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Why Does the Repaired Len Small Levee, Alexander County, Illinois, US Continue to Breach during Major Flooding Events?

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Abstract

One only needs to study the soil and geologic history and location of the ancient Mississippi and Ohio Rivers to understand why Len Small levee if patched will continue to fail. Much of Dogtooth Bend located in Alexander County, Illinois was originally in the ancient Ohio River valley (Figure 1) alluvial sediments north and east of the confluence with the ancient Mississippi River. The ancient Ohio River valley soils underlain by alluvial sediments and have been easily eroded by the re-aligning modern Mississippi River which now travels through the bedrock controlled Thebes Gap (Figure 2) and into the Ancient Ohio river valley. The primary objectives of this paper are: 1) to explain why Len Small levee, Alexander County, Illinois, US will continue to breach during major flooding events if repaired and 2) to develop a new combined raised causeway and levee system which will provide a Mississippi River floodwater bypass, be sustainable, encourage and fund a land use change, restore the degraded highway road beds, protect remaining Dogtooth Bend farmsteads and farmland that have not yet been degraded by past flooding events and provide floodwater storage during major flooding events at the confluence of the Mississippi and Ohio Rivers.

Keywords

Mississippi River, Flooding, Navigation, Water Storage, Land Use Change, Len Small Levee, Little River Diversion Channel, Land Degradation, Levee Breach

1. Introduction

Historically, the Mississippi River flowed southwest of the current city of Cape Girardeau, Missouri [1]. However, glacial meltwaters and seismic activities allowed the Mississippi River to cut a channel through the bedrock controlled upland between Thebes, Illinois and Commerce, Missouri approximately 15,000 yr ago [2]. The ancient Mississippi River Valley and Big Swamp (Missouri) then served as a relief valve when the modern Mississippi River was above flood stage. In the late 1880s the Missouri land owners and farmers south of both Commerce and Cape Girardeau built earthen levees (**Figure 1**) to block the floodwaters from entering the ancient Mississippi River Valley and the Big Swamp.

In 1905, the Missouri Little River Drainage District (LRDD) was organized to divert the Ozark Plateau runoff water from the Big Swamp so the swamp could be drained, timbered, cleared and farmed. The LRDD diversion channel and embankment diverted the runoff water from the Little River to the Mississippi River south of Cape Girardeau and north of the Thebes Gap. This finally made it possible to drain the swamp, remove the timber from the Big Swamp and clear the land of stumps for agriculture. However, little attention was given to what happened to the diverted runoff water, which after 1915 increased the Mississippi River flow between Cape Girardeau, Missouri and Helena, Arkansas. The additional Ozark Plateau runoff water contributed to the Great Flood of 1927 which breached levees between Cairo, Illinois and the Gulf of Mexico and killed over 800 people. While the primary source of the 1927 floodwaters was the Ohio River valley watershed; however, the runoff from the 400,000 ha Ozark Plateau watershed with shallow to bedrock and steep sloping soils added to the Lower Mississippi River peak height of the 1927 flood.

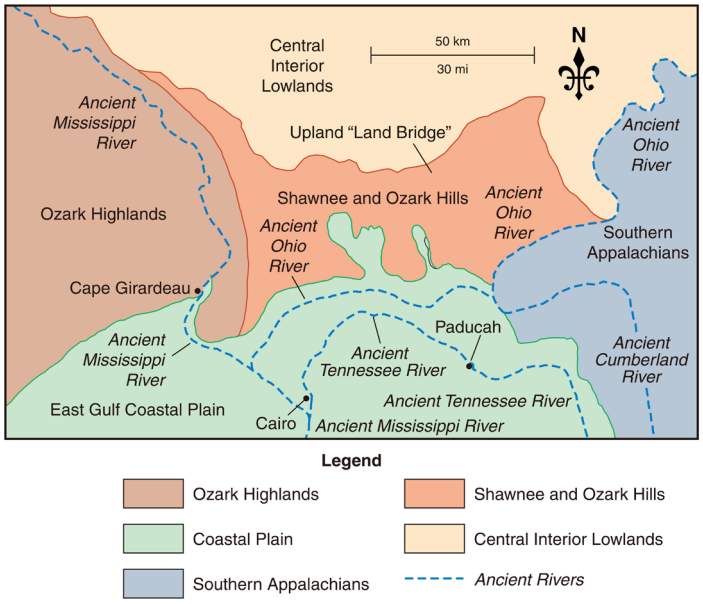

Figure 1. Location of the Ancient Ohio and Ancient Mississippi Rivers. Reprinted with the permission from the Soil and Water Conservation Society. Was figure 2 in Journal of Soil and Water Conservation 71:13A-19A.

From 1915 to 1943 the Illinois farmers on Dogtooth Bend in Alexander County experienced increased flooding and crop loss. They organized a Levee and Drainage District levee (Illinois Drainage Law authority) and built a levee to prevent their land from flooding annually. The Len Small levee did protect the peninsula land for the next 50 years. However, the levee failed in 1993 and resulted in extensive soil and crop damage including a new channel, a crater lake, many gullies and huge sand deposits. The levee was repaired, however, it breached again in 2011 with floodwaters extending the new short-cut channel. The levee was repaired and the crater lakes, gullies and thick sand deposits were filled in or removed. The Len Small levee failed in 2016 and the rapidly flowing floodwaters extended the 1993 channel, damaged the soils and prevented most of the Dogtooth area from being cultivated. This time the levee was not repaired in part because the USACE cost-benefit ratio was too low. The total repair cost was estimated to be $16 million with a $3 million dollars local match required. In 2017, 2018 and 2019 floodwaters continued to flow through the Len Small levee breach and the floodwater bypass channel was extended by the river into and across Dogtooth Bend peninsula. The agricultural land could no longer be cultivated as a result of the floodwaters, crater lakes, channel, gullies and thick sand deposits covering hundreds of hectares of peninsula land. After 2016, most local farmers were not able to continue to farm their land and some even had to sell their farm equipment.

The primary objectives of this paper are: 1) to explain, based on the alluvial parent material and soils present on Dogtooth Bend peninsula, why Len Small levee, Alexander County, Illinois, US will continue to breach during major flooding events if repaired in current location and to the previous height and 2) to develop a new combined raised causeway and levee system which will provide a Mississippi River floodwater bypass, be sustainable, encourage a land use change for land already eroded by the 1993, 2009, 2011, 2016, 2017, 2018, and 2019 floodwater which created a bypass channel and gullies and land covered by thick sand deposits from past flooding events and 3) restore the degraded highway road beds, protect remaining Dogtooth Bend farmsteads and farmland that have not yet been degraded and provide floodwater storage during major flooding events at the confluence of the Mississippi and Ohio Rivers.

1.1. Missouri Drainage District Farmers Block Floodwaters from Flowing into the Big Swamp and the Ancient Mississippi River Valley

Prior to the late 1880s, the Mississippi River had 4 major natural overflow or floodway areas near the confluence of the Ohio and Mississippi Rivers (Big Swamp southwest of Cape Girardeau, Missouri; south of Hickman, Kentucky; south of Birds Point and extending to New Madrid, Missouri and Dogtooth Bend south of Thebes, Illinois). Eventually all 4 Mississippi River overflow areas were blocked by levees to protect agricultural and public lands. The Big Swamp

and ancient Mississippi River Valley was blocked by Missouri drainage district farmers in the 1880s (Figure 2) and later by the 1915 Little River Drainage District (LRDD) diversion and channel [3]. By 1926 the Hickman overflow area or bypass, which extended into Kentucky and Tennessee, was blocked by the federal frontline levee. The Birds Point—New Madrid floodway was blocked by an earthen levee before 1926. After a levee breach in 1927 the New Madrid floodway

