Declaration of Edward J. Brauer, P.E.

I, Edward J. Brauer, P.E., declare as follows:

Professional Experience and Background

1. I am a hydraulic engineer at the Applied River Engineering Center, U.S. Army Corps of Engineers (USACE, Corps), St. Louis District. I have an M.S. in Civil Engineering (Environmental Hydrology and Hydraulic Engineering) from the University of Illinois, Champaign-Urbana and a B.S. in Civil Engineering from Southern Illinois University, Edwardsville. I started at the Applied River Engineering Center in the student career experience program in 2001 and continued my career with the Corps as a hydraulic engineer after completion of my B.S. degree in May 2004. I am a licensed Professional Engineer in the State of Missouri (license number 2009018695).

2. Throughout my career I have worked with and been trained by current and retired experts in river engineering and hydraulics from the Corps (District, Division, and the U.S. Army Engineer Research and Development Center), U.S. Geological Survey (USGS), and Academia (Institute of River Studies – Missouri University of Science and Technology) who have extensive institutional knowledge. This knowledge has been critical in understanding the applicability and limitations of historic hydrologic and spatial data.

3. My professional technical experience covers a broad area of river engineering, including sediment transport, hydrodynamics, physical and numerical modeling, dike construction design and physical effects analysis of river training structures in the Mississippi River. As either the lead engineer or the engineer responsible for project oversight, I have been involved in numerous river engineering studies focusing on navigation channel improvement, environmental restoration, and bank erosion on large and small streams and rivers. The physical modeling

includes both large scale and small scale physical sediment modeling of river training structures, including my research on the effect of dikes on water surfaces in a mobile bed at the Ven Te Chow Hydrosystems Laboratory at the University of Illinois, Urbana-Champaign. I have also initiated and provided technical oversight for multi-dimension numerical modeling efforts focusing on physical effects of river training structures.

4. I have conducted detailed analysis on the geomorphological changes in the Mississippi River and its tributaries. On the Middle Mississippi River (MMR), I have compiled, reviewed and analyzed all available historic spatial, bathymetric, and hydrologic data. I have conducted specific gage analyses on the rated gages on the MMR to evaluate the changes to the stage-discharge record and their causes. Gages are locations on the river where the river stage (or height of water) is collected. Rated gages are gage locations where both stage and discharge (or volume rate of water flowing past a particular location) are measured. As part of my geomorphological analysis, I have conducted an extensive literature review on the physical effects of river training structures, including their impact on flood levels.

5. I have developed data collection and data analysis studies to monitor the physical effects of river training structures. I have analyzed hydrographic, velocity and water surface data over and around river training structures including single-beam and multi-beam bathymetric data, Acoustic Doppler Current Profiler (ADCP) velocity data, and water surface elevation data collected with Real Time Kinematic (RTK) satellite navigation.

6. I have authored and co-authored several technical reports and papers on the topics of geomorphology, design of river engineering structures, physical modeling and the physical effects of river training structures. I have made presentations at technical conferences on the aforementioned topics in the Unites States, Europe, and Central America.

Documents Reviewed

7. I am the primary author, in conjunction with other Corps experts in hydraulics and river engineering, of the Summary of Research on the Effects of River Training Structures on Flood Levels, which was Appendix A to the Environmental Assessments (EA) for Dogtooth Bend Phase 5, Mosenthein/Ivory Landing Phase 4, and Eliza Point/Greenfield Bend Phase 3 (referred to herein as Appendix A) (links to these EAs with Appendix A are provided in Defendants' Opposition to Plaintiff's Motion for Preliminary Injunction). I am a contributing author to the aforementioned EAs. I have read and am familiar with the Declaration of Nicholas Pinter, Ph.D. ("Pinter Decl."), including the sources cited.

Review and Analysis of Issue by Corps

8. The Corps takes seriously the claims that the construction of river training structures has caused significant increases in flood levels and poses a risk to public safety. The Corps has actively studied the impact of river training structures on water surfaces dating to the 1930's and continuing to today. Recently, the Corps worked with technical experts in the fields of river data collection, river engineering, hydraulics, geomorphology and statistics to analyze the impacts of river training structure construction on water surfaces using state-of-the-art tools and the most recent data available. The results of these independent expert external reviews all lead to the conclusion that river training structure construction has not resulted in an increase in flood levels. These conclusions are supported by engineers from the Corps and scientists and engineers from the USGS and academia. The Corps continues to evaluate new data and research on the physical impacts of river training structures, including their impact on flood levels as it becomes available.

