata*), Fanshell (*Cyprogenia stegaria*), Spectaclecase (*Cumberlandia monodonta*), and Rayed bean (*Villosa fabalis*), the threatened Rabbitsfoot (*Quadrula cylindrica cylindrica*), and the extinct Round combshell (*Epioblasma personata*), Forkshell (*Epioblasma lewisii*), and Leafshell (*Epioblasma flexuosa*) (Haag and Cicerello 2016, Watters and Flaute 2010). Of these endangered species, Fanshell may be the only one remaining in the Markland pool, although it, Sheepnose, Spectaclecase, Snuffbox, Rayed bean, and Pink mucket remain further upstream within the Ohio River Islands National Wildlife Refuge (USFWS 2013).

However, not all high dams have been destructive of freshwater mussel populations, as described by Hornbach *et al.* (1996) for the Federally endangered Winged mapleleaf (*Quadrula fragosa*) in the St. Croix River, Minnesota and Wisconsin. At the time the species was listed as endangered in 1991, the only known population of this once wide-spread species was in the St. Croix in the Interstate Park area downstream of St. Croix Falls and its hydroelectric peaking-power dam, which prior to damming was a natural waterfall. The researchers found that *Q. fragosa* was present in areas of slightly lower water velocity and shallower depth than sites without it, and that these occupied sites retained these differences even when the dam rapidly increased flows to generate peaking-power electricity. Other mussel species were at their highest richness and diversity within these same micro-habitats, indicating that the site-specific riverine substrate and flow conditions were conductive for freshwater mussels, whereas in rivers with other instream conditions the habitat in a dam tailwater could be unsuitable for mussels (Hornbach *et al.* 1996). Winged mapleleaf remain extant at this location in the St. Croix River, and the dam is now operated as run-of-the river; the species has since also been found in several other rivers within its historic range and it is being re-established in other historic locations as well (USFWS 2009, 2012).

Dam-induced modifications to a river's thermal regime (thermal pollution) can have both direct and indirect effects on freshwater ecosystems (Galbraith and Vaughn 2011, Novotny 1985, Olden and Naiman 2010, Vaughn and Taylor 1999, Watters 2000). Releases can be from the hypolimnetic (cold) deep portion of a reservoir or epilimnetic (warm) surface portion, and either one can be detrimental to mussels and other species in the tailwaters because they are not the natural water temperatures to which the species are adapted (Layzer *et al.* 1993, Watters 2000). For example, Harman (1974) found few mussels with 10 to 20 miles downstream of dams on the Delaware River due to cold and fluctuating discharges. Since water temperatures affect reproduction timing, mussels in cold water can stop eggs and sperm production. Heinricher and Layzer (1999) relocated non-reproducing mussels out of a cold water discharge in the Cumberland River into warmer water in Kentucky Lake, where the mussels began to reproduce. In addition, water releases from dams often result in both abnormally high or low flows, sometimes on a daily basis, and often these occur at an unnatural time of year, *e.g.* spring flows are usually naturally high due to snow melt, etc., and later summer flows are often naturally low, but dams can change these flow regimes to be the opposite (Bunn and Arthington 2002, Cushman 1985, Galbraith and Vaughn 2011, Miranda and Krogman 2014, Novotny 1985, Vaughn and Taylor 1999, Watters 2000).

Because streams are linear systems, the altered flow, temperature, and other affects in rivers below dams can continue for some distance downstream before natural conditions are restored (Hardison and Layzer 2001, Harman 1974, Layzer and Scott 2006, Vaughn and Taylor 1999). The shape and size of river channels, the distribution of riffles, pools, and runs, and the stability of the substrate are largely determined by the interaction between the flow regime and local geology and landform, and the complex interaction between flows and physical habitat is a major determination of the distribution , diversity, and abundance of riverine organism (Arbuckle and Downing 2002, Bunn and Arthington 2002, Gangloff and Feminella 2007, Hegeman *et al.* 2014, Vaughn 1997, 2012).

Many low-head dams (hydraulic height 10 meters [33 feet] or less) are present on streams and rivers of all sizes; for example, Walter and Merritts (2008) indicated that local census records showed > 65,000 low-head dams were present in the eastern United States by 1840, with many more constructed across the Midwest and West as European settlements continued westward. Therefore, thousands of grist or saw mill dams likely existed in North America by the time the first naturalists began studying freshwater mussels: Martin Lister in Virginia 1685-88; Linnaeus beginning in 1758; Retzius in 1788; Lamarck in 1799; followed by Thomas Say, Rafinesque, Barnes, Timothy Conrad, and Isaac Lea in the early- to mid-1800's (Bogan and Roe 2008). Therefore, there is no way of knowing if these numerous low-head dams adversely affected freshwater mussel populations before the naturalists identified them, but several modern researchers have investigated the impacts of such dams (Abernethy *et al.* 2013, Dean *et al.* 2002, Gangloff *et al.* 2011, Watters 1996).

Gangloff *et al.* (2011) studied the effects of small dams on freshwater mollusks, including snails, fingernail clams (*Sphaeriidae*), and unionids, in 22 streams across Alabama. Ten of the dams were intact, 6 had been breached (obstructed 25-95 percent of the channel), and 6 were relict (mostly gone but still obstructing < 25 percent of the channel). They described most low-head dams as overflow (top-release) structures with run-of-the-river operations unless in periodic active use to run machinery. They also indicated that the more moderate changes to stream habitats associated with the small dams "produce relatively subtle and spatially-limited changes" along streams compared to major dams (Gangloff *et al.* 2011). They found that mussel catch-per-unit-effort (CPUE or person-hours) was significantly greater in streams with intact dams than those with breached or relict dams, and that mussel density and diversity were also greater with intact dams. They reviewed historic mussel data on 13 of the 22 streams and determined that those without intact dams have lost > 80 percent of their historic mussel assemblages, while those with intact dams averaged 8.4 percent losses, with several streams having no losses; all 13 of the streams had intact dams at the times of the historic surveys. They believed that the breached or relict dams had uncontrolled breaks and that the resultant impacts both up- and downstream had somehow been detrimental to mussel beds, while stream channels associated with intact old dams (many being in place >100 years) are "stable across broad temporal and spatial scales" (Gangloff *et al.* 2011). The dam age and height, stream physiochemistry, and watershed land use may be key factors for the observed benefit of these small dams on higher mussel density and richness immediately downstream of small dams compared to other parts of the same watershed.

Another study of small dams in Alabama and North Carolina looked at impacts of the dams on gene flow in 2 species of *Elliptio* mussels (Abernethy *et al.* 2013). The dams were less than 5 meters (16.5) feet) high, had been constructed in 1836 (Alabama) and 1797 (North Carolina), and have not been operational as mill dams for at least 50 years, so all flow is run-of-river over the dams, with small mill ponds upstream. The researchers found no strong evidence of genetic isolation between mussels up- and downstream of the dams. However, the mussel populations in the streams are large, and the researchers postulated that the 200 year± time period of the dams may not be long enough to have affected the DNA markers they studied and that other genetic markers might have a different result.
Watters and Flaute (2010) did not observe any serious impacts to Ohio River mussel populations due to the original low-head wicket dams; for Ohio River reaches having historic mussel data, pools lacking urban developments (*e.g.* McAlpine just upstream from Louisville and Smithland upstream from Paducah) do not show a decline in mussel diversity prior to construction of the large locks and dams. However, Watters (1996) found that low dams on 5 other Midwestern streams that he studied had an impact on the 2 species of mussels he investigated (Fragile papershell *Leptodea fragilis* and Pink heelsplitter *Potamilus alatus*), apparently because the dams blocked the host fishes. Dean *et al.* (2002) studied mussels above and below 2 small dams on the Neosho River in Kansas and got mixed results, but believed that the results showed some impact of the dams that warranted further investigation. Therefore, the impacts of small low-head dams may be as postulated by Gangloff *et al.* that it depends upon conditions of individual watersheds and mussel populations.

Zebra mussel (*Dreissena polymorpha*) invaded Lake St. Clair between Lakes Huron and Erie in the late 1980's, apparently as a result of ballast water discharge from ocean going ships from Eurasia (Schloesser *et al.* 2006). They rapidly colonized the lake and the Detroit River and by the mid 1990's had decimated the native unionid population, which was essentially gone by 1998 (Ricciardi *et al* 1998). Zebra mussels spread from the Great Lakes to the Mississippi River through the connecting Chicago waterways system and from pleasure boats that were moved between waterways. They invaded the Ohio River in the early 1990's, moving upstream from the Mississippi River to Pittsburgh within 3 years; freshwater mussel survey data show dramatic declines after zebra mussel arrival in the Ohio (Watters and Flaute 2010). Zebra mussels attach to solid surfaces using adhesive byssal fibers and have a planktonic larva (veliger) that can remain alive in the water column for several weeks before settling on rocks, pilings, and almost anything else, including native freshwater mussels. The species can be easily transported in small amounts of water that can remain in pleasure boats even after draining and in aquatic vegetation attached to boats or trailers; under cool, humid conditions the adults can stay alive for several days out of water (ANS Task Force 2016). The adult zebra mussels therefore biofoul whatever they attach to, and can be found by the hundreds on individual native mussels (Haag *et al.* [1993] found as many as 200 zebra mussels on individual unionids in the western basin of Lake Erie) and at densities on various other surfaces exceeding 10,000 and even 100,000 per square meter (Higgins and Vander Zanden 2010) (Photograph No. 1).

Photograph No. 1. This fat mucket (*Lampsilis siliquoidea*) was removed from the sediment of the Upper Mississippi River by divers; all exposed areas were covered by zebra mussels. Minnesota Department of Natural Resources photograph.

Dreissenids impact unionids by smothering their siphons, preventing opening and closing of valves, interfering with normal feeding and burrowing activity, and reducing energy stores needed for shell formation, reproduction, and survival, leading to high rates of mortality (Schloesser *et al.* 2006). North American unionid species evolved in the absence of such fouling organisms, and no native unionid has shown an ability to avoid fouling (Haag *et al.* 1993, Ricciardi *et al.* 1998). Even if the dreissenids are not attached to unionids in great numbers, large densities of zebra mussels also can affect unionid survival indirectly by reducing or removing food resources from the water column (Baker and Levinton 2003, Haag *et al.* 1993, Higgins and Vander Zanden 2010, Parker *et al.* 1998, Ricciardi *et al.* 1998, Strayer *et al.* 1998). Zebra mussels can filter the water column much more efficiently and at a faster rate than unionids, with rates varying by unionid species; zebra mussels have been found to have a filter rate 2 to 10 times faster (ml/hour) than unionids (Parker *et al.* 1998). Therefore, even relatively small populations of zebra mussels can affect the feeding, and food availability, of unionid mussels. Some researchers have predicted that zebra mussels will cause the extinctions of many North American species of freshwater mussels (Haag *et al.* 1993, Ricciardi *et al.* 1998, Watters and Flaute 2010).

Because freshwater mussels are largely sedentary, live in or on river substrates, and live in rivers subject to runoff and deposition from the watershed and airshed, any pollutants affecting water and substrate quality can have a profound effect on these species (Newton 2003, Strayer *et al.* 2004, Strayer and Dudgeon 2010, Williams *et al.* 1993). Mussel populations are continuing to decline despite dam removals and flow modifications at major dams and despite the Clean Water Act and the control of most point source pollution through the NPDES permit system. However, waste water treatment plants (WWTPs) currently do not remove all pharmaceuticals and other complex chemicals; although these compounds can be released at small concentrations that are not expected to affect humans, they do impact aquatic life (Augspurger *et al.* 2003, Bringolf *et al.* 2007, 2010, Gagné *et al.* 2002, Gangloff *et al.* 2009, Liu *et al.* 2009, Quinn *et al.* 2004, Sumpter 2005, Wang *et al.* 2016). In addition, legacy pollutants remain, particularly in stream sediments, and non-point sources continue to discharge pollutants, including soils and other particulate matter, often with pesticides, herbicides, and other chemicals associated with them (Audry *et al.* 2004, Beckingham and Ghosh 2011, Effler and Hennigan 1996, Frank and Gerstmann 2007, Gillis 2012, Niemitz *et al.* 2012, Peck *et al.* 2007); air pollutant deposition, whether dry or within precipitation, is also occurring (Driscill *et al.* 2007, Eisenreich *et al.* 1981, Gouin *et al.* 2004, Lohmann and Jones 1998, Newton 2003, Schroeder and Munthe 1998, Wu *et al.* 1991). Although some chemicals may not directly kill freshwater mussels, they can impair reproduction, leaving beds of aging adults with little or no augmentation (Bringolf *et al.* 2010, Geist and Auerswald 2007, Johnson *et al.* 2014, Jones *et al.* 2014, Österling *et al.* 2008, 2010, Sovic 2016, Strayer and Malcom 2012).

There are numerous examples of acutely toxic spills causing mortality of freshwater organisms, both localized and for miles downstream. These include long-time discharges of elemental mercury and chloride salts into the North Fork Holston River in southwestern Virginia from a chemical company that became a Superfund site in 1982 (Henley and Neves 1999), and 2 catastrophic spills into the Clinch River, also in southwestern Virginia, in 1967 (fly ash) and 1970 (sulfuric acid) (Jones *et al.* 2014). These are but 2 examples of the types of events that have happened throughout the United States, but are significant because of the exceptional quality of historic freshwater mussel populations in the rivers, which are upstream of the major TVA dams that eliminated mussels throughout most of the Tennessee River basin (see previous discussion), and therefore they served as refugia for many endangered mussel species. According to The Nature Conservancy,"with its 29 rare mussel species and 19 rare fish species, the Clinch River above Tennessee's Norris Reservoir is home to a remarkable level of aquatic diversity. In fact, the Clinch and Powell rivers harbor a collection of freshwater mussels unmatched anywhere in the world", which is why TNC has ranked the Clinch River as the Number 1 most important river in the entire United States for preserving imperiled aquatic species (TNC 1998).

Even though such toxic spills continue to occur, the current widespread decreases in mussel populations more likely are the result of the subtle effects of chronic, low-level contamination, often from diffuse sources (Gangloff *et al.* 2009, Hickey *et al.* 1997, Johnson *et al.* 2014, Newton 2003, Strayer and Malcom 2012). Toxicity tests have shown that a number of chemicals are acutely toxic to mussels, particularly to glochida and juveniles, which are the most vulnerable life stages (Bringolf *et al.* 2007, Cope *et al.* 2008, Kelly 1993, Wang *et al.* 2016).

Ammonia is one of the most ubiquitous pollutants in aquatic systems and is toxic at relatively low concentrations to aquatic life, including freshwater mussel glochidia and juveniles (Augspurger *et al.* 2003, Bartsch *et al.* 2003, Mummert *et al.* 2003, Newton 2003, Newton *et al.* 2003, Roley 2012, Roley and Tank 2016, Whiteman *et al.* 1996). Aqueous ammonia occurs in 2 forms, ionized (NH4) and un-ionized (NH3) and the proportion of each is dependent on temperature and pH. Ionized ammonia generally is relatively benign, but the un-ionized form can have substantial toxic effects on aquatic organisms. Sources of ammonia to surface waters include precipitation, industrial and sewage discharges, animal waste and fertilizer runoff, and natural processes, such as bacterial production through nitrogen fixation. Sediment pore-water concentrations of ammonia typically exceed those in the overlying water column, so mussels burrowed in the sediment are exposed to these elevated ammonia concentrations (Augspurger *et al.* 2003, Frazier *et al.* 1996). Given that juvenile mussels spend months to years burrowed within the sediments, and that at least some species feed on sediment-associated fine particulate organic matter (FPOM) through pedal-feeding, it is apparent that juvenile mussels can be exposed to toxic ammonia more than many adults (Augspurger *et al.* 2003, Bartsch *et al.* 2003, Cope *et al.* 2008, Geist and Auerswald 2007, Morales *et al.* 2006, Mummert *et al.* 2003, Newton *et al.*2003, Strayer and Malcom 2012). One result of this research on toxic effects of un-ionized ammonia on juvenile freshwater mussels was the water quality criteria update for ammonia in 2013 by the U.S. Environmental Protection Agency (USEPA 2013). The 2013 recommended criteria take into account data for several sensitive freshwater mussel species that had not previously been tested; the criteria are expressed as total ammonia nitrogen (TAN) and take into account pH and temperature. The EPA criteria provide scientific recommendations to States and Tribes authorized to establish water quality standards for their jurisdictions and are not regulations themselves.

A more recent threat to freshwater mussels in a number of states is associated with production of unconventional sources of oil and gas via hydraulic fracturing ("fracking"), which requires large volumes of water and other constituents to fracture the rocks and produces high salinity water that backflows to the surface in advance of the oil or gas. Although much, perhaps most, of this brine is re-injected underground, some is discharged into surface waters after treatment, including into the Allegheny River in Pennsylvania. Therefore, the FWS studied impacts of brine discharge into the Allegheny River at Warren, Pennsylvania, utilizing caged Federally endangered Northern riffleshell juveniles raised at the FWS's White Sulphur Springs National Fish Hatchery (USFWS 2015). The mussel cages were placed at 6 locations, 2 upstream from the brine discharge, 1 at the discharge, and 3 downstream; they also collected water quality data, including specific conductance (SC), which is a measure of ion concentrations and electrical conductivity. Conductivity increases with increasing amount and mobility of ions. Therefore, SC is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution, in this case the presence of chloride from the brine discharge. A strong dose-response relationship between juvenile Northern riffleshell mortality and specific conductance was observed, with the sites closest to the brine discharge having both high SC (chloride ions) and high mortality (USFWS 2015). The researchers were able to map the SC plume movement within the river and its gradual dilution as it progressed downstream, with the most-downstream caged mussels exhibiting normal behavior and survival like those in the control site upstream. Mussel sampling within the river also revealed decreased numbers and diversity within the plume area as it moved downstream, with the plume flowing a specific course within the river channel based upon river geometry and flow patterns.