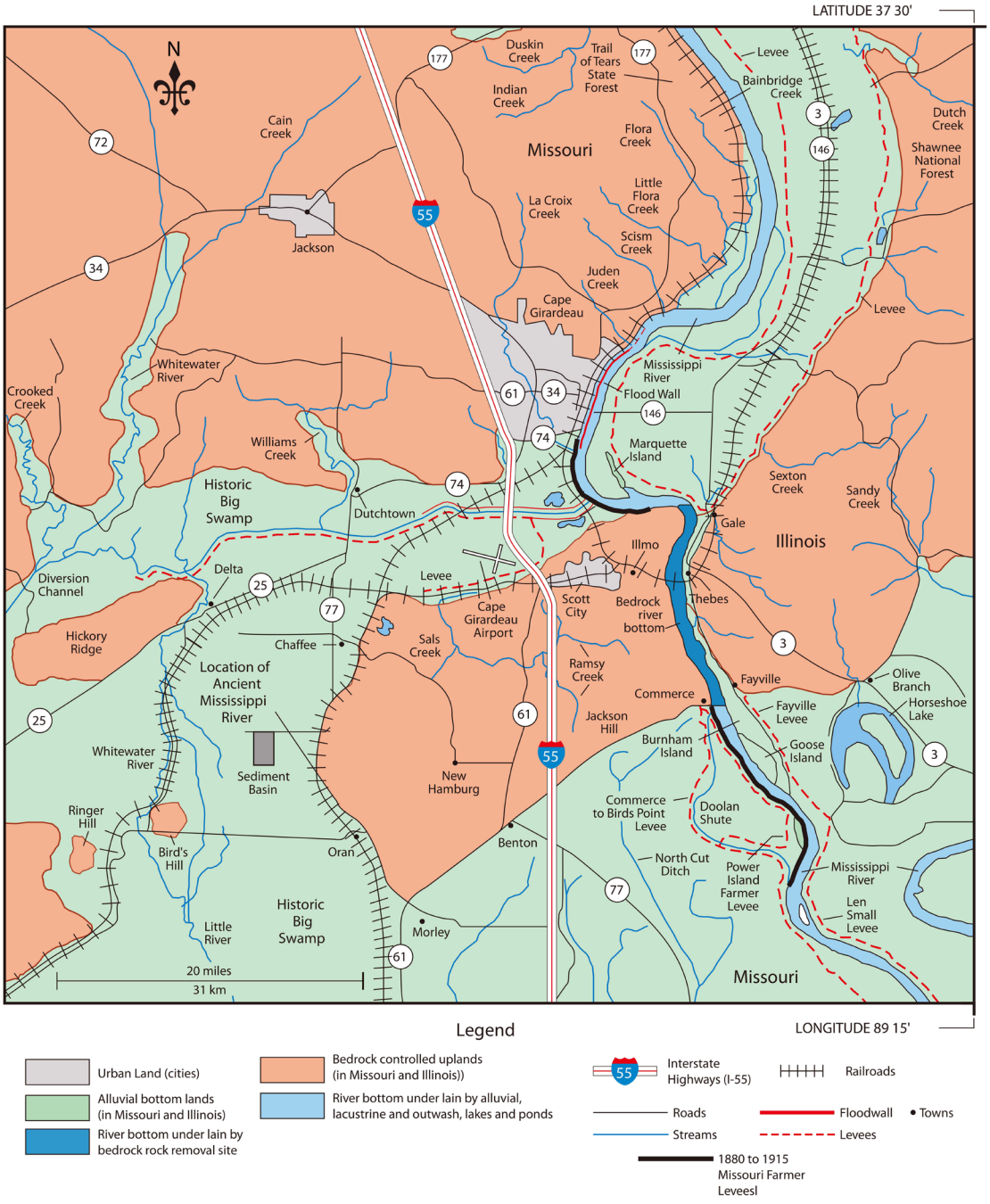

Figure 2. Location of the late 1880s Missouri farmer levees and historic Big Swamp, Ancient Mississippi River pathway and Thebes Gap. Reprinted with the permission from the Soil and Water Conservation Society. Was figure 15.2 in the book, Managing the Mississippi and Ohio River Landscapes.

with both a frontline and set back levee was built between 1928 and 1932. The Dogtooth Bend peninsula (Illinois) floodwaters were blocked by a levee south of Thebes in 1943. After the 1980s the USACE developed an extensive system of levees and wing dikes throughout the upper Mississippi River. These river training structures including structures on Mississippi River at Dogtooth Bend, have reduced overall channel capacity and increased major flood stage by up to 4 meters [4]. Without access to these flooding relief valves the Mississippi River will continue to challenge the federal frontline and local levee and drainage district levees (**Figure 3**), grounded on outwash and alluvial materials, and other

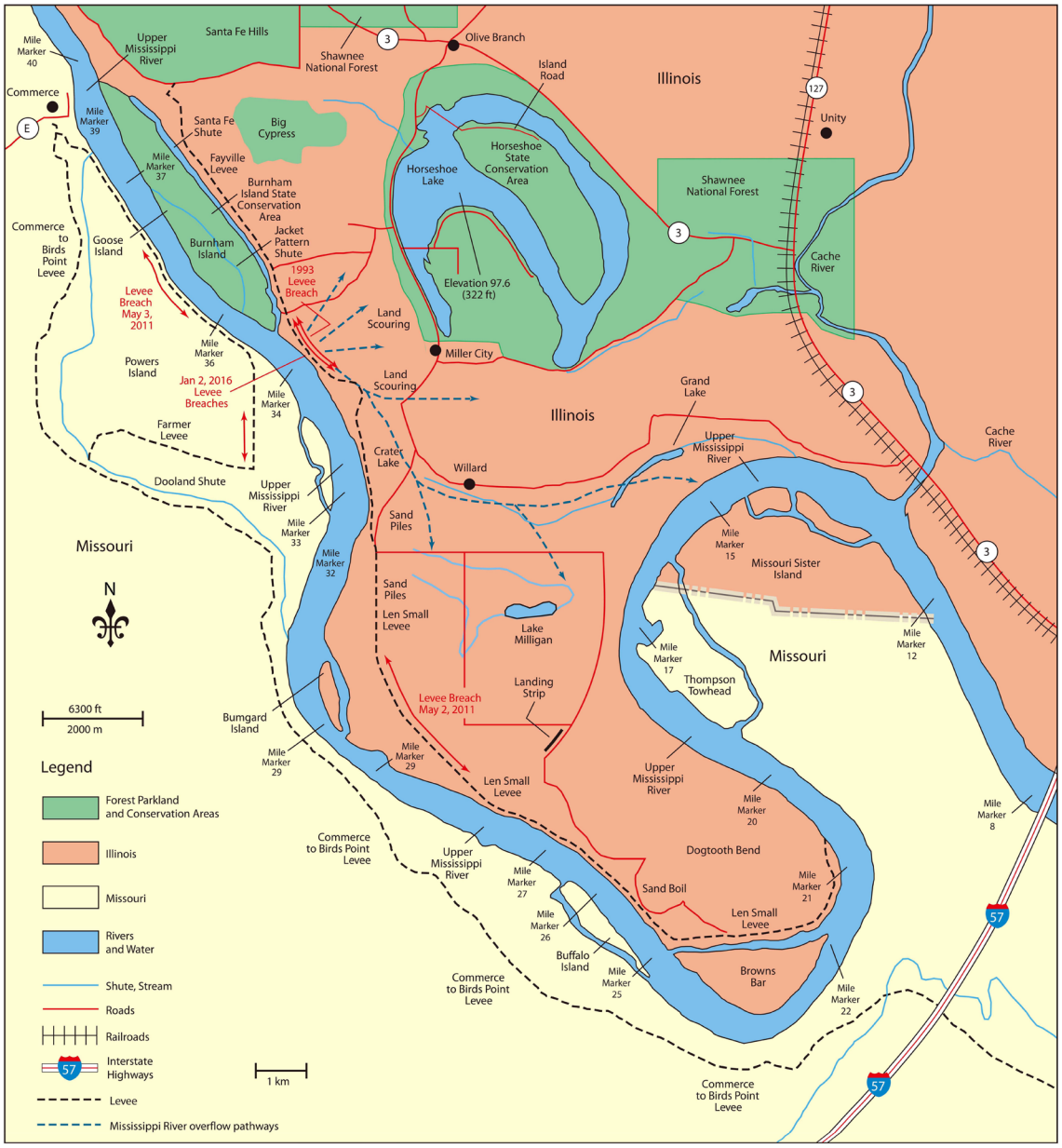

Figure 3. Dogtooth Bend peninsula showing the narrow distance between Illinois and Missouri drainage district levees. Reprinted with the permission of the Journal of Soil and Water Conservation, 2016. 71: 140A-146A. Was figure 1.

river training structures which have increased the magnitude and frequency of Dogtooth Bend peninsula flooding and contributed to district and farmer levee breaches. The Len Small levee first breached in 1993 after extensive wing dike construction on the adjacent Mississippi River between Commerce, Missouri and Cairo, Illinois.

Olson and Morton [1] recommended three alternatives to USACE at a Mississippi River Commission (MRC) public hearing to address the Len Small levee breaching problem. The first alternative was to repair the 2016 Len Small levee breach, the second alternative was to proactively construct a diversion channel or by-pass from mile marker 33 to 15, and the third alternative was to create a new Mississippi River navigation channel where the bypass floodwaters currently flow. None of these options were implemented. Instead a notch dike or barrier was created in front of the 165 m Len Small levee breach. Dogtooth Bend became a floodwater storage area during the floods of the 2016, 2017, 2018 and 2019. The degraded farmland on Dogtooth Bend has for the most part been abandoned as a result of the craters, channels, gullies and extensive sand deposition. The remaining farmsteads have earthen berms to keep the floodwater out. However, the remaining farmers and land owners were trapped in their homes for weeks at a time since 2016 whenever the Mississippi River was above flood stage and the land and roads were covered by floodwaters. Farmland which could be cultivated prior to 2015 is now non-arable. The land use has permanently changed as a result of the decision not to repair the Len Small levee breach in 2016. The landowners remaining on the peninsula are unable to leave without compensation for the damaged land and loss of their livelihoods. We now suggest that the Dogtooth Bend land south and west of the Miller City to Olive Branch road be used for a floodwater bypass and as a Mississippi River floodwater storage area. The existing Miller City road should become a raised causeway, converted into an earthen levee, with a floodway by-pass or diversion created just southwest of the proposed causeway for floodwaters to pass over the Dogtooth peninsula between mile markers 33 to 15 (**Figure 3**). Any floodwater overflow could be stored on Dogtooth Bend peninsula, which could become a wetlands, conservation and forestry area and produce marketable timber in future years. Any remaining infrastructure would have to be removed and wells and sewer systems environmentally capped by new managing authority after the purchased by FEMA at a fair market value or leased or enrolled in perpetual programs at negotiated pre-2015 farmland fair market value.