9. Comments received by the National Wildlife Federation, Izaak Walton League of America, Missouri Coalition for the Environment, Prairie Rivers Network, and the Sierra Club (three of which are plaintiffs to this lawsuit) on the draft EAs included a list of 51 studies that claimed a link between "the construction of instream structures [river training structures] to increased flood levels." Appendix A included an analysis and discussion of all 51 of these studies in conjunction with other available research and literature, totaling 89 references on the topic. This analysis as detailed in Appendix A supports the conclusion that flood levels have not been increased as a result of construction of river training structures and, therefore, no impact to public safety.

10. Twenty-seven of the 51 studies provided to the Corps did not discuss the construction of river training structures and/or increases in flood levels. They addressed flow frequency, physical modeling and model scale distortion, levee construction, or simply referenced one of the other studies listed (see Appendix A, Section 4). Further, many of the remaining journal articles, technical notes, book chapters, and conference papers were the same analyses presented in multiple papers (see Appendix A, Section 3).

11. Dr. Pinter's Declaration provided an additional 12 references, which were not included in the comments received on the draft EAs. The Corps has made requests but to date has not received Hathaway (1933). Upon receipt, the Corps will review and evaluate as it does all new information brought to its attention relevant to its projects' impacts. In conjunction with other technical experts in the fields of river engineering and hydraulics, I have reviewed 11 of the 12 additional references.

12. Most of the references cited in Dr. Pinter's Declaration provide background information including information on levees and flood damages (Pielke 1999, Helms et al. 2002, Munich Re

Group 2007, Olson and Morton 2011) and flow structure around river training structures (Yeo and Kang 2008, Azinfar and Kells 2011, Yossef and de Vriend 2011, and Jamieson et al. 2011). Schneiders (1996) provides a history of the Missouri River channelization project and does not present any new research or information, nor draw any conclusions on the impact of river training structure construction on flood levels. Azinfar (2010) is the Ph.D. thesis on the research that is the foundation of Azinfar and Kells (2011, 2009, 2008 and 2007). Since the study was conducted in a rigid, fixed bed flume, Azinfar and Kells (2011) and Azinfar (2010) have the same limitations as Azinfar and Kells (2009, 2008, and 2007) as discussed in Appendix A and below in Paragraph 25.

13. The additional 11 references cited by Dr. Pinter (described above) and available to the Corps do not provide analysis and conclusions which, in conjunction with the analysis and conclusions of studies and literature previously considered, would lead the Corps to a different conclusion on the impacts of river training structure construction on flood levels and public safety than what was established in the EAs.

14. The river is made up of both flowing water and flowing sediment. The purpose of river training structures is to change the bottom of the river and/or the way the river water and sediment flows in a reach. This can be done to achieve different goals including deepening the navigation channel, adding or enhancing environmental features, or redirecting the flow for a safer navigation channel. If the objective is to create a deeper channel, the river training structure initially creates a narrower channel by blocking part of it off. The resulting narrower channel will cause the river to naturally deepen the channel providing adequate depth for navigation (Figure 1). Field data taken on the MMR have shown that the narrower and deeper channel will have the same cross sectional area and average velocity as before the placement of

the structure. Generally, river training structures on the MMR are constructed with a top elevation 15 feet below the top of the riverbank and are under water 30 percent of the time (Figure 2).

15. River training structures have been constructed and subsequently monitored on the MMR since the early 1800's. The designs used by the Corps today are the result of over a century of research and experience. The term river training structures describes structures of many different sizes, shapes and elevations. For example, traditional wing dikes are structures constructed perpendicular to the bank, notched dikes are dikes that are notched (material is removed) to allow flow to pass through a section of a structure, Chevron dikes are horseshoe shaped dikes designed to divide the passing flow to create a secondary channel. Weirs are dikes that are constructed in bends well below the water surface that work by redirecting the river flow so the highest velocities are away from the banks. This provides a safer alignment and channel width through the river bends.