Little is known about diseases and parasites in freshwater mussels and what part these may play in the endangerment of mussel species. It is known that there are parasitic mites and trematodes that affect mussel health, particularly reproduction. During studies on mussel reproduction, Haag and Staton (2003) found a small percentage of 5 of the 8 species they studied were infected by parasitic trematode flatworms that had completely taken over and replaced the gonads. These trematodes were apparently host-castrating (digenetic) types, which have been found to affect overall condition of mussels in addition to sterilization (Gangloff *et al.* 2008, Gustafson *et al.* 2005, Taskinen 1998). Gangloff *et al.* (2008) found that 23 of the 29 mussels they examined contained glochidia and were parasitized by both mites and trematodes, with a mean number of 136.5 mites per mussel and 41.3 trematodes per mussel, and a mean mussel age of 12 years. Gangloff *et al.* (2008) also determined that mites adversely affect the physiological condition of mussels and may also affect reproduction; mites may feed and lay eggs on mussel gill tissues (Fisher *et al.* 2000), which of course are utilized for both gas exchange and glochidial development. A possible scenario is that mites interfere with glochidial development and retention by damaging gill tissues while feeding on mucus (Gangloff *et al.* 2008). The researchers noted that their data suggest that mussels with high mite abundance also typically had high trematode abundance, but they could not determine any direct cause and effect.

Chittick *et al.* (2001) studied the health of *Elliptio complanata*, a common freshwater mussel that is often used as a surrogate for rare species during research. Mussels from 2 streams in North Carolina were examined for bacteria and parasites; different bacteria were associated with mussels from the different sites, and mussels at only 1 site contained trematodes. A number of protozoans were also found but could not be identified; these symbionts or parasites have been found in freshwater mussels by other researchers, but the roles they play are unknown, as are the roles of the various bacteria (Grizzle and Brunner 2009). Therefore, more research is needed to study possible pathogens in freshwater mussels and how they may relate to other stressors being faced by these species.

Climate change could significantly impact freshwater mussels in a variety of ways. Changes in temperature may affect a number of factors that are important to mussel survival, including individual growth and health, longevity, and reproductive success. Their complex reproductive cycle could also be affected by impacts on host fish species (Galbraith *et al.* 2012, Ganser *et al.* 2015, Hastie *et al.* 2003, Spooner *et al.* 2011). Even if adults successfully produce glochidia, water temperature increases may affect survival of juveniles (Ganser *et al.* 2015, Pandolfo *et al.* 2010). Freshwater mussels have been and are being affected by water and land management activities and clearing of riparian woodlands along rivers, all of which are impacting the thermal regime in which they live. Higher biological oxygen demand occurs simultaneously with a decrease in the oxygen capacity of water and increasing water temperatures (Galbraith *et al.* 2012), which is comparable with severe drought conditions that mussels are already experiencing in some areas; more areas are expected to experience similar impacts with climate change (Spooner *et al.* 2011).

For example, both Golladay *et al.* (2004) and Johnson *et al.* (2001) studied the impacts of drought on mussels in the Flint River watershed, Georgia. The area suffered from severe drought between 1999 and 2002 that significantly reduced flows throughout the entire stream system, which historically contained 29 native mussel species, some of which are now Federally endangered. The researchers determined that decreasing stream flows and associated reductions in dissolved oxygen (DO) led to increased mortality of mussels; as DO levels fell below 5 mg/L, unionid mortality increased steadily (Johnson *et al.* 2001). The mussel communities at individual survey sites were comprised of different species, each of which had different sensitivities to hypoxia and other chemical and physical conditions, so sites did not show the same reactions to the stressors. For example, Chen *et al.* (2001) found that mussels that inhabit lakes, pools and other slack water in rivers, and sand and mud riverine habitats were better able to maintain oxygen consumption rates under low DO conditions than were species that inhabit riffles and runs. Cooler water temperatures improved the mussel species abilities to maintain normal oxygen consumption rates, even for the most sensitive species. The presence of high densities of nonnative Asiatic clams (*Corbicula* spp.) at some sites in the Flint River system seemed to exacerbate hypoxic conditions; *Corbicula* are very intolerant of low DO levels and die quickly as levels drop (Golladay *et al.* 2004). It was postulated that decay of the soft organs of huge numbers of *Corbicula* drove the DO levels even lower and more rapidly than would otherwise have occurred.

During that same drought period, Haag and Warren (2008) studied the impacts on mussels in streams in adjacent Alabama. Their work was in small streams within the Bankhead National Forest in hilly northwest Alabama in the upper Mobile River watershed, where they surveyed mussels pre-drought in 1993 and post-drought in 2001-02. Although the streams studied are protected in the National Forest, the mussel populations are fragmented and isolated by 2 major reservoirs. Drought impacts to the streams were dependent upon their local geology and ground water availability, with most retaining shallow water within low-flow channels and moist substrates in riffles. However, 1 stream in a limestone area dried almost completely, with only isolated moist substrates; although mussels had been abundant in that stream in 1993, only a few survived in the moist locations and hundreds died in place in the dry reaches (Haag and Warren 2008). Taken together, mussel populations in the small streams declined by an estimated 63 to 100 percent. They also sampled 2 large rivers outside of the Forest; the large rivers lost hundreds of mussel in some dewatered areas but otherwise did not experience extensive dewatering and streambed exposure. The researchers indicated that the drought had no measurable effect on mussel assemblages in these 2 large rivers.

During another drought in 2011, Gough *et al.* (2012) researched dewatering impacts on mussels in a low gradient Coastal Plain stream near Tuskegee, Alabama. They conducted a field manipulation utilizing 3 mussel species to evaluate their response to receding water levels. Thirty individuals of each species were placed at varying depths along 3 transects perpendicular to the flow on 6 June and were monitored through 15 weeks of drought; the study reach was completely dried by 9 August and flows did not return until heavy rains on 26 September. The 3 species studied were Southern fatmucket (*Lampsilis straminea*), Pondhorn (*Uniomerus tetralasmus*), and Giant floater (*Pyganodon grandis*), with Pondhorn showing the greatest desiccation tolerance, Southern fatmucket being intermediate, and Giant floater having the lowest tolerance. Pondhorn and Southern fatmucket burrowed in response to becoming stranded but Giant floater rarely burrowed. No Giant floater survived the 15-week drought, while 45 percent of the Southern fatmuckett and 77 percent of Pondhorn survived; the authors indicated that some of the lost mussels likely were removed by predators rather than being killed by the drought (Gough *et al.* 2012).

Hurricanes have dramatic effects on river flows not just due to extremely heavy rains but also because of natural and anthropogenic debris blown or washed into the waterways, with both water volume and floodway debris affecting river geomorphology. It has long been known that mussels are not uniformly spread across stream bottoms but instead are highly patchy, living in distinct "beds" composed of a variety of species that can be quite dense (Strayer *et al.* 2004). Strayer (1999b) suggested that mussel beds will generally be found within rivers where shear stresses along the streambed during floods are below some threshold value, with the flood intervals being low to moderate (*e.g.* 3 to 30 years). However, it is generally unknown how mussel beds react to extremely high floods generated by hurricanes or major thunderstorms, both of which are expected to increase in strength and frequency with global climate change.

In 2007, Brown *et al.* (2010) resampled Louisiana's Pearl River 2 years after Hurricane Katrina had devastated the area and 10 years after their initial sampling. They indicated that the river channel had been altered by the affects of the hurricane, likely stranding mussels in the old channel, so they were not able to resample all of the same sites. In 1997 they found 29 mussel species distributed among 29 sites while in 2007 they collected 23 species distributed across 23 sites. They also noted that the most abundant species in 2007 was one known to be more estuarine in distribution and much less sensitive to salinity than other freshwater mussels; this marked change in dominance may have been the result of Katrina's storm surge that pushed salt water 12+ miles upstream from the ocean (Brown *et al.* 2010). Bleufer (*Potamilus purpuratus*), a species of quiet slow-moving water in rivers and lakes, was the third most common species in 1997 (~ 500) but fell to eighth (91) in 2007, with few large adults found. The researchers could not determine if the Katrina flood flows adversely affected the Bleufer or if a drought in 2006-07, which produced extremely low flows, was a contributing factor.

Status of *Pluerobema clava*

Historically, the Clubshell was widespread in the Ohio River and many of its tributary systems in Kentucky, Illinois, Indiana, and Ohio, and to a lesser extent in Ohio River tributaries in West Virginia and Pennsylvania, and in the Maumee River system in Michigan, Indiana, and Ohio. Figures No. 3 (Fisher 2008), No. 4 (Watters *et al.* 2009), and No. 5 (Haag and Cicerello 2016) show the historic and current distributions of the Clubshell within Indiana, Ohio, and Kentucky. It was also present in the lower Tennessee River system in Tennessee and Alabama. Although it was formerly widespread and common, at the time of listing it was thought to exist in about a dozen isolated populations, most of which were small and peripheral (USFWS 1993). As shown in Figure No. 3, *P. clava* was well distributed throughout much of Indiana. In Ohio it was concentrated in the Scioto River system, which includes Little Darby Creek, in the center of the state (Figure No. 4), while in Kentucky it was primarily found within the Green and Licking River systems (Figure No. 5).

As shown by studies of Pre-Columbian (*i.e.* prior to European settlement, also called Pre-Historic) Native American community sites, Clubshell were regularly used as food items, along with numerous other species; mussel shells were also utilized to make ornamental items and tools and as a tempering agent in pottery (Genheimer and Hedeen 2014, Hughes and Parmalee 1999). For example, the Hahn Site along the Little Miami River, east of present-day Cincinnati about 5 miles upstream of the Ohio River, was found to have 2 trash pits full of mussels, including fragments and complete shells; Clubshell was found to be the 3rd and 4th most common species utilized by the Native Americans at that village site, despite being smaller than the other species taken (Genheimer and Hedeen 2014). The authors hypothesized that the Native Americans utilized whatever freshwater mussel species were readily available in dense beds in the Little Miami River, and that the species found in the pits are representative of the local mussel diversity at the time of the village's existence 500 to 600 years ago. During surveys of the Little Miami River and its tributaries in 1990-91, Hoggarth (1992) found signs of 36 mussel species (living, dead, weathered, subfossil) at 105 sites; 1 each weathered and subfossil shells of *P. clava* were found in the middle reach of the river and none were found in the lower river in the vicinity of the Hahn Site, nor is the lower Little Miami River shown as an historical Clubshell site on Figure No. 4.

Similarly, Hughes and Parmalee (1999) investigated 15 mussel shell middens along the Tennessee River between Knoxville and the confluence with the Ohio River; 75 species were identified, including *P. clava*. However, as discussed in the Clubshell Recovery Plan (Watters 1994), *P. clava* is difficult to separate from the Cumberlandian (*i.e.* endemic to the Cumberland River system of the Appalachian Mountains) species *Pleurobema oviforme* (Tennessee clubshell), and that specimen from the upper Tennessee River may represent *P. oviforme*. It is noteworthy that *P. clava* was listed as being present in varying numbers at more of the midden sites than *P. oviforme*, but it was also known almost entirely just from the midden sites, having been collected alive only from the Muscle (Mussel) Shoals section of the river prior to 1910 and not seen since (Hughes and Parmalee 1999). *P. oviforme* is known from several of these midden sites as well as from river collections both before and after impoundment of the Tennessee River and remains present in headwater streams such as the Clinch River, Holston River system, and Powell River in Virginia and Tennessee, and upper Little Tennessee River system in North Carolina, as well as the Duck River further west in central Tennessee (Schilling 2015), and in Cumberland River tributaries in Kentucky (Haag and Cicerello 2016). Therefore, questions remain about the midden sites identification of *P. clava*, but even if the was once present it has been extirpated for approximately 100+ years. As previously discussed, Haag and Cicerello (2016) and others (Campbell *et al.* 2008, Ortmann 1925, Sickel *et al.* 2007) indicate that *P. clava* likely was restricted to the lower reaches of the Tennessee and Cumberland River drainages and was replaced by *P. oviforme* in the middle and upper sections of these rivers.

Pleurobema clava was formerly abundant in the Wabash River of Indiana and Illinois as reported by Call (1896, 1900) and as evidenced by the numerous sub-fossil shells still present on the gravel bars and shoals of the river (Cummings *et al.* 1998). However, surveys in 1987, 1988, and 1996 at over 50 sites yielded no live or fresh-dead Clubshells, and it is believed to be extirpated from the mainstem of the Wabash River (Cummings *et al.* 1992, 1998). It was also present in Wabash tributaries in Indiana, such as the Tippecanoe, Eel, Salamonie, Mississinewa, and West and East Fork White Rivers and their tributaries, plus Wildcat Creek (Figure No. 3) (Fisher 2006); at the time of listing it remained only in the Tippecanoe River. On the Illinois side of the Wabash River, *P. clava* was historically found in the North, Middle, and Salt Forks of the Vermilion River (Cummings *et al.* 1998) and in the Embarras River (Shasteen *et al.* 2012), but was not considered present in Illinois at the time of listing. In addition, in Indiana there are reports of relict shells from the mainstem Ohio River and 2 direct tributaries, Blue River (Weilbaker *et al.* 1985) and Laughery Creek (Figure No. 3), while in Illinois a relict was found in 1999 in the Ohio River near Metropolis (Tiemann *et al.* 2007). In the Maumee River drainage in Indiana, Clubshell were found in Fish Creek and the mainstem St. Joseph River as well as the Maumee itself, while in Ohio it was in the St. Joseph and its West Branch (which extends into Michigan), Fish Creek, the Maumee, and the Auglaize River (Figure No. 4); when listed it was only known from Fish Creek in Indiana and Ohio and in the West Branch of the St. Joseph River in Ohio and Michigan. At the time of listing, *P. clava* was also thought to be present in Ohio's Little Darby Creek and Walhonding River (USFWS 1993). Elsewhere, it was thought to still be present in the Alleghany River and its tributary French Creek, LeBoeuf Creek, and Conneautee Creek in Pennsylvania and the Elk River (Kanawha River watershed) in West Virginia (USFWS 1993).

River channelization for navigation, flood control, or agricultural drainage also occurred during the same 60 year time period as major dam building (1924-1984), with the channelization often occurring on smaller streams rather than large rivers, *e.g.* much of the Auglaize River system in Ohio was channelized in the 1970's, as were numerous streams in Indiana, Mississippi, Alabama, and other states, with flood control and agricultural drainage being the major purposes (Public Law 566 Small Watershed Projects constructed by the U.S. Department of Agriculture). Channelization of the Auglaize River system eliminated habitat for Clubshell and numerous other species (Figure No. 4); it is unknown if the Clubshell was once present in the Indiana streams that were channelized (*e.g.* parts of Rock Creek, a Wabash River tributary in Carroll and Cass Counties of central Indiana, and parts of another Rock Creek, a Wabash tributary in Wells County in the east-central part of the state).

Since listing, living Clubshell have been found in Pymatuning Creek in in Ashtabula County, Ohio, in the Ohio River drainage of the far northeastern corner of the state (Huehner and Corr 1994); 10 living animals were found at 4 of the 5 most downstream sites in the county. *P. clava* has also been confirmed in Little Darby Creek and is considered "not uncommon" in the middle reach of the stream in Madison County (Watters 1998a). In 2006 a single live Clubshell was found in Big Darby Creek, where the species had not been recorded for many years (USFWS 2008). The species has since been translocated to Big Darby Creek from populations in the Allegheny River in Pennsylvania as part of a bridge replacement project mitigation (ORVET 2015a).

During 1996-98, *P.clava* was found alive (1 animal) in the Middle Branch, North Fork Vermilion River in Illinois (Szafoni *et al.* 2000); prior to this discovery, Clubshell was thought to be extirpated from Illinois. Beginning in 2005, Illinois natural resources agencies partnered with the USFWS and state agencies in Ohio and Pennsylvania and began planning the release of this species into the Vermilion River system (USFWS 2008). A bridge construction project over the Alleghany River in Pennsylvania provided an opportunity to translocate Clubshell from that site to Illinois (as well as to Ohio [Big Darby Creek mentioned above], Kentucky, Indiana, and West Virginia as discussed below). Between 2010 and 2014, a total of 1,766 Clubshell were translocated to 8 sites within the Vermilion River basin, 5 in the Middle Fork and 3 in the Salt Fork, and have been monitored since that time (Tiemann 2014, 2015, Tiemann *et al.* 2015).

Relict shells of Clubshell were found at 2 sites in the Indiana portion of Brouilletts Creek, a tributary of the Wabash River, in 2004 during the first comprehensive survey of that basin in Illinois and Indiana; since this stream system had not previously been studied, this finding constituted new information about the species historic range (Tiemann 2005).

In Kentucky, Clubshell were present at only a few sites in the Green River at the time of listing (Haag and Cicerello 2016), with 1 of the sites being within Mammoth Cave National Park (Olson 2005). A 1998 survey of the river from Mammoth Cave upstream to Green River Dam confirmed living and reproducing Clubshell at 4 sites (Southeastern Fishes Council 1999), as shown in Figure 5. Changes in releases from Green River Dam are being investigated through the Sustainable Rivers Project to determine what flows might best support the Green River mussel populations, including Clubshell (Konrad *et al.* 2012, Moles and Layzer 2008). In 2013 and 14, Clubshell were reintroduced to 4 sites in the Licking River in northcentral Kentucky, using animals translocated from the Allegheny River in Pennsylvania (Haag and Cicerello 2016).

In Pennsylvania, a reproducing population of Clubshell was found in Muddy Creek within the Erie National Wildlife Refuge in 2003 (Mohler *et al.* 2006). Muddy Creek is a tributary of French Creek, where there has been a known population of the species (Smith and Crabtree 2010).

The largest remaining populations of Clubshell are in the Allegheny River in Pennsylvania, with major concentrations present within the free-flowing 100-mile± stretch of the river downstream from the City of Warren, which includes about 80 miles of National Wild and Scenic River in its lower 2 segments (48 miles from Mead Island to Alcorn Island and 32 miles between Franklin and Emlenton) (Villella and Nelson 2006). Clubshell has also been found intermittently further downstream, including at Foxburg, which is upstream of Navigation Pool 9 (Anderson 2000), and sparsely within Navigation Pools 7 (Smith and Meyer 2010) and 8 (USFWS 2004). The population between Mead and Alcorn Island is exceptional, while the Franklin to Emlenton population is smaller. These river segments also include phenomenal populations of the Federally endangered Northern riffleshell and smaller populations of endangered Rayed bean, Sheepnose, and Snuffbox and threatened Rabbitsfoot (Villella and Nelson 2006). The river reach between Franklin and Emlenton/Interstate 80 (35.6 miles) is designated as critical habitat for the Rabbitsfoot (as previously stated, critical habitat has not been designated for *P. clava*, nor has it been designated for the other listed species).

