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UPDATE OF ARKANSAS' NONPOINT SOURCE POLLUTION WATERSHED RISK MATRIX

REVISED
July 18, 2022

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Prepared for

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NRD Project 18-102

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1.0 INTRODUCTION

In the early 2000s, a collaborative learning matrix (risk matrix) was developed for the Arkansas Nonpoint Source Task Force to use in prioritizing eight-digit hydrologic unit code (HUC8) watersheds for the 2004 update of the Arkansas Nonpoint Source Pollution Management Plan. The risk matrix provides a numeric score that is used for ranking each of the 58 HUC8 watersheds that are partially or completely within Arkansas. The scoring system is designed to rank watersheds as candidates for focusing further efforts for addressing nonpoint source pollution. The assessment components (i.e., the types of data and information that are used) and the scoring system for the risk matrix were modified in 2010 as part of the Nonpoint Source Pollution Management Plan update at that time (Hancock et al. 2010).

This report presents an update to the 2010 risk matrix using the same general procedure as before, but utilizing the most recent available data and information. The results of this updated risk matrix will be incorporated in the 2023-2028 Arkansas Nonpoint Source Pollution Management Plan.

2.0 OVERVIEW OF PROCEDURE

The overall procedure for developing/updating the watershed risk matrix can be summarized in the following four steps:

1. Various categories of information/data (assessment components) were compiled for each HUC8 watershed. These categories are listed in Table 2.1.
2. A numeric score was assigned for each category for each HUC8 watershed. The possible range for each score is shown in Table 2.1 and the methods for assigning each score are discussed in Section 3.
3. An overall score was calculated for each HUC8 watershed using the following formula:

   Overall score = Category 1 score × Sum of scores for other categories
4. The 58 HUC8 watersheds were ranked according to their overall score and a percentile value was assigned corresponding to the rank. The HUC8 watersheds with rankings between the 80th and 100th percentiles (i.e., the top 12 of the 58 watersheds) were identified as the highest priority watersheds.

Table 2.1. Categories of data/information for watershed risk matrix.

Category	Category name	Subcategory	Score Range
1	Waterbody impairment	None	0-10
2	Designated use impact	None	0-10
3	Biotic impacts	None	0-10
4	Potential human exposure	None	0-10
5	Urban/suburban population	None	0-10
6	Impervious surface area	None	0-10
7	Economic activity	Construction Activity	0-5
		Shale Gas Development	0-4
		Other Mining Activity	0-1
8	Cropland area	None	0-10
9	Livestock and pasture	Pasture	0-5
		Livestock	0-5
10	Unpaved roads	None	0-10
11	Forestry	State Forest	0-2
		Federal Forest	0-3
		Private Forest	0-5
12	Priority of a bordering state	None	0-10

3.0 UPDATED DATA SOURCES

Updated data and information were compiled for each of the categories and subcategories listed in Table 2.1. The most notable change in these data since 2010 is the impairment status of waterbodies, which is documented in the Arkansas Department of Energy and Environment Division of Environmental Quality (DEQ) List of Impaired Waterbodies ("303(d) List"; DEQ 2020b). Other data such as land use, population, and economic activity have changed significantly in some areas of the state since 2010. Wherever possible, updated data were retrieved from the same sources that were used in the 2010 risk matrix in order to provide consistency. For data sources that are no longer available, similar data were identified and utilized.

3.1 Category 1: Waterbody Impairment

Data that were used for this category were from the final 2018 303(d) List (DEQ 2020b) and the GIS maps identifying watersheds that have been designated as nutrient surplus areas by the Arkansas Natural Resources Commission (ANRC).

The scores for Category 1 of the risk matrix were assigned using the procedure described below. This procedure is the same as in Hancock et al. (2010) except for the addition of 303(d) categories 4b and 5alt. As noted in Hancock et al. (2010), waterbodies that were impaired for mercury only were not considered to be impaired for the purposes of the risk matrix. The rationale for excluding mercury impairments was based on difficulties of addressing the impairments due to the influence of natural sources and lack of available data.

- Score = 10: A score of 10 was assigned to watersheds having one or more waterbodies in any of the following 303(d) categories:
  - 4a (impaired with an approved total maximum daily load (TMDL) for the constituent(s) causing the impairment), or
  - 4b (impaired but without an approved TMDL because other management alternatives are expected to result in attainment of water quality standards), or
  - 5alt (impaired but without an approved TMDL because alternative restoration approaches may be more immediately beneficial or practicable in achieving water quality standards).

Note: 303(d) categories 4b and 5alt were not mentioned by Hancock et al. (2010) because no waterbodies in Arkansas had been assigned to those categories prior to the 2018 List. Categories 4b and 5alt were scored the same as 4a because all three categories represent impaired waterbodies for which there is data or information (i.e., a TMDL or some type of plan or approach) that places them at least slightly further along the path towards attaining water quality standards compared to Category 5 waterbodies, which are impaired but without this data or information. The definition for each 303(d) category was taken from DEQ's 2020 assessment methodology (DEQ 2020a).

- Score = 8: A score of 8 was assigned to watersheds with one or more waterbodies in 303(d) category 5 with a priority of "high" (impaired waterbodies for which a TMDL needs to be developed).
- Score = 6: A score of 6 was assigned to watersheds with one or more waterbodies in 303(d) category 5 with a priority of "medium" (waterbodies that are impaired but the impairments may be addressed by either future revisions to the water quality standards or future permit restrictions on point source discharges).
- Score = 5: A score of 5 was assigned to watersheds within areas designated by the ANRC as a Nutrient Surplus Area. A shapefile identifying the Nutrient Surplus Area boundaries was retrieved from Arkansas Geographic Information Systems (GIS) Office (http://gis.arkansas.gov/product/nutrient-surplus-area-polygon/).
- Score = 2: A score of 2 was assigned to watersheds with one or more waterbodies in 303(d) category 5 with a priority of "low", which consists of:
  - waterbodies that are not attaining numeric water quality standards but are supporting designated uses; or
  - waterbodies for which there is insufficient data to determine designated use attainment; or
  - waterbodies that were assessed as unimpaired by DEQ, but were assessed as impaired by EPA.

If a watershed qualified for multiple scores, the highest score was selected. An example is shown in Table 3.1, where the Poteau River watershed had one or more waterbodies in 303(d) category 4a, 303(d) category 5 (both medium and low priority), and in a Nutrient Surplus Area. The final Category 1 score for this watershed was equal to the highest individual score (10). The final Category 1 scores for all 58 HUC8s are shown on Figure 3.1.

Table 3.1. Example of scoring for Category 1.

HUC8	HUC8 name	Individual scores					Final score for Category 1
		303(d) cat. 4a, 4b, 5alt	303(d) cat. 5, high priority	303(d) cat. 5, medium priority	303(d) cat. 5, low priority	Nutrient Surplus Area	
11110105	Poteau River	10	--	6	2	5	10

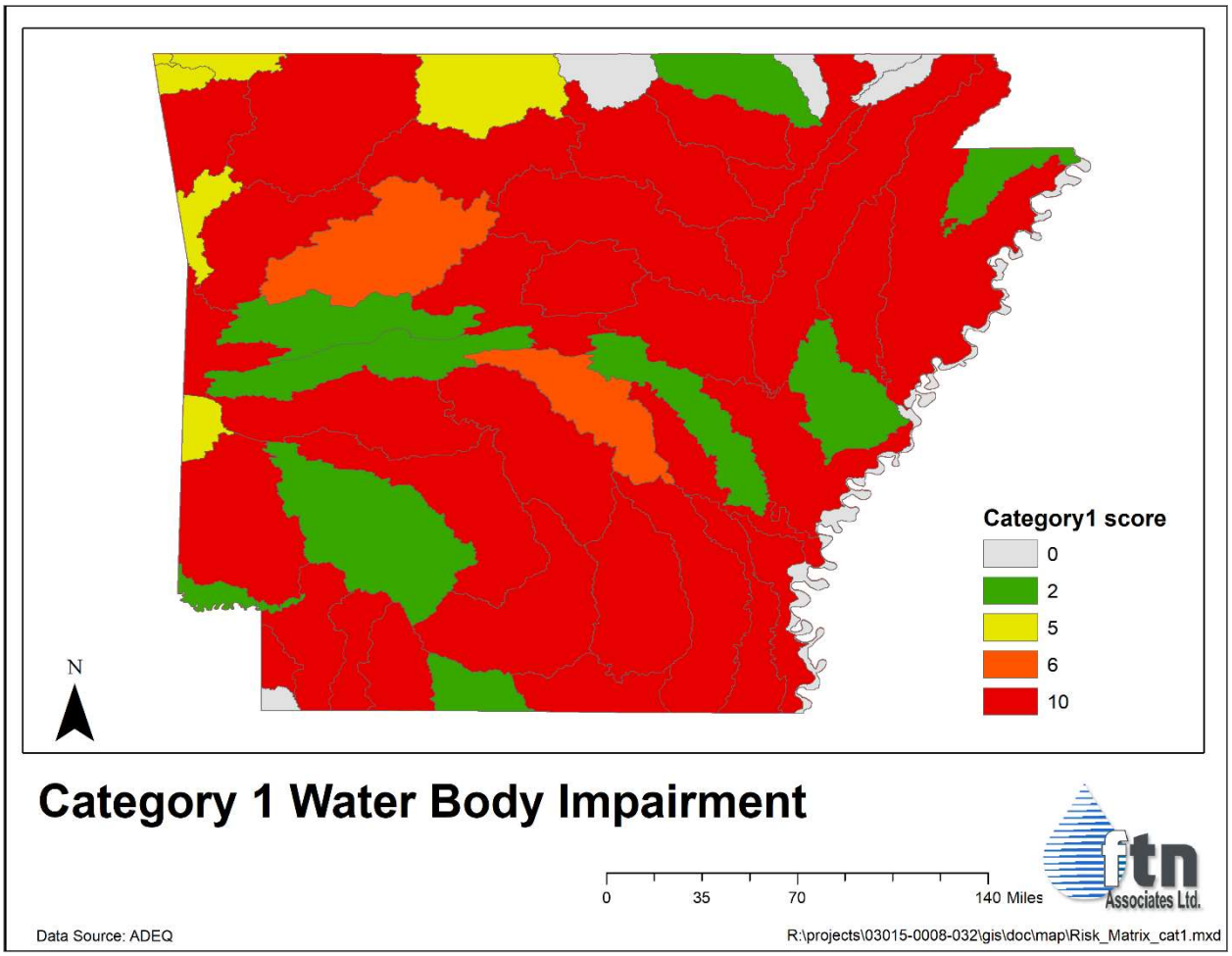

Figure 3.1. Category 1 scores.

3.2 Category 2: Designated Use Impact

Category 2 provides scores based on which designated use(s) has(have) been impacted. Updated data used to determine scores for this category consisted of the following:

- the "Designated Use Not Supported" columns from the final 2018 303(d) List, for waterbodies in 303(d) category 4a and in 303(d) category 5 with high priority; and
- shapefiles that identify Ecologically Sensitive Waterbodies and Extraordinary Resource Waters (published by DEQ, updated 2017; downloaded from the Arkansas GIS Office website).

The scores for Category 2 of the risk matrix were assigned in the same manner as in Hancock et al. (2010):

- Score = 10: A score of 10 was assigned to watersheds with at least one impaired waterbody that is not supporting its designated use of aquatic life (AL), which is equivalent to the fisheries (FSH) designated use in the 2010 risk matrix.
- Score = 9: A score of 9 was assigned to watersheds with at least one impaired waterbody that is not supporting the designated use of either primary contact (PC) or secondary (SC) contact recreation.
- Score = 8: A score of 8 was assigned to watersheds with at least one impaired waterbody that does not support its drinking water (DW) designated use.
- Score = 5: A score of 5 was assigned to watersheds with at least one waterbody designated as an Ecologically Sensitive Waterbody (ESW).
- Score = 4: A score of 4 was assigned to watersheds that contain at least one waterbody designated as an Extraordinary Resources Water (ERW).
- Score = 2: A score of 2 was assigned to watersheds with at least one impaired waterbody that is not supporting its agricultural and industrial water supply (AI) designated use.

