Water Resource Inventory and Assessment (WRIA):

Cache River National Wildlife Refuge

Jackson, Monroe, Prairie, and Woodruff Counties, Arkansas

U.S. Department of the Interior
Fish and Wildlife Service
Southeast Region
Atlanta, Georgia

August 2015

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COVER PHOTO: Bayou DeView, Cache River National Wildlife Refuge.
Photo credit: Jonathan Windley, Deputy Project Leader, Cache River National Wildlife Refuge.

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Table of Contents

List of Figures

List of Tables

1 Executive Summary

This Water Resource Inventory and Assessment (WRIA) for Cache River National Wildlife Refuge (Cache River NWR or the refuge) summarizes available and relevant information for refuge water resources, including aquatic resource needs and issues of concern, both immediate and long-term. A primary purpose of the document is to provide recommendations to address any perceived water resource related threats, needs, or concerns on the refuge. Topics addressed within the WRIA report include the refuge's natural setting (topography, climate, geology, soils, hydrology), effects of development within the associated watershed(s), potential effects from climate change, assessment and evaluation of refuge infrastructure in relation to water resources, historic and current water monitoring activities on and near the refuge, water quality and quantity information, and state water use regulatory guidelines. All of this information was compiled from publicly available documents (e.g., published and unpublished research reports), databases (e.g., websites maintained by government agencies, academic institutions, and non-governmental organizations), and geospatial datasets from federal, state, and local agencies.

The primary drivers of threats, needs, and issues of concern identified in this assessment are anthropogenic and environmental stressors occurring within the Cache River Basin (including the Cache River and Bayou DeView) and, to some degree, influences from the White River, which is located at the southern portion of the refuge. These areas together comprise the Region of Hydrologic Influence (RHI) for Cache River NWR. For the purposes of this assessment, the RHI was defined as the Cache subbasin (08020302); the Raft Creek-White River watershed (0802030105), which extends along the White River upstream from the confluence of the White and Cache Rivers; and the Roc Roe Bayou-White River subwatershed (080203030502), which is downstream of the confluence along the White River and contains the southernmost portion of the refuge approved acquisition boundary. Water levels and conditions on the White River have a direct effect on the lower Cache River hydrology. Thus, in order to inventory data which characterize these hydrologic relationships, the two smaller hydrologic units were included with the Cache subbasin to define the RHI for the refuge.

1.1 Findings

- The RHI, defined as the area potentially influencing the hydrology and water quality on the refuge, encompasses an area of 1,440,780 acres or 2,251 square miles (mi^2)[1].
- Within the RHI, there are a total of 5,356 miles of streams (985 miles of named streams and 4,371 miles of unnamed streams). Within the Cache River NWR acquisition boundary, there are 33 named streams totaling over 349 miles. In addition to these named streams, there are over 850 miles of unnamed streams within this area. The major stream within this system is the Cache River.
- The Cache River mainstem flows 203 miles from its origin in Butler County, Missouri, through portions of eleven Arkansas counties to its confluence with the White River near Clarendon, Arkansas. It flows through the refuge within the acquisition boundary for 136 miles.
- Bayou DeView is the major tributary stream to the Cache River. Bayou DeView begins on Crowley's Ridge north of Jonesboro, Arkansas, and flows through five Arkansas counties for a distance of 107 miles. The upper 65 miles have been channelized for flood control.

[1] For the purposes of this report, all units are expressed in English measures, unless citing information from a primary source where the native data are presented in metric units. In those cases, the English unit conversions are also provided.