The mussel surveys within the Allegheny River were completed for the Pennsylvania Department of Transportation because of PennDOT's need to replace a number of bridges (Villella and Nelson 2003, 2004, 2005, 2006, Villella and Smith 2002). Earlier bridge replacements at Kennerdell (Parsons and Brinkerhoff 1997) and Foxburg (Anderson 2000) had shown that both Clubshell and Northern riffleshell are present in the river between the Kinzua Dam (a Corps of Engineers flood control dam upstream of Warren) and the navigation pools (9 Corps of Engineers locks and dams downstream from East Brady). Therefore, it was determined that detailed studies were needed, to include both qualitative surveys to find the extent of the mussel beds and quantitative sampling to determine the estimated population sizes (Villella and Nelson 2003). Section 1 covered the river from Mead Island to Tionesta, a distance of 51.4 km (about 32 miles), and Section 2, from Tionesta to downstream of Kennerdell, covered 70.6 km (about 44.5 miles). In Section 1, the researchers quantitatively sampled 70 percent of the high density sites and 20 percent of the low density sites; including the West Hickory alternate bridge location, which was an additional site in Section 1, they estimated the total density of all mussels at 28,648,380 (Villella and Nelson 2006). Throughout the entire 51.4 km of Section 1, they calculated an estimated total abundance of 1,117,273 Clubshell, with few individuals in the upper 40 km and the greatest densities at and downstream of West Hickory.

More mussels were found in the upper portion of Section 2 than in Section 1, with Clubshell found at all 22 sample sites between Tionesta and Oil City, with the highest relative abundance of 39 percent at site 72.4, based on km below Mead Island (Villella and Nelson 2006). Riffleshell was also found at all 22 sample sites in upper Section 2, with highest relative abundance of 49 percent at site 55. At 2 sites in Section 2, *P. clava* was the dominant species, although higher actual numbers were found at 5 other sites (Villella and Nelson 2006). Riffleshell had even higher numbers and was the dominant species at 14 sites, with Clubshell being the second most dominant species at 8 of those 14 sites. At site 56.2, almost 6,000 individual *P. clava* and almost 7,000 *E.t.rangiana* were found within the 200-meter-long sample site (each site was the width of the river by 200 meters long [Villella and Nelson 2003]), while at the next downstream site (56.8) approximately 4,700 Clubshell and 5,500 Northern riffleshell were found (Villella and Nelson 2006). These 2 sites are up- and downstream of Hunter Station Bridge. Therefore, the total population of each *P. clava* and *E.t. rangiana* in the upper and middle Allegheny River are estimated to be several million (Villella 2007).

The FWS determined that in order to avoid a jeopardy decision under Section 7 of the ESA for the Hunter Station Bridge replacement, it would be necessary to relocate the thousands of Clubshell and Northern riffleshell found within the project action area. During the past several years, these endangered mussels, plus non-endangered species, have been translocated to other streams in Pennsylvania, Ohio, Indiana, Illinois, West Virginia, Kentucky, and the Seneca Nation in New York (FHWA 2006).

As previously described, Clubshell from the Allegheny River bridge reconstruction project areas have been translocated to the Vermilion River system in Illinois and Big Darby Creek in Ohio after the species was rediscovered in those streams (ORVET 2015a, Tiemann 2014, 2015, Tiemann *et al.* 2015). They have also been translocated to the Ohio River in West Virginia (ORVET 2015a, b, WVDNR 2015), the Licking River in Kentucky (Haag and Cicerello 2016, ORVET 2015a, b), and at 3 sites in the

Eel River in Indiana (Fisher 2016), all of which have been at sites where they were historically located. Monitoring to date indicates that all these translocated populations are doing well. A 5-year review of Clubshell that is currently underway by the FWS will provide an update on these recovery actions (FWS 2011).

As announced in the June 14, 2001 Federal Register (USFWS 2001), the FWS determined the advisability of reintroducing *P. clava* and 15 other species of endangered freshwater mussels, plus 1 freshwater snail, to the remaining portion of Muscle (Mussel) Shoals in Alabama. These nonessential experimental populations (NEP) would be established within the Tennessee River from the base of Wilson Dam (River Mile 259.4) to the backwaters of the Pickwick Reservoir (RM 246.0); the NEP habitat also includes the lower 5 miles of all tributaries that enter the Wilson Dam tailwaters. None of the 17 species were known to exist within the NEP habitat area as natural populations but had been found there historically. NEP are treated differently under ESA because they have been determined to not be essential/necessary to the continued existence of the species. It is believed that as many as 78 freshwater mussel species were historically present at Muscle Shoals prior to the impoundment of the area in the 1920's and 30's, which destroyed about 41 RM of the shoals and left only about 12 RM between Wilson Dam and Pickwick Dam. TVA's Reservoir Releases Improvement (RRI) Plan, implemented in 1991, was part of an attempt to address deteriorated ecological processes within the Tennessee River watershed; through the RRI, TVA implemented modifications to their dams to improve dissolved oxygen and minimum flows in tailwaters below its dams (Bednarek and Hart 2005). In most tailwaters, this program resulted in improvements in the fish and benthic macroinvertebrate populations, suggesting that mussels might be successfully re-established (Scott *et al.* 1996, Layzer and Scott 2006). These improvements lead to the FWS's proposal to re-establish Clubshell and other native mussel species within the Wilson Dam tailwaters (USFWS 2001). These reintroductions are recovery actions for these 17 endangered species and are part of a series of reintroductions and other recovery actions that the FWS and partners area considering and conducting throughout the species' historical ranges.

The Tippecanoe River, Indiana, supports the second largest known population of Clubshell in 2 segments, with populations at various locations in the upper river above the influence of Lake Shafer (Norway Dam) and in the lower river downstream of Lake Freeman (Oakdale Dam) (Fisher 2006). Because of the blockage of the river caused by the 2 dams, these populations can essentially be considered separate because there is little chance of intermingling. The Tippecanoe River originates as a chain of glacial lakes in Noble and Whitley counties and flows southwest to the Wabash River in Tippecanoe County; Kosciusko County is located within the upper portion of the Tippecanoe River Watershed.

Surveys of the Tippecanoe River population since the 1980's have found living and/or dead Clubshell mussels at numerous locations. During surveys in 1987 at 16 sites from the lake area headwaters to the confluence with the Wabash River, Cummings *et al.* (1987) (also discussed in Cummings and Berlocher 1990) found 19 living *P. clava* at 4 sites and fresh dead specimens at 2 others; 9 of the living Clubshells were found in the vicinity of Kosciusko County Road 300 North, which is the current project area. Neither Cummings *et al.* (1987) nor Cummings and Berlocher (1990) indicate whether the sampling was conducted up- or downstream from the bridge or both or for what length; the only description is that the site was sampled by hand for 4 person-hours.

The 1991-92 survey by ESI (1993) found living Clubshells at 9 sites and fresh-dead shells at 9 additional sites. ESI sampled the same 16 site as Cummings *et al.*, including the CR 300 North bridge area in Kosciusko County; 4 live *P. clava* were found here, but again the exact sample area was not described in the report. ESI also sampled 3 additional sites upstream from CR 300 North toward the outlet of Oswego/Tippecanoe/James Lakes (the 3 lake basins are interconnected and controlled by a single outlet at the southwest end of Oswego Lake), and found living Clubshell at 2 of these sites; fresh dead shells were found at the site just downstream of the lakes control structure at the community of Oswego. In the downstream area below Lakes Shafer and Freeman, weathered shells were mostly found except at the 2 most downstream sites within a few miles of the confluence with the Wabash River.

A 1995 survey by ESI (1998) found living Clubshell mussels at 11 sites. The sites sampled by ESI in 1995 were primarily new sites upstream and downstream of 16 tributaries of the Tippecanoe River, so many of the Clubshell found were at sites not previously surveyed; none of the sample sites were near CR 300 North. Additional Clubshell have been found during various sampling events by several investigators. For example, on August 22, 2003, a living animal was found near CR 375 West in Fulton County north of Pershing (Dr. Melody Myers-Kinzie, 2003 Federal permit report). A living and numerous fresh-dead Clubshells were also found near CR 650 West south of Atwood in Kosciusko County in September 2003 (Dr. Melody Myers-Kinzie, 2003 Federal permit report). Thirteen living Clubshell mussels were found on November 14, 2003 at the site of the new Warsaw wastewater treatment plant, about 1 straightline-mile south of CR 300 North (Brant Fisher, 2003 Federal permit report). In November 2010, Fisher found 4 living Clubshell south of US 30 in Warsaw near the Hidden Lake Water Treatment Facility, about 0.75 straightline-mile south of CR 300 North (Brant Fisher, 2010 Federal permit report). In May 2016, Fisher found a live Clubshell just upstream of the SR 15 bridge in Warsaw/Monoquet, about 1 straight-line mile northeast of the CR 300 North bridge (Brant Fisher personal communication 2016). Therefore, we know that living and reproducing Clubshell are found in suitable habitat throughout the Tippecanoe River between the Oswego Lake Outlet and the inlet of Lones Ditch on the northwest side of Warsaw, which includes the project area, as well as downstream at various locations.

The only other extant population of Clubshell in Indiana waters until recently is a small one in Fish Creek (Steuben and Dekalb Counties) in the Maumee River drainage. Watters (1998b) surveyed this stream in Indiana and Ohio at 30 sites in 1996 and found 25 species, with Clubshell being located throughout as weathered shells and as living or freshly dead specimen at 9 sites, mostly in Ohio.

As with other Unionid mussels, the Clubshell is a sedentary, filter-feeding, benthic animal. It typically burrows completely beneath the substrate, apparently relying on water to percolate between the sediment particles (Watters 1994). Therefore, this species is very susceptible to siltation, which clogs the sand interstices and suffocates the animal. The Clubshell generally is found in clean, coarse sand and gravel in runs, often just downstream of a riffle. Clubshells cannot tolerate mud or slackwater conditions.

As previously described, unionid mussels reproduce sexually, with sperm being released into the water by males and picked up by females through their siphons. The eggs hatch into glochidia, which are stored in the female's gills until released into the water. The glochidia then parasitize a vertebrate host and metamorphose within the host, changing into the bivalve adult form over a period of several weeks to several months, before releasing from the host and dropping to the bottom of the stream. With one known exception, the hosts of unionids are fish (the Salamander mussel [*Simpsonaias ambigua*] uses the mudpuppy as its host). While natural hosts for the Clubshell have not been found in the wild, laboratory studies in aquaria have identified 4 fish species which served as hosts for the Clubshell (O'Dee and Watters 1998). The 4 species are Blackside darter (*Percina maculata*), Central stoneroller (*Campostoma anomalum*), Log perch (*Percina caprodes*), and Striped shiner (*Luxilus chrysocephalus*). Based upon fishery surveys of the Tippecanoe River, the Striped shiner is known from the project reach of the river (ESI 1993, Simon and McWilliams-Munson 2001).

Description of the Proposed Action

The Kosciusko County Commissioners propose to rehabilitate the CR 300 North bridge because the existing superstructure is deteriorating and is too narrow for the trail that will be constructed along the south side of the roadway between SR 15 on the east and CR 150 West/Madison Elementary School to the west. The superstructure of the existing 3-span Bridge 18 carrying CR 300 North over the Tippecanoe River will be reconstructed and widened to replace the deteriorating beams and add a multi-use greenway trail. The existing 29-foot wide superstructure will be replaced with a prestressed spread concrete box beam superstructure approximately 40 feet wide. The existing asphalt pavement will be cut at the joints of the box beams and the beams will be removed using a one-step removal process and placed directly onto a truck for removal off-site. Prior to the removal of the superstructure, a tarp will be attached to the end bents under the entire span of the bridge to catch any debris produced during the superstructure removal. If any errant debris falls into the Tippecanoe River, it will be removed by hand or equipment lifting it straight up, with no dragging of the material across the river bottom.

The piers will be extended downstream by 14'-10"; the abutments along the river banks will be widened by 16'-7" after the removal of the existing southern wingwalls. New piles will be driven to an elevation approximately 46 feet below the stream bed to support the proposed widened superstructure. The existing steel piles supporting the 2 internal bents (piers) will be wrapped with fiber, which will be filled with epoxy above elevation 809.0 feet NAVD, as described below. Wrapping of the piles and the placement of the epoxy will not be performed unless the water level is at an elevation equal to or below 808.5 feet NAVD. The river embankments under the bridge will be armored with 18-inch revetment riprap over geotextiles and keyed into the slope.

As part of the project, Kosciusko REMC needs to move the power line south of and parallel to CR 300 North to a location about 3 feet north of the new southern right-of-way. Some tree/shrub clearing will be necessary along the route of the relocated power line; cleared trees will not be dragged across the ground during removal. Four power poles will be installed in wetlands adjacent to the Tippecanoe River, requiring 0.3 cubic yards of fill per pole. Also as part of the project, NIPSCO will be relocating their natural gas pipeline to the south of its current location near the bridge. The line will be bored under the river and adjacent wetlands, with no open trenching and the boring sites located in uplands. The bore pits will be filled with the excavated material with no impacts to the river or wetlands. It is possible that the existing telephone and fiber optic cables will need to be relocated; if so, these lines will be bored under the river and wetlands.

Specifically, the existing bridge has 2 end bents (support structures) outside of the normal river flow channel and 2 internal bents (piers) within the normal flow channel. The internal bents each consist of 6 14-inch diameter steel casings filled with concrete supporting concrete caps, which in turn support the bridge beams (Photograph No. 1). The bridge beams and pier caps will be removed and 6 new steel piles will be pounded into the river bed on the downstream side, 3 piles per pier, and filled with concrete. Prior to installation, these piles will be epoxy coated off-site to an elevation that will be 5 feet below the river bed after installation. The existing piles were coated with epoxy at the time of their installation in 1980, but this coating has worn off and the piles are deteriorating. Therefore, they will be wrapped with a fiber reinforced composite system which will be filled with epoxy. The fiber wrap is loose fitting, allowing a several-inch gap between the wrap and the steel piles; the epoxy will be poured into this gap after the bottom 6 inches of the encircling wrap tube is filled with high density foam to close the bottom. Twelve inches of the epoxy will be poured over the foam and allowed to set before the remainder of the sheath is filled. A drawing of the fiber wrap system and the product data sheets for the fiber wrap and epoxy are provided in Attachment A.

Photograph No. 2. The south side of existing Bridge 18, showing the interior pile bents (piers) which will be extended to the left with 3 additional piles for each pier. USFWS Photo December 19, 2014

Only local funds will be used for the bridge reconstruction, with no Federal funds involved. However, a permit under Section 404 of the Clean Water Act is required in order to place fill material into the Tippecanoe River and adjacent wetlands. Therefore, the proposed project constitutes a federal action as defined by the ESA, and the U.S. Army Corps of Engineers, Detroit District is the Action Agency. The action area included the impact zone, defined as the stream reach including the adjacent floodplain, from 500 feet upstream of the bridge to 1500 feet downstream of the bridge. The Tippecanoe River is about 100 feet wide at the bridge site and the length of the project is 600 feet (beginning of incidental construction on the west and end of incidental construction on the east). Attachment B contains the project erosion control plan.

Several alternatives were considered for the bridge rehabilitation, most notably the method of treatment of the existing steel piles with an epoxy coating, and the selected construction alternatives were based on a combination of cost feasibility and reduction of impacts on the mussels and other aquatic resources of the river.

Environmental Baseline

The Tippecanoe River contains the largest remaining population of Clubshell in Indiana. The river is nationally recognized for its unique biological diversity, with The Nature Conservancy (TNC) ranking the Tippecanoe River as the eighth most important river in the entire United States for preserving imperiled aquatic species (TNC 1998). Historically, the Tippecanoe River supported a rich unionid fauna that consisted of 57 species and included 10 species presently listed as Federally endangered and 1 Federally threatened species, plus several Indiana listed species. The freshwater mussel community currently consists of 49 extant species, including the endangered Clubshell, Fanshell (*Cyprogenia stegaria*), Northern riffleshell (*Epioblasma torulosa rangiana*), Rayed bean (*Villosa fabalis*), Snuffbox (*Epioblasma triquetra*), and Sheepnose (*Plethobasus cyphyus*), plus the threatened Rabbitsfoot (*Quadrula cylindrica cylindrica*) (ESI 1998). The river also supports populations of at least 3 additional Indiana endangered species: Longsolid (*Fusconaia subrotunda*), Round hickorynut (*Obovaria subrotunda*), and Pyramid pigtoe (*Pleurobema rubrum*); and 5 additional Indiana special concern species: Wavy-rayed lampmussel (*Lampsilis fasciola*), Ohio pigtoe (*Pleurobema cordatum*), Kidneyshell (*Ptychobranchus fasciolaris*), Purple lilliput (*Toxolasma lividus*), and Little spectaclecase (Villosa lienosa). During the mussel survey for this project, 13 living Clubshell were found both up- and downstream of the bridge, 33 Kidneyshell were found up- and downstream of the bridge, and 4 Wavyrayed lampmussel were found downstream of the bridge, plus 10 more common species were found, also up- and downstream of the bridge. Two species were found directly under the bridge, including 1 Kidneyshell and 1 Wabash pigtoe (Cardno JF New 2014).