During glacial times (15,000 B.C.) the glacial meltwaters and seismic activities centered at New Madrid, Missouri allowed the modern Mississippi River to cut a channel through the bedrock controlled upland (**Figure 2**) south of Cape Girardeau and near the town of Thebes, Illinois. The Thebes cutoff shortened the Mississippi River navigation distance to the Gulf of Mexico by 80 km. The ancient Mississippi River valley was approximately 48 km to the west [2] of the current pathway and remained as a relief valve when the river was at flood stage [1]. The floodwaters would enter the higher ancient Mississippi River valley and

flowed into the Missouri Big Swamp which drained south via Little River and St. Francis River [3]. The Big Swamp also received runoff water from the Ozark Plateau [5] and the Francois Mountains northwest of Cape Girardeau (**Figure 2**). The runoff and floodwaters made it difficult to drain, clear and farm the Big Swamp. Early attempts to drain and cultivate the 400,000 ha Big Swamp failed periodically.

Initially in the late 1880s the farmers in the Ancient Mississippi Valley south of Cape Girardeau, Missouri and south of Commerce, Missouri (**Figure 2**) built earthen levees to block floodwaters of the modern Mississippi River from entering the ancient Mississippi River valley which permitted agricultural use of some of the alluvial soils. However, the runoff from the Ozark Plateau and the Francois Mountains was sufficient to maintain the Big Swamp. These earthen levees may have breached or been topped during major flooding events and could have contributed to the Big Swamp.

In 1905 the Little River Drainage District was created. The goals were to divert the Ozark Plateau runoff water (**Figure 4**) and to drain the swampland. By 1915 a Little River Diversion channel and levee was built [3] and it diverted the runoff water to the Mississippi River just south of Cape Girardeau and north of the Thebes gap (**Figure 2**). Historically this runoff water drained into the Big Swamp, the Little River and the St. Francis River which flowed into the Mississippi River (**Figure 5**) near Helena, Arkansas [5]. This division channel resulted in a significant amount of runoff waters entering the Mississippi River over 300 river miles to the north of Helena [1] and contributed to the flooding peaks after 1915 including the Great Flood of 1927. The additional runoff water from the Ozark Plateau caused a pool of water north of the Thebes gap to back up 14 km into the LRDD Diversion channel and raised the flooding peak height in the Thebes Gap, increased the energy of the floodwaters when discharged from the bedrock controlled Thebes Gap and spread out in the ancient Ohio River valley to the south of Commerce (**Figure 2**). This resulted in flooding of agricultural lands on both sides of the river.

Missouri land owners built levees which by 1915 re-routed the Ozark Plateau floodwaters into the Mississippi River just north of the Thebes Gap. In 1943 the Illinois farmers in Alexander County built the Len Small district levee (**Figure 2**) to protect their farmland and farmsteads from floodwaters. In the 1960s the levee was extended. The Len Small breached in 1993 and was repaired. The Len Small levee failed in 2011 and was restored. When the levee failed again in 2016 (**Figure 6**) it was not fixed due in part the extent of the land and levee damage, and the estimated total cost was $16 million with a local required match of $3 million. Since 2016 the Dogtooth agriculture land flooded every year with tens of hectares of land eroded and hundreds of hectares land and ditches and roads covered with thick sand deposits (**Figure 7** and **Figure 8**). The floods of 2017, 2018 and 2019 all entered and covered most of Dogtooth Bend and continued to make agriculture production (**Figure 9**) on Dogtooth Bend difficult or impossible.

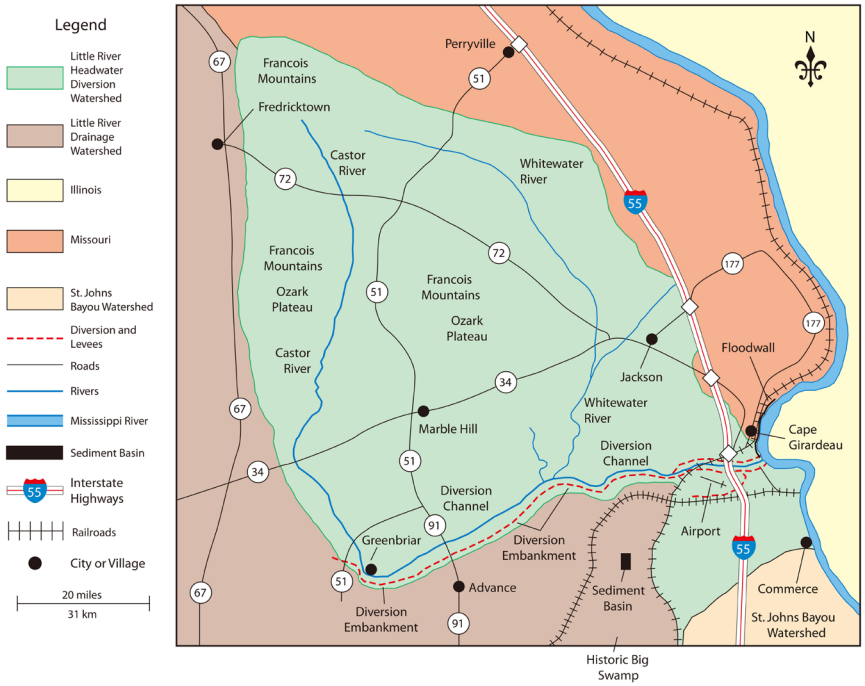

Figure 4. Ozark Plateau and Little River diversion. Reprinted with the permission of the Journal of Soil and Water Conservation, 2016. 71: 13A-19A. Was figure 1.

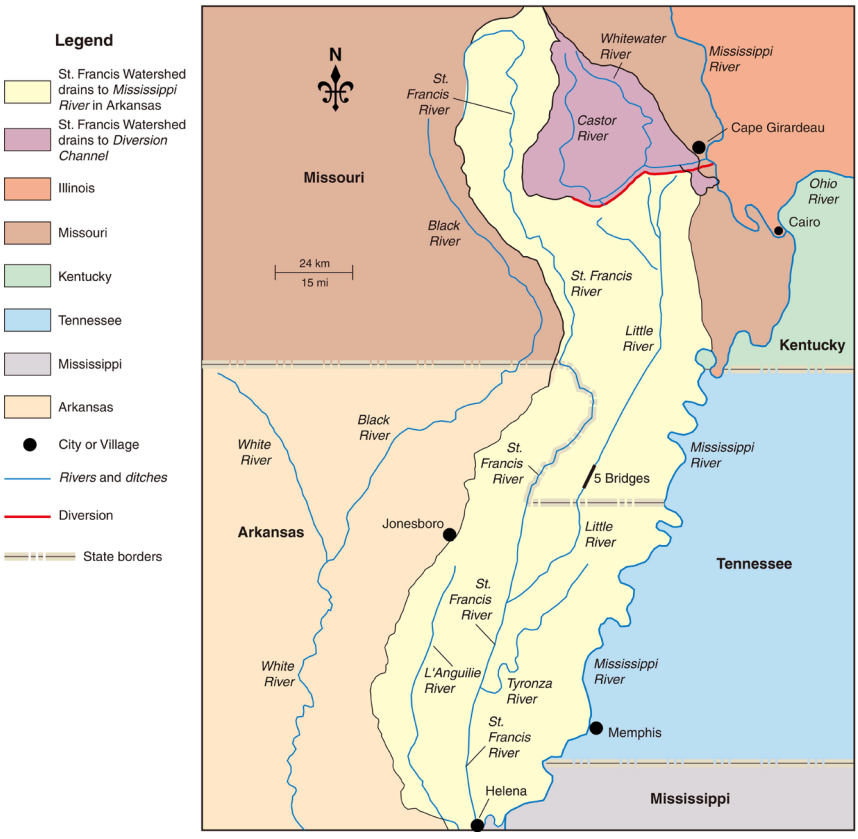

Figure 5. Little River diversion channel and Little River and St. Francis River. Printed with the permission from the Soil and Water Conservation Society. Journal of Soil and Water Conservation 71:13A-19A. Was figure 2.

Figure 6. Len Small levee breach after the 2016 flood which was not repaired.

Figure 7. Sand dunes and roadway as a result of the 2016 flood which required graders to push back the sand overlying the road.

Figure 8. The flood of 2016 covered fields with sand which made cultivation impossible.

Figure 9. Tilling around gullies in an attempt to farm the land which proved to be impossible with no crop yields after 2016.