If a watershed qualified or multiple scores, the highest score was selected. Table 3.2 shows the L'Anguille River watershed as an example. This watershed had one or more waterbodies not supporting designated uses of aquatic life, primary contact recreation, and drinking water, and there were one or more waterbodies designated as an Extraordinary Resource Water. The final Category 2 score for this watershed was equal to the highest individual score (10). The final Category 2 scores for all 58 HUC8s are shown on Figure 3.2.

Table 3.2. Example of scoring for Category 2.

HUC8	HUC8 name	Individual scores						Final score for Category 2
		AL	PC or SC	DW	ESW	ERW	AI	
08020205	L'Anguille River	10	9	8	--	4	--	10

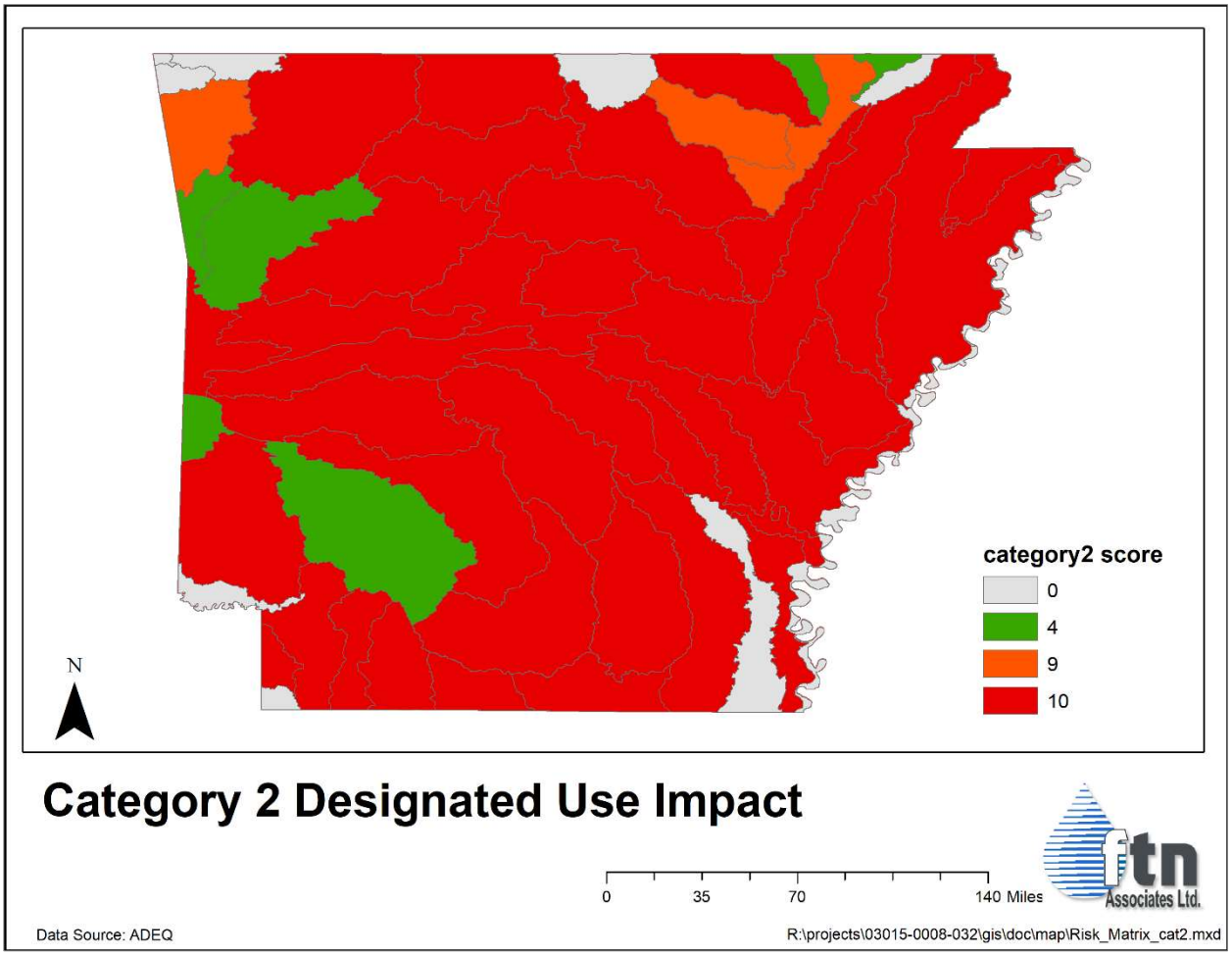

Figure 3.2. Category 2 scores.

3.3 Category 3: Biotic Impact

The scores for this category of the risk matrix were assigned based on information from the "Designated Use Not Supported" and "Water Quality Criteria Non-Attainment" sections in the final 2018 303(d) List. Scores for Category 3 were assigned in the same manner as in Hancock et al. (2010):

- Score = 10: A score of 10 was assigned to watersheds with at least one impaired waterbody that was not supporting its designated use of aquatic life (AL).
- Score = 10: A score of 10 was assigned to watersheds with at least one waterbody that was impaired due to siltation/turbidity (Tb).
- Score = 9: A score of 9 was assigned to watersheds with at least one waterbody that was impaired due to dissolved oxygen (DO).
- Score = 8: A score of 8 was assigned to watersheds with at least one waterbody that was impaired due to priority organics (PO).
- Score = 4: A score of 4 was assigned to watersheds with at least one waterbody that was impaired due to ammonia nitrogen (AM).

If a watershed qualified for multiple scores, the highest score was selected. The final Category 3 scores for all 58 HUC8s are shown on Figure 3.3. All of the watersheds that had impairments due to dissolved oxygen, priority organics, or ammonia also had at least one impaired waterbody that was not supporting its designated use of aquatic life. Therefore, all of the watersheds had a score of either 10 or 0.

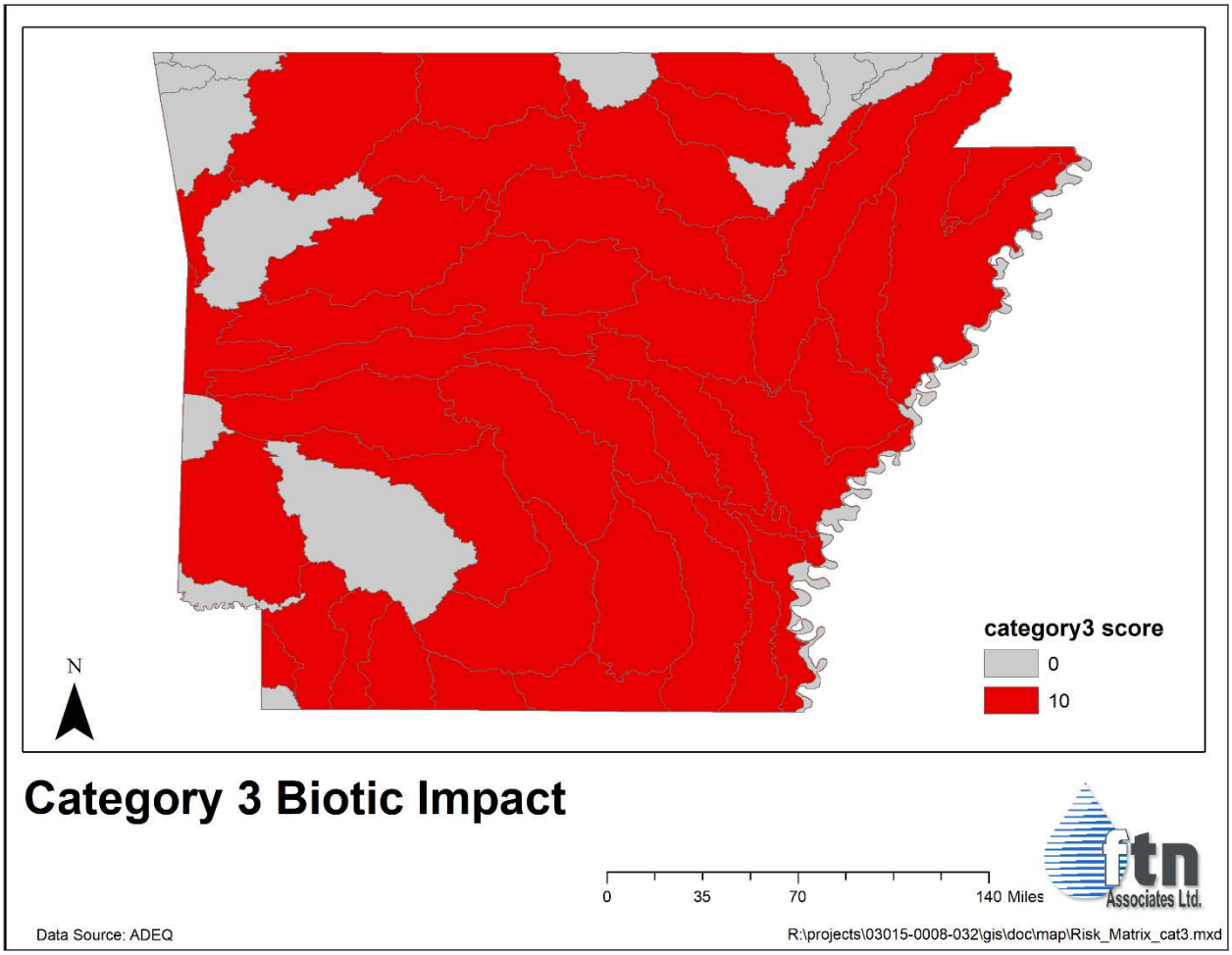

Figure 3.3. Category 3 scores.

3.4 Category 4: Potential Human Exposure

The risk matrix scores for this category account for the likelihood of adverse effects to humans as a result of exposure to pollutants in waterbodies. Types of human exposure that were considered were public water supply as well as recreation in or on lakes, natural and scenic rivers, and urban streams. The data that were used to assign the scores for this category included:

- Impaired Waterbodies from 2018 final 303(d) list (GIS layer retrieved from Arkansas GIS office, 2018, updated 2020);
- Public water systems impacted by the impaired assessment units as compiled by the Arkansas Department of Health (ADH) in their public comments on the 2018 draft 303(d) List;

- Recreational Lakes from Arkansas Game and Fish Commission (AGFC) ArcGIS REST Services (accessed August 2021);
- Public boating access locations were extracted from the AGFC Public Use Facilities GIS layer (AGFC REST Service, accessed August 2021);
- Natural and Scenic Waterways GIS layer (published by DEQ, updated 2017); and
- Municipal Boundaries (City Limits) of Arkansas (Arkansas GIS office, updated 2021).

Scores for Category 4 were assigned in the same manner as in Hancock et al. (2010):

- Score = 10: A score of 10 was assigned to watersheds with at least one impaired waterbody either serving as a public water supply, or that was a tributary to a public water supply source.
- Score = 8: A score of 8 was assigned to watersheds with at least one impaired waterbody that was a recreational lake or a tributary to a recreational lake. This score was also assigned to watersheds with at least one impaired waterbody within a state or federal park, and watersheds that have public boat ramps connected to impaired waterbodies.
- Score = 8: A score of 8 was assigned to watersheds with at least one impaired waterbody that is either classified as a Natural and Scenic Waterway or is an urban stream.
- Score = 2: A score of 2 was assigned to watersheds with at least one impaired waterbody. This assumes that at least some human exposure is likely to occur for any impaired waterbody.

If a watershed qualified for multiple scores, the highest score was selected. The final Category 4 scores for all 58 HUC8s are shown on Figure 3.4.