- The Cache River Basin drains a portion of the relatively flat area of the Gulf Coastal Plain province to the south and east of the Ozarks. Elevation ranges from 500 feet above mean sea level (MSL) at the north end, along Crowley's Ridge near the Missouri state line, to 125 feet MSL at the confluence of the White River.
- Cache River NWR is located within the Western Lowlands of the Mississippi Alluvial Plain. The primary elements of relief in this area are river terraces and natural levees. However, the topography within the area is relatively flat and characterized by braided-stream terraces, meander belts and backswamps.
- Both the Cache River and Bayou DeView are underfit streams, meaning that current hydrologic conditions within the watershed result in stream discharges that are too small to have eroded the surrounding valleys and meanders. The present-day channels are thought to occupy abandoned historic channels of the Black and St. Francis Rivers.
- The Mississippi Embayment Aquifer System (MEAS) underlies the Mississippi Alluvial Plain section of the Gulf Coastal Plain province in Arkansas. It is composed of six aquifers in poorly consolidated to unconsolidated bedded sand, silt, and clay. In Arkansas, the extent of MEAS ranges from the upper northeast corner of the state to the lower southwest corner, roughly corresponding with the Gulf Coastal Plain boundary. The uppermost unit of MEAS in the vicinity of the refuge and along the core of the Mississippi Embayment is the Mississippi River Valley alluvial aquifer, commonly referred to as the alluvial aquifer. This alluvial aquifer produced 94% of the groundwater withdrawn in Arkansas in 2010, and is primarily used for irrigation. Groundwater wells drawing from the alluvial aquifer can yield from 50 to more than 500 gallons per minute.
- The Mississippi Embayment Regional Aquifer Study (MERAS) estimates that groundwater withdrawals have increased 132% in the agricultural areas of Arkansas from 1985 to 2000. Total net volumetric depletion for the entire MEAS between 1900 and 2008 is estimated at 182 km^3 (43.6 mi^3). The most dramatic depletion rates are estimated to have occurred between 1991 and 2000 (5.9 km^3/yr) and between 2001 and 2008 (8.1 km^3/yr).
- Much of the original meandering channel of the Cache River has been straightened and channelized to facilitate navigation and expedite runoff. Eighty-nine (89) miles of the upper Cache River were channelized through combined efforts of private landowners and local authorities in the early portion of the twentieth century. Efforts to channelize the lower section of the Cache River above the confluence with the White River were initiated by the United States Army Corps of Engineers (USACE) in the early 1970s. However, these efforts were halted due to local opposition.
- The USACE and The Nature Conservancy (TNC) have proposed to restore a portion of the channelized reach located in Monroe County, Arkansas, which is partially within the Cache River NWR boundary. The project involves removing plugs from the upper three meanders (just below the confluence of Bayou DeView) to reestablish the meanders of the channel using closure weirs to divert flow. This project, known as the *Lower Cache River Restoration Project*, is intended to improve habitat for aquatic species such as freshwater mussels and help restore hydrologic function of the landscape and Cache/White River drainage. A construction contract for the first phase (Phase 1) of the project was awarded in March 2013, and construction was completed in the summer of 2014. Phase 2 is pending future funding and has not been scheduled for completion at this time.

- There are no major levees within the RHI; however, hydrology has been greatly altered by the cumulative effects of many small, privately-constructed levees and other anthropogenic modifications. In addition to these effects, inundation along the White River results in backwater flooding of the lower Cache River Basin to an extent approximately 25 miles upstream of the confluence during flood stages.
- Based on the United States Geological Survey (USGS) gage at Egypt, Arkansas (Site ID# 07077380), for a period of record from 1964 – 2012, the average annual discharge for the Cache River is 875 cubic feet per second (cfs). The average monthly discharge is highest between December and May and lowest between June and November.
- Streamflow on the Cache River at Egypt, Arkansas, is highly variable; however, 2007 – 2011 was a period of consistently above average streamflow, while predominantly below average streamflow occurred from 1967 – 1972, which corresponded to two drought periods.
- Recently (in 2008 and 2011), substantial floods occurred on the White River. The White River stage at Clarendon, Arkansas (near the Cache River confluence), reached 33.73 feet NGVD29 in April 2008, which was the highest stage since the flood of 1973. Three years later (May 2011), the White River stage at Clarendon peaked at 37.47 feet NGVD29, the highest recorded stage height since the 1927 flood. Both of these events led to a "stacking effect" within the Cache River and many areas were sequentially inundated throughout the Cache subbasin.
- The National Hydrography Dataset (NHD) inventories a total of 32,479 acres of unnamed lakes and ponds and 4,380 acres of named lakes and ponds within the RHI. Within the refuge acquisition boundary there are 19,922 acres of waterbodies classified as lakes or ponds, of which 5,705 acres have been acquired.
- The National Wetland Inventory (NWI) indicates that wetlands within the Cache River NWR are primarily palustrine with large freshwater forested/shrub areas. Of the Refuge owned lands, 57% are considered wetlands, as compared to 36% of the areas within the acquisition boundary.
- There are no major dams (i.e., those used for hydropower, large-scale flood control, etc.) within the Cache River NWR RHI. However, as identified by Arkansas Natural Resources Commission (ANRC), the Cache River NWR RHI contains a total of 44 small dams, none of which are on the refuge. These small dams primarily consist of small ponds that capture runoff and contribute to very little, if any, flood issues within the RHI.
- There are sixteen USGS surface water quantity monitoring sites within the RHI. Fifteen active and historic sites are within 20 miles of the Cache River NWR acquisition boundary; seven of these sites are located within the acquisition boundary.
- The gages at Morton (Site ID# 07077700) and Patterson (Site ID# 07077500), Arkansas, have a period of record beginning in 1951 and extending into 2013. These two sites are the more frequently used gages by refuge staff to assess water levels on Bayou DeView and the Cache River, respectively.
- The USACE web site RiverGages.com lists the locations of nine active sites which measure water quantity (stage, precipitation, pool level) within the RHI. Four of these sites overlap with current or historic USGS surface water stations. Both the USACE and USGS have assumed responsibility for gage management throughout the history of these sites. In general, the USACE has collected data over a longer period of record, and, at present, manages many of the active stations.