Based upon fishery studies from the 1870's to the present, 110 species of fish have been recorded from the Tippecanoe River; FWS sampling of 34 sites throughout the river in 1994 found 97 species, which is about half of the entire State fauna (204 species) (Simon and McWilliams-Munson 2001). Sampling by ESI in 1992 found 38 species in the upper portion of the river (Kosciusko and Marshall Counties), with

20 species in the vicinity of CR 300 North and 70 total species at 23 sites along the length of the river (ESI 1993); Carney *et al.* (1993) found 68 species at 22 sites riverwide. While none of the 20 fish species found at CR 300 North are Indiana listed as endangered or special concern, 13 of the species are sensitive to a wide variety of environmental disturbances and/or are sensitive to sedimentation and require clean gravel for spawning (ESI 1993); these include Striped shiner (*Luxilus chysocephalus*), River chub (*Nocomis micropogon*), Bigeye chub (*Hybopsis amblops*), Sand shiner (*Notropis lundibundis*), White sucker (*Catostomus commersoni*), Northern hogsucker (*Hypentilium nigricans*), Spotted sucker (*Minytrema melanops*), Brindled madtom (*Noturus miurus*), Longear sunfish (*Lepomis megalotis*), Smallmouth bass (*Micropterus dolomieu*), Greenside darter (*Etheostoma blennioides*), Rainbow darter (*Etheostoma caeruleum*), and Dusky darter (*percina sciera*). Simon and McWilliams-Munson (2001) sampled just downstream from the US 30 crossing, which is about 3,000 feet south of CR 300 North; they found 27 fish species at that site, including 6 darters (ESI 1993 found 4 darter species). They also found Ohio lamprey (*Ichthyomyzon bdellium*), Rock bass (*Ambloplites rupestris*), and Largemouth bass (*Micropterus salmoides*), which ESI (1993) did not. Both Bigeye chub and Ohio lamprey are considered uncommon in Indiana (Carney *et al.* 1993) and the Bigeye chub is listed as endangered by the State of Illinois (Page and Retzer 2002). All 3 of these fishery surveys agreed that the Tippecanoe River is among North American streams with the highest species richness and biological integrity, which agrees with TNC's Rivers of Life evaluation of the river (TNC 1998).

It seems apparent that the forces which eliminated these mussel and fish species from most other streams in the Midwest have thus far failed to have the same drastic results in the Tippecanoe River, although the distributions of the most sensitive species within the river have been considerably reduced in the mainstem and essentially eliminated from the tributaries, most of which have been channelized for agricultural drainage (Roley 2012). Studies in other Midwestern states have shown that intensive agriculture has a significant adverse impact on freshwater mussels. For example, Poole and Downing (2004) in 1998 resampled sites that had previously been investigated in 1984-85 as the best potential mussel habitat remaining within Iowa (Frest 1987); in 1984-85, living mussels were absent from 6 percent of the minimally degraded survey sites, whereas in 1998 47 percent had no living mussels (Poole and Downing 2004). The researchers believed that the sharp decline in species richness found in 1998 suggested that habitat conditions for mussels in Iowa declined precipitously due to the conversion of native tall grass prairies with wooded riparian areas to intensive agriculture with minimum riparian buffer. They did find, however, that stream reaches with ≥ 50 percent forested riparian buffers had sustained their mussel diversity while those with ≤ 50 percent forested riparian buffers lost mussel diversity; stream reaches having 80 percent forested riparian buffers lost almost no mussel species (Poole and Downing 2004). In Ontario, Morris and Corkum (1996) also determined that agricultural activity and loss of riparian vegetation appear to be major threats to mussels, with increasing agricultural activity resulting in a shift towards dominance by a single common mussel species (Giant floater [*Pyganodon grandis*]). They also showed that stream shading by riparian trees affect water temperatures and ammonium concentrations, which also affect mussel diversity and survival. Therefore, the forested riparian habitat along much of the Tippecanoe River, which includes numerous forested wetlands, appears to be ameliorating the impacts of agriculture and other land uses.

The stream reach that contains the action area is in a developing area of Kosciusko County on the north side of Warsaw, where commercial, residential, and some industrial uses have been expanding along US 30, SR 15, and CR 150 West on the uplands above the forested river valley. Beyond the developing zone, land use remains largely row crop agriculture, although the upstream lakes are generally surrounded by residential areas. However, the prevailing soils and river hydraulics have not resulted in the substantial sedimentation seen in many other Midwestern stream reaches subject to long-term agricultural runoff (Brim Box and Mossa 1999, Hopkins and Whiles 2011, Landis *et al.* 2013, Morris and Corkum 1996, Poole and Downing 2004). Substrate in the middle Tippecanoe River is generally sand, with cobble and gravel in riffles and runs (ESI 1993, 1998). The stream channel throughout most of the Tippecanoe River has not been substantially modified from its natural state, thus avoiding direct habitat loss, altered hydraulic conditions, and the severe bank erosion which is often another major source of sedimentation in channelized streams (Brim Box and Mossa 1999). The presence of a stable zone of woody riparian vegetation along most of the river, including palustrine forested wetlands, also reduces the potential impacts of bank erosion. Although damming has occurred downstream of the action area, at Lake Shafer and Lake Freeman in Carroll and White Counties, the stream reach of the action area has not been adversely affected by dams or other modifications.

The previous Warsaw waste water treatment plant (WWTP) discharged effluent to Walnut Creek, which enters the Tippecanoe River approximately 12,000 feet downstream of CR 300 North, at the downstream end of an approximate 4,500 foot channelized section of the river between Lones Ditch and Walnut Creek. The current WWTP, constructed about 2003-04, discharges directly into the river within this channelized reach, which also includes a low-head dam. Marsh Ditch, a small tributary along the west side of Warsaw, joins the river about 7,000 feet below the Walnut Creek confluence. The 1995 ESI mussel survey (1998) included sites upstream (about 2000 feet) and downstream (about 6,500 feet) from Marsh Ditch.

Community characteristics at both Marsh Ditch sites suggested that they were impaired, including that much of the river bottom was covered with a thick layer of brownish periphyton (a mixture of algae, cyanobacteria, and detritus that attaches to submerged surfaces) (ESI 1998). It was indicated that there may have been diverse mussel communities at both sites at one time because weathered shells were fairly abundant, but only 13 living species were found at the 2 sites combined, and all were considered to be younger than 20 years old. Only 5 species were found at the downstream site, including 1 living *P. clava* estimated at 13 years old. The authors surmised that "[p]erhaps the Warsaw discharge in 1986 that resulted in a fish kill and/or other disturbances in this river reach has affected unionids at these sites" (ESI 1998). Sediment samples from Marsh Ditch found that they exceeded Threshold Effect Level (TEL) for a variety of chemicals, including Anthracene, Naphthalene, Phenanthrene, and Pyrene (Ruessler *et al.* 2001). Additionally, sediments from Marsh Ditch had metal concentrations at the moderately polluted level and exceeded TEL for total Polycyclic Aromatic Hydrocarbon (PAH) (McWilliams-Munson 2001). As discussed previously, contaminated sediments are a major concern for the survival of freshwater mussels; based upon the data from these studies between 1995 and 2001, we know that there are some locations within the Tippecanoe River that contain sediments that are unsuitable for mussels. Considering that these studies are 20 years old, the current conditions at these and other sites within the river are unknown.

However, Roley (2012) and Roley and Tank (2016) specifically studied Clubshell in the Tippecanoe River in relation to sediments, pore water quality, and ionized and un-ionized ammonia. They studied 6 sites in the upper Tippecanoe River, 4 in Kosciusko County and 2 in Marshall County, with 3 of the sites supporting Clubshell and the other 3 being sites where Clubshell were once found but are no longer present. Since *P. clava* spends most of its life buried within the sediments and depends on pore water for food and oxygen, it is likely to be more susceptible to the effects of polluted sediments than species that are found closer to the sediment surface (Sovic 2016, Watters *et al.* 2009). Interstitial sedimentation can limit burrowing mussels such as Clubshell by filling pore spaces and preventing oxygen-rich surface water from percolating into the lower sediments (Brim Box and Mossa 1999, Wood and Armitage 1997). Also, microbial decomposition of organic matter in the sediments results in the consumption of interstitial oxygen, further limiting its availability for mussels (Chen *et al.* 2001), and ammonium is also produced during the decomposition of organic matter, as discussed previously (Augspurger *et al.* 2003, Frazier *et al.* 1996).

Roley (2012) and Roley and Tank (2016) measured pore water oxygen levels, sediment organic matter content, and sediment-bound ammonium, plus interstitial sedimentation rates, ground water input or output, and general water chemistry. They determined that the sites without Clubshell more commonly had pore water with dissolved oxygen (DO) levels low enough to be lethal for juvenile mussels (Sparks and Strayer 1998). However, in general the pore water DO varied considerably between years (2009 and 2010) and sites, with occupied site occasionally reaching adult stress levels, as determined by Lewis (1984) for *Elliptio complanata* and *Anodonta grandis* (DO tolerance levels have not specifically identified for Clubshell) (Roley 2012, Roley and Tank 2016). The researchers noted that DO in ground water was significantly higher in sites with Clubshell than those without, which may be due to the numerous wetlands along the upper Tippecanoe River. Concerning NH3 concentrations in pore water, they also varied considerably; at no time did pore and surface water ammonia concentrations exceed previously identified toxic thresholds in sediments for juvenile mussels (Newton *et al.* 2003). Instead, NH3 stress appeared to occur occasionally and at all site equally (Roley 2012, Roley and Tank 2016). The researchers did find that interstitial sedimentation rates were higher at sites without Clubshell and that this sedimentation coincided with low DO levels at these sites. They believe that there is the potential for NH3 stress at several of the studied locations but this potential stress seems unrelated to Clubshell presence or absence. Therefore, more research is necessary within the Tippecanoe River to determine why Clubshell are found in some areas but absent from others that physically appear to be suitable habitats.

The largest population of *Pleurobema clava* is in the upper Tippecanoe River in Kosciusko, Marshall, and a small portion of Fulton Counties (ESI 1993, 1998). Since different age classes have been found (varying from 3 to 34 years), it is apparent that the species is successfully reproducing in this portion of the river. Based upon studies prior to 1992, it was thought that the best remaining population was upstream from Warsaw in Kosciusko County (ESI 1993). But the 1995 studies downstream of Warsaw found numerous Clubshells, with the largest numbers found upstream (15) and downstream (5) of Baker Ditch in Marshall County (ESI 1998).

Both living and fresh-dead Clubshell have been collected within the middle portion of the river, which includes most of Fulton County, plus Pulaski and northern White Counties, but in much smaller numbers than within the upper river. During the 1991-92 study (ESI 1993), the 3 living Clubshell that were found in this section of the river ranged in age from 4 to 7, so it appears that reproduction had occurred here in the 1980's, although no explanation was provided about the lack of older adults. Two of the Clubshell found in 1992 were in northeastern Fulton County several miles upstream from the Chippewanuck Creek confluence and the other was at Winamac (ESI 1993). During the 1995 survey, only 2 living Clubshell were found in the middle portion of the river, both downstream of Chippewanuck Creek (ESI 1998). They were 3 and 10 years old, so reproduction was occurring.

In the most downstream section of the river, below the hydroelectric dams to the Wabash River, 2 living Clubshell at 3 and 15 years of age were found at different sites during the 1991-92 survey, so reproduction occurred at least in 1 area in the late 1980's (ESI 1993). During the 1995 survey, only one living Clubshell was found upstream of Moots Creek in Tippecanoe County, and it was 17 years old (ESI 1998).

The Nature Conservancy (TNC) has established a Tippecanoe River Project aimed at the protection and preservation of the river and its species. Goals of this Project include development of a comprehensive bio-sampling program of water quality, invertebrates, mussels, and fish, and helping private landowners implement conservation best management practices in the watershed. During 2003 and 2004, TNC characterized the aquatic fauna of the Tippecanoe River through a sampling program at 7 representative sites in the middle and upper portions of the stream, between the Kosciusko County lakes and Winamac (TNC 2004).

During 2012-13, drought conditions affected Indiana, including the Tippecanoe River. Low flows and management prescriptions at Oakdale Dam, the downstream hydroelectric dam on the river, led to the standing and death of numerous mussels, including Clubshell and other Federally endangered and threatened species. The FWS therefore worked with the dam owner (NIPSCO) to avoid take of listed species through changes in releases from the dam so that the river would not be dewatered during future low-flow events. The FWS provided a Technical Assistance Letter to NIPSCO on August 13, 2014 (USFWS 2014) detailing the dam management modifications necessary to be protective of the mussels and critical habitat during abnormal low flow conditions. FWS and Indiana DNR also initiated an outreach program and mussel stewardship campaign with local landowners along the river and the 2 lakes to inform and work with them on mussel conservation (IDNR 2014a).

We are aware that zebra mussels are present in the upper watershed lakes of the Tippecanoe River (Oswego, Tippecanoe, James, and Webster) and they have essentially eliminated native freshwater mussels from these lakes (IDNR 2014b). We are also aware that they are listed as present within the Tippecanoe River is Kosciusko County (IDNR 2016). However, we have not received any information that they are adversely affecting the native freshwater mussels within the river or fouling bridges or other structures to a major extent.

The Clubshell and Fanshell (*Cyprogenia stegaria*) were the subject of a Section 7 consultation and Biological Opinion in 1998 concerning the replacement of the Bicycle Road Bridge over the Tippecanoe River in Carroll County, Indiana. Living Fanshell were found there and relocated but no living Clubshell were found. The Clubshell was addressed in a Biological Opinion in 2004 concerning the Fulton County Bridge No. 2 replacement project over the Tippecanoe River at Leiters Ford, Fulton County, Indiana.

Aside from the subject proposal, there are no federal actions which are the subject of a formal consultation near the action area. However, at some time in the future Kosciusko County and the City of Warsaw are considering constructing a canoe launch facility at CR 300 North, which may require a federal Section 404 permit. If and when such an action is proposed, the FWS will address impacts on listed species, including mussels.

Effects of the Proposed Action

"Effects of the action" refers to the direct and indirect effects of an action on listed species or critical habitat, together with the effects of other activities interrelated and interdependent with that action, which will be added to the environmental baseline. Indirect effects in the Endangered Species Act are defined as those caused by the proposed action and which are later in time, but are still reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration.

Direct effects are the immediate effects of the project on the species or its habitat. Direct effects result from the agency action and include the effects of interrelated and interdependent actions. Future federal actions that are not part of the action under consideration (and not included in the environmental baseline or treated as indirect effects) were not evaluated.

The zone within which direct effects are expected to occur extends 600 feet along CR 300 North between Stations 17+50 and 23+50 and within a right-of-way 55 feet south of the roadway centerline throughout that length; on the north side of the roadway the direct effects zone is a right-of-way 30 feet wide between Stations 17+50 and 20+85 and 25 feet wide between Stations 20+85 and 23+50. The major effects of the bridge rehabilitation project will be the physical impacts of construction on the river substrate, consisting of pounding 6 new piles 43 feet into the substrate and the placement of riprap along the river banks under the bridge, and a short-term increase in sediment load in the river. Other potential impacts include long-term sediment increase if bank failure occurs or if there are spills of hazardous materials during construction of the bridge and relocation of the utilities. Within this zone, minimization efforts and commitments by the project sponsor have reduced adverse effects. These include removing the existing bridge superstructure in a one-step process by lifting the beams and placing them on trucks; this work will take place from the existing roadway, with no equipment within the river. The 6 new piles will be pounded into the riverbed utilizing equipment staged along the existing roadway, again with no equipment within the river. Therefore, no temporary work bridges/causeways or cofferdams will be necessary.

The extent of adverse effects outside of the direct effects zone depend upon construction practices, river flows, silt load in disturbed substrates, and the effectiveness of erosion and sedimentation control measures. Construction materials and equipment may affect mussels if the materials are washed into the river and either physically transported downstream by currents, or if toxic materials such as fuel spill into the river. Such spills could directly or indirectly affect endangered mussels, resulting in take. However, due to the project proponents commitment to develop and implement a Pollution Prevention Plan, toxic spills are not anticipated; therefore, the effects of such spills have not been evaluated in this opinion.

Physical construction impacts may damage or kill mussels and disrupt the substrate which comprises their habitat. Increased sedimentation can physically impair mussels' feeding and reproductive ability, smother individuals (especially juveniles), and render habitat unsuitable. Short-term sediment runoff and bank erosion can have substantial adverse impacts if extreme precipitation events occur while large areas of bare soil are exposed. All of these impacts would constitute a take of the listed species within the affected area. Also, any long-term impairment of the habitat which reduces its suitability for mussels would constitute a take by reducing suitable habitat, which is a limiting factor for the species.

Cumulative Effects of the Proposed Action

We are aware of a possible future local action to construct a canoe launch facility at CR 300 North that might adversely affect the Clubshell in the action area; however, at this time this proposal is speculative. Ongoing agricultural activities and residential and commercial/industrial developments in the watershed of the action area may be causing long-term deterioration of the habitat quality in some reaches of the Tippecanoe River, but the quality of the habitat in the action area is not being seriously impaired at this time to our knowledge.

The effects of in-stream bridge maintenance activities on Federally listed species were not evaluated or considered in this opinion. Therefore, the permit applicant will need to consult with the FWS prior to implementing any future maintenance activities that may directly or indirectly affect any Federally listed species, including mussels or their habitat (*e.g.* channel clearing, scour-hole repair, pier and abutment work, etc.).

Biological Opinion

Based on our review of the information concerning the proposed action and considering the information available to us on the biology, ecology, distribution, and abundance of the Clubshell mussel, we have made the following conclusions about the effects of the Kosciusko County Bridge 18 rehabilitation project on this federally endangered species.

It is the Service's Biological Opinion that the proposed action is not likely to jeopardize the continued existence of the Clubshell. The proposed action will not result in the adverse modification of critical habitat, which has not been designated for this species. Since the FWS has concluded a no-jeopardy opinion, the identification and implementation of "reasonable and prudent alternatives" to avoid the likelihood of jeopardy are not relevant to this discussion. However, the COE can implement discretionary actions at any time, with respect to the proposed action, in partial fulfillment of the COE's Section 7 (a)(1) responsibility.

Conservation Recommendations

Section 7(a)(1) of the Act directs federal agencies to use their authorities to carry out conservation programs that benefit endangered or threatened species. Conservation measures are not mandatory, and are intended to minimize or avoid adverse impacts on listed species or critical habitat beyond the level necessary to avoid the likelihood of jeopardy. To assist the COE in meeting this responsibility, the FWS recommends the following conservation measures:

1. Provide educational materials for Federal, State, County, and local communities regarding the importance of the Tippecanoe River for federally endangered mussels and the need to address potential project impacts on these species when designing projects within the watershed that may require a permit from the COE.

Incidental Take Statement

Section 9 of the Act prohibits any taking of listed species without special exemption. Section 7(b)(4) and Section 7(o)(2) exempt taking that is incidental to and not intended as part of an agency's action from the taking prohibitions of the Act as long as that taking complies with the incidental take statement of a Biological Opinion. The measures described below are nondiscretionary and must be implemented by the action agency so that they become binding conditions of any grant or permit issued to the applicant, as appropriate, in order for the 7(o)(2) exemption to apply.