1.2. Navigation on Mississippi River Compromised

In 2019 the flooding resulted in 6 empty runaway barges (Figure 10) passing through the Len Small breach (Figure 6) and knocking down power lines, crossing a road and coming to rest on an irrigation system in a farmer's field. As noted in Olson and Morton [6] the Mississippi River is cutting 5.8 km channel across Dogtooth Bend and trying to cut off 24 km of the current Mississippi River navigation channel (between mile marker 33 and 15) (Figure 3). To date the barge company has been only able to remove 4 of the barges from the farmer fields. The other two still remained (Figure 10) in September of 2019. Previous testimony at the Mississippi River Commission public hearings by Drs. Olson and Morton and by Jeff Denny, the Alexander County highway engineer, and 3 year lobbying efforts by the Farm Bureau have failed to get the 2016 Len Small levee breach repaired as more and more Dogtooth Bend farmers are going out of business. However, the runaway barges which traveled through the rock piles, notch dike and Len Small breach indicate that the Mississippi River navigation channel has now been compromised.

Congressman Mike Bost, Illinois 12th district which includes Alexander County and Dogtooth Bend met with the USACE Under Secretary R.D. James to see if the project, after 3 years, could be moved up on the USACE priority list. Currently the Len Small levee breach repair ranking is low based on flooding criteria and its cost-benefit ratio. Congressman Bost hopes to get the damages to the navigation channel included. Mississippi River navigation requires a stable channel without cross currents for commercial barges. If the existing river channel is not maintained around Dogtooth Bend peninsula the shipping on barges will have to be replaced by trucks which would add to the transportation costs. The criteria change, even if made, will probably not happen until late 2020 and perhaps be part of the next USACE authorization bill.

1.3. Impact of the Little River Drainage District Diversion Channel, Embankments and Ditches on Mississippi River between Cape Girardeau, Missouri and Helena, Arkansas

A historical and regional scale perspective of the effects of the LRDD diversion

Figure 10. Runaway barges that passed through the Len Small breach during June-July 2019 flood. Picture taken by Lois Wright Morton.

and ditches on the Little River and St. Francis River drainage (ancient Mississippi River Valley) on both the Arkansas bottomlands [5] and the Mississippi River is needed. Prior to 15,000 B.P. the ancient Mississippi River drained into the Big Lake Wildlife area and the 16-km wide Arkansas bottomlands (ancient Mississippi River Valley) (**Figure 5**) to the west of the current Mississippi River. The ancient Mississippi River flow included water from the ancient Ohio, ancient Tennessee, and ancient Cumberland rivers (**Figure 1**).

The Mississippi River re-aligned (**Figure 2**) as a result of seismic activity and meltwaters from glacial events. Between the creation of the Thebes gap 12 - 15,000 years B.P. and until 1915 all the Francois Mountains and Ozark Plateau runoff water (Castor River, Crooked Creek and Whitewater River) and any surface overland water from the Little River flowed into the Big Swamp of Missouri, the Arkansas bottomlands (**Figure 5**) and the St. Francis River. After the Civil War (1860s) and before 1915, Missouri farmer levees were constructed to block Mississippi River floodwater (**Figure 2**) from entering the ancient Mississippi River valley both south of Cape Girardeau, Missouri and south of Commerce, Missouri [5].

After the Little River Diversion and the adjacent levees were constructed (1913 to 1924), the Upper Mississippi River could no longer return to its ancient pathway when the river was above flood stage (**Figure 2**). The LRDD diversion and adjacent levee blocked Mississippi floodwater from flowing into the Big Swamp (**Figure 2**) located in the ancient Mississippi River valley and subsequently draining south toward Arkansas. Further, after the construction of the Diversion in 1915, the 288,000 ha headwaters area (Ozark Plateau and the Francois Mountains) runoff no longer flowed into the Little River basin and instead was diverted into the Mississippi River south of Cape Girardeau (**Figure 4**). The 208,000 ha of Little River bottomlands south of the Headwater Diversion did continue to drain into Arkansas during periods of high rainfall and local flooding [5]. In addition, runoff from 0.28 million ha of adjacent agricultural and for-

est land in the 0.48 million ha of the Little River watershed would have drained into Big Swamp and eventually into Arkansas and the St. Francis River and flowed into the Mississippi River at Helena, Arkansas.

The construction of the Headwaters diversion channel did reduce the St. Francis River volume by diverting the runoff from a 400,000 ha Missouri watershed away from the Arkansas state border by reducing the Little River flow at the confluence of the Little River and St. Francis northwest of Helena, Arkansas (**Figure 5**). The diversion diverted Ozark Plateau upland runoff water directly into the Mississippi River and away from the Little River and St. Francis drainage basin. When the Little River drainage ditches were being constructed, the Arkansas land owners and politicians claimed that the Little River volume would be increased 5 to 10 fold and result in the ruination of Arkansas bottomlands. This estimate did not seem to account for the Headwaters (Francois Mountain and Ozark Plateau) runoff water being diverted directly into Mississippi River south of Cape Girardeau (**Figure 4**). After 1915 the Ozark Plateau runoff was no longer draining into the Big Swamp or the Little River [5]. The ditches did enhance the drainage of the Little River basin and increased the water velocity and volume into Arkansas bottomlands during the initial ditch construction which drained the ponded and flooded Big Swamp.

However, after 1915 the Little River [5] no longer carried any of the Headwaters (Francois Mountains and Ozark Plateau) runoff (a reduction per year of about 287,647 ha m/yr assuming 20% soil retention in mountains of the 1.2 m of annual rainfall) and most likely carried about 51,313 to 102,626 ha m/yr of additional ditch drainage water from the 208,000 ha of Little River bottomlands through the Little River ditches (assuming a 60% to 80% soil retention in bottomlands of the 1.2 m of annual rainfall). The 280,000 ha of adjacent agricultural land and forest land in the Little River watershed may have contributed another 74,009 to 148,018 ha m/yr of flow into Arkansas through the Little River drainage ditches (**Figure 5**).

Some of the Ozark Plateau Headwaters runoff (if no Headwaters Diversion channel) would have historically flowed into the Big Swamp and perhaps been evapotranspired by swamp vegetation or infiltrated into the soil profile, so not all of it would have flowed across the Arkansas border as either overland and subsurface flow [5]. Both the surface and subsurface flow through the alluvial materials to the south and Arkansas would however have been greater as a result of the Little River ditches. This would still have been much less than the Headwaters (Francois Mountains and Ozark Plateau) runoff total from 288,000 ha which was redirected away from the Little River, thus reducing the volume of water it carried southward.

1.4. Impact of the LRDD Diversion on Illinois, Missouri and Kentucky Bottomlands

The role of levees and diversions in protecting agriculture lands and the impacts of breaching of Len Small levee on the agricultural land soil resources was stu-

died by Olson *et al.* [3] [5]. These researchers addressed the impact of the 1913-1916 Little River Diversion on the Mississippi River peak flow and impact on 360 river miles of Illinois, Missouri and Kentucky agricultural bottomlands between Cape Girardeau, Missouri and Helena, Arkansas [5]. The Little River Diversion contributed significantly to the Mississippi River peak flow during the great Flood of 1927 which caused levees to breach and the loss of hundreds of lives on the lower Mississippi River.

The construction of the Little River Drainage District (LRDD) Headwater Diversion channel [3], one of the most remarkable engineering feats of the 20th Century, expanded agricultural production into the alluvial bottomlands of Missouri. This channel diverted runoff water originating in the Ozark Plateau and Francois Mountains directly into the Mississippi River just south of Cape Girardeau (**Figure 4**). Located in the northeastern corner of the LRDD, the Headwater Diversion isolates the upland drainage basin from the lower historic Mississippi River floodplain to the south and prevents overloading the lower drainage system constructed to drain the low-gradient, slow moving bottomland waters. Before the Diversion channel and a series of large levees were constructed, floodwaters from the Castor and Whitewater Rivers and Crooked Creek regularly spilled into the bottomlands and created the Big Swamp unsuitable for agriculture and human settlement [5]. The Headwater Diversion system consists of three large basins, ~80 km of channels, and 72 km of levees designed in the early 1910s by the LRDD to divert and temporarily store ordinary and flood waters running off 288,000 ha of uplands and mountains. Today, the long Headwaters Diversion (**Figure 4**) helps drain and protect 0.48 million ha of agricultural lands in southeast Missouri from internal seasonal flooding and Mississippi River backflow at flood stage [5].

However, the diversion of upland water into the Mississippi River has led to increased peak flows of the Mississippi River between Cape Girardeau, Missouri (where the LRDD Headwater Diversion drains into Mississippi River) and Helena, Arkansas (where the St. Francis River drains into the Mississippi River). This increase in river height during high water conditions contributed to the need for construction of the Len Small (built in 1943)-Fayville (built in 1969) farmer levee in Illinois (**Figure 2**) and the Commerce farmer levee in Missouri (built in 1880s), both designed to protect agricultural lands from flooding. When the Ozark uplands and Francois Mountains experience above average rainfall for extended periods of time they add to the peak river height at the confluence of the Ohio and Mississippi Rivers and increases the chances of Mississippi River levee breaches south of Commerce, Missouri (**Figure 2**).