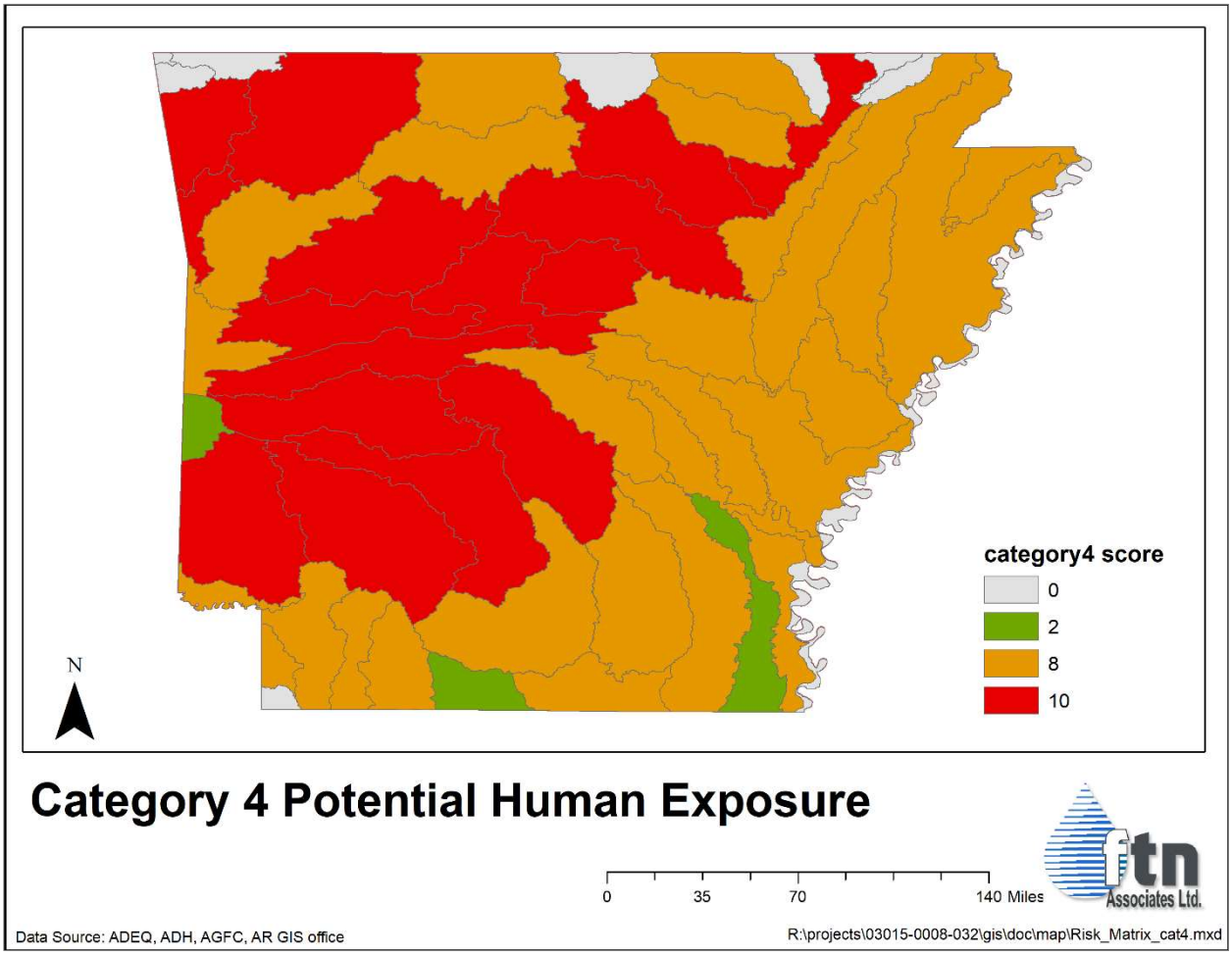

Figure 3.4. Category 4 scores.

3.5 Category 5: Urban/Suburban Population

In urban areas with high population density, nonpoint source pollution is often greater than in less populated rural areas. The population density of each county was calculated based on the 2019 Annual Estimates of the Resident Population for Counties in Arkansas (US Census Bureau 2020). Since the HUC8 watersheds are generally not consistent with county boundaries, the population of each watershed was estimated by summing the products of the percentage area of each county within the watershed and the population of that county. The estimated watershed population was then divided by the watershed area to estimate the average population density for the watershed. The population density in each watershed was then compared with the values from the other HUC8s in Arkansas to generate percentile rankings. The final scores for

Category 5 were calculated by multiplying the percentile ranking of population density by 10, resulting in a 0-10 score for all watersheds. This is the same scoring procedure that was used by Hancock et al. (2010). The final scores for Category 5 are shown on Figure 3.5.

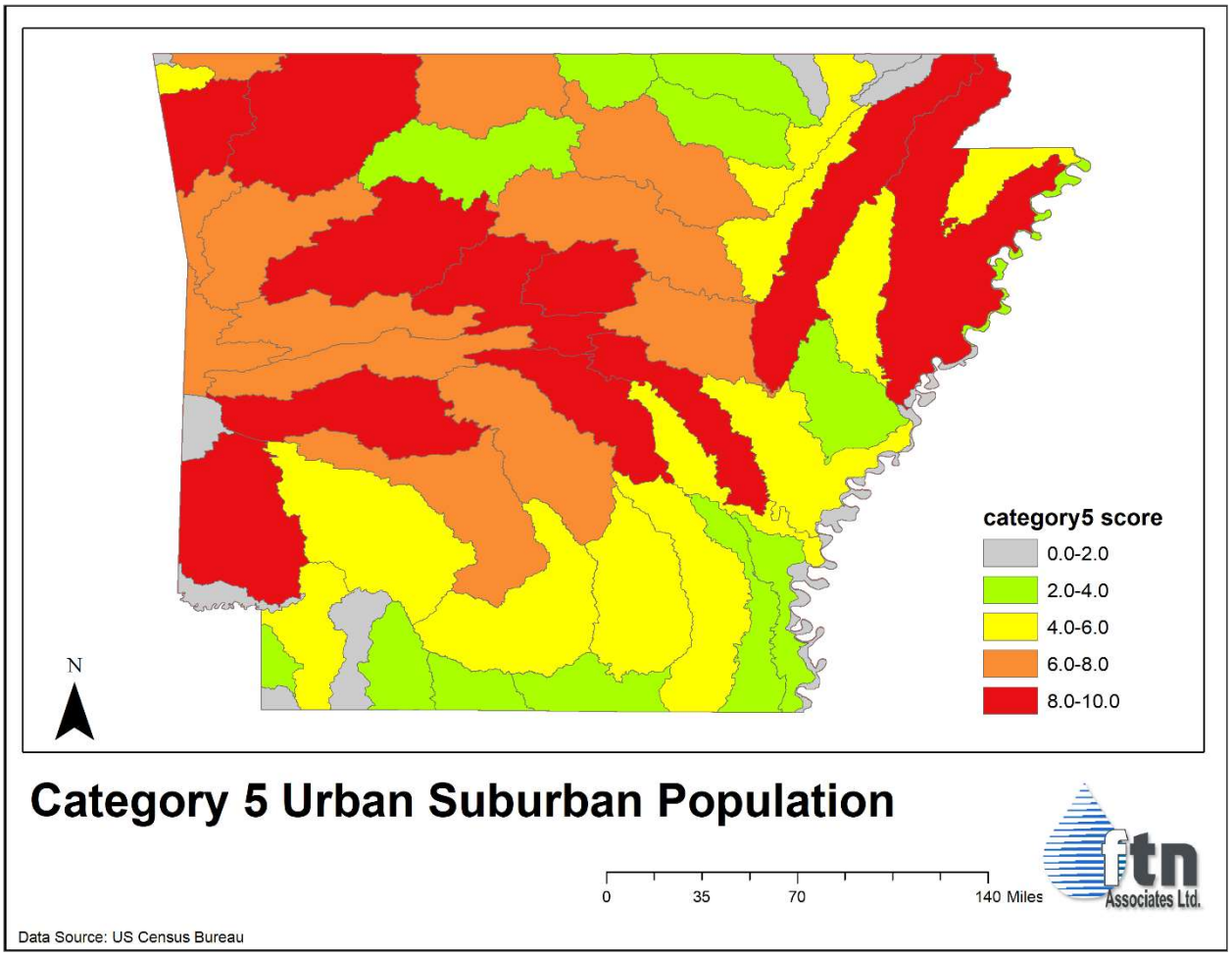

Figure 3.5. Category 5 scores.

3.6 Category 6: Impervious Area

Impervious areas affect nonpoint source pollution because the pollutants that accumulate on the surfaces are washed off easily, and the additional runoff can cause increased erosion of stream banks and channels. In the 2010 update of the risk matrix, the developed land cover within each of the 58 HUC8s was used as a surrogate for the impervious surface. However, in recent years, NLCD data has included imperviousness in addition to land use. The most recent

2019 NLCD imperviousness product (Multi-Resolution Land Characteristics (MRLC) 2021), displays urban impervious surfaces as a percentage of developed surfaces for every 30-meter cell. For the current risk matrix update, the NLCD impervious percentage was multiplied by the pixel area to calculate the actual impervious area. These areas were then summed for each watershed. The total impervious area in each watershed was then ranked with other HUC8s in Arkansas to evaluate the percentile ranking of impervious acreage. The final scores for Category 6 were calculated by multiplying the percentile of total impervious acreage by 10, resulting in a 0-10 score among all watersheds. This is the same scoring procedure that was used by Hancock et al. (2010). The final scores for Category 6 are shown on Figure 3.6.

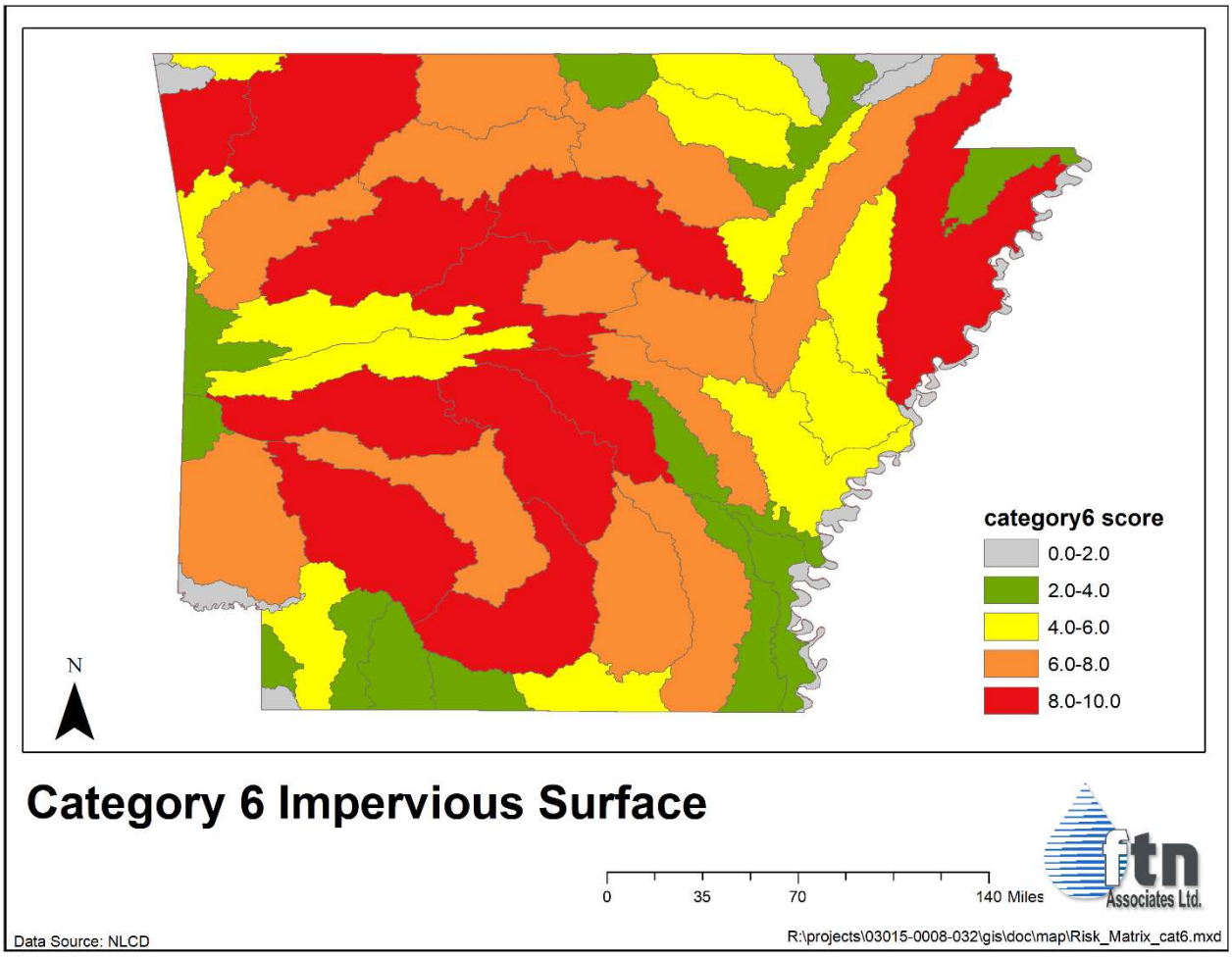

Figure 3.6. Category 6 scores.