Level of Incidental Take

With respect to the Kosciusko County Bridge 18 project, incidental take addresses both the bridge superstructure removal and replacement activities. There is a residual possibility for take by the construction activities because habitat impairment could result from the project if the epoxy coating material leaks into the Tippecanoe River.

Based on the information available, the COE is also authorized to harm 3 Clubshell mussel during bridge superstructure removal and replacement, driving of 6 new piles, encasing the existing piles in fiber wrap and epoxy, and the relocation of the utilities.

In order for the COE to achieve this authorized take level, FWS has identified the following "reasonable and prudent measures" to minimize incidental take.

Reasonable and Prudent Measures

1. The project shall be designed to minimize physical impacts on the mussel habitat:

   (a) The piers and bridge shall be constructed from the river banks. No temporary bridge or causeway is allowed within the Tippecanoe River.

   (b) Stream channel modifications shall be limited to those which are necessary for bridge construction, such as the shaping of the banks under the bridge and the placement of riprap along these banks.

   (c) Removal of the existing bridge superstructure shall take place from one or both river banks rather than through the stream channel. A construction net, tarp, or similar protective devise shall be utilized under the existing bridge when removing the superstructure in order to catch any falling concrete or other debris. Any material that inadvertently falls into the river from the deck or the pier shall be immediately removed without dragging it through the stream channel.

2. The project shall be designed and constructed to minimize erosion and sediment runoff. The best available methods of erosion control shall be used during construction. Required measures include, but are not limited to, the following: sodding and revetment riprap in all ditches on approach roads, sediment traps in ditches at appropriate locations, sodding or erosion control blankets on all exposed soils near the river banks, pipe inlet protection, and silt fences between all disturbed soil areas and the river.

3. Clearing of woody riparian vegetation and other actions which would reduce stream bank stability shall be limited to the minimum necessary for bridge construction. The disturbed stream

banks wherever possible shall be revegetated with native tree or shrub species, or other native vegetation in areas unsuitable for woody plants. Riprap or bioengineering methods for permanent stream bank stabilization shall be utilized wherever planting of trees or other vegetation is not feasible (*e.g.* spill slopes).

4. Even though zebra mussels are already known to be present within portions of the Tippecanoe River within Kosciusko County, in order to keep the infestation from increasing and spreading to additional sites, all equipment used in construction shall be free of zebra mussel adults and veligers before it enters the Tippecanoe River. Any construction equipment, including silt barriers, that has been used in waters that could have been infested with zebra mussels will be appropriately disinfected and inspected for zebra mussel adults and veligers prior to use in the Tippecanoe River.

5. Erosion and sedimentation control measures will be monitored during construction and bridge demolition. Similarly, contingency plans for rapid response or remediation of impacts from unexpected events in the construction area (*e.g.*, floods, fuel spills, and siltation) will be submitted to the FWS for review and comment. During construction, the Kosciusko County Highway Department shall provide an inspector proficient in erosion and sedimentation control; preparedness, prevention, and contingency plan implementation; and other environmental issues related to bridge and roadway construction. This inspector shall be on-site daily when the site is not stabilized, and will supplement, not replace, inspections carried out by the contractor(s). All sites shall be stabilized during winter or non-construction seasons.

Terms and Conditions

In order to be exempt from the prohibitions of Section 9 of the ESA, the COE must comply with the following terms and conditions, which implement the reasonable and prudent measures described above.

1. The COE shall ensure that the permit applicant and their agents and contractors will implement all proposed avoidance and minimization measures as described in the Biological Assessment, including the erosion and sedimentation control plan, to reduce adverse effects to the Clubshell.

2. The permit applicant and contractors will monitor the project site daily when the site is active and not stabilized, and as soon as possible following severe storms or ice flows when the site is inactive and/or otherwise stabilized, to ensure the erosion and sedimentation control practices are implemented, and to identify any project-related impacts due to scouring or sedimentation. Best Management Practices for erosion and sedimentation control will be in place before, during, and after any work is conducted.

3. A spill avoidance/remediation plan shall be developed and made part of the permit, utilizing the most effective prevention and remediation practices to prevent hazardous materials (*e.g.*

epoxy, petroleum products, solvents, paints, etc.) from entering the Tippecanoe River and its adjacent wetlands or from contaminating soils or waters within the watershed. Such measures shell include, but are not limited to, stationing of emergency response equipment at the project site and designation of contained fueling and fuel storage areas at least 150 feet away from the river. If flooding is anticipated, weather and river stages shall be monitored and hazardous material shall be removed from the river banks and floodplain. Notify the FWS immediately of any spills of hazardous materials.

4. No project-related or project-generated materials, waste, or fill shall be deposited in areas that would result in fill of or sedimentation to the Tippecanoe River.

5. Evidence shall be provided to the FWS that either all equipment to be used in the Tippecanoe River has never been in zebra mussel-infested waters or that the equipment has been appropriately cleaned, disinfected, and inspected for zebra mussel adults and veligers, using accepted protocols.

6. During the bidding process, prospective project contractors shall be notified regarding the presence of endangered mussel species within the project area and the special provisions necessary to protect them. The successful contractor(s) shall be instructed on the importance of the natural resources within the project area and the need to ensure proper implementation of the required erosion and sedimentation control and spill avoidance/remediation practices. The following conditions (language) shall be included in all demolition and construction contracts awarded for project implementation:

(a) Endangered species are present in the project area and there is a risk of take (Endangered Species Act section 9 violation) if the Terms and Conditions of the FWS's biological opinion are not closely followed.

(b) All equipment to be used in the Tippecanoe River and adjacent wetlands during demolition or construction must either never have been used in zebra mussel-infested waters, or have been appropriately cleaned, disinfected, and inspected for zebra mussel adults and veligers, using accepted protocols.

(c) Best Management Practices for erosion and sedimentation control shall be in place before, during and after any work is conducted.

(d) Contractors shall monitor the project site daily when the site is active and not stabilized, and as soon as possible following severe storms or ice flows when the site is inactive and/or otherwise stabilized, to ensure the erosion and sedimentation control and spill avoidance practices are implemented.

(e) A spill avoidance/remediation plan shall be developed and implemented based on the most effective prevention and remediation practices to prevent hazardous materials (*e.g.* epoxy, petroleum products, solvents, paints, etc.) from entering the Tippecanoe River or adjacent wetlands, or contaminating soils or waters within the watershed. Such measures shall include, but are not limited to, stationing of emergency response equipment at the project site, and designation of contained fueling and fuel storage areas at least 150 feet away from the river.

(f) Contractors shall monitor weather and river stages, and remove any hazardous materials from the river and the floodplain in the event that flooding is expected.

(g) If a spill does occur, emergency remediation procedures shall be implemented to contain the spill, and prevent the spill from entering the Tippecanoe River or adjacent wetlands.

(h) The FWS shall be notified immediately of any failures of erosion and sedimentation control measures or spills of hazardous materials.

(i) No project-related or project-generated materials, waste, or fill shall be deposited in areas that would result in fills of, or sedimentation in, any streams inhabited by endangered mussels.

Evidence shall be provided to the FWS that these Terms and Conditions 1 have been included in demolition and construction contracts prior to the initiation of construction.

7. Preserve any specimens of the Clubshell accidentally killed or found fresh-dead or moribund, according to standard museum practices, and submit them to the FWS. All specimens of Clubshell, including dead shells, are to be labeled and submitted to the FWS's Bloomington, Indiana Field Office for disposition to appropriate toxicological laboratories and museums.

8. Notify the FWS's Bloomington, Indiana Field Office prior to commencement of project activities and allow the FWS the opportunity to participate in a pre-construction meeting with the involved parties to discuss the requirements of this biological opinion. All correspondence should be addressed to the U.S. Fish and Wildlife Service, 620 South Walker Street, Bloomington, Indiana 47403 [Bloomington telephone (812) 334-4261 ext. 1214 and NISO telephone (219) 983-9753].

Reinitiation of Consultation

The COE must reinitiate consultation with the FWS if, during the course of the action, any of the following conditions occur:

1. The federal action exceeds the amount or extent of the incidental take allowed by this statement.

2. Construction plans or schedules are altered in any way that would affect the implementation of this biological opinion.

If any of the above conditions occur, COE must contact the FWS to determine if activities associated with the federal action must be stopped, and to determine if formal consultation must be reinitiated. The FWS will evaluate the effects of the action on listed species and may provide a new incidental take statement. As part of the information package to reinitiate consultation, the COE should provide a description of and explanation for the departure from the conditions of the incidental take statement.

Opportunities for Further Consultation

This concludes formal consultation on the proposed replacement of Kosciusko County Bridge 18, varying SR 300 North over the Tippecanoe River. The COE is required to reinitiate formal consultation with the FWS if:

(1) New information reveals effects on listed species or critical habitat that were not considered in this Biological Opinion;

(2) The action is modified in a manner that affects listed species or critical habitat that were not considered in the Biological Opinion; or

(3) If, prior to project completion, a new species is listed or critical habitat is designated that may be affected by the action.

1/18/17
Date

Supervisor
Bloomington Indiana Field Office

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Clubshell *Pleurobema clava* (Lamarck, 1819)

A St. Joseph River, 2.2 inches.

B Fish Creek, 2.1 inches.

C Fish Creek, 2.1 inches.

Quick ID

Small shell, with distinctive green rays near umbo (A). Beak set near anterior end (C).

Natural History Notes

Habitat	Historically small streams to rivers, often buried in sand and gravel.
Maumee Occurrence	Rare. Small populations in headwater tributaries of the St. Joseph River. Much more widespread historically (USFWS, 1994).
Known Fish Hosts	Central stoneroller, striped shiner, logperch and blackside darter.
Conservation Status	State: Endangered (OH, MI, IN) Federal: Endangered

Full Description

Overall Appearance	Up to 3 inches. Shell triangular and moderately thick, with beak distinctly set near anterior end.
Valve Exterior	Yellowish-brown to brown, with distinctive interrupted green rays.
Valve Interior	Nacre white, iridescent posteriorly. Muscle scars well impressed, pallial line moderately impressed.
Beak	External: Beak sculpture of indistinct ridges, often eroded (C); umbo slightly raised above hinge-line. Internal: Beak cavity relatively shallow.
Pseudocardinal Teeth	Well developed, although small and slightly serrated.
Lateral Teeth	Well developed, long and straight to slightly curved.

FIGURE NO. 1.

Grabarkiewicz and Crail 2006

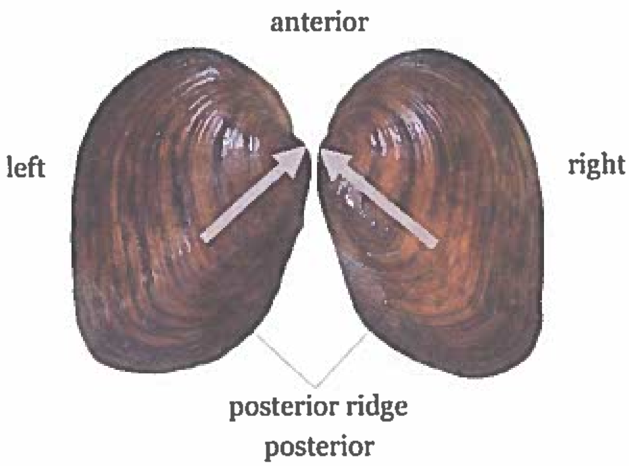


Figure 11: Shell orientation (wabash pigtoe - *Fusconaia flava*).

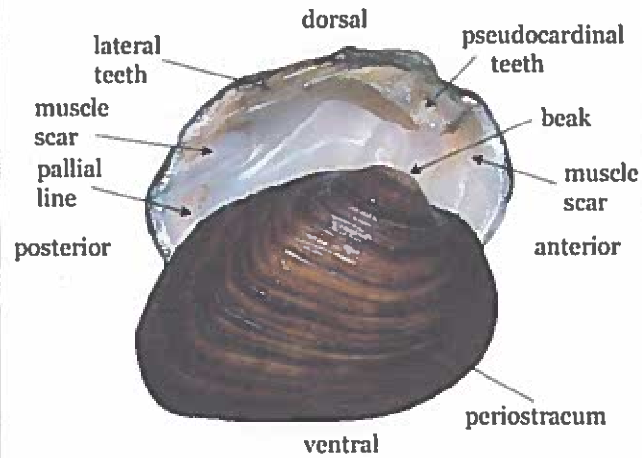


Figure 12: Basic shell anatomy (wabash pigtoe - *Fusconaia flava*).

3. GENERAL SHELL FEATURES

Using Fig. 12, identify characteristics that make the valve unique. Is the shell thick or thin? What color is the periostracum? Are pseudocardinal teeth and lateral teeth present? If so, what do they look like? Is the posterior margin pointed, rounded, or truncated? These questions and others are important in identifying any shell. Refer to the species profiles for individual descriptions.

4. BEAK SCULPTURE

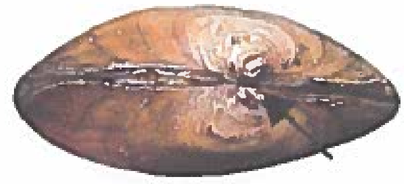
Critical to the identification of many juvenile valves is the presence and type of "beak sculpture". Perhaps best described as topography on the beak or umbo, beak sculpture varies in both texture (fine to coarse) and pattern. As unionids age, it tends to erode, and hence is more distinct in juveniles or young individuals.

concentric coarse ridges

numerous wavy ridges

elevated and heavy ridges

double-looped bars

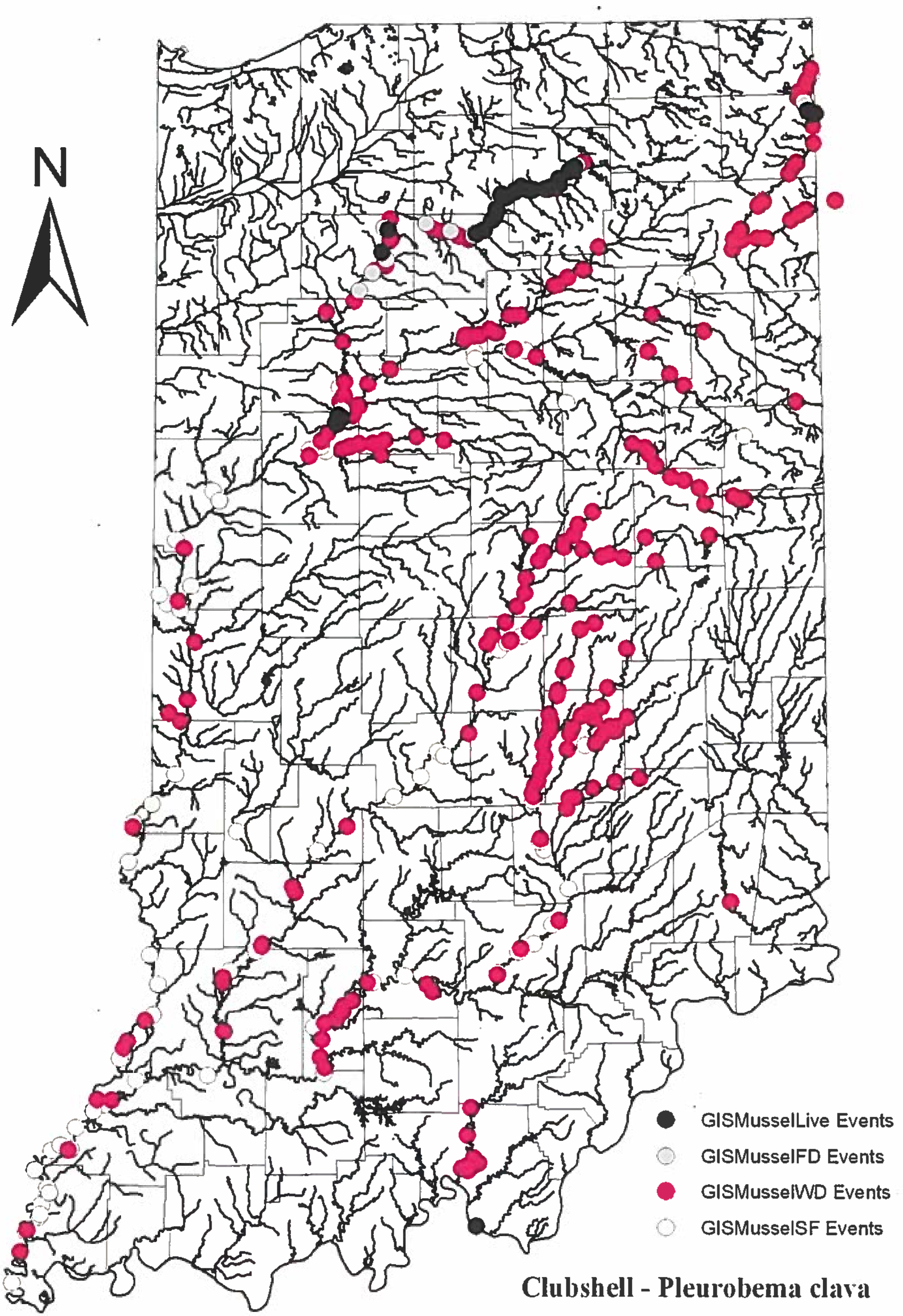


elevated and heavy loops

5. MALE AND FEMALE

Male and female of the same species may differ in appearance (fig. 13). Females often have an expanded ventral posterior, the result of an enhanced gill used for brooding. Of the Maumee mussel fauna, this is only apparent in a few genera, mainly *Lampsilis, Ligumia, Toxolasma* and *Villosa*.

FIGURE NO. 2.



Clubshell - Pleurobema clava

FIGURE NO. 3.