1.5. Levees and Other Engineering Structures

The Mississippi River basin is controlled and regulated by the river engineering structures including earthen levees [1], locks and dams [7] and wing dikes (**Figure 11**) step up dikes (**Figure 12**) on the main stem, notched dikes [8] and

dams on the tributaries. These dams on the Missouri River [9], a Mississippi River tributary, and other river engineering structures have reduced the magnitude of peak floods, increased base discharges, and reduced the seasonal variability of intra-annual discharges of water and sediment. This extensive system of river engineering structures throughout the basin provides protection from intermediate magnitude floods. However, these engineering structures have reduced the overall channel capacity by up to 4 m for the major floods and resulted in 4 m higher peak heights [4]. Levees and other river-engineering structures in the Mississippi River basin have also provided many socioeconomic benefits. These modifications have resulted in year around navigation, hydropower, flood control, bank stabilization and recreation. Unfortunately these structures have also transformed the hydrologic, sediment transport, geomorphic, water-quality and ecologic characteristics of the Mississippi River and its delta.

Figure 11. Wing dikes, river training structure, used to protect the river bank from erosion and to maintain the navigation channel. Picture taken by Lois Wright Morton.

Figure 12. Step up dikes on Mississippi River to prevent sediment from accumulation along the shoreline. Picture taken by Lois Wright Morton.

1.6. Impacts of 2011 Len Small-Fayville Levee Breach on Private and Public Illinois Lands

The Len Small levee was constructed in 1943 between mile marker 21 and mile marker 35 (Figure 3). The Fayville levee was constructed in 1969 between mile marker 35 and mile marker 39 and connects to the Len Small levee and to the bedrock controlled Thebes gap to the north [10]. The Len Small-Fayville levee is located south of where the Diversion channel outlets to the Mississippi River. The Len Small-Fayville is a private landowner levee built by the Farmer Levee and Drainage District on the southern Illinois border near Cairo in Alexander County to protect private and public lands from 20-year floods [11]. The combined Len Small-Fayville have 46 km of levees protecting 12,000 to 24,000 ha of Illinois farmland and public land, including the Horseshoe Lake Conservation area (Figure 2).

Changes in land use and agricultural intensification have altered the floodplain hydrology and an increasingly variable climate with a 37% increase in precipitation across the upper Midwest over the past 50 years have affected the volume and speed of runoff throughout the Upper Mississippi River basin. The extensive systems of US Army Corps of Engineers (USACE) and private farmer or district levees from the upper Mississippi River near Cape Girardeau, Missouri, southward confine the river and protect low-lying agricultural lands, rural towns, and public conservation areas from flooding [1].

The floods of 1993, 2011 and 2016 severely tested these levee systems, challenged public officials and landowners to make difficult decisions, and led to extensive damage to crops, soils, buildings, roads and homes (Figure 13 and Figure 14). One of these critical levees, the Len Small-Fayville, failed during this flood and created breaches where fast-moving water scoured farmland, deposited sediment, and produced gullies and a crater lake.

The flood protection offered by the combined Len Small-Fayville levees is important to the landowners, homeowners, and farmers in southwestern Alexander County, Illinois. However, the Len Small-Fayville levees are not the

Figure 13. The 2019 high water mark on building. Picture taken by Lois Wright Morton.

Figure 14. Flood damaged home purchased by FEMA along the 1993 channel. Picture taken by Lois Wright Morton.

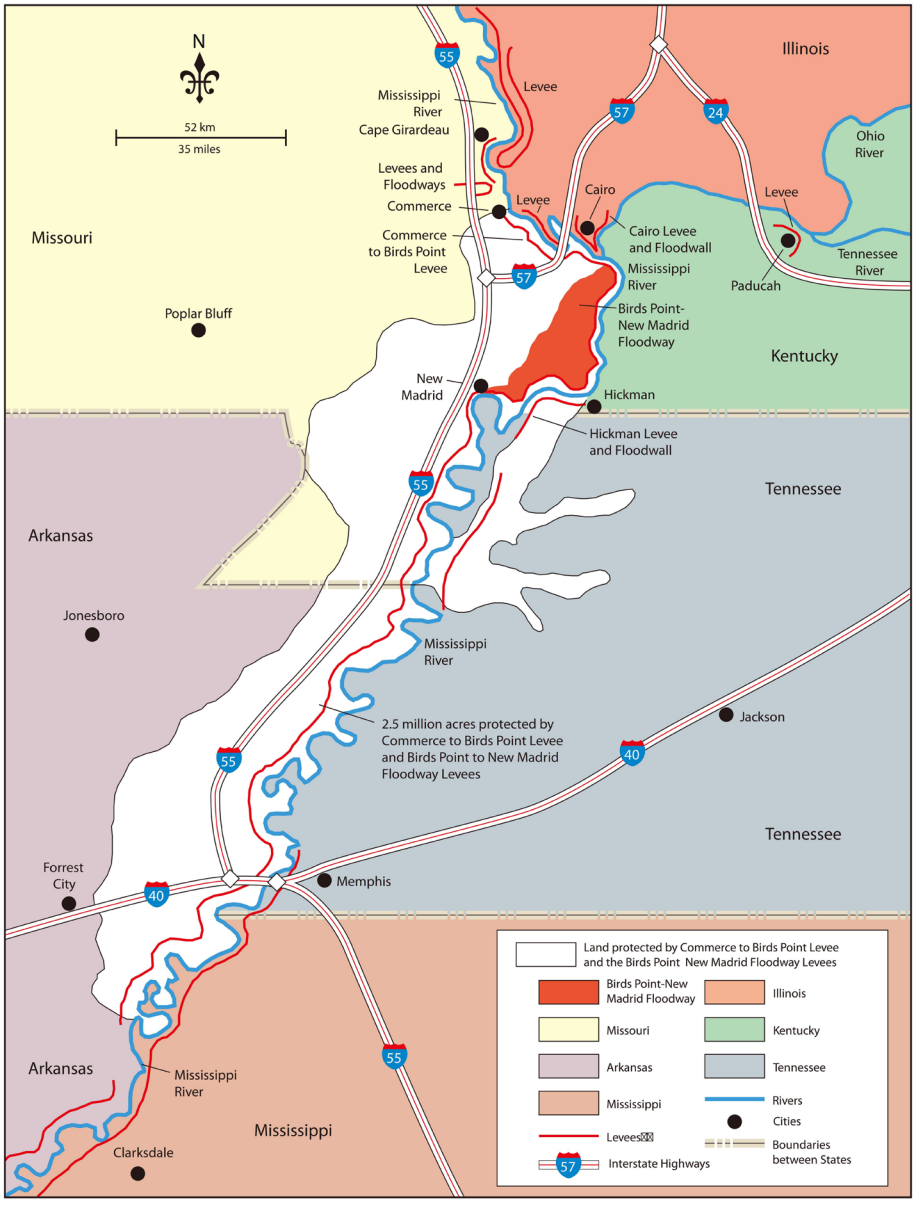

Figure 15. Mississippi River bottomland protected by levees which is a sentence "Map by Mic Greenberg".

mainline levees which control the width and height of the Mississippi River. The controlling mainline levees are the frontline Cairo levee located in Illinois at the Ohio and Mississippi river confluence and the Commerce to Birds Point levee, 54 river miles south of the Headwater Diversion channel in Missouri. These two frontline levees, by design, are much higher and stronger than the Len Small-Fayville levees [1]. The Commerce to Birds Point levee connects to a setback levee on the west side of the Birds Point-New Madrid Floodway, which extends the protection another 52.8 km to the south where it joins the frontline levee at New Madrid, Missouri, further extending the protection of 0.8 million ha of Bootheel and Arkansas bottomlands—much of it highly productive agricultural land. A failure in 2011 of the Hickman (Kentucky) levee on the east side of the Mississippi River would have resulted in the flooding of 68,000 ha of protected bottomlands in Tennessee and Kentucky (**Figure 15**).

The floodwater height and pressure on the Commerce to Birds Point and Birds Point to New Madrid frontline levees have increased over the years during Mississippi River flooding events with the construction of Len Small-Fayville levees and with a strengthening of the mainline levee near Hickman, Kentucky (**Figure 15**). This had the effect of adding more water, narrowing the Mississippi River corridor, and removing valuable floodplain storage areas for floodwaters [11]. The Len Small levee breach on the Mississippi River occurred on the morning of May 2, 2011 and flooded agricultural lands and homes just hours before the New Madrid floodway was opened to relieve the pressure on the confluence area levees and floodwall.

1.7. Commerce, Missouri Farmer Levee and Drainage District Breach

When the Ozark uplands and Francois Mountains experience above average rainfall for extended periods of time in 2016, the additional runoff transported by the Diversion channel increases the chances of farmer levee breaches south of Commerce on both sides of the Mississippi River. Like the Len Small levee in Illinois, the additional volume and height of water contributed to the need for the construction and maintenance of the Commerce farmer levee to protect Missouri agricultural bottomlands from flooding.