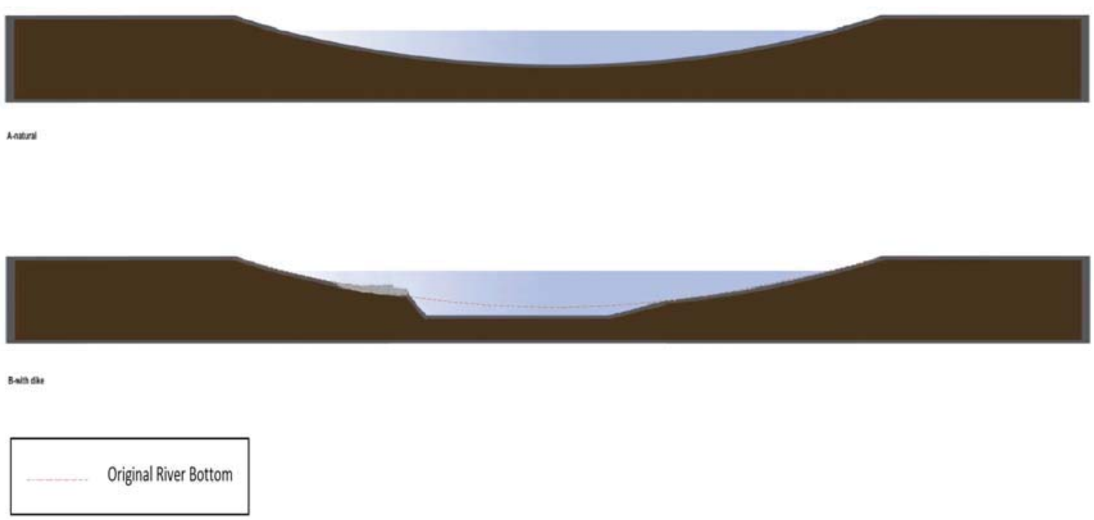

Figure 1: Simplified illustration of a River Cross-Section before (top) and after (bottom) installing a river training structure (not to scale).

Figure 2: (left) river training structures at low flow (right) river training structures at above average flow (approx)

16. The research which attempts to link river training structures to an increase in flood levels can be grouped into three categories: specific gage analysis, numerical simulations and physical fixed bed modeling. Major errors were found in the source data or methodology used in the analyses by the researchers that puts into question their conclusion that the construction of river training structures impacts flood levels and consequently public safety. Below is a brief discussion of these studies, but a more detailed technical analysis of these studies can be found in Appendix A.

17. The assumptions, source data, and methodology used in the specific gage analyses studies that claim a link between river training structure construction and an increase in flood levels is not supported by many in the scientific and engineering communities (Stevens 1976, Brauer 2009, Huizinga 2009, Samaranayake 2009, Watson and Biedenharn 2010, Brauer 2012, and Watson et al. 2013b). Major flaws in the specific gage analyses conducted by the researchers include use of inaccurate early discharge (Appendix A, Section 3.1.3.1), use of estimated daily discharge data (Appendix A, Section 3.1.3.2), statistical errors (Appendix A, Section 3.1.3.4), not accounting for other physical changes within the channel (Appendix A, Section 3.1.3.5), and the use of non-observed interpolated synthetic data points (Appendix A, Section 3.1.3.6).

18. Early discharge data collected before the implementation of standard instrumentation and procedures by the USGS in 1933 has been proven to be inaccurate (Ressegieu 1952, Dyhouse 1976, Dyhouse 1985, Dieckmann and Dyhouse 1998, Huizinga 2009, Watson et al. 2013a). An analysis of early discharge data by Watson et al. (2013a), which was co-authored by Robert R. Holmes, Jr., P.E. (National Flood Hazard Coordinator, U.S. Geological Survey), found that "pre-1930's discrete streamflow measurement data are not of sufficient accuracy to be compared with modern streamflow values in establishing long-term trends of river behavior," which is exactly what Dr. Pinter does in his research. In an attempt to disprove this long standing conclusion supported by both the Corps and USGS, Pinter (2010) analyzes 2,150 historical, pre-1933 discharge measurements to reach the conclusion that early Corps discharge measurements are of the same accuracy as the post-1933 USGS measurements and can be used as a homogeneous data set (*see* Pinter Decl., Para. 15). However, Pinter (2010) fails to go further in comparing this data with the post-1933 USGS data to confirm that the two data sets can be used together. By only analyzing one set of data, the conclusion in Pinter (2010) does not reach a valid conclusion and does not contradict the conclusions in the references described above.

19. Another major error in Dr. Pinter's analyses is the use of daily discharge data. Daily discharges are discharge values estimated from the daily stage measurement. They are not measured or observed but rather estimated from a rating curve of previously observed data. The use of computed daily discharge data in a specific gage analysis has been shown to be invalid by engineers and scientists because "the computed daily discharge data lacks the natural variability found in measured stream flow [variability in channel roughness] and can lead to conclusions that are due to artifacts created by errors in the original rating curves" (Samaranayake 2009).

20. A majority of the hydrologic data in the database referenced by Dr. Pinter (data at 49 of the 67 stations on the Mississippi River and Lower Missouri River) were fabricated using interpolation schemes developed by Jemberie et al. (2008), and they are not real data points.