Fisher 2008

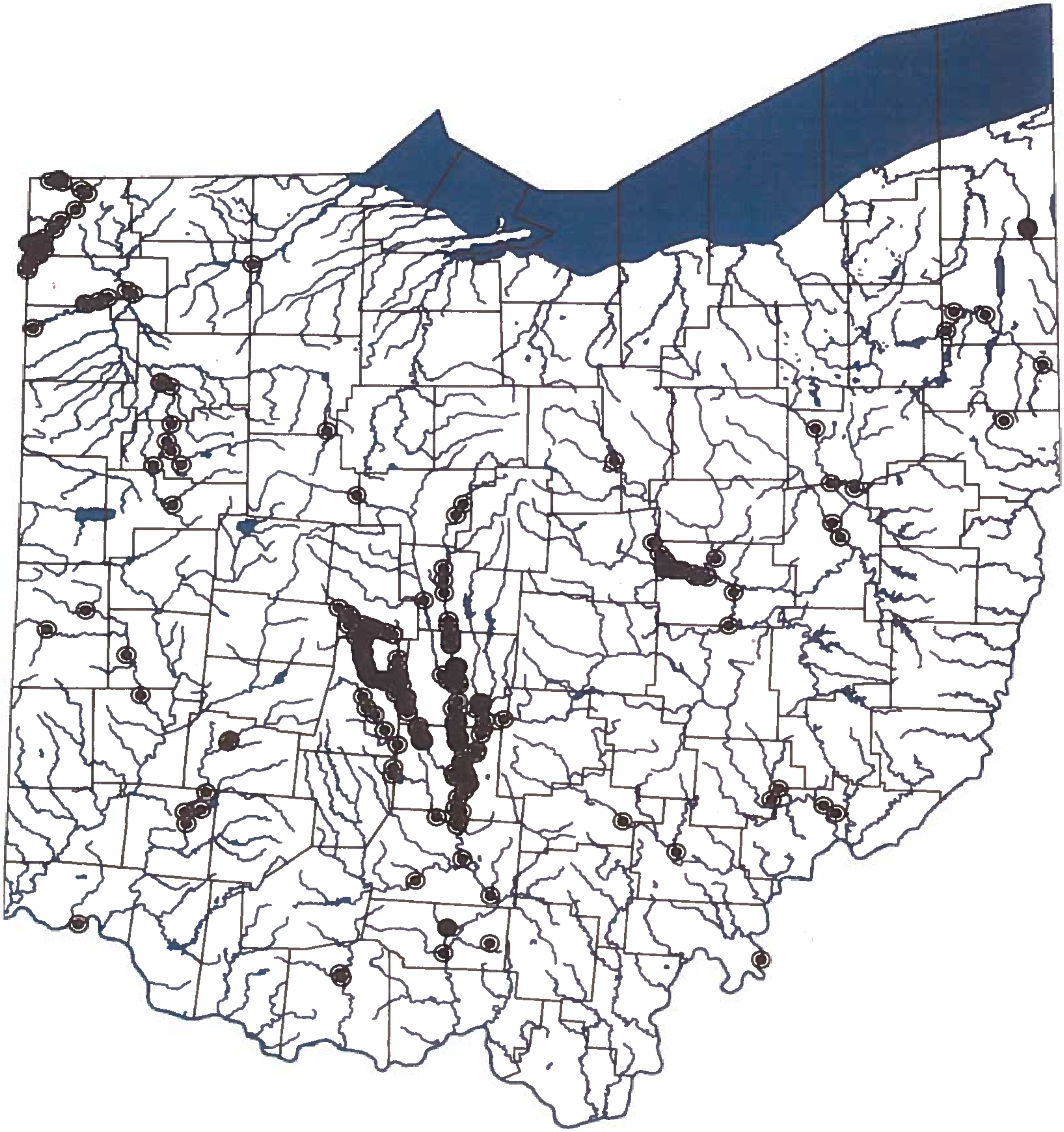


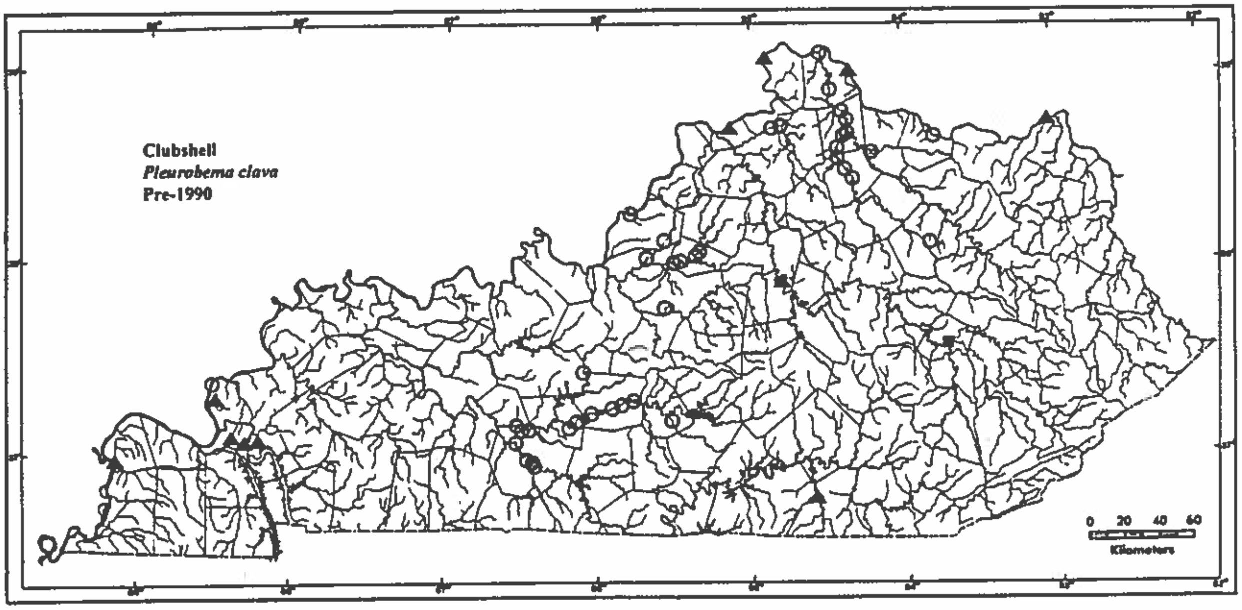
Fig. 146. *Pleurobema clava* (Lamarck, 1819)

FIGURE NO. 4.

Watters et al. 2009

Pleurobema clava (Lamarck, 1819)

Clubshell



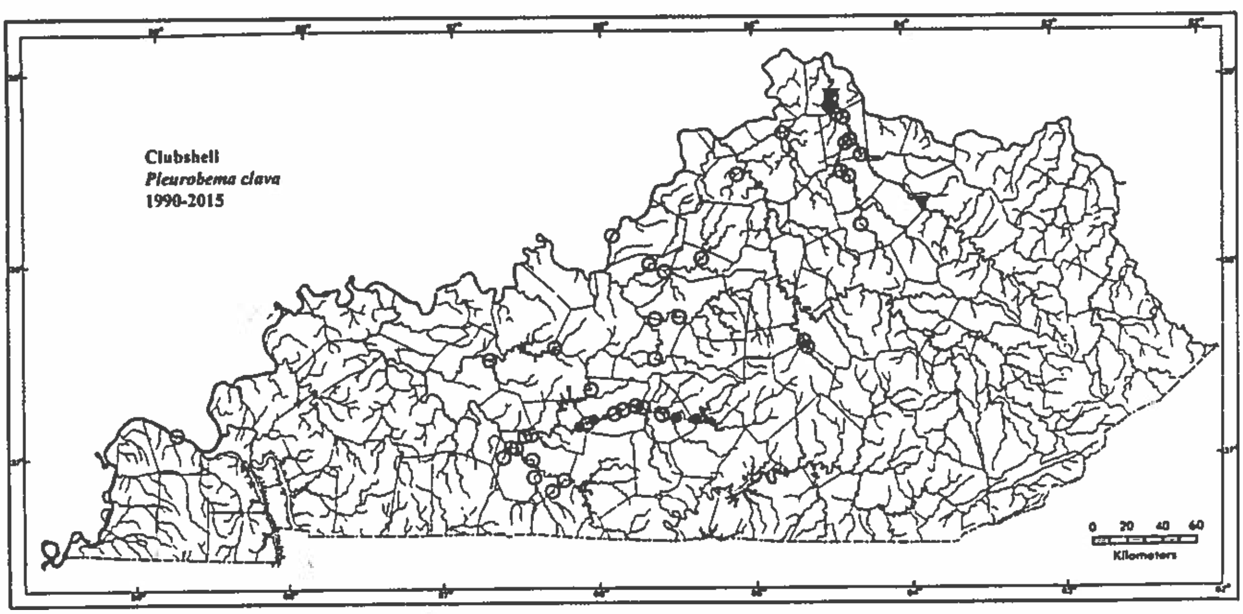


FIGURE NO. 5.

Haag and Cicerello 2016

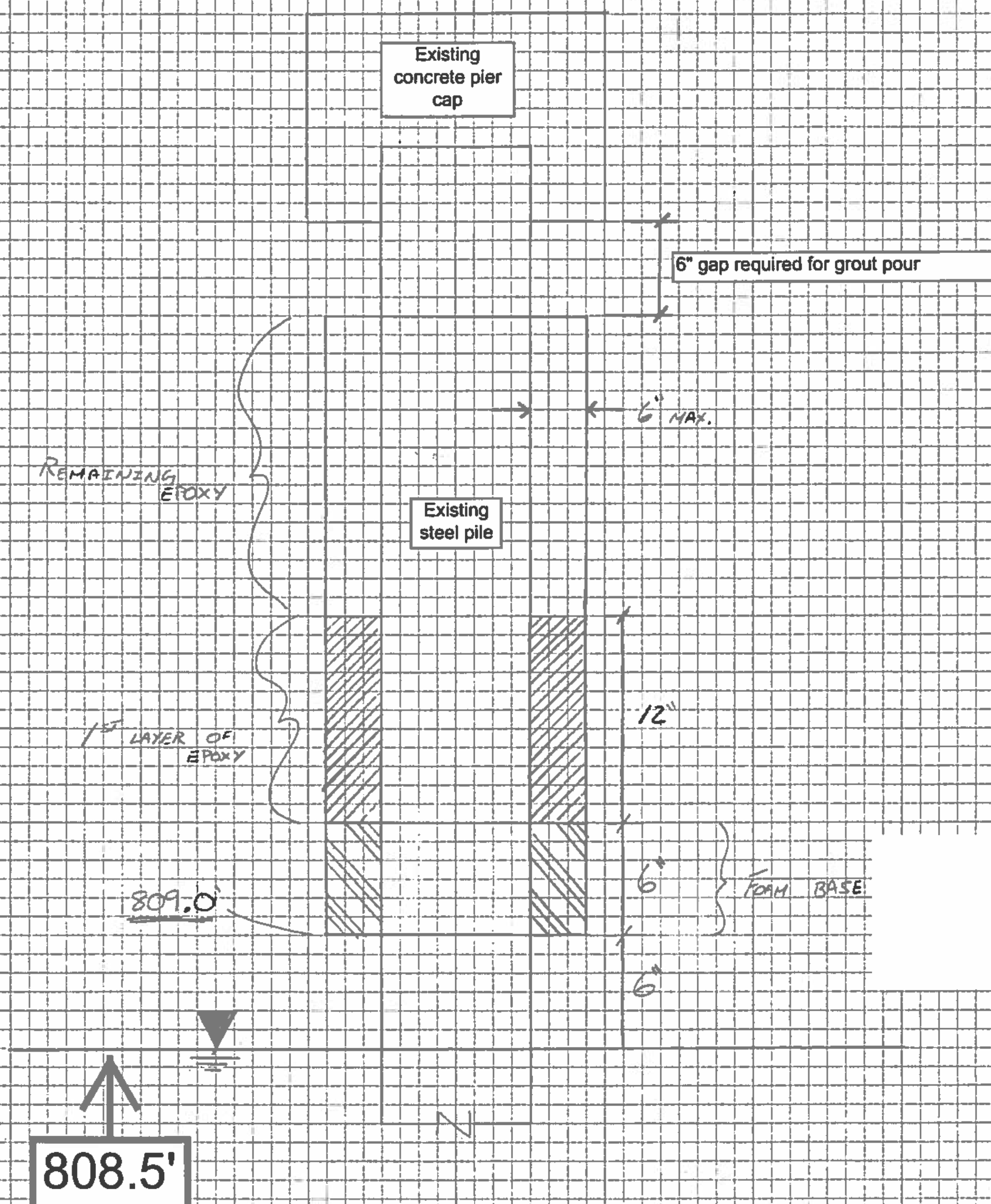
ATTACHMENT A

Pile Epoxy Treatment
Drawing and Material Safety Data Sheets

USI consultants
engineers & land surveyors
OFFICE
Indiana
8415 East 56th Street
Indianapolis, Indiana 46216
Phone: 317-544-4996
Fax: 317-544-4997

NOT TO SCALE

Initials MKT Date 6/2/16 Sheet No ____ of ____
Chkd by ________ Date ________ Job No. 2013-035
Subject FIBER WRAP DETAILS



PileMedic, LLC
2055 E. 17th Street
Tucson, AZ 85719 U.S.A.
Phone: (520) 791-7000
Fax: (520) 791-0600
www.PileMedic.com

Product Data Sheet

PileMedic™ PLC150.10

For Structural Strengthening of Columns and Submerged Piles

DESCRIPTION

PileMedic™ PLC150.10 is a high-strength high-modulus Fiber Reinforced Polymer (FRP) laminate constructed with unidirectional carbon fabrics providing strength primarily in the longitudinal. The laminate is wrapped around the column or pole and the overlapping portions are bonded together using QuakeBond™ 220UR (Underwater Resin) or QuakeBond™ J201TC (Tack Coat) to create a strong shell around the existing structure. PileMedic™ is unique in that it allows construction of a seamless structural shell around an existing column, utility pole or submerged pile. The annular space between PileMedic™ Jacket and the host pile can be filled with QuakeBond™ 320LV Low Viscosity epoxy resin or high-strength non-shrink grout.

USE.

- Repair of underwater piles
- Repair of bridge piers
- Repair & strengthening of corroded steel columns
- Repair & strengthening of timber utility poles & bridge piling
- Applicable to all materials: concrete, steel and timber

ADVANTAGES.

- One flat sheet can be used to construct a shell of *any size in the field*, eliminating the expense and delays of special order jackets.
- The jacket provides significant *lateral confining pressure* (in the hoop direction) that increases the axial compressive capacity of the pile or column.
- The *seamless shell prevents migration of moisture and oxygen* into the column, significantly reducing future rate of corrosion and deterioration.
- Annular space can be adjusted in the field *to minimize the volume of grout or resin*.
- Eliminates or reduces the need for costly divers in underwater pile repairs
- *Corrosion-resistant* system can withstand various chemicals.
- *Non-toxic, odorless* resins are approved for potable water.
- Strength of the laminates can be verified *prior to installation in the field* (in contrast with wet layup FRP systems).
- A polyester scrim is provided on both faces, eliminating the possibility of galvanic corrosion when the laminate is installed in contact with steel columns.
- Laminates can be installed as single shells with overlapping joints along the column height or as a continuous spiral shell.
- The laminates are manufactured in our plant with the highest quality control.

PACKAGING

Standard rolls are 50 in. X 150 feet (1.27 m X 45.7 m). PileMedic™ laminates can be custom manufactured in widths up to 60 inches (1.52 m).

SHELF LIFE

PileMedic™ laminates have unlimited shelf life when stored properly.

STORAGE CONDITIONS

Store in dry place at 30°-120° F (0°-50° C).

APPLICATION

1) Cut the required length of PileMedic™ considering the number of layers necessary and the overlap length beyond the starting point.
2) Wipe PileMedic™ with appropriate cleaner (e.g. acetone or MEK) using clean cloth.
3) Apply QuakeBond™ 220UR (Underwater Resin) or QuakeBond™ J201TC (Tack Coat) on the over-lapping regions of the laminate sheet.
4) Wrap the laminate around the pile or column to create a multi-layer jacket as required. Spacers may be used to control the size of the annular space between the host pile and the PileMedic™ jacket.
5) Use ratchet straps to temporarily hold the jacket in the desired size.
6) Seal the bottom of the annular space.
7) Before the epoxy cures, fill the annular space with non-shrink grout or resin; the hydrostatic pressure from the weight of the grout will press the PileMedic™ laminate plies against each other for improved bonding. For underwater applications, the grout or resin must be compatible for such applications.
8) For longer piles, repeat the above steps for additional 4-ft wide bands of jacket along the height of the pile; insert the lower portion of the new jacket a minimum of 4 inches inside the previously installed jacket.
9) Leave the installation undisturbed for 24 hours before removing the ratchet straps.
10) Apply appropriate coating on the exterior of the jacket.

Installation of PileMedic™ products must be performed only by specially- trained and approved contractors.

Laminates can be cut to appropriate length using commercial quality heavy duty shears. Care must be taken to support both sides of the laminate during cutting to avoid splintering. Since dull or worn cutting tools can damage, weaken or fray the fiber, their use should be avoided.

LIMITATIONS
Design calculations must be made and certified by a licensed professional engineer.

CAUTION
PileMedic™ PLC150.10 laminates are non-reactive. They do not require a Material Safety Data Sheet (MSDS). However, caution must be used when handling since a fine carbon dust may be present on the surface. Gloves must therefore be worn to protect against skin irritation. Care must also be taken when cutting the laminates to protect against airborne carbon dust generated by the cutting procedure. Use of an appropriate, properly fitted NIOSH approved respirator is recommended.

PILEMEDIC™ PLC150.10 PROPERTIES			
		US Units	SI Units
Longitudinal (0°) Direction:			
Tensile Strength	(ASTM D3039)	156 ksi	1,080 MPa
Modulus of Elasticity	(ASTM D3039)	13,800 ksi	95,500 MPa
Ultimate Elongation	(ASTM D3039)	0.77 %	0.77 %
Transverse (90°) Direction:			
Tensile Strength	(ASTM D3039)	9.3 ksi	64 MPa
Modulus of Elasticity	(ASTM D3039)	1,190 ksi	8,200 MPa
Ultimate Elongation	(ASTM D3039)	1.0%	1.0%
Laminate Properties:			
Ply Thickness		0.026 in.	0.66 mm
Barcol Hardness	(ASTM D 2583)	40 min	40 min
Water Absorption	(ASTM D 570)	0.7% max	0.7% max

Jacket Diameter inches (mm)[1]	Confining pressure psi (MPa)[2]	Gain in strength psi (MPa)[3]
12	1350 (9.3)	5410 (37.3)
24	675 (4.7))	2700 (18.7)
36	450 (3.1)	1800 (12.4)
48	335 (2.3)	1350 (9.3)
60	270 (1.9)	1080 (7.5)

(1) Cylindrical jackets constructed with two plies of PileMedic™ PLC150.10 laminate plus an 8-inch (200-mm) overlap beyond the starting point.
(2) Nominal confining pressure for a cylindrical jacket.
(3) Nominal increase in compressive strength of concrete column & grout due to confining pressure of jacket.