3.7 Category 7: Economic Activity

The economic activities that were addressed by this category were construction activity, shale development (natural gas), and mining activity. These activities can contribute to erosion and/or degradation of water quality. The data used to develop scores for Category 7 included:

- 2011 and 2019 National Land Cover Database (published by MRLC, 2013 and 2021);
- Arkansas Oil and Gas Wells layer downloaded from the Arkansas GIS office database (published by Arkansas oil & Gas Commission, updated 2017); and
- Environmental Permits Site Location layer from the Arkansas GIS office database (published by DEQ, updated 2017).

Using these data, scores were assigned for each of the three subcategories as described below. The subcategory scores were then summed to obtain the final score for Category 7. This is the same general procedure that was used by Hancock et al. (2010).

- Construction activity: The urban acreage in each HUC8 watershed was calculated for 2011 and for 2019 using the NLCD land use data, with assumption that urban land includes all of the NLCD land use categories that were labeled as "Developed". The difference in urban acreage between 2011 and 2019 was considered to be indicative of the construction activity in each watershed. The magnitude of urban acreage change in each watershed was ranked among all the HUC8s in Arkansas to develop the percentile ranking. The percentile ranking of each watershed was multiplied by 5 to determine the score for the construction activity subcategory. This resulted in scores ranging from 0 to 5.
- Shale Development: Based on the GIS layer titled Arkansas Oil and Gas Wells, watersheds with at least one active permit for extracting natural gas were assigned a score of 4. All other watersheds were assigned a score of zero for this subcategory.
- Mining Activity: Using DEQ's Environmental Permits Site Location layer, watersheds with at least one active permit for "Coal Mining" or "All Other Nonmetallic Mineral Mining" were assigned a score of 1. All other watersheds were assigned a score of zero for this subcategory.

The final scores for Category 7 are shown on Figure 3.7.

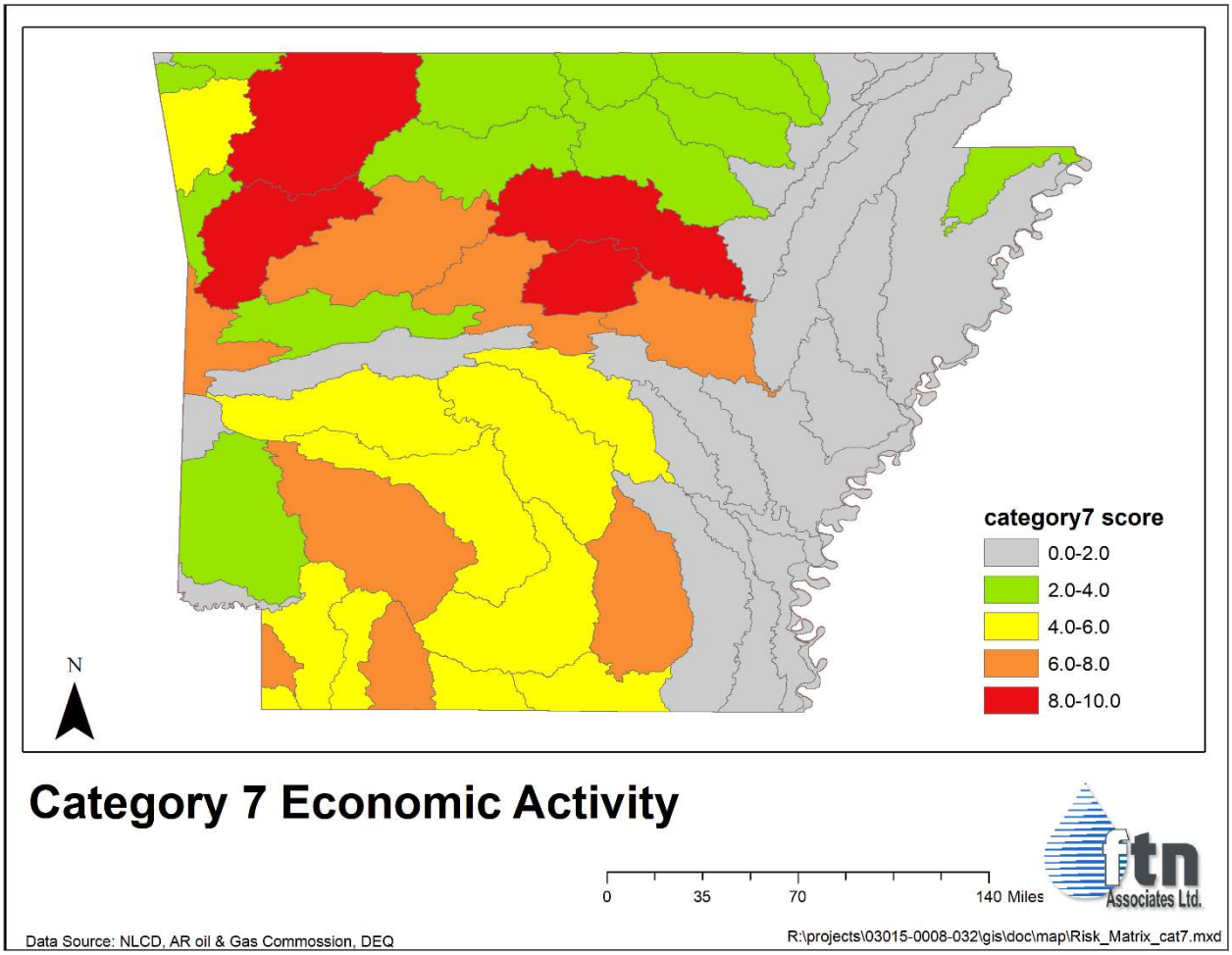

Figure 3.7. Category 7 scores.

3.8 Category 8: Cropland

Cropland can contribute nutrients and suspended sediment to waterbodies through runoff and erosion. The acreage of harvested cropland in each watershed was calculated based on the US Department of Agriculture (USDA) 2017 Census of Agriculture (USDA 2019). Because USDA reports data by county rather than HUC8, the cropland acreage in each HUC8 was estimated according to the percentage of watershed area in each county. The cropland acreages by watershed were ranked among all the HUC8s in Arkansas to develop the percentile ranking. The percentile ranking of each watershed was multiplied by 10 to determine the score for Category 8. The final scores for Category 8 are shown on Figure 3.8. The scoring procedure described here is the same as used by Hancock et al. (2010).

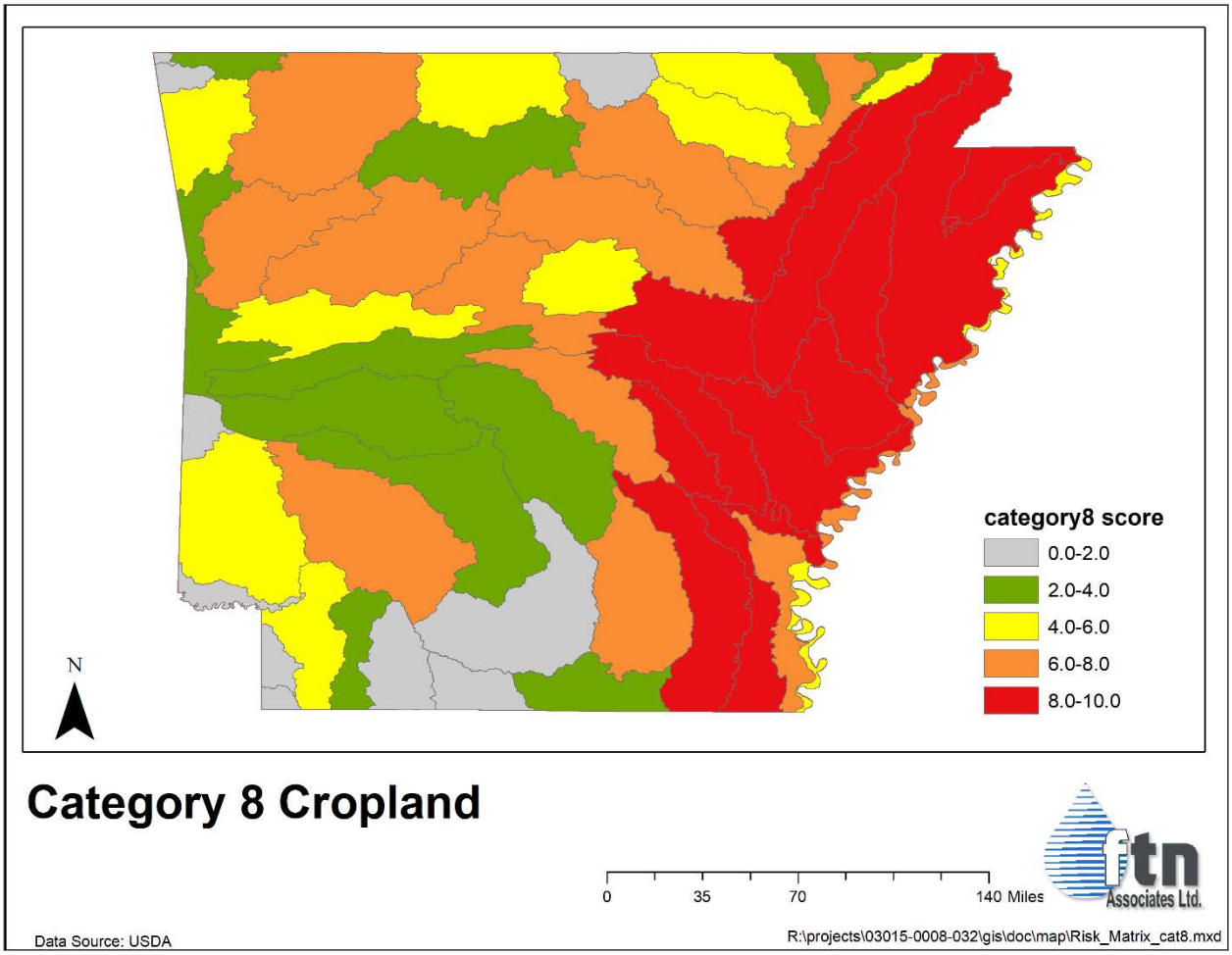

Figure 3.8. Category 8 scores.

3.9 Category 9: Livestock and Pasture

Livestock operations are a source of bacteria and nutrients that can enter waterbodies if pastures and animal waste are not managed carefully. The final score for Category 9 for each watershed was the sum of its scores for pasture (0 – 5) and livestock (0 – 5). The scoring procedure described here is the same as used by Hancock et al. (2010).

The density of pasture land in each watershed (i.e., the area of pasture as a fraction of the total area) was determined using the 2019 NLCD land use layer. The density of pasture land for each watershed was then ranked with all the HUC8s in Arkansas to develop the percentile ranking. The percentile ranking of each watershed was multiplied by 5 to determine the pasture score.

Populations of each species of livestock and poultry were obtained for each county from the 2017 Census of Agriculture (USDA 2019). Animal numbers in each HUC8 watershed were estimated according to the percentage of the watershed in each county. The populations of different species were combined using the following equation to calculate numbers of animal units (Hancock et al. 2010):

$$\begin{aligned}\text{Number of animal units} = \; & 1.00 \times \text{number of beef cattle} \\ & + 1.429 \times \text{number of dairy cattle} \\ & + 0.4 \times \text{number of swine (> 55 lbs)} \\ & + 0.1 \times \text{number of swine (< 55 lbs)} \\ & + 2.0 \times \text{number of horses} \\ & + 0.1 \times \text{number of sheep or lambs} \\ & + 0.0182 \times \text{number of turkeys} \\ & + 0.0333 \times \text{number of laying hens} \\ & + 0.0074 \times \text{number of broilers}\end{aligned}$$

Following Hancock et al. (2010), numbers of hogs weighing more than 55 lbs were assumed to be approximately the same as numbers of breeding hogs. Because the 2017 Census of Agriculture does not provide separate values for numbers of breeding hogs, the ratio of breeding hogs to total hogs was taken from the 2012 Census of Agriculture and multiplied by total numbers of hogs from the latest (2017) Census of Agriculture.