During the Great Flood of 2011, the Commerce Farmer Levee and Drainage District between the USACE Commerce to Birds Point levee and the Mississippi River breached about 3 km south of Commerce, Missouri. This breach occurred when a sand boil undermined the earthen Commerce Farmer levee shortly after the New Madrid floodway was opened on May 2nd [8]. Floodwaters poured through the Commerce farmer levee breach in the early hours of May 3, 2011 and were not discovered until morning light by local residents and eventually covered with floodwater the entire 2040 ha of agricultural lands between the Commerce to Birds Point frontline federal levee and the Commerce farmer levee (**Figure 2**). The floodwaters left behind a thin organic-clay coating when it

drained off. The entire 2010 winter wheat crop drowned. This area drained by the middle of June (2011) and soybeans were planted. The Commerce farmer levee was temporarily repaired in 2011 and fully repaired in the drought year of 2012. The cost of the levee repair raised the Commerce Farmer Levee and Drainage District assessment from $12.5 per ha to $62.5 per ha in 2013 [1].

1.8. Battered by Floods the Confluence of the Mississippi River and Ohio River Needs More Water Storage Capacity

Additional temporary water storage capacity (**Figure 15**) is required near the confluence of the Ohio and Mississippi rivers to handle peak flows and to avoid the flooding that occurs during extended periods of above-average rainfall. Levees, diversions and floodways built over the past 140 years have allowed land conversion from wetlands to agriculture in southeast Missouri and Mississippi River bottomlands of surrounding states. These pieces of infrastructure have substantively altered the hydrologic cycle of the region. The Little River levee and Little River Drainage District Headwaters Diversion channel, built in the 1910s, permitted draining the 0.48 million-ha Big Swamp in southeast Missouri (**Figure 2**). However, it also had the unintended consequence of increasing the peak flow of Mississippi River water south of Cape Girardeau through the Thebes gap and south to Helena, Arkansas, a distance of 360 river miles (**Figure 5**).

The increase in Mississippi River peak flow as a result of LRDD diversion placed additional river pressure on levees and led to increased flooding, especially during the floods of 1927, 1937, 2011, 2016 and 2019. The Kentucky, Illinois and Missouri farmers' and landowners' response to the additional volume and height of the Mississippi River from the diversion channel valley, and the prevention of the Mississippi River floodwaters from flowing into the ancient Mississippi River valley and Big Swamp, was to build floodwalls, levees and berms around farmsteads (**Figure 16**) [1].

Figure 16. Berm or levee around home. Picture taken by Lois Wright Morton.

After a 1915 flood, Cape Girardeau had to build a floodwall to protect the city. The floodwall construction was started in 1939 and completed by 1949. The city turned the maintenance over to the USACE. Likewise, after the Great Flood of 1927, Cairo built a floodwall, strengthened levees and USACE created the Birds Point-New Madrid floodway. Missouri farmers built the Commerce Farmer levee closer to the river than the frontline federal level, which failed in 2011. In addition, Kentucky farmers built the Hickman levee—strengthened later by the US Army Corps of Engineers (USACE)—which has not failed. Illinois farmers re-built the Fayville-Len Small levee that breached in 1993 and 2011 [8]. It breached a third time on Jan. 2, 2016, when the Thebes river gauge reached a record 15.5 m or 4.5 m above flood stage. Climate scientists predict a continued pattern of extreme rainfall events in the upper Mississippi River region.

1.9. Mississippi River Could Make Dogtooth Bend Peninsula in Illinois an Island

The receding floodwaters of the Mississippi River in January, 2016 left behind barren sand dunes (**Figure 7**) on southern Illinois farmland reminiscent of the windswept dunes of the movie *Lawrence of Arabia*. Large sand deposits up to 1.2 m deep (**Figure 7**) covered nearly 800 ha of farmland near Miller City, Illinois in the Dogtooth Bend peninsula [8]. Rainfall almost three times above average in November and December, 2015 over Missouri (Francois Mountains) set in motion record flooding. The Cape Girardeau river gauge exceeded the 1993 record at 14.9 m and led to the breaching of both the Commerce and the Len Small levee on January 2, 2016. The Thebes river gage also set a record; making these two main stem Mississippi River gages the only new flood records in 2016. Runoff water from the Ozark uplands (**Figure 4**) rapidly drained into the Headwaters diversion south of Cape Girardeau to confluence with the near-record Mississippi floodwaters flowing south of St. Louis. Constrained at the Thebes gap, the height of the Mississippi River rose as it pushed against the bedrock controlled banks (**Figure 2**). However, once past the gap, the river released its energy against the earthen levees of the Len Small, breaching and cutting deep crater lakes and gully fields on the farmland the levee was designed to protect. After the river breached the levee at mile marker 34, the fast-moving water scoured the landscape and then followed an old meander channel across the narrow neck of Dogtooth Bend peninsula and reconnected with the Mississippi River at mile marker 15 (**Figure 3**).

1.10. Road Degradation

The most recent flood in 2019 on the Mississippi River flowed through the unrepaired levees resulting in substantial Alexander County highway destruction. The remaining roads look like they were degraded by seismic activity or caught in a landslide. The most extensively damaged area (**Figure 17**) was between Olive Branch and Miller City just south of the entrance Horseshoe Lake. The

Figure 17. Extensive road damages caused by the 2019 flood. The road is located between Miller City and Olive Branch and just south of entrance to Horseshoe Lake.

berms were removed from a 1 km section of pavement and the road bed was washed out with pavement broken and in some places had 1 meter deep drop offs in the road and on the edges (Figure 17). The entire road base will need to be reconstructed before re-paving. Considerable amount of trees and drift wood accumulated on the road and was piled up and/or was burned. Other sections of the road had berms removed by the flowing water and had 1 m or more drop offs which required vehicle drivers to avoid pulling onto the former berms (Figure 17). The road had to be closed after the floodwater receded and was not opened during the rest of 2019. The Alexander County highway and road reconstruction and repairs will cost millions of dollars and will probably be the focus of future litigation.

The 1993 and 2011 levee breaches resulted in the flooding of 6800 to 14,000 ha with an unknown number of buildings damaged and removed after the 1993 flood and 169 structures damaged during the 2011 flood [8]. The Federal Emergency Management Agency awarded the State of Illinois an US$8.7 million grant that required a state match to purchase these structures beginning in April of 2015, but only a few homes were purchased before July 1, 2015. After the Illinois legislature failed to pass a state budget in July of 2015, the state matching funds were not available and the program could not be fully implemented before the 2016 flood. In 2018 an Illinois State Budget passed and the purchase of structures resumed. By not repairing the 2016 Len Small breach, Dogtooth Bend has become the defacto floodwater storage area. In the early 1990s there were 100 homes on Dogtooth Bend. After the 2011 flood FEMA began purchasing many of the remaining homes (Figure 14). Today there are only a few and most with berms around the homes or farmsteads (Figure 16).

Levee breaches and land scouring are not new events for this region, occurring in 1993, 2011, 2016, 2017, 2018 and 2019; and there is a likelihood these farmlands will experience similar events in the future since the 2016 Len Small levee breach was not repaired. Each event deepens and extends the meander channel (Figure 18) when the floodwaters take a 5.8 km shortcut and threaten to permanently reroute the Mississippi River leaving Dogtooth Bend peninsula an

island. This would result in landowners and farmers in the 6000 ha Dogtooth Bend area no longer have road access to their land if the Mississippi River re-aligns naturally. The MRC/USACE and the Len Small Levee and Drainage District are partners in managing the river landscape and need to develop and evaluate alternative strategies for addressing the river-land relationships in the Dogtooth Bend area. Several alternative courses of action were presented. While each alternative needs to be evaluated and negotiated, they offer a start in visioning different scenarios to guide preparation for future [5]:

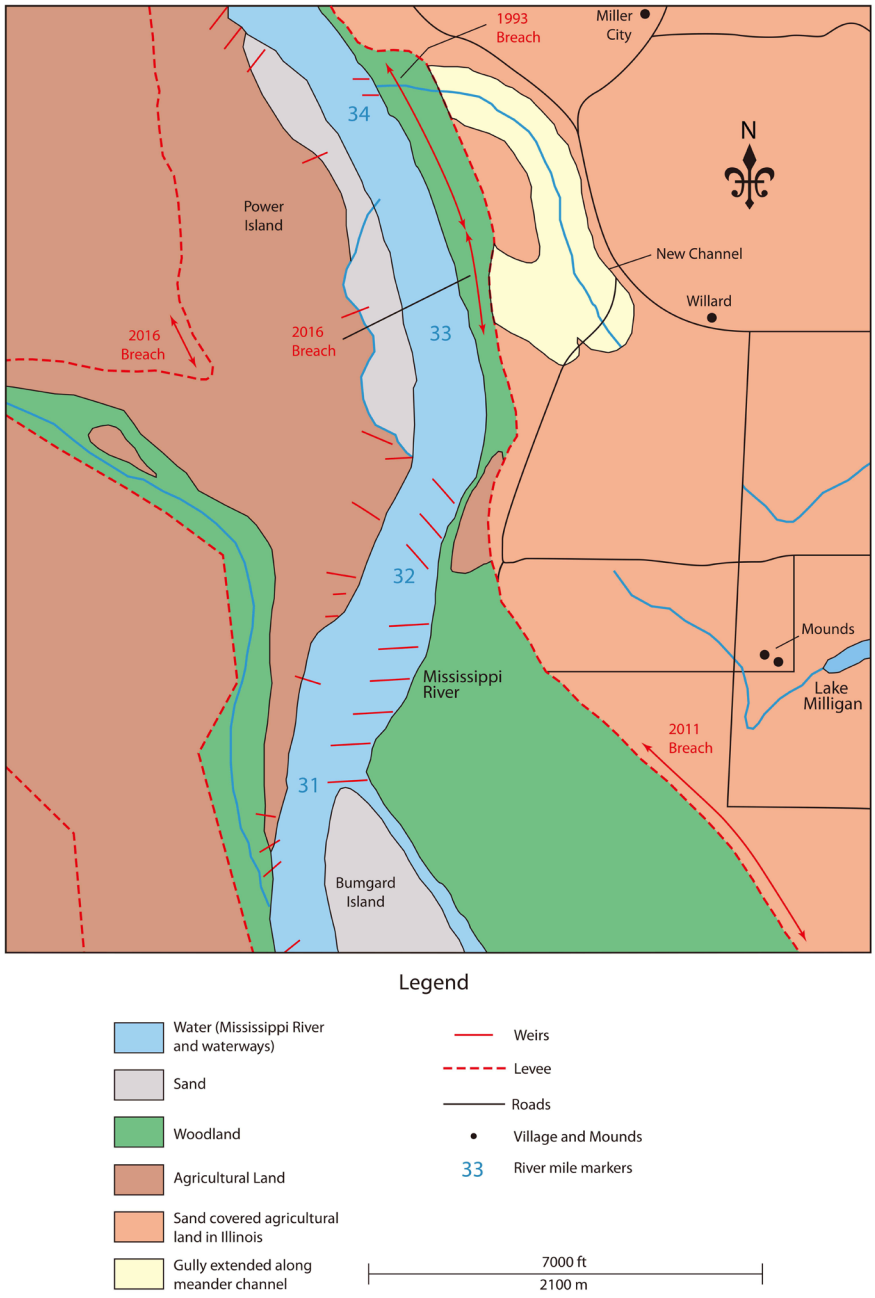

Figure 18. Len small breach channel started in 1993 and extended in 2011, 2016, 2017, 2018 and 2019. Map by Mic Greenberg.

The first alternative is to continue as in the past, to repair the Len Small levee [8]. This could impede and delay the eventual and natural tendency of the Mississippi River to take a shortcut and re-align its downstream course. This alternative is a near-term fix. There is a high likelihood at some future date that another major flood event will occur and the Len Small levee will breach again, creating new craters and gullies and flooding farmland. Since 1993, barriers, wing dikes, step up dikes, notch dikes and bank stabilizing efforts along the Mississippi River banks in this area have been put in place three times. Although these structures have slowed the water and bank erosion, they have not prevented the breaches of 2011 and 2016 and are likely inadequate to deter levee damage during future high water events.

A second alternative [8] is to proactively construct a diversion channel, with embankments on both sides, where the old meander channel is currently located (between mile marker 32 and 33 and 15 and 16). During high water periods, the channel would temporarily redirect excess Mississippi River floodwaters across the neck of Dogtooth Bend peninsula and allow the water to exit back into the river between mile marker 15 and 16 (**Figure 3**). The existing Mississippi River 2.7 m channel between mile markers 33 and 15 would be maintained for navigation. A bridge or boat dock would need to be built over the diversion channel to allow access and recreational hunting, fishing, bird watching, and other uses. Hydrologic studies, environmental, economic and social acceptability analyses would be necessary to fully evaluate the investments needed and land use impacts on the region.

A third alternative [8] is to assist the Mississippi River re-alignment tendency and construct a 1 km wide new Mississippi River navigation channel through the 10 km short cut between mile marker 33 and 15 where the Mississippi River is already cutting with each major flooding event. The USACE could accelerate this process even more by making this overflow channel between mile markers 33 and 15 (**Figure 3**) the main stem river navigation channel. This would also require thorough hydrologic, environmental, social and economic assessments.

An elaboration of the third alternative is to create a new Mississippi River channel across Dogtooth Bend peninsula with low rise levees on each side of the navigation channel and set back about 1.1 km. This would make Dogtooth Bend an island in Illinois [8]. This new Mississippi River channel would replace the current Mississippi River navigation channel between mile markers 33 and 15 and make Dogtooth Bend south and west of the navigation channel into a floodwater storage area. Dogtooth Bend Island could be used for floodwater storage during major flooding events since it is 4800 ha in size, which along other nearby islands and adjacent land not levee protected within the current main line federal and farmer levees, would enlarge Mississippi River flood storage capacity. If the new Mississippi River channel is used for navigation, the current Mississippi River shipping channel length would be reduced by 24 km. Land owners would need to be compensated if the Dogtooth Bend area is used for a

new Mississippi River channel and for floodwater storage.

Historically, the Mississippi River bottomlands have experienced hundreds of Mississippi River re-alignment events and course changes in the river. The large number of oxbow remnants and interior old meanders (e.g. nearby Horseshoe Lake area) are evidence of the past and harbingers of the future. Federal, state and local managers of the Mississippi and Ohio River landscapes can impede or delay the Mississippi River's natural re-alignment using river training structures but attempts to maintain the current alignment even if the Len Small levee breach was repaired will eventually fail even with these structures. The mighty Mississippi River will eventually win as it always has and time is on the river's side.

2. Summary and Conclusions

In conclusion, there has been a tendency to underestimate the impact of the LRDD Headwaters Diversion runoff water that was re-directed into the Upper Mississippi River south of Cape Girardeau, into the Thebes gap and Dogtooth Bend and away from Little River, St. Francis River and Arkansas. After the Little River Drainage District ditches initially drained the flooded and ponded swampland, the volume of water the basin carried annually was reduced by as much as 39,471 to 160,353 ha m/yr [3] and increased the volume of water flowing passed Dogtooth Bend by the same amount. The LRDD Headwaters Diversion and adjacent levees also blocked floodwaters of the current Mississippi River from entering the ancient Mississippi River Valley during major flooding events and resulting in floodwaters staying in Mississippi River and increasing the peak heights at Cape Girardeau, Thebes and Dogtooth Bend.

Prior to the construction of the Farmer (Len Small-Fayville) levee in Illinois and the Farmer (Commerce to Birds Point) levee in Missouri, the Mississippi River at flood stage was 16 km wide between mile markers 39 to 15. The creation of these two district farmer levees in Illinois and Missouri restricted the Mississippi River floodplain to less than a 2.4 km width (**Figure 3**) and increased the peak height of the river during flooding events that occurred after 1943. The resulting increased velocity and river height at both levees as well as downstream levees at a greater risk of failure. The USACE/MRC mission includes the maintenance of the mainline levees which protect Cairo and the Illinois, Missouri, Kentucky and Arkansas bottomlands and the maintenance of navigation on the Mississippi River. The USACE cannot strengthen the existing Len Small-Fayville levee without increasing the risk of losing their own mainline levees (Cairo levee and floodwall, the Hickman levee and floodway, the Commerce to Birds Point levee and the New Madrid Floodway frontline levee).

If the Cairo floodwall and levee were to fail, it would put nearly 2800 residents and 400 structures at risk. If the Commerce to Birds Point levee, or Hickman levee or the New Madrid floodway front line and setback levees were to fail 800,000 ha in Missouri, Kentucky, Tennessee and Arkansas bottomlands could

be flooded with both crops and soils damaged (**Figure 15**). The opening of the New Madrid Floodway, built between 1928 and 1932, can be used to reduce the pressure and peak height by as much as 0.6 m per day on confluence area levees. The floodway was used in 1937 and 2011. There is a need for additional floodwater storage capacity [5] in the confluence area of the greater Ohio and Mississippi rivers (**Figure 15**). A regional effort on all sides of the Ohio and Mississippi Rivers is needed to strategically identify floodplain areas that could provide temporary water storage and policy incentives for landowners of low-lying bottomlands to profitably invest in crops and income alternatives.

Climate scientists predict a continued pattern of extreme rainfall events in the upper Mississippi River region. This suggests that unexpected above-average rainfall events in the Ohio and Mississippi River basins will continue to increase the frequency of extreme flooding events on these Great Rivers. As the frequency of intense precipitation events increase, the current Illinois and Missouri farmer levee systems are likely to repeatedly fail if repaired to previous height and strength. The current solution to prevent flooding in the Dogtooth Bend area is not working [8]. Combinations of land use changes and new structures are needed to address the problem. The Dogtooth Bend area south and west of Olive Branch to Miller City road may need to be converted into the more permanent floodwater storage area. The current land owners would need to be compensated for the land use change or for the ownership of their land. Whatever solutions are chosen there will need to be a significant investment of human and financial resources to prepare for the future and in some cases the land use would likely shift from agriculture to other land uses.