21. Remo and Pinter (2007) developed a one dimensional unsteady-flow numerical model, or 'retro-model,' to evaluate the impacts of river training structures on flood levels (Appendix A, Section 3.2.1). The discharge values used to develop the 'retro-model' (1900-1904) have been proven to be inaccurate by the Corps and USGS through comparative discharge studies, detailed in Paragraph 20 (and Appendix A, Section 2.1). The use of the early inaccurate discharge data resulted in surprisingly low roughness values for the historic condition, which experts from the Corps and academia believe are not representative of the characteristics of the historic channel (See, Appendix A, Section 3.2.1.2). The results and conclusions of Remo et al. (2009) are dependent on the 'retro-model' and are impacted by the same errors in source data.

22. Dr. Pinter attempts to use a recent theoretical analysis by Huthoff et al. (2013) to support his claim that increase in flood levels are caused by river training structure construction (Pinter Decl., Para. 13). A discussion article (Brauer and Duncan, in print) addresses the major errors in the applicability of the effective roughness equation (Appendix A, Section 3.2.3.1.1), bank roughness values used (Appendix A, Section 3.2.3.1.2), and model verification (Appendix A, Section 3.2.3.1.3), which leads to incorrect conclusions on the magnitude of change in water surface by the author.

23. The results of fixed bed physical flume studies (Azinfar and Kells 2009, 2008, 2007, and Azinfar 2010) have been used to attempt to attribute construction of river training structures to increases in flood levels. As detailed in Paragraph 16, river training structures cause important physical changes to the river bed. These changes are not accounted for in these studies due to

the absence of sediment and the fixed nature of the flume bottom. In a fixed bed flume, without channel scour, the only possible outcome is an increase in water level upstream of the structure. This major limitation is acknowledged by Azinfar and Kells (2011), "The fixed bed scenario is not a reasonable description of a natural river channel with a moving sediment bottom, and is expected to yield a conservative result for the backwater effect relative to that likely to be experienced in a non-erodible boundary channel (Azinfar and Kells 2011)."

Analysis of Dr. Pinter's Conclusions in the Declaration

24. Listed below are areas in Dr. Pinter's Declaration that have been found to be erroneous, misleading or imply that he has a misunderstanding of river engineering:

a) Dr. Pinter's Declaration discusses many rivers and river reaches in an attempt to imply that dikes on the MMR, and specifically, the project sites on the MMR are increasing flood levels. Although there are similarities between all rivers, the way that the rivers are managed for navigation can be very different. As acknowledged by Pinter et al. (2010), the Mississippi River can be subdivided into distinct reaches based upon the way the river is managed (i.e., pooled reaches, open river, channel cutoffs, etc.). The way the Missouri River is managed contrasts largely with the Mississippi River. Furthermore, the physical characteristics of the rivers/river reaches are much different. The flow and sediment load on the Upper Mississippi River, Middle Mississippi River, Lower Mississippi River and Lower Missouri River are very different, which has resulted in different sediment management practices. Much of the research conducted by Dr. Pinter that claims river training structure construction has resulted in an increase in flood levels on rivers and river reaches other than the MMR has the same critical flaws discussed above and in Appendix A.

b) Dr. Pinter describes in his Declaration that "statistically significant increase in flood levels have also been identified downstream of wing dikes" (paragraph 32). He states that the hydraulics causing this increase in flood levels is due to the upstream dikes triggering a "simultaneous incision and conveyance loss at sites downstream" (Paragraph 19). For a loss of conveyance downstream of a structure to occur, one of the following would need to happen: (1) the dike caused the cross sectional area downstream to decrease or (2) the dike caused the velocity to decrease. However, this does not happen in the MMR. Field observations have shown that, in most cases, the cross sectional area recovers after the construction of a dike due to the local scour at individual dike tips, combined with constriction scour that increases depths in the navigation channel (Maher 1964, Biedenharn et al. 2000, Huizinga 2009). Further, Huizinga (2009) analyzed velocity patterns over time at Mississippi River gages at St. Louis, MO and Chester, IL and found that at both gages, average velocity fluctuates around a period of record average for all flows.