The number of animal units in each HUC8 was divided by the area of the HUC8 to obtain the animal density for each HUC8 (Table 3.3). The values of animal density were then ranked among all the HUC8s in Arkansas to develop the percentile ranking. The percentile ranking of each watershed was multiplied by 5 to determine the livestock score.

The final scores for Category 9 are shown on Figure 3.9.

Table 3.3. Animal unit density for each HUC8.

HUC8	HUC8 Name	Animal units (AU)	HUC8 area (acres)	Animal unit density (AU/acre)*
11010001	Beaver Reservoir	181,665	1,389,311	0.13076
11070206	Lake O' The Cherokees	1,599	14,148	0.11301
11070208	Elk	15,983	141,430	0.11301
11070209	Lower Neosho	10,395	91,978	0.11301
11110103	Illinois	40,693	484,538	0.08398
11010003	Bull Shoals Lake	37,503	703,325	0.05332
11110202	Dardanelle Reservoir	46,727	1,192,774	0.03918
11110201	Frog-Mulberry	29,649	822,579	0.03604
08040103	Little Missouri	47,462	1,342,697	0.03535
11110204	Petit Jean	20,804	702,925	0.02960
11140109	Lower Little Arkansas, Oklahoma	32,084	1,147,183	0.02797
11110104	Robert S. Kerr Reservoir	5,521	211,219	0.02614
11010011	Eleven Point	2,763	113,436	0.02436
08040204	Lower Saline	23,319	971,690	0.02400
11010010	Spring	8,409	470,577	0.01787
11110105	Poteau	6,239	356,221	0.01752
11010006	North Fork White	4,625	282,482	0.01637
11010012	Strawberry	7,963	486,616	0.01637
11140201	McKinney-Posten Bayous	8,371	513,396	0.01631
11110206	Fourche La Fave	11,373	712,913	0.01595
11110203	Lake Conway-Point Remove	10,695	728,759	0.01468
11140203	Loggy Bayou	5,698	406,413	0.01402
11140205	Bodcau Bayou	4,033	299,431	0.01347
11110205	Cadron	6,400	484,309	0.01321
11010008	Current	800	67,582	0.01184
11010009	Lower Black	5,192	450,826	0.01152
08040205	Bayou Bartholomew	10,788	982,094	0.01098
11010005	Buffalo	8,462	856,964	0.00987
11140105	Kiamichi	1	81	0.00984
11140108	Mountain Fork	1,551	157,612	0.00984
11140304	Cross Bayou	528	54,341	0.00972
11140302	Lower Sulpher	1,165	119,902	0.00972
08040101	Ouachita Headwaters	8,678	990,184	0.00876
08040201	Lower Ouachita-Smackover	8,589	1,153,695	0.00745
11010014	Little Red	8,551	1,152,283	0.00742

HUC8	HUC8 Name	Animal units (AU)	HUC8 area (acres)	Animal unit density (AU/acre)*
08020401	Lower Arkansas	3,202	441,455	0.00725
08040206	Bayou D'Arbonne	1,932	279,417	0.00691
11010007	Upper Black	783	116,805	0.00670
11010004	Middle White	6,186	943,986	0.00655
11110207	Lower Arkansas-Maumelle	4,008	702,541	0.00571
08020301	Lower White-Bayou Des Arc	4,056	726,669	0.00558
08040102	Upper Ouachita	5,742	1,121,158	0.00512
08050001	Boeuf	2,405	494,356	0.00487
08040203	Upper Saline	4,596	1,097,048	0.00419
11010013	Upper White-Village	1,651	473,908	0.00348
08020402	Bayou Meto	2,220	641,115	0.00346
08040202	Lower Ouachita-Bayou De Loutre	1,428	442,146	0.00323
08020302	Cache	2,324	1,251,651	0.00186
08020203	Lower St. Francis	2,238	1,936,417	0.00116
08050002	Bayou Macon	387	365,301	0.00106
11140106	Pecan-Waterhole	125	143,074	0.00087
08020204	Little River Ditches	178	311,085	0.00057
08020205	L'Anguille	327	611,538	0.00054
08020303	Lower White	336	870,808	0.00039
08030100	Lower Mississippi-Greenville	47	123,261	0.00038
08020304	Big	174	606,272	0.00029
08010100	Lower Mississippi-Memphis	27	101,038	0.00027
08020100	Lower Mississippi-Helena	46	173,720	0.00027

* Identical values occur when multiple watersheds are located entirely within a single county. For example, Lake O' The Cherokees, Elk, and Lower Neosho watersheds are all located within Benton County; therefore, their animal density numbers are based on data for Benton County.

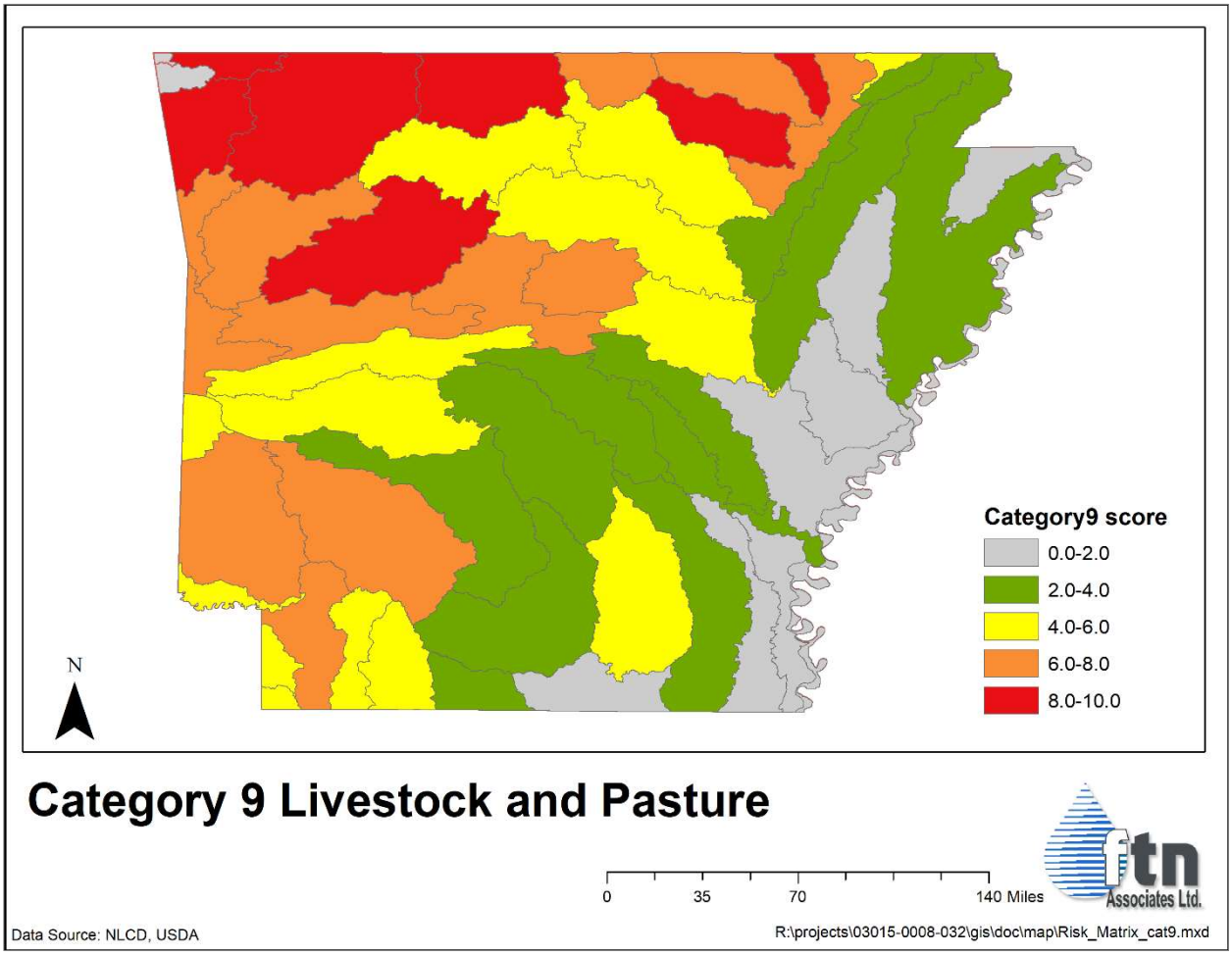

Figure 3.9. Category 9 scores.

3.10 Category 10: Unpaved Roads

According to the Arkansas Unpaved Roads Program, over 85% of Arkansas county roads are unpaved (Arkansas Department of Agriculture Natural Resources Division [NRD] 2015). During storm events, erosion from unpaved roads can deliver sediment to streams and lakes.

The Arkansas Centerline File (ACF; published by the Arkansas Geographic Information Systems Board) was downloaded from the Arkansas GIS Office to determine unpaved road mileage within each HUC8 watershed. The total mileage in each watershed was divided by watershed area to calculate the density of unpaved roads in each HUC8. The density of unpaved roads in each watershed was then ranked among all the HUC8s in Arkansas to develop the percentile ranking. The percentile ranking of each watershed was multiplied by 10 to determine

the score for Category 10. The final scores for Category 10 are shown on Figure 3.10. The scoring procedure described here is the same as used by Hancock et al. (2010).

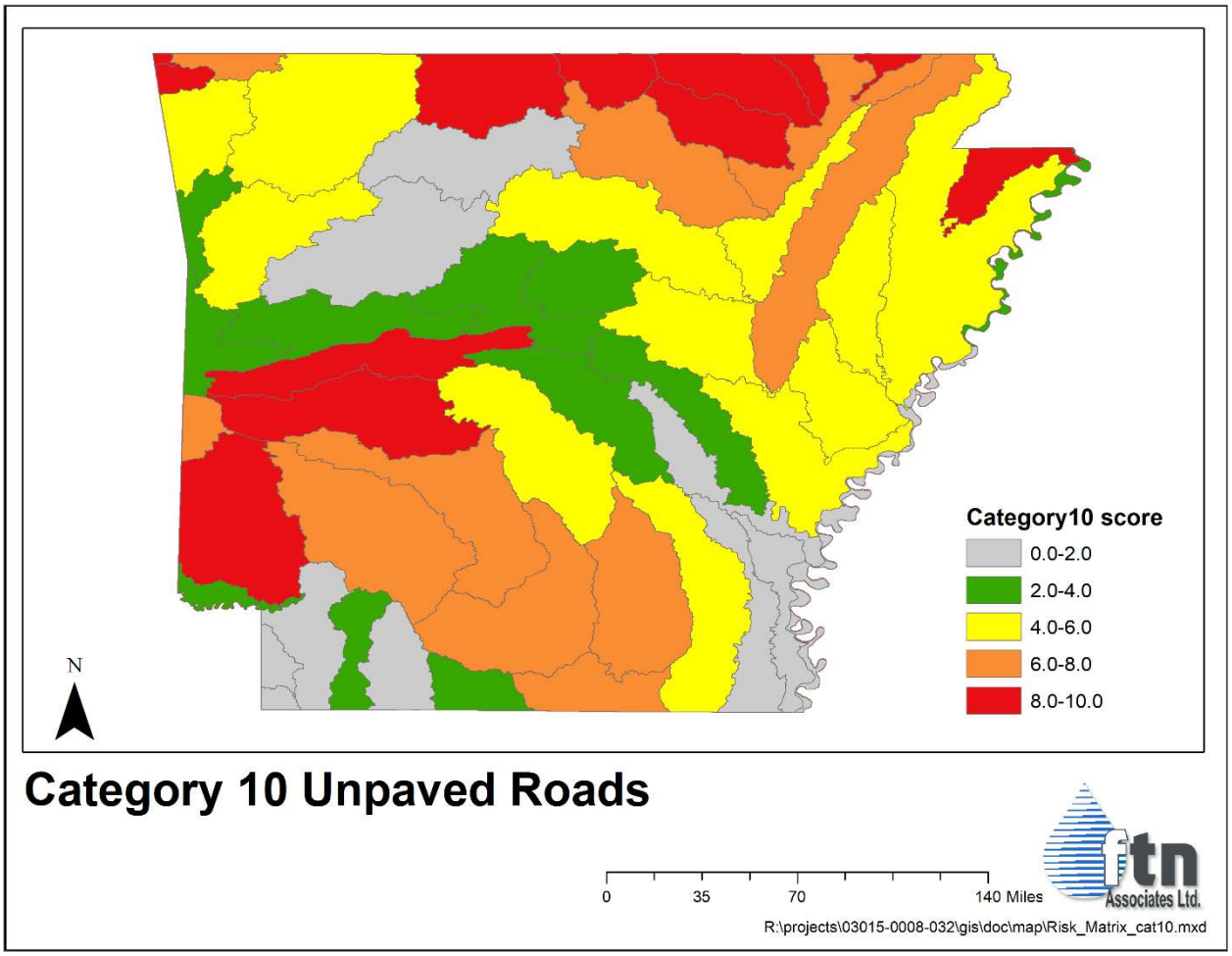

Figure 3.10. Category 10 scores.