FORCE EQUIVALENCY
A double layer of PileMedic™ PLC150.10 provides the following equivalent forces:
No. 4 Gr. 40 stirrup placed at 1.0 inches on center
Negligible strength along the height of column

PileMedic, LLC
2055 E. 17th Street
Tucson, AZ 85719 U.S.A.
Phone: (520) 791-7000
Fax: (520) 791-0600
www.PileMedic.com

Product Data Sheet

PileMedic™ UW Epoxy Grout

Underwater Epoxy Coating and Grouting System

DESCRIPTION

PileMedic™ UW Epoxy Grout is a two part 100% solids epoxy specifically designed for underwater concrete and masonry applications. PileMedic™ UW Epoxy Grout can be used in fresh or salt water applications. PileMedic™ UW Epoxy Grout is a low viscosity liquid that can be used neat for coating, crack injection or mixed with aggregate to grout or patch concrete.

USE

PileMedic™ UW Epoxy Grout can be used for coating, injecting, patching or grouting underwater concrete or steel piers or piles. Infra-Structure PileMedic™ UW Epoxy Grout can also be used for underwater tuckpointing, pile.

ADVANTAGES

- Versatile applications
- High strength adhesion and durability
- Excellent underwater cure
- Forms a pumpable low viscosity epoxy grout
- VOC Compliant

PACKAGING

5 gallon unit (3 gal. part A and 2 gal. part B)
15 gallon unit (10 gal. part A and 5 gal. part B)
150 – 200 lbs of PileMedic™ Epoxy Grout

SHELF LIFE

PileMedic™ UW GROUT should be stored in a cool, dry interior area. At no time should material be exposed to high moisture, rain, or snow conditions. When stored in the original, tightly closed container, the shelf life is one year from the date of manufacture.

STORAGE CONDITIONS

PileMedic™ UW Epoxy Grout should be stored in a dry environment between 50-95°F. Under these conditions, the shelf life is twelve (12) months in unopened, damage free containers.

CLEANING

All tools and equipment should be cleaned before the system gels. Use xylene or toluene when necessary or acceptable solvent.

APPLICATION

Surface Preparation: Surfaces must be clean and sound and free of any dirt, grease, loose coatings, rust, marine growth or any material that will impede the adhesion of the PileMedic™ UW Epoxy Grout to the substrate. Sandblasting and high pressure water blasting are preferred methods of preparation and removal of contaminates. When working in tidal or splash zones, coat cleaned areas as soon as possible to minimize corrosion or contamination.

Mixing Instructions: Condition material above 75°F at time of mixing. Stir each component separately before blending. Thoroughly mix Part A with Part B for a minimum of three minutes with a low speed drill and mixing paddle or until a uniform gray color is achieved.

Epoxy Mortar/Grout: PileMedic™ UW Epoxy Grout can be mixed with clean dry silica aggregate to make a high strength epoxy grout. Adding 180 – 225 lbs. of clean dry silica aggregate to a 5 gallon unit (3 gal part A and 2 gal. part B) of the mixed epoxy resin will yield approximately 1.9-2.50 cu. ft. of epoxy mortar/grout. The aggregate should be slowly added to the thoroughly mixed epoxy resin and blended to a uniform desired consistency.

For Pumping Applications: Please consult the epoxy gradation chart to determine pumpability of a specific aggregate. The properly blended epoxy mortar/grout will have a uniform consistency without any segregation.

Application: PileMedic™ UW Epoxy Grout should be applied at water and surface temperatures of at least 55°F and rising. PileMedic™ UW Epoxy Grout must be mixed above water and transferred to the application with minimal agitation.

Coating: Apply the PileMedic™ UW Epoxy Grout by brush, or gloved hand in a thin primer coat, scrubbing it into the substrate displacing the water. Additional applications may follow to achieve the desired thickness.

Grouting/Patching: To assure proper adhesion, prime all surfaces that come in contact with PileMedic™ UW Epoxy Grout with neat PileMedic™ UW Epoxy Grout applied so as to displace the water. Once primed, place the mixed epoxy mortar/grout from the bottom and/or side of the form displacing water and proceed up. Finish the top surface with a trowel.
Anchor Bolt Grouting: Clean all debris from the hole to be grouted, fill half the hole from the bottom up with the PileMedic™ UW Epoxy Grout. Push the anchor bolt into the hole, twisting the bolt to make sure full contact is made.

LIMITATIONS AND PRECAUTIONS

- Use of solvents for thinning PileMedic™ Epoxy UW Grout will prevent proper cure.
- Product will not reach full adhesion or cure when applied at temperatures below 50°F.

- Danger! Causes severe eye and skin burns. May cause blindness. Harmful if swallowed. May cause allergic reaction. Do not handle or use until the Material Safety Data Sheet has been read and understood. Do not get into eyes, on skin or clothing. Use safety glasses with side shields and wear protective rubber or polyethylene gloves. Avoid breathing vapor or mist. Keep container closed. Use only in well ventilated locations. In case of contact, wash immediately with soap and water. Remove contaminated clothing and clean before reuse. Wash thoroughly after handling and before eating, drinking, or smoking. Use only potable water for mixing.
- Keep away from food and food containers.
- Avoid hazards by following all precautions found in the Material Safety Data Sheet (MSDS) product labels.

TYPICAL PROPERTIES	
Mixing Ratio	2:1 by Volume
Mixed Viscosity	750-1250 cps
Gel Time	50 minutes
Color (mixed)	Gray
TYPICAL CURED PROPERTIES	
Tensile Strength (ASTM D-638)	5100
Bond Strength: Type I	1800 psi
Type II	1650 psi
Tensile Elongation (ASTM D-638)	4-8%
Compressive Strength (ASTM D-695)	8500psi
Compressive Strength (mortar)(ASTM D-695) sand/epoxy	8500±500
Hardness Shore D (ASTM D-2240)	85-90

PileMedic™ Laminates

Engineering Specifications

QuakeWrap, Inc. • PileMedic, LLC
2055 E. 17th Street
Tucson, AZ 85719
Phone: (866) 782-5397
Fax: (520) 791-0600
PileMedic.com

PART 1 – GENERAL

1.1 SUMMARY

A. This Section specifies requirements for restoring deteriorated piles using Fiber-Reinforced Polymer (FRP) Laminate encasement. The work shall consist of using a fiber–reinforced laminate to create a helical jacket around the pile to be restored, and filling the annulus between the jacket and the pile with underwater resin.

B. Contractor shall provide all labor, materials, tools, and equipment required for the completion of the following Work, as shown on the Contract Documents and specified herein:

1. Prepare existing areas, as defined by these specifications and related Contract Drawings, designated to receive pile restoration
2. Design, furnish, fabricate, and install all jackets, shores, and bracing
3. Prepare installation and placement shop drawings listed below
4. Prepare design drawings for shores, and bracing if required
5. Furnish all submittals required by this Section of the Specifications
6. Coordinate all work with other trades on site.

1.2 REFERENCES

A. The latest edition and addenda of the following publications in effect on the date of Contract Award are part of this Specification and, where referred to by title or basic designation only, are applicable to the extent indicated by the specific reference:

- SOCIETY FOR PROTECTIVE COATINGS
- SSPC SP-12 WJ-2 Surface Preparation and Cleaning of Metals by Water Jetting
- ASTM F-2207

1.3 SUBMITTALS

A. Comply with pertinent provisions of Section 01xxx, Submittals.

B. Details shall be carried out in accordance with the local building codes, and as shown on plans.

C. Product Data:

1. Fiber-Reinforced Laminate catalog cuts showing material properties and strength.
2. Fill resin catalog cuts showing material properties and strength.
3. Adhesive resin catalog cuts showing material properties and strength.
4. Fill and Adhesive Resin MSDS sheets.
5. Miscellaneous fasteners, anchors, straps, spacers, etc. catalog cuts showing material properties.

D. Design and Shop Drawings:
The following information must be provided and sealed by a professional civil engineer:

1. Calculations showing the confining pressure provided by the jacket being used.
2. Shop drawings showing the FRP jacket installation steps, spacer sizes, overlap details, and the filler material to be placed in the annular space.

E. Certifications

1. ASTM F-2207 test report showing the jacket provides a minimum confining pressure of 850 psi.
2. Product approval by the US Army Corps of Engineers and FEMA
3. Material certification for FRP laminates to show date of fabrication.
4. Material certification for fill and adhesive resin to show date of manufacture.

F. Quality Assurance Documents

1. Daily installation reports showing air and water temperatures
2. Daily installation reports showing lot numbers of FR laminates and resins used on each pile

PART 2 - PRODUCTS

2.1 FIBER-REINFORCED POLYMER (FRP) LAMINATES

1. The laminate shall be a high-strength Fiber Reinforced Polymer (FRP) laminate constructed with bidirectional carbon or glass fabrics that provides strength in both longitudinal and transverse directions.
2. The FRP laminates shall have the minimum properties listed in the table below.

FRP Laminate Properties			
Property	**Standard**	**Glass**	**Carbon**
Longitudinal Direction			
Tensile Strength, ksi	ASTM D3039	62	101
Modulus of Elasticity, ksi	ASTM D3039	3,500	7,150
Ultimate Elongation, %	ASTM D3039	1.31	0.85
Transverse Direction			
Tensile Strength, ksi	ASTM D3039	60	64
Modulus of Elasticity, ksi	ASTM D3039	3,650	2,940
Ultimate Elongation, %	ASTM D3039	1.06	1.42
Other Properties			
Barcol Hardness	ASTM D2583	50	45
Max. Water Absorption, %	ASTM D 570	0.8	0.7
Laminate Thickness, in.		0.026	0.026

3. The FRP Laminate must provide the structural values listed in the table below.

Pile Jacket Dia. (in.)	PLG60.60 (Glass)		PLC100.60 (Carbon)	
	Confining Pressure* (psi)	Long. Steel Equiv.**	Confining Pressure* (psi)	Long. Steel Equiv.**
10	64	12	1050	13
12	535	14	875	15
15	430	18	700	19
18	355	22	580	23
24	265	29	435	31

*Assuming a 2-ply jacket
**Equivalent number of #4 Gr. 40 steel reinforcement distributed around the circumference of the pile

4. FRP Laminate shall be PileMedic™ PLG60.60, or PLC100.60, www.PileMedic.com; (2055 E. 17th St., Tucson, AZ 85719 U.S.A.; Tel: +1.520.791.7000) or approved equal.

2.2 ADHESIVE RESIN

1. The adhesive resin shall be a two-component high-strength structural epoxy designed for underwater applications. It shall have an immediate high tack consistency both in air and water and shall trowel easily.
2. The adhesive resin shall be a 100% solids formulation with low toxicity and low odor during cure.
3. The adhesive resin must be NSF-61 Certified for potable water application.
4. The adhesive resin is QuakeBond™ 220UR or approved equal and shall meet the properties listed in the table below.

Adhesive Resin Properties		
Property	**Standard**	**Value**
Tensile Strength, psi	ASTM D-638	4,360
Compressive Strength, psi	ASTM D-695	11, 700
Flexural Strength, psi	ASTM D-790	8,900
Tensile Elongation, Max. %	---	5%

2.3 FILL RESIN

1. The fill resin shall be a two-component, high-strength, low-viscosity structural epoxy. The resin shall cure underwater and shall provide excellent durability and chemical resistance. The resin shall be a 100% solids formulation with low toxicity and low odor during cure.
2. The fill resin must have a low viscosity of 780 cps at 77 F to ensure that it will fill small cracks and voids in the pile.
3. The resin must be heavier than water, with a density greater than 1.10 to flow to the bottom of the annular space and displace the water.
4. The fill resin must be so that its color would show through the glass laminate.
5. The fill resins shall be QuakeBond™ 320 LV Low Viscosity Resin or approved equal and shall meet the properties listed in the table below.

Fill Resin Properties		
Property	**Standard**	**Value**
Viscosity @ T=77° F, cps	ASTM D-1290	780
Tensile Strength, psi	ASTM D-638	7,900
Compressive Strength, psi	ASTM D-695	11,200
Density	---	1.11
Tensile Elongation, Max. %	---	5%
Hardness, Min. Shore D	ASTM D-2240	86

2.4 SPACERS

Spacers used to create an annulus around the pile shall be of the non-reactive type.

2.5 ALTERNATIVE MATERIALS

Any alternative materials proposed as a substitute for the materials specified in this specification shall be submitted for review and approval to the Project Engineer at least 15 days prior to the bid date.

PART 3 - EXECUTION

3.1 PREPARATION

A. Timber Piles

1. All timber piles scheduled to receive FRP encasements shall be cleaned using high pressure water jetting with rating of 5000 psi. Contractor shall take precautions in order not to remove intact timber section from the existing timber piles during preparation activities. The purpose of this preparation is to remove all marine growth and any soft surface layer that may have accumulated on the piles. Severely deteriorated timber may be removed with water blast.
2. The elapsed time between the cleaning of a timber pile and the installation of the encasement on that timber pile shall not exceed 72 hours. If this time frame is exceeded contractor shall re-clean the pile prior to encasement.
3. Contractor shall remove any marine growth that has accumulated on the pile prior to the installation of the FRP jacket.

B. Concrete

1. All loose and deteriorated concrete shall be removed using hydraulic or pneumatic hand tools.
2. Contractor shall take precautions not to damage non-spalled or cracked concrete at location of scheduled repair.
3. After loose concrete is chipped away, all concrete surfaces scheduled to receive encasements shall be cleaned using high pressure water-jetting with rating of 5000 psi. The purpose of this preparation is to remove all marine growth and any soft surface layer that may have accumulated on the extension. The elapsed time between the cleaning of the concrete surface and the installation of the FRP encasement shall not exceed 72 hours. If this time frame is exceeded contractor shall re-clean the pile prior to encasement.
4. Contractor shall remove any marine growth that has accumulated on the concrete surface prior to encasement.

3.2 APPLICATION

A. Epoxy Paste

1. The epoxy paste shall be QuakeBond™ 220UR (for underwater installations) or QuakeBond™ J201TC (for dry installations). The epoxy shall be mixed in small batches at the point of installation. Great care shall be given to application of the epoxy paste to the laminate. Thoroughly clean the laminate surface per manufacturer's recommendation prior to the application of the epoxy paste. Air, water and laminate surface temperature shall be between 50 and 90 degrees F. DO not begin application if air, water or laminate surface temperature is below 50 or expected to fall below 50 F within 12 hours of application. Do not begin application if the dew point is within 5 F of the temperature. Adhere strictly to Manufacturer's Recommendations.
2. All epoxy components shall be conditioned to a temperature between 65 and 85 F prior to the time of mixing.

B. FRP Laminate

1. Cut the required length of the 4-ft (1200-mm) wide laminate in the field. Note that the jacket must wrap a minimum of twice around the pile (720 degrees) plus an 8-inch (200-mm) overlap.
2. Thoroughly mix the epoxy paste.
3. Apply a 30-mil thick film of the epoxy paste to the overlapping portion of the laminate. A notched trowel can be used to ensure uniform epoxy thickness.
4. Secure two injection tubes at opposite faces (180 degrees apart) along the height of the pile to be repaired. Grooved may be cut into the pile to place the tubes flush with the face of the pile.
5. Wrap the laminate around the pile ensuring the second layer is in full contact with the first layer. Adjust the diameter of the jacket as necessary.
6. Use ratchet straps or shrink wrap as temporary means to keep the FRP diameter in the desired size.
7. When necessary, additional 4-ft (1200-mm) sections of laminate can be installed similarly. Apply epoxy paste over the overlapping portion of the first laminate to create a longer jacket.
8. At the contractor's discretion Steps 5 through 7 can be performed on a portion of the pile above water and the assembly lowered below the waterline.
9. Seal the bottom of the annular space.

C. Fill Resin

1. QuakeBond™ 320LV (Low Viscosity) resin shall be used as the fill material. Mix the resin at the point of installation. Introduce resin at the bottom of the annular space using tubes of the appropriate size. Minimum application temperature shall be 45 F. All epoxy components shall be conditioned to a temperature between 65 and 85 F prior to the time of mixing. Adhere strictly to Manufacturer's Recommendations.

D. Fill Resin Placement Equipment

1. The resin may be proportioned and mixed separately before placing the mixed resin in a dispensing pump.
2. For larger projects, an automatic measuring, mixing and dispensing pump must be used. Contact the FRP Manufacturer for recommended mixing equipment.

E. Application

1. Fill the lower 6 inch (150 mm) of the annular space with resin. Allow sufficient time for this resin to set and penetrate into the pile, creating a horizontal seal layer at the bottom of the FRP jacket.
2. Fill the remaining height of the annular space with resin. Fill resin placement shall begin from the bottom of the laminate jacket until it reaches the top of the jacket. The density of the fill resin that is heavier than water will push the water to the top of the annular space.
3. Allow fill resin to overtop the jacket until all water and laitance has been removed from the inside of the jacket.