- Erosion and sedimentation are legacy effects of past land use activities (e.g., forest clearing resulting in loss of riparian buffers) and continue to remain significant problems in the Cache subbasin because of current land use practices (e.g., agriculture).
- Fifty-five percent (55%) of the soils within the Cache River NWR acquisition boundary are classified as all hydric (i.e., wetland soils) and 42% are partially hydric. Only about 4% of soils are classified as not hydric.
- USGS lists 10,302 wells within the RHI that have been or could potentially be sampled for groundwater levels. There are 1,465 wells located within refuge's acquisition boundary, 352 of which are located on lands currently owned by the refuge. Of these, 35 have had groundwater level measurements conducted by USGS since 1957.
- Within the RHI, there are 44 well sites at which groundwater quality is monitored. Of these, four groundwater monitoring well sites are within the refuge acquisition boundary and one (Site ID MON905) is located on refuge owned lands.
- Saltwater intrusion into the alluvial aquifer near Brinkley, Arkansas, was documented as early as 1946. In the 1970s and 1980s the USGS and Arkansas Geological Commission conducted a study of saltwater intrusion in this area and found that a 56 mi^2 area of the aquifer had elevated chloride concentrations, indicating saltwater intrusion. The source was determined to be upward seepage of saline groundwater from the deeper Sparta aquifer.
- According to the most recent information available (from 2005), agricultural irrigation accounted for 90% of water use in Arkansas.
- Impaired waters (waters identified in 303(d) list), and waterbodies with total maximum daily loads (TMDLs) determined, were identified within or near the refuge acquisition boundary. In 2008, Cache River and Bayou DeView did not meet the designated fisheries use due to high concentrations of lead and sedimentation (turbidity) in the surface waters. Non-point sources (e.g., agriculture practices) were identified as the primary contributors to increased sedimentation. These increased levels of sedimentation result in increased accumulation of heavy metals (i.e., lead) as the lead is bound to the sediment loads.
- Excessive sedimentation is of primary concern on the refuge; however, the majority of sources of erosion and sediment transport occur outside the refuge boundaries in areas of disturbance (i.e., agriculture practices).
- Within the RHI there are a total of 505 National Pollutant Discharge Elimination System (NPDES) permitted facilities. This includes ten NPDES facilities within the Cache River NWR acquisition boundary; three of which are on refuge owned lands.
- The ordinary high water mark (OHWM) is defined in the Arkansas code as "the line delimiting the bed of a stream from its bank, that line at which the presence of water is continued for such length of time as to mark upon the soil and vegetation a distinct character" (Ark. Code Ann. § 15-22-202). If the water is non-navigable, the riparian owner has rights to the center of the stream. For navigable waters, the public has the right to use the water and beds "for the purposes of bathing, hunting, fishing, and the landing of boats" in addition to navigation and commerce (Craig 2007-Anderson v. Reames, 161 S.W.2d 957, 960-61 [Ark. 1942]). The Cache River and Bayou DeView are not designated as "navigable waters" by USACE standards. However, state of Arkansas designations for recreational use would include these streams.

1.2 Key Water Resources Issues of Concern

The RHI and the refuge's location within the RHI, lends to a multitude of perceived threats and issues of concern that can directly or indirectly impact the water resources. Most of the specific threats and issues of concern are related to anthropogenic changes within the basin and are most associated with water quantity and water quality issues. Anthropogenic changes within the RHI, such as channelization, levee construction, groundwater withdrawals, and conversion of bottomland hardwoods to agricultural fields, greatly influence the hydrology within the basin and, ultimately, on the refuge. The greatest threat to the Cache River NWR biotic communities results from alterations to the hydrologic regime (timing, duration, and quantity of surface water flows) and water quality (particularly excess sediment contamination from agricultural practices) occurring in the Cache River basin beyond the refuge acquisition boundary.

A *Needs Assessment Survey* was conducted on May 2013. Within the Needs Assessment, refuge staff identified the top three environmental threats that currently impact Cache River NWR resources as: 1) water quantity and quality conditions, 2) changes in disturbance regime, and 3) human use/disturbance. When specifically asked to identify the top issues or concerns regarding threats to the refuge's water supply (quantity), the following were identified: 1) minimum flows in Cache River and Bayou DeView, 2) surface and groundwater extraction, and 3) alterations to hydrologic conditions. When specifically asked to identify the top issues or concerns regarding threats to the refuge's water quality, the following were identified: 1) erosion, 2) sedimentation, and 3) agricultural run-off (in regards to nutrient and chemical introductions).

To further expand upon the issues identified within the Needs Assessment, primary water resource issues and threats currently impacting the refuge include the following:

- Channelization, ditching, and stream straightening have worked together with the conversion of forested areas to agriculture fields and associated land leveling to increase flashy stream flows characterized by rapid rates of flow increase and decrease during runoff events, high peak discharges, and low baseflows. Peak flows during runoff events are often accompanied by high concentrations of nonpoint source pollutants, particularly suspended sediment.
- Flashy streamflows have increased headcutting, channel incision and bank collapses in many areas. Additionally, debris collects at the confluence of straightened and natural channels due to different channel conveyance capacities, resulting in blockages and increased local flooding. This is particularly evident on the Cache River near the town of Grubbs, Arkansas, near the upstream extent of the refuge acquisition boundary. A recent project by the Willow Slough Drainage District removed approximately 18,000 cubic yards of logs and debris from the river, which could potentially lead to