3.11 Category 11: Forestry

Undisturbed forest land typically has very little erosion, but disturbance of forest land through timber harvesting can increase erosion and sediment yields, especially if best management practices are not utilized. Following the methods used by Hancock et al. (2010), the extent of forest disturbance within a watershed was estimated based on forest density (the area of forest as a fraction of the total area) and land ownership (federal, state, or private).

Based on the 2019 NLCD land use layer, the public land boundary layer from the Arkansas Highway and Transportation Department, and the land ownership layer from the Center for Advanced Spatial Technologies (CAST), forest land in Arkansas was divided into federal, state, or private ownership categories. Table 3.4 shows how ownership was assigned for forest land.

Table 3.4. Ownership assigned for different forest areas.

Description	Ownership
US Forest Service National Forest	Federal
Military Reservations	
US National Park Service	
US Fish and Wildlife Refuge System	
US Forest Service Wilderness Areas	
US Army Corps of Engineers	
US National Park Service Wilderness Areas	
Arkansas State Parks	State
Arkansas Game and Fish Commission	
Arkansas Natural Heritage Commission Natural Areas	
Arkansas State Forest	
Private Ownership	Private
University Forest	

The density of forest was calculated for each ownership sector (federal, state, or private) by taking the area of forest within that ownership sector and dividing it by the total area of the HUC8 watershed. For each ownership sector, the forest density in each watershed was ranked among all the HUC8s in Arkansas to develop the percentile ranking. The final score for Category 11 was the sum of the state forest density percentile multiplied by 2, the federal forest density percentile multiplied by 3, and the private forest density percentile multiplied by 5. This is the same scoring procedure used by Hancock et al. (2010). The final scores for Category11 are shown on Figure 3.11.

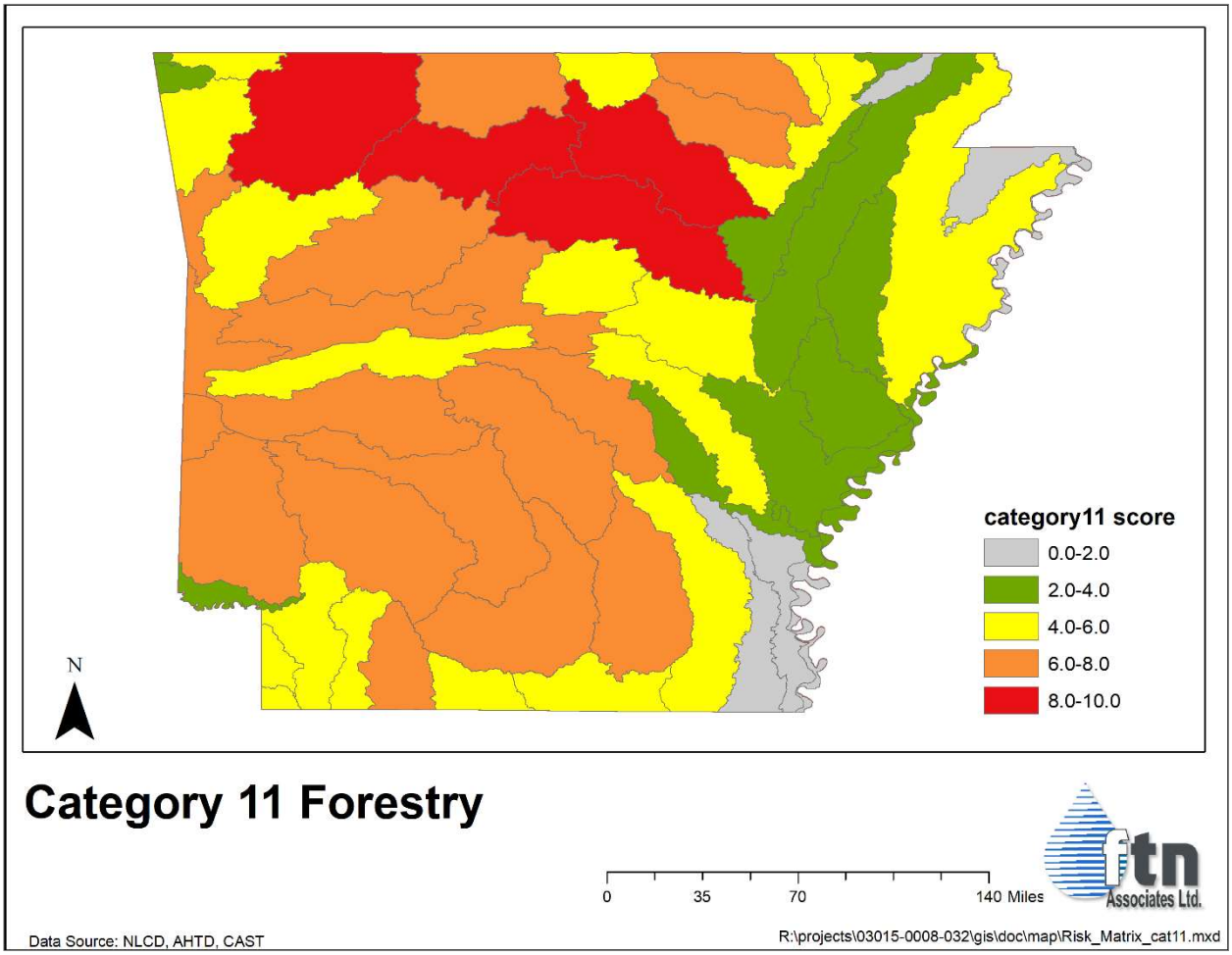

Figure 3.11. Category 11 scores.

3.12 Category 12: Adjacent State Priority

Some of the watersheds that drain from Arkansas into adjacent states are considered priority watersheds in the adjacent state. Following the procedure used in Hancock et al. (2010), a score of 10 was assigned to Arkansas HUC8 watersheds if the adjacent state considers the portion of the HUC8 within their state to be a priority watershed for addressing nonpoint source pollution. Adjacent state's priority watersheds were identified from the sources listed in Table 3.5. The final scores for Category 12 are shown on Figure 3.12.

Table 3.5. Sources used to identify priority watersheds in adjacent states.

State	Agency	Publication
Oklahoma	Oklahoma Conservation Commission (OCC)	Oklahoma's Nonpoint Source Management Program, 2019-2029 (OCC 2021)
Missouri	Missouri Department of Natural Resources (MDNR)	Missouri Nonpoint Source Management Plan, Update 2020-2025 (MDNR 2021)
Tennessee	None of the HUC8 watersheds drain from AR to TN	
Mississippi	None of the HUC8 watersheds drain from AR to MS	
Louisiana	Louisiana Department of Environmental Quality (LDEQ)	2019 Addendum to State Nonpoint Source Management Plan for Louisiana (LDEQ 2019)
	USDA Natural Resources Conservation Service (NRCS)	Mississippi River Basin Healthy Watershed Initiative 2019 Progress Report (NRCS 2019)
Texas	None of the HUC8 watersheds drain from AR to TX	

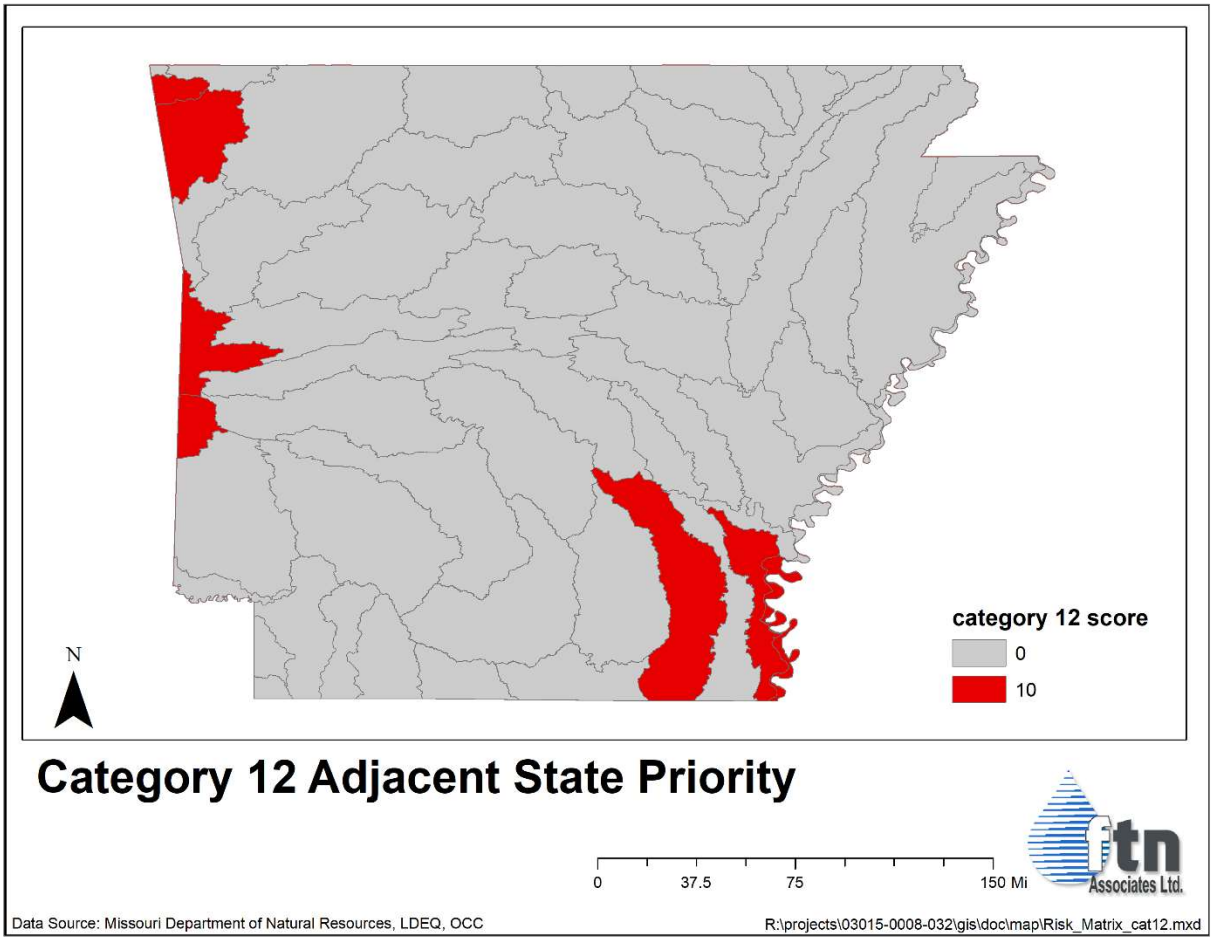

Figure 3.12. Category 12 scores.

3.13 Comparison of Previous and Updated Data Sources

The data sources used for updating the risk matrix were the same as the sources used in the 2010 risk matrix assessment if updated versions of the same data were available. However, some of the data sources that were used in the 2010 risk matrix are no longer updated or supported. Table 3.6 compares sources of data used for the 2010 risk matrix and for the current (2022) update.