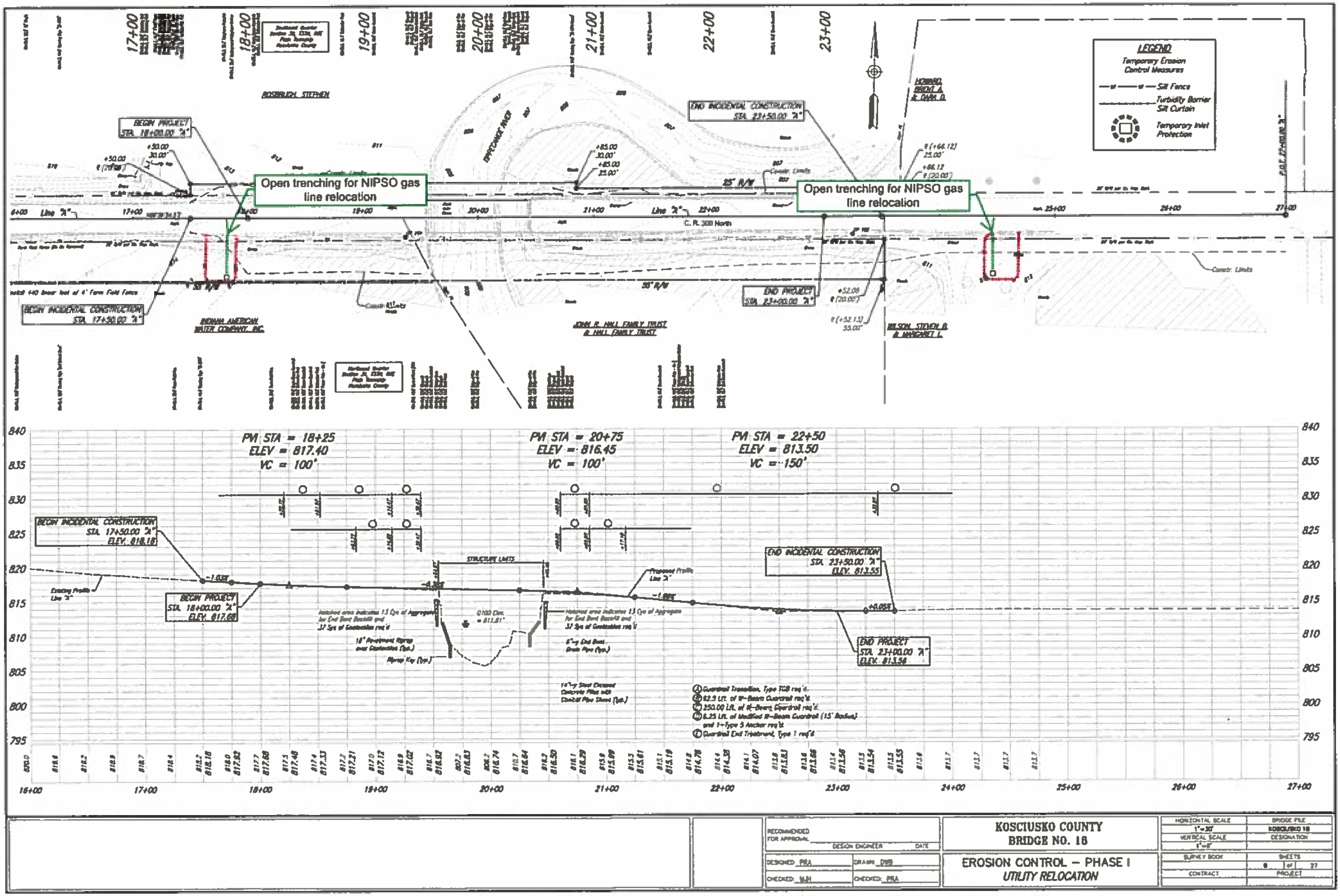
3.3 INSPECTION

1. The Work to be provided in accordance with this Section of the Specification shall be subject to inspection by Owner at any time(s) during the progress of the Work. Contractor shall provide access and any labor, materials, tools, and equipment required by Owner to complete inspection of the Work as specified herein.
2. Completed installations shall be visually inspected to confirm the integrity of the laminate encasement and the resin fill. Any deficiencies shall be corrected at the Contractor's expense. The Contractor shall propose a repair method and submit it to the Engineer for approval prior to implementing said repair.
3. Acceptance of structure shall be contingent on the Work meeting all of the requirements of the Contract Documents as indicated by the results of all testing, inspection, and other quality assurance procedures required by Owner.

END OF SECTION

ATTACHMENT B

EROSION CONTROL PLAN



LEGEND
Temporary Erosion Control Measures
Silt Fence
Turbidity Barrier Silt Curtain
Temporary Inlet Protection
Open trenching for NIPSO gas line relocation
Open trenching for NIPSO gas line relocation
BEGIN PROJECT STA. 18+00.00 "A"
END PROJECT STA. 23+00.00 "A"
BEGIN INCIDENTAL CONSTRUCTION STA. 17+50.00 "A"
END INCIDENTAL CONSTRUCTION STA. 23+50.00 "A"
C.R. 300 North
PVI STA = 18+25
ELEV = 817.40
VC = 100'
PVI STA = 20+75
ELEV = 816.45
VC = 100'
PVI STA = 22+50
ELEV = 813.50
VC = 150'
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BEGIN PROJECT STA. 18+00.00 "A" ELEV. 817.68
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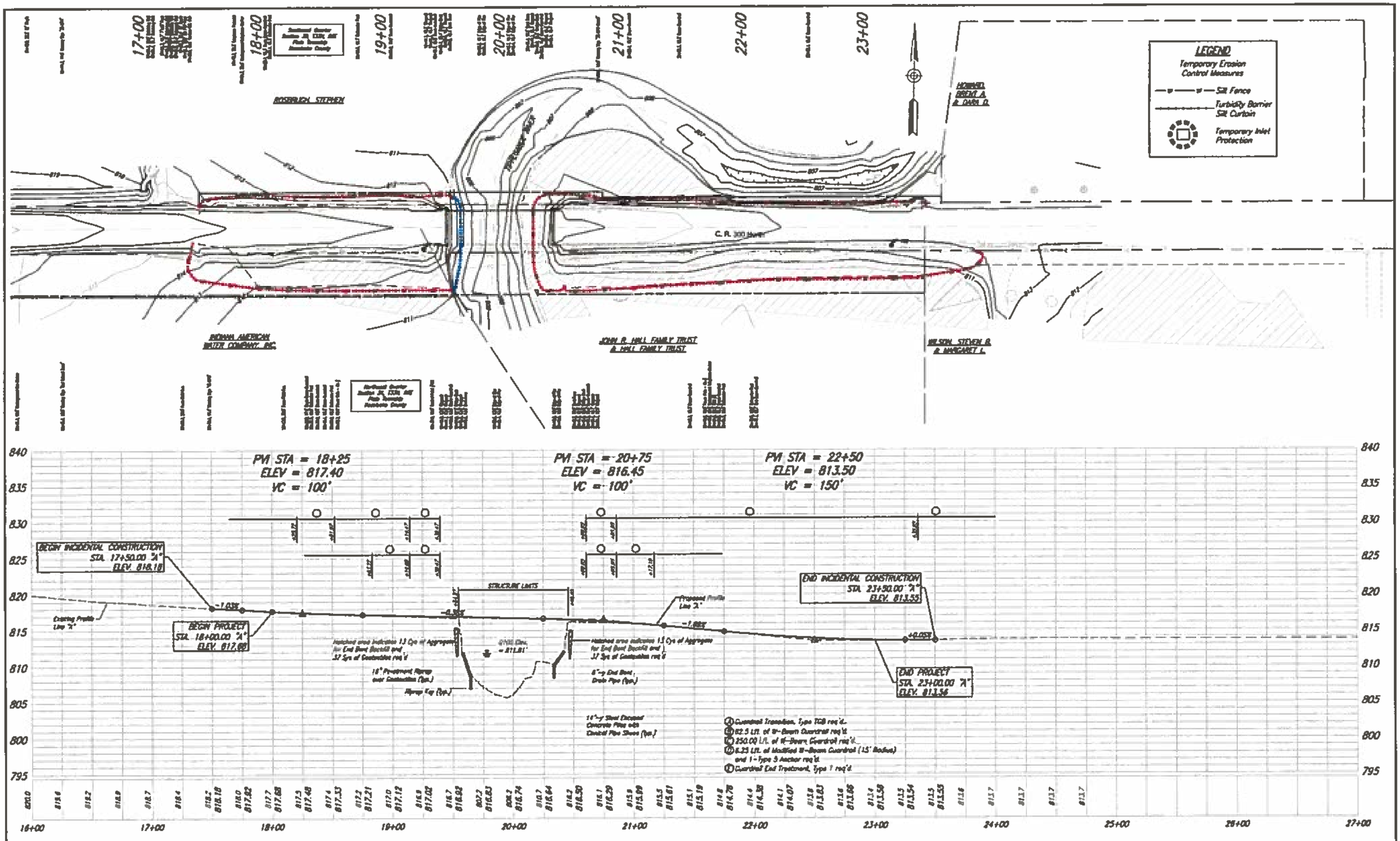
STRUCTURE LIMITS
840
835
830
825
820
815
810
805
800
795
16+00
17+00
18+00
19+00
20+00
21+00
22+00
23+00
24+00
25+00
26+00
27+00
KOSCIUSKO COUNTY
BRIDGE NO. 18
EROSION CONTROL – PHASE I
UTILITY RELOCATION

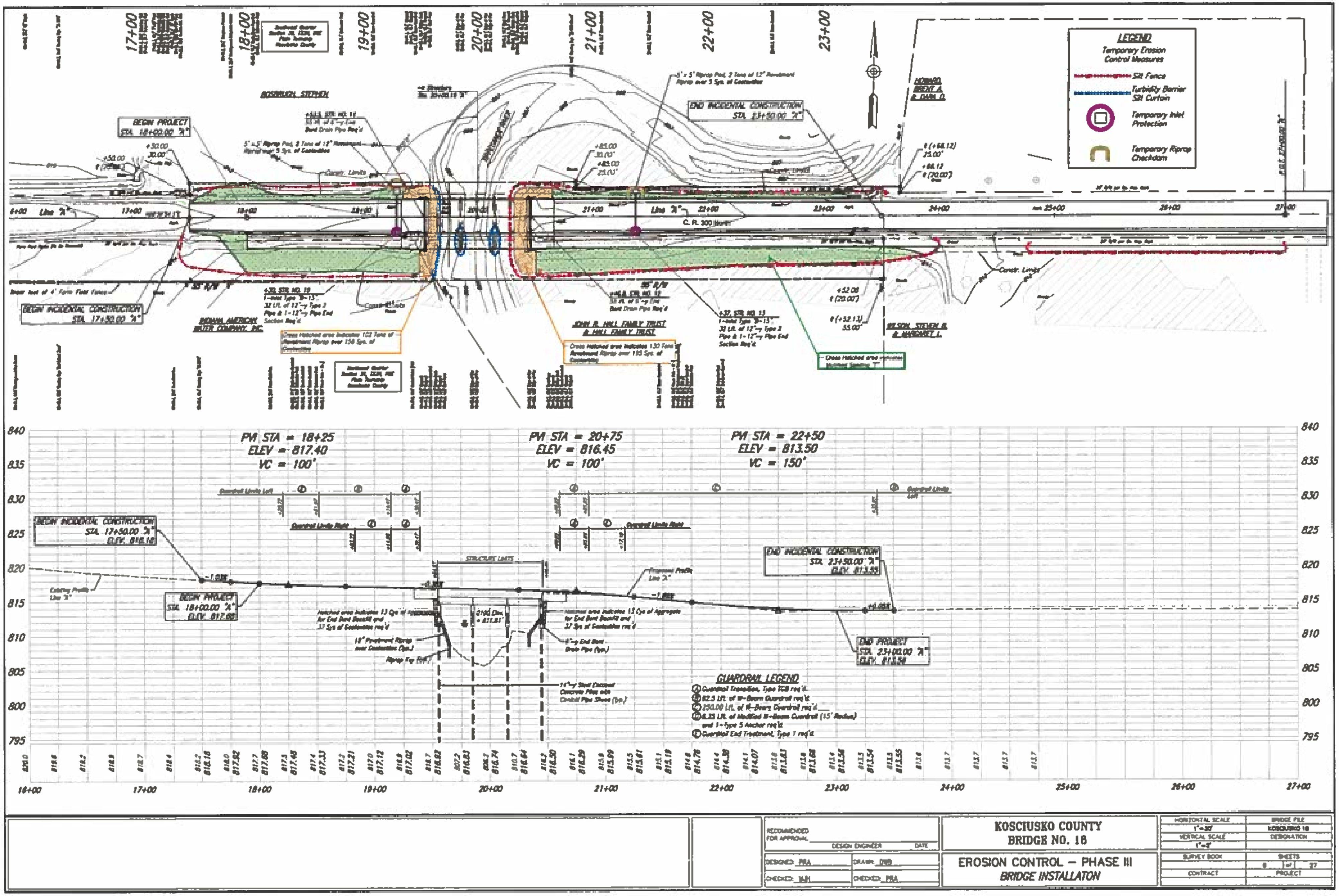


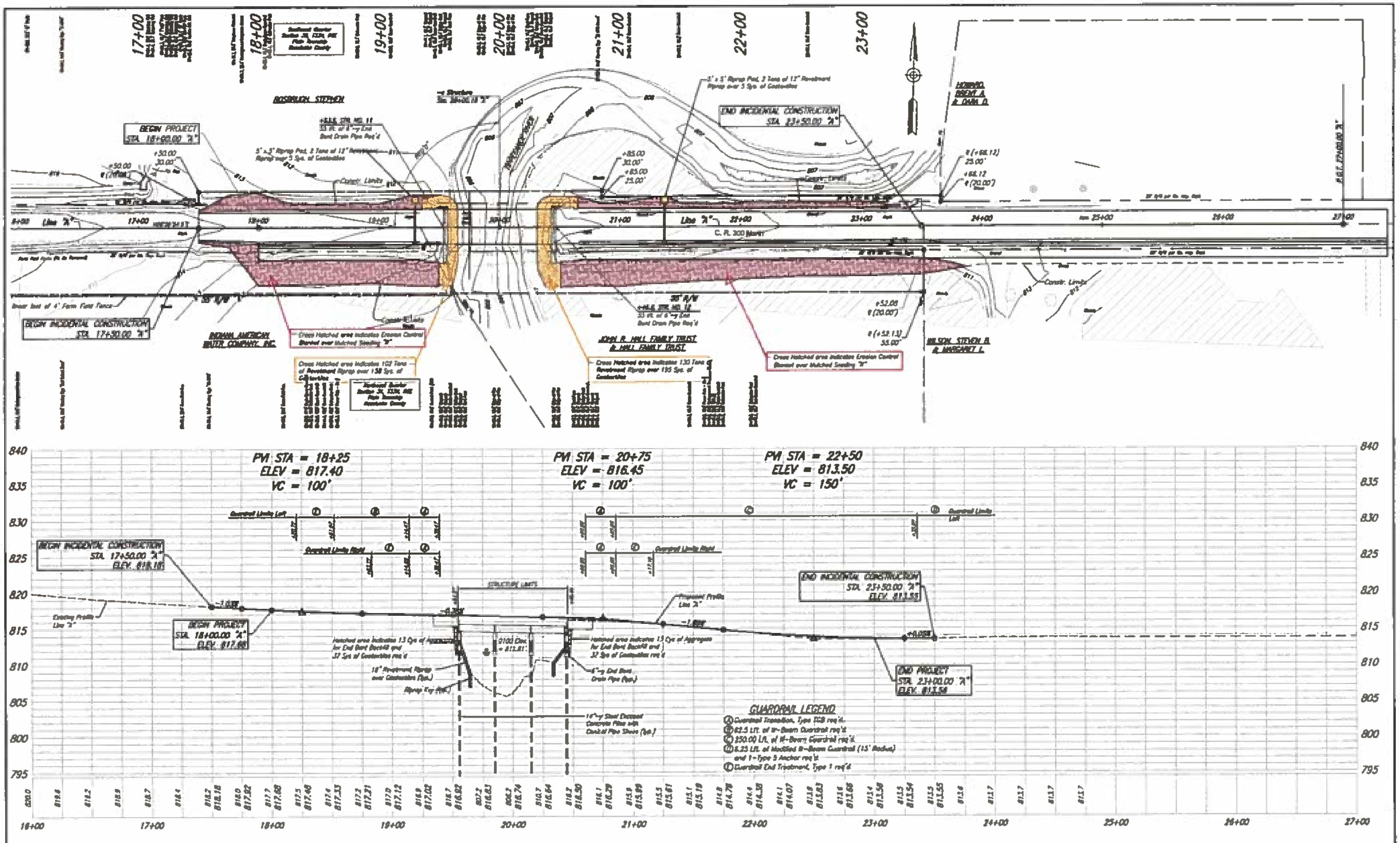
RECOMMENDED FOR APPROVAL	DESIGN ENGINEER / DATE
DESIGNED: PRA	DRAWN: DWB
CHECKED: MJH	CHECKED: PRA

KOSCIUSKO COUNTY
BRIDGE NO. 18

EROSION CONTROL – PHASE II
EXISTING STRUCTURE REMOVAL

HORIZONTAL SCALE 1"=30'	BRIDGE FILE KOSCIUSKO 18
VERTICAL SCALE 1"=5'	DESIGNATION
SURVEY BOOK	SHEETS 8 of 27
CONTRACT	PROJECT


LEGEND
Temporary Erosion Control Measures
Silt Fence
Turbidity Barrier Silt Curtain
Temporary Inlet Protection
Temporary Riprap Checkdam
BEGIN PROJECT STA. 18+00.00 "A"
END INCIDENTAL CONSTRUCTION STA. 23+50.00 "A"
BEGIN INCIDENTAL CONSTRUCTION STA. 17+50.00 "A"
C.R. 300 North
PVI STA = 18+25
ELEV = 817.40
VC = 100'
PVI STA = 20+75
ELEV = 816.45
VC = 100'
PVI STA = 22+50
ELEV = 813.50
VC = 150'
END PROJECT STA. 23+00.00 "A"
GUARDRAIL LEGEND
KOSCIUSKO COUNTY
BRIDGE NO. 18
EROSION CONTROL – PHASE III
BRIDGE INSTALLATON



KOSCIUSKO COUNTY
BRIDGE NO. 18

EROSION CONTROL – PHASE IV
PERMANENT EROSION CONTROL

RECOMMENDED FOR APPROVAL	DESIGN ENGINEER / DATE
DESIGNED: PRA	DRAWN: DWB
CHECKED: MJH	CHECKED: PRA

HORIZONTAL SCALE 1"=30'	BRIDGE FILE KOSCIUSKO 18
VERTICAL SCALE 1"=6'	DESIGNATION
SURVEY BOOK	SHEETS 8 of 27
CONTRACT	PROJECT