Construction of the levees, diversions and floodways and the land use conversion from wetlands to agriculture for the last 140 years, have substantively altered the hydrology of the region. The 1915 LRDD Diversion channel flow added to the Mississippi River depth in the Thebes gap (**Figure 2**) which reduces the need for dredging in the bedrock-lined and 2.7 m deep shipping channel. However, it also has the unintended consequence of increasing the volume of flow and peak height of Mississippi water south of Cape Girardeau through the Thebes gap and south to Helena, Arkansas, a distance of approximately 360 river miles. The Kentucky, Illinois, Tennessee and Missouri farmers and land owners' response to the additional volume and height of the Mississippi River from the Diversion channel was to build the Hickman, Len Small-Fayville and Commerce farmer levees. The Len Small-Fayville levee failed in 1993 and both the Commerce farmer and Len Small-Fayville levees failed during the 2011 flood. Over time the Kentucky landowners were able to get the USACE to strengthen the main line Hickman levee which did not fail in 1993, 2011, 2016 or 2019.

One of the most difficult issues the USACE, state, levee districts and local citizen partner's face is how to reconcile the differential geographic impacts levees and diversion channel have upstream and downstream on land use and flood risk. Leveed systems have allowed agricultural intensification [5] but have led to

loss of natural floodplain ecosystems that can store excess water for short periods of time and reduce and slow down water discharge. As a result, benefits to one locale can quickly translate into increased risk and vulnerability downstream when the river begins to rise. These are difficult tradeoffs which must be evaluated and negotiated among partners considering not only economic efficiencies but also social impacts and damages to the soil and water resources that are the basis of land value and use. Drained, fertile soils protected by levees support root and plant growth necessary for high levels of agricultural productivity. However, levee breaching can quickly erode and degrade soil resources resulting in changes in composition and structure and loss of soil functions, lower the soil productivity and the land's agricultural productive capacity and in some cases making it unsuitable for that use. The agricultural productivity of the land in Dogtooth Bend southwest of the proposed causeway has declined to almost zero. In contrast, including the basin floodways of un-leveed wetlands to flood during high water will much less likely result in severe soil degradation.

3. Recommendations

We propose the following modified options be considered [8]:

1) Expand the Dogtooth Bend peninsula floodwater storage area in the greater Ohio-Mississippi river confluence area. There is an urgency to strategically identify the area that should not be leveed so as to protect those areas that are leveed from future failure. This is critical to the economic, social, and environmental well-being of communities in Missouri, Illinois and Kentucky. Replace the current degraded Miller City to Olive Branch road with a raised causeway and the road east from Miller City to Route 3. All the former agricultural land south and west of the combined levee and raised causeway (**Figure 19**) would become a floodwater storage area with a land use changed to wetlands and as a wildlife habitat and or lowland forestry.

2) Coupled with increasing un-leveed floodplain storage area is the need to increase research and policy incentives for private and public landowners of these low-lying lands to profitability invest in diverse crops, wetlands and income alternatives that are resilient (able to absorb the shock) to seasonal and intra-seasonal flooding. Targeted research and conservation planning are needed to develop viable agricultural and non-agricultural uses and public payments to private land owners may be needed for ecosystem services that benefit the larger society.

3) Strengthen regional relationships on both sides of the Ohio and Mississippi Rivers at the greater confluence region to increase understanding of the impacts of different flood control and river training structures on the river and the interior landscape. Increasing the up- and down-stream citizen knowledge and understanding of these impacts will not resolve all issues but can improve recognition of the necessity of making these very difficult trade-offs so the entire region does not lose its viability. Without stronger relationships and collaborative

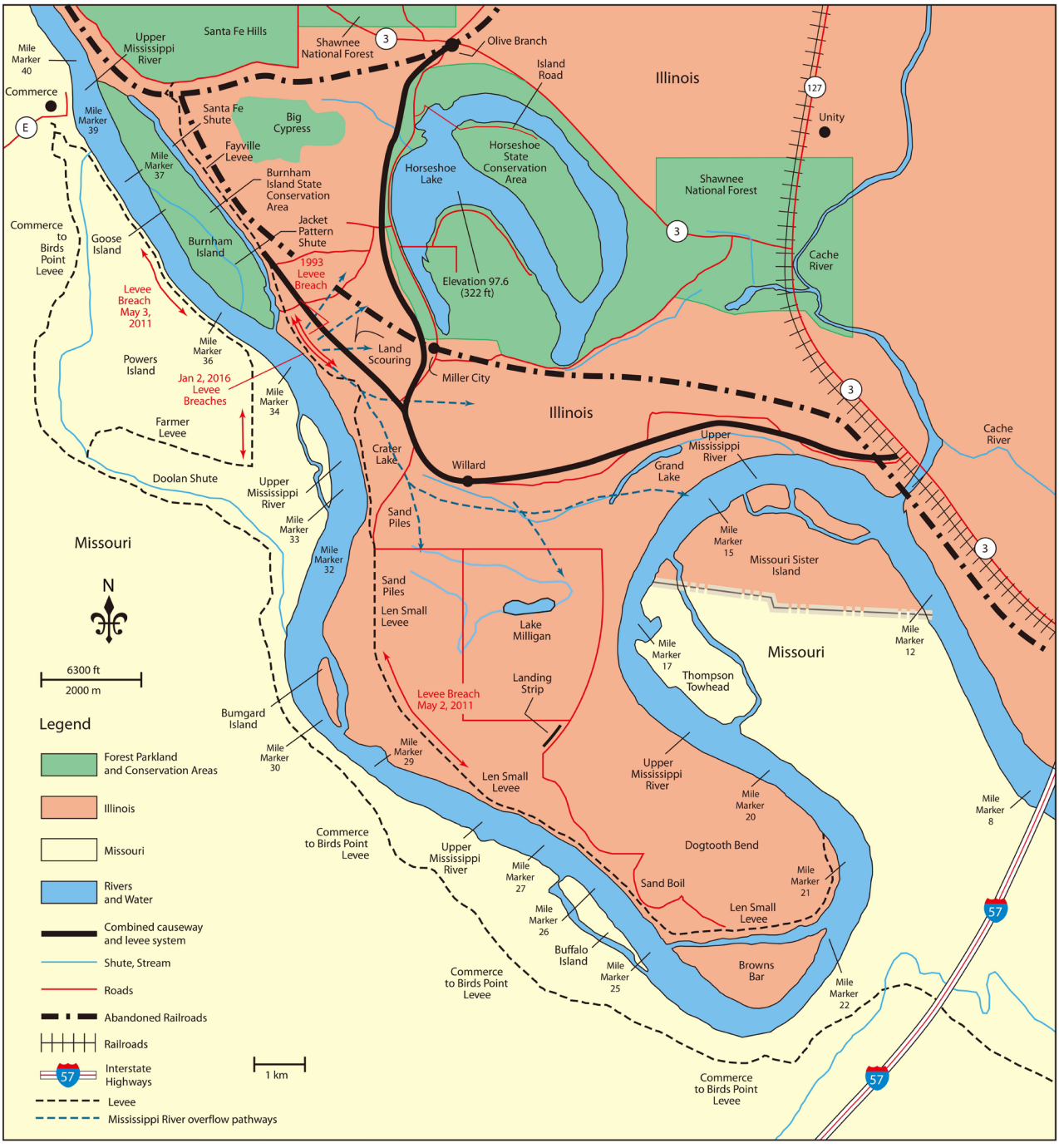

Figure 19. Dogtooth Bend peninsula showing the location of the proposed combined levee and causeway. Map by Mic Greenberg.

partnerships, Missouri, Illinois and Kentucky residents will compete for higher and more expensive levees rather than find cooperative solutions.

4) If the Len Small-Fayville and/or Commerce farmer levees are allowed to fail and not repaired, these bottomlands could be converted to uses that benefit from and are able to absorb seasonal and intra-seasonal temporary flood conditions, providing increased storage in the greater width for the Mississippi River between the mainline levees in Illinois and Missouri. This option could include

state and federal buy out, investments in research to make non-leveed floodplains profitable, landowner incentives to change uses, or some combination. To those heavily invested in leveed agricultural uses, this proposal will be difficult to accept and will require creative solutions and investments by regional partners with high levels of engagement of land owners, home owners and farmers exploring a variety of scenarios.

5) In the event the 2016 Len Small levee breach is not repaired, the agricultural land and roads on Dogtooth Bend peninsula will continue to degrade with each subsequent flooding event. If the levee breach is not repaired then we recommend the road from Route 3 to Miller City and the road from Miller City to Olive Branch be raised to become a causeway (**Figure 19**). This highway project could probably be funded from local and state highway funds and in partnership with the Mississippi River Commission and the USACE since the causeway will function as a levee and protect the remaining land on Dogtooth Bend peninsula from future Mississippi River flooding. The land south and west of the proposed causeway and east and north of the Mississippi River would become a permanent flood water storage area. It is also recommended that USACE create a floodwater bypass started near Mississippi River mile markers 35 and 33, across Dogtooth Bend peninsula to mile markers 17 to 13. The existing Len Small levee from the bedrock underlain upland south of Thebes gap (**Figure 2**) to approximately mile marker 36 would be strengthen (perhaps a cement wall) and extended and re-aligned to the south and east of the causeway (**Figure 19**). The Mississippi River navigation channel would remain in the current location but USACE would need to install river training structures near the mouth of the floodwater bypass to maintain the existing navigation channel.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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