Table 3.6. Data sources used for 2010 risk matrix and 2022 update.

Data Type	Data sources for 2010 risk matrix	Data sources for 2022 update
Impaired waterbodies	2010 final 303(d) list Categories 4a and 5	2018 final 303(d) list Categories 4a, 4b, 5, and 5alt
Public surface water supply	Source of data was not documented	Arkansas Department of Health public comments on 2018 draft 303(d) list
City boundaries	No information on whether this data type was utilized	Municipal boundaries from Arkansas GIS Office (updated 2021)
Recreational lakes	Source of data was not documented	Arkansas Game and Fish Commission GIS data
Natural or Scenic Rivers	Source of data was not documented; assumed to be Regulation No. 2 (current version at that time)	2020 Arkansas Pollution Control and Ecology Commission Regulation No.2, Appendix D
Population	U.S. Census Bureau 2009 population estimates	U.S. Census Bureau, Population Division, 2019 population estimates by county
Land use	2006 Land Use/Land Cover by Univ. of Arkansas Center for Advanced Spatial Technology (CAST)	2019 National Land Cover Database (NLCD)
Cropland and livestock	USDA 2007 Census of Agriculture	USDA 2017 Census of Agriculture
Shale development	Active permit GIS layer from Arkansas Oil & Gas Commission (2010)	GIS layer from Arkansas Oil & Gas Commission (updated 2017)
Mining activities	DEQ “Environmental Permitted Sites” GIS layer (2006)	DEQ “Environmental Permitted Sites” GIS layer (updated 2017)
Unpaved roads	Arkansas Highway and Transportation Department (AHTD) road data (2006)	Arkansas Centerline File (ACF) (updated 2021)
Land ownership	AHTD road data (2006)	“Public Land Boundary” GIS layer from AHTD (updated 2014)
Priority watersheds in adjacent states	Morgan and Matlock (2008)	Oklahoma’s Nonpoint Source Management Program, 2019-2029; Missouri Nonpoint Source Management Plan, Update 2020-2025; 2019 Addendum to Louisiana Nonpoint Source Management Plan; NRCS Mississippi River Basin Healthy Watershed Initiative 2019 Progress Report

4.0 OVERALL SCORES AND RANKING

As mentioned in Section 2.0, the overall score for each HUC8 watershed was calculated using the following equation from Hancock et al. (2010):

Overall score = Category 1 score × Sum of scores for other categories

The 58 HUC8 watersheds were then ranked based on overall score and a percentile was calculated for each watershed using the equation $100 \times (1 - (m\text{-}1)/n)$, where m = rank and n = number of watersheds (58). The watersheds that ranked between the 81st and 100th percentiles were considered the highest priority watersheds and are listed in Table 4.1. A map showing the ranking of all 58 watersheds (grouped by quintile) is presented on Figure 4.1. A tabular listing of the scores for each category for all 58 watersheds is presented in Appendix A.

Table 4.1. Watersheds with overall ranking between 81st and 100th percentiles.

HUC8 ID	HUC8 name	Area within Arkansas (km^2)	Overall score	Percentile ranking
11010001	Beaver Reservoir	5625	876.5	100.0
11140109	Lower Little Arkansas, Oklahoma	4644	811.2	98.3
11010014	Little Red	4665	810.1	96.6
11110203	Lake Conway-Point Remove	2950	798.6	94.8
11110103	Illinois	1962	777.3	93.1
08040101	Ouachita Headwaters	4009	770.4	91.4
08040205	Bayou Bartholomew	3976	752.7	89.7
11010004	Middle White	3822	750.8	87.9
11110105	Poteau	1442	749.5	86.2
11110205	Cadron	1961	741.3	84.5
08020301	Lower White-Bayou Des Arc	2942	724.5	82.8
08040204	Lower Saline	3934	724.2	81.0

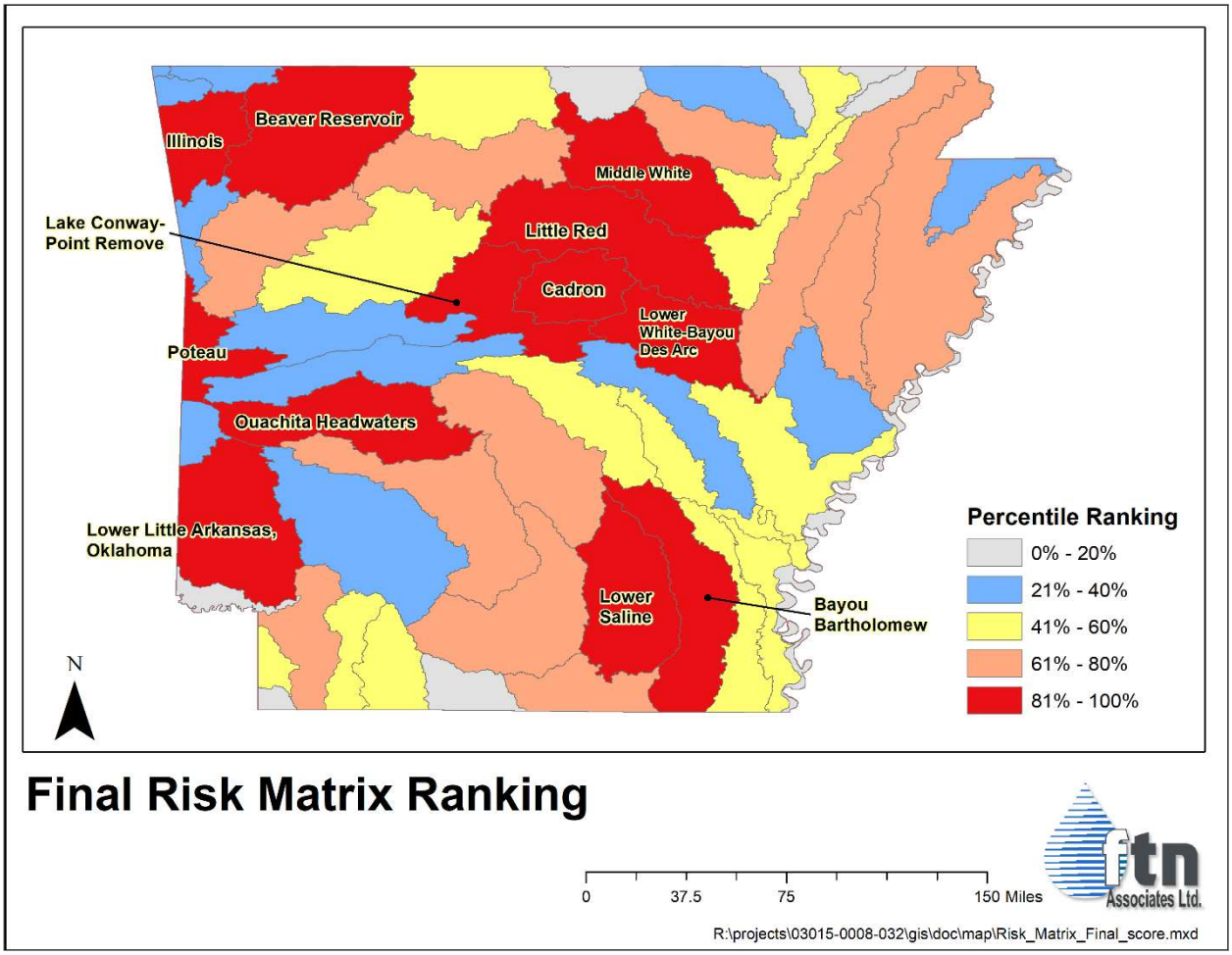

Figure 4.1. Final ranking for 2022 risk matrix.

Each of the 12 watersheds in the top quintile (the 81st to 100th percentiles) had a score of 10 in Category 1 and a score of 10 in at least two other categories. Each of these watersheds also scored 7.0 or higher in six of the 12 categories. Because the equation for calculating the overall score emphasizes the Category 1 score, all of the watersheds that scored less than 10 in Category 1 were below the 50th percentile in the final ranking.

Some of the watersheds that ranked in the top quintile (the 81st to 100th percentiles) also ranked in the top quintile for the 2010 risk matrix. This is not surprising because the scoring procedure used here was the same as in 2010; differences in results between 2010 and 2022 are due only to the use of updated data. Table 4.2 shows a comparison of watersheds in the top quintile for the 2010 risk matrix and for the current update.

Table 4.2. Watersheds in the top quintile for the 2010 and 2022 risk matrices.

Percentile ranking	2010 risk matrix		2022 risk matrix	
	HUC8 name and ID	Score	HUC8 name and ID	Score
100.0	Beaver Reservoir (11010001)	839.0	Beaver Reservoir (11010001)	876.5
98.3	Poteau (11110105)	725.0	Lower Little AR, OK (11140109)	811.2
96.6	Bayou Bartholomew (08040205)	707.2	Little Red (11010014)	810.1
94.8	Illinois (11110103)	650.3	Lake Conway-Point Remove (11110203)	798.6
93.1	Ouachita Headwaters (08040101)	640.7	Illinois (11110103)	777.3
91.4	Lake Conway-Point Remove (11110203)	620.7	Ouachita Headwaters (08040101)	770.4
89.7	Upper Ouachita (08040102)	616.6	Bayou Bartholomew (08040205)	752.7
87.9	Upper Saline (08040203)	566.1	Middle White (11010004)	750.8
86.2	Cache (08020302)	564.3	Poteau (11110105)	749.5
84.5	L'Anguille (08020205)	564.3	Cadron (11110205)	741.3
82.8	Strawberry (11010012)	555.3	Lower White-Bayou Des Arc (08020301)	724.5
81.0	Lower Ouachita-Smackover (08040201)	546.9	Lower Saline (08040204)	724.2

Note: Watersheds listed in orange-brown text dropped out of the top quintile from 2010 to 2022, while watersheds listed in green text moved into the top quintile.

However, six of the twelve watersheds in the top quintile are different between 2010 and 2022. The Lower Little and Little Red watersheds were not in the top quintile in 2010 but they moved up to the second and third highest ranking, respectively, in 2022. The large jump in rankings for these two watersheds was largely due to the increases in the Category 1 scores. Both watersheds received a Category 1 score of 10 in 2022, but their Category 1 scores in 2010 were 8 for Lower Little and 2 for Little Red. The rationale for the Category 1 score for the Little Red watershed in 2010 is unclear because the currently available version of the 2010 303(d) list shows two reaches of the Middle Fork Little Red River in Category 4a of the 303(d) list, which would result in a score of 10 rather than 2 for the Little Red watershed.