c) As detailed in the Affected Environment, Biological Resources section of the EAs, in response to the physical (and resulting hydrologic changes) in the watershed, the MMR went through a period of planform (combined width of the river channel, islands and side channels) widening in the mid-nineteenth century. This was followed by a period of planform narrowing from the end of the nineteenth century through the mid-twentieth century, mostly due to the loss of side channels. The average planform width was reduced by forty percent between 1817 and 2011. This width includes large islands that existed in the nineteenth century. The resulting channel width was reduced by only thirty percent between 1817 and 2011 (Brauer et al. 2013). Both of the planform widths and channel widths have remained in a state of dynamic equilibrium since the 1960's. When Dr. Pinter describes a river channel that "has narrowed to one-half or less of their original width" in paragraph 24 of his declaration, he may be referring to a river other than the MMR. Studies have shown (Maher 1964, Biedenharn et al. 2000) that although the channel has been narrowed due to river training structure construction, the cross sectional area of the deeper channel is preserved and the channels ability to pass flow (conveyance) is the same or in some cases increased.

d) Dr. Pinter gives an oversimplified and misleading description of the relationship between velocity and depth in paragraph 25 of his Declaration by stating that "all factors being equal, a flood that passes through a river reach with half the average flow velocity will result in average water depths that are double what they would otherwise be." In rivers that are natural, compound channels, all factors are not equal. The cross section is irregular in shape, varying from approximately parabolic to approximately trapezoidal (Chow, 1959). Due to the compound nature of the channel, the roughness is variable (i.e., floodplain, banklines, main channel, etc. all provide different magnitudes of roughness). The resulting velocity distribution in a natural, meandering channel is not uniform. The statement by Dr. Pinter is only true in the special case of a prismatic fixed-bed rectangular channel, which is not the type of channel found in neither natural rivers nor the MMR.

e) In paragraph 26 of his Declaration, Dr. Pinter describes in detail the flow resistance associated with flow turbulence and large-scale vertical and horizontal eddy circulation. This flow resistance is one of many roughness elements resisting the flow of water and is accounted for in the stage for which a particular flow passes through a given reach of river (in a specific gage analysis). It is important to note that this flow resistance is inversely related to the submergence of the dikes (Yossef 2005, Azinfar and Kells 2007, Yossef and de Vriend 2011, and Huthoff et al. 2013) as detailed in Huthoff et al. (2013), which was co-authored by Dr. Pinter. In other words, the greater the depth of water over the dikes, the less the resistance. Therefore the flow resistance is greatest at stages in which the dikes are the least submerged (stages below flood stages). This relationship is exactly the opposite of the relationship proposed by Dr. Pinter in other studies including Pinter et al. (2001) and Remo and Pinter (2007).

f) Dr. Pinter points to the "Room for the River" program being implemented in the Netherlands as evidence that "the role of river training structures in increasing flood heights is well recognized" (Pinter Decl., Para. 27). As noted in the response to comments in the EAs, the Dutch are modifying their dikes (referred to in the Netherlands as 'groynes') in conjunction with other measures including the lowering of the floodplain, deepening of the summer bed, creation of storage basins, levee relocation, creation of high water diversion channels, and obstacle removal as part of the "Room for the River" program. The structures used on the MMR are much different in size, spacing, and top elevation than those used by the Dutch; the MMR structures have greater spacing, smaller crown width and are constructed to a much lower top elevation relative to the average water surface elevations. Unlike the structures in the Netherlands, which have a crest elevation of top of bank, the structures on the MMR are constructed to an elevation of approximately one-half of the elevation of the top of the banks. Structures used on the MMR are still lower than the modified structures in the Netherlands.

g) There is no support for the claim by Dr. Pinter in his Declaration, Paragraph 30, that the structures proposed in the Grand Tower project would lead to large increases in flood levels due to an assumption of bedrock within the reach. As described by Dr. Pinter in his Declaration, Paragraph 20, the purpose of river training structures is to "stimulate channel scour which can reduce the amount of dredging required to maintain adequate navigation depths (e.g. COPRI 2012)." Scour is only induced by the river training structure in the reach adjacent to the location of the structure. The nearest bedrock formation (at an elevation capable of having an impact) to the Grand Tower work area is approximately five and a half miles upstream and over twenty miles downstream. The reach adjacent to the Grand Tower work area has repeatedly been dredged successfully to the desired depth, which indicates that the bedrock in this area is not a factor. Furthermore, bed samples taken in the Grand Tower reach confirm that the bed material is a combination of medium to coarse sands and pebbles up to one inch in diameter. As part of the river engineering design process, the historical geomorphology and physical characteristics are analyzed and studied. If it was determined that bedrock was present that would reduce the ability for the channel to scour, the construction of river training structures would not be recommended.

25. I declare under penalty of perjury that the foregoing facts are true of my personal knowledge, that the foregoing expressions of professional judgment are honestly held in good faith, that I am competent to and if called would so testify, and that I executed this declaration on July 29, 2014 in St. Louis, Missouri.

Edward J. Brauer, P.E.

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