5.0 REFERENCES

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APPENDIX A

Individual and Overall Scores for all 58 HUC8 Watersheds

Appendix A. Individual and Overall Scores for each HUC8 Watershed for the 2022 Risk Matrix Update

HUC8 Number	HUC8 Name	Area within Arkansas (km^2)	Score for each category												Matrix Score	Matrix Percentile	Percentages of each HUC8 covered by selected land uses						
			Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	Cat. 6	Cat. 7	Cat. 8	Cat. 9	Cat. 10	Cat. 11	Cat. 12			Developed land	Forest	Cultivated crops	Hay / pasture	Other undeveloped land	Wetlands	Open water
08010100	Lower Mississippi-Memphis	409.06	0	0	0	0	2.2	0.69	1.47	5.69	1.03	2.11	1.50	0	0.00	9	2.0	0.3	41.2	1.0	0.2	31.9	23.4
08020100	Lower Mississippi-Helena	703.32	0	0	0	0	1.6	0.86	1.12	7.07	0.60	0.53	3.34	0	0.00	9	1.4	4.4	25.7	0.3	0.8	39.7	27.8
08020203	Lower St. Francis	7839.74	10	10	10	8	9.5	9.83	0.09	10.00	2.32	5.79	4.41	0	699.39	78	6.6	6.2	74.4	3.0	0.2	8.1	1.5
08020204	Little River Ditches	1259.45	2	10	10	8	4.7	3.79	2.64	8.45	0.78	8.95	1.15	0	116.92	22	7.7	0.0	81.0	0.0	0.0	9.6	1.1
08020205	L'Anguille	2475.86	10	10	10	8	4.8	6.03	0.52	9.14	1.90	5.96	3.29	0	596.38	62	5.2	6.3	73.7	2.2	0.1	11.6	0.9
08020301	Lower White-Bayou Des Arc	2941.98	10	10	10	8	7.8	6.55	7.53	8.97	5.00	4.39	4.21	0	724.52	83	6.4	20.6	30.0	21.8	0.7	17.5	3.1
08020302	Cache	5067.41	10	10	10	8	8.6	7.24	0.17	9.83	2.50	6.32	3.96	0	666.26	74	4.3	7.2	70.6	3.3	0.1	13.3	1.1
08020303	Lower White	3525.54	10	10	10	8	4.1	5.86	0.26	9.66	1.04	4.04	3.24	0	562.01	57	3.5	4.2	56.6	0.2	0.1	31.9	3.5
08020304	Big	2454.54	2	10	10	8	2.9	4.31	0.43	9.48	1.04	5.26	3.14	0	109.12	21	4.3	1.1	79.7	0.1	0.0	14.3	0.5
08020401	Lower Arkansas	1787.27	10	10	10	8	5.5	2.24	1.29	8.10	2.94	1.23	2.76	0	520.64	48	2.5	0.5	61.1	0.3	0.4	28.2	7.1
08020402	Bayou Meto	2595.61	2	10	10	8	9.1	7.76	1.21	9.31	3.11	3.33	4.14	0	131.92	28	9.3	9.5	51.8	6.4	0.3	18.5	4.0
08030100	Lower Mississippi-Greenville	499.03	0	0	0	0	0.5	0.52	1.38	5.17	0.77	0.18	1.33	10	0.00	9	1.1	0.0	6.8	0.1	0.0	63.3	28.0
08040101	Ouachita Headwaters	4008.84	10	10	10	10	9.0	9.14	5.74	3.28	4.66	8.77	6.45	0	770.41	91	7.3	72.6	0.0	12.0	3.1	0.1	4.9
08040102	Upper Ouachita	4539.10	10	10	10	10	6.6	7.93	4.88	2.41	3.62	6.14	7.45	0	690.29	76	5.5	58.9	1.3	11.7	5.9	15.1	1.7
08040103	Little Missouri	5436.02	2	4	0	10	5.9	8.28	6.84	6.03	6.98	7.89	7.86	0	127.57	24	4.7	58.0	0.2	17.6	8.5	10.0	0.9
08040201	Lower Ouachita-Smackover	4670.83	10	10	10	8	5.3	8.79	4.78	1.38	3.45	6.67	6.05	0	644.17	71	6.0	53.7	0.1	6.2	6.2	27.2	0.6
08040202	Lower Ouachita-Bayou De Loutre	1790.07	10	10	10	8	3.8	5.52	5.55	2.59	2.07	7.19	5.71	0	604.28	66	6.5	42.8	0.3	6.2	7.1	34.2	2.8
08040203	Upper Saline	4441.49	10	10	10	10	7.9	9.31	5.91	3.45	3.36	5.09	6.47	0	714.91	79	8.1	57.2	0.2	10.1	7.4	16.2	0.7
08040204	Lower Saline	3933.97	10	10	10	8	5.0	6.72	7.79	6.21	5.52	7.02	6.16	0	724.20	81	4.8	47.5	0.3	8.5	7.2	30.9	0.7
08040205	Bayou Bartholomew	3976.09	10	10	10	8	5.7	7.07	0.95	8.79	3.97	5.61	5.19	10	752.74	90	5.4	34.0	27.1	5.1	5.6	22.1	0.6
08040206	Bayou D'Arbonne	1131.24	2	10	10	2	2.8	2.41	5.72	0.69	3.02	3.68	5.72	0	92.09	19	4.3	62.3	0.0	7.7	6.1	19.4	0.2
08050001	Boeuf	2001.44	10	0	10	2	2.6	3.45	0.34	8.62	1.73	1.93	1.67	0	323.47	41	4.3	0.8	83.7	0.1	0.1	9.5	1.4
08050002	Bayou Macon	1478.95	10	10	10	8	2.1	2.59	0.60	7.93	1.04	1.75	1.41	10	554.25	53	3.6	0.2	83.8	0.1	0.1	9.3	3.0
11010001	Beaver Reservoir	5624.74	10	10	10	10	9.7	9.48	9.00	7.76	9.31	4.21	8.19	0	876.53	100	6.4	60.1	0.0	30.0	1.0	0.2	2.4
11010003	Bull Shoals Lake	2847.47	5	10	10	8	6.7	6.90	4.48	4.14	9.06	9.47	6.34	0	375.48	43	6.8	52.4	0.0	33.6	1.7	0.1	5.4
11010004	Middle White	3821.81	10	10	10	10	7.1	7.59	4.14	6.38	5.00	6.84	8.04	0	750.84	88	6.0	66.1	2.7	22.3	1.3	0.6	1.0
11010005	Buffalo	3469.49	10	10	10	8	3.6	6.38	4.40	3.62	5.52	0.35	8.14	0	600.08	64	4.2	79.3	0.0	15.2	1.0	0.1	0.2

HUC8 Number	HUC8 Name	Area within Arkansas (km^2)	Score for each category												Matrix Score	Matrix Percentile	Percentages of each HUC8 covered by selected land uses						
			Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	Cat. 6	Cat. 7	Cat. 8	Cat. 9	Cat. 10	Cat. 11	Cat. 12			Developed land	Forest	Cultivated crops	Hay / pasture	Other undeveloped land	Wetlands	Open water
11010006	North Fork White	1143.65	0	0	0	0	4.0	3.10	3.62	1.55	7.59	9.82	5.38	0	0.00	9	6.4	58.3	0.0	26.4	1.7	0.0	7.2
11010007	Upper Black	472.89	0	0	0	0	0.7	1.72	1.81	4.31	2.50	7.72	1.66	0	0.00	9	4.4	0.0	59.1	0.1	0.0	34.3	2.0
11010008	Current	273.61	0	4	0	0	0.3	1.03	2.07	3.10	5.17	8.42	2.91	0	0.00	9	3.8	9.2	62.9	10.2	0.4	11.4	2.0
11010009	Lower Black	1825.21	10	9	0	10	4.3	3.28	1.98	7.59	6.21	6.49	4.09	0	529.38	52	4.6	28.9	34.7	21.2	0.6	8.3	1.6
11010010	Spring	1905.17	2	10	10	8	3.3	4.83	3.36	4.66	7.59	9.65	7.64	0	138.06	31	5.7	66.7	0.3	25.3	1.1	0.2	0.6
11010011	Eleven Point	459.26	0	4	0	0	0.9	1.55	2.76	2.93	8.36	9.3	5.81	0	0.00	9	3.8	63.9	0.2	29.9	0.8	0.5	0.8
11010012	Strawberry	1970.11	10	9	10	8	3.4	4.14	2.67	5.34	8.11	8.07	6.62	0	653.53	72	5.2	56.1	1.5	35.1	1.3	0.4	0.4
11010013	Upper White-Village	1918.66	10	10	10	8	4.5	5.17	0.69	8.28	3.02	4.91	3.17	0	577.41	60	5.7	12.9	61.9	5.6	0.2	12.0	1.8
11010014	Little Red	4665.11	10	10	10	10	7.6	8.97	9.83	6.72	5.26	4.56	8.07	0	810.07	97	6.1	63.4	2.5	21.5	1.6	1.8	3.1
11070206	Lake O' The Cherokees	57.28	5	0	0	0	1.7	0.34	2.41	0.52	9.74	8.25	2.71	0	128.35	26	6.3	20.8	0.0	71.2	1.6	0.0	0.1
11070208	Elk	572.59	5	0	0	0	7.4	5.34	3.71	2.07	8.97	7.37	5.90	0	203.76	34	19.4	51.7	0.0	27.5	0.6	0.0	0.7
11070209	Lower Neosho	372.38	5	0	0	0	6.0	1.90	3.02	1.21	9.83	9.12	3.91	10	224.95	38	8.0	37.5	0.0	52.9	1.4	0.0	0.1
11110103	Illinois	1961.69	10	9	0	10	9.8	9.66	4.66	4.48	9.49	5.44	5.21	10	777.31	93	18.5	32.9	0.0	47.1	0.9	0.2	0.4
11110104	Robert S. Kerr Reservoir	855.14	5	4	10	10	6.2	5.00	3.28	2.76	6.81	3.16	7.57	0	293.87	40	12.8	68.4	0.6	13.7	0.6	1.4	2.5
11110105	Poteau	1442.19	10	10	10	8	6.4	3.97	7.10	2.24	7.33	3.51	6.40	10	749.48	86	7.1	64.2	0.0	24.6	3.1	0.3	0.8
11110201	Frog-Mulberry	3330.28	10	4	0	8	8.1	7.41	9.22	6.55	7.93	4.74	5.92	0	618.71	69	6.8	61.8	2.7	24.0	1.1	1.8	1.8
11110202	Dardanelle Reservoir	4829.04	6	10	10	10	8.3	8.45	8.05	7.24	8.37	0.70	6.34	0	464.73	47	5.5	62.5	1.1	25.6	1.3	0.9	3.1
11110203	Lake Conway-Point Remove	2950.44	10	10	10	10	8.8	8.62	8.31	6.90	7.50	2.63	7.10	0	798.63	95	9.0	43.5	6.6	30.9	1.7	4.8	3.5
11110204	Petit Jean	2845.85	2	10	10	10	6.9	5.69	3.19	5.00	7.93	3.86	7.00	0	139.14	33	4.3	62.5	1.1	24.4	3.4	3.4	0.9
11110205	Cadron	1960.77	10	10	10	10	8.4	6.21	8.97	4.83	7.76	2.98	4.98	0	741.29	84	6.7	43.1	1.4	45.1	1.3	1.5	0.8
11110206	Fourche La Fave	2886.29	2	10	10	10	7.2	4.66	2.16	3.97	5.69	8.60	5.76	0	136.07	29	3.7	77.5	0.7	11.8	3.3	1.9	1.1
11110207	Lower Arkansas-Maumelle	2844.30	6	10	10	8	10.0	10.00	5.57	7.41	3.37	2.46	6.02	0	436.96	45	18.8	35.8	19.6	6.9	2.9	10.3	5.7
11140105	Kiamichi	0.33	0	0	0	0	0.2	0.17	2.33	0.17	2.63	0.00	3.40	0	0.00	9	0.0	93.3	0.0	0.0	0.0	0.0	0.0
11140106	Pecan-Waterhole	579.24	2	0	0	8	1.0	1.38	1.90	0.34	5.35	2.28	2.53	0	45.56	17	2.7	15.4	14.0	43.5	2.8	17.1	4.6
11140108	Mountain Fork	638.11	5	4	0	2	1.2	2.07	2.50	1.03	5.48	7.54	7.39	10	216.07	36	5.2	70.2	0.0	18.8	5.4	0.0	0.4
11140109	Lower Little AR, OK	4644.46	10	10	10	10	9.3	8.10	3.45	5.86	7.24	10.00	7.17	0	811.22	98	5.5	48.8	0.3	23.1	8.5	10.7	3.1
11140201	McKinney-Posten Bayous	2078.53	10	10	10	8	5.2	4.48	4.86	5.52	7.50	1.40	4.24	0	612.05	67	5.0	29.0	18.7	28.8	3.4	12.1	3.0
11140203	Loggy Bayou	1645.40	10	10	10	8	3.1	3.62	6.93	1.90	5.09	1.58	6.69	0	569.12	59	5.6	64.6	0.0	11.4	7.4	10.3	0.8
11140205	Bodcau Bayou	1212.27	10	10	10	8	1.9	2.76	5.03	3.79	5.69	2.81	5.64	0	556.21	55	4.6	61.6	0.0	18.2	5.0	8.3	2.2
11140302	Lower Sulphur	485.43	10	10	10	8	2.4	2.93	6.59	1.72	5.35	0.88	4.98	0	528.50	50	13.1	35.8	2.0	18.5	4.2	24.9	1.5
11140304	Cross Bayou	220.00	0	0	0	0	1.4	1.21	6.24	0.86	4.92	1.05	5.47	0	0.00	9	5.2	59.2	0.0	16.1	6.9	12.3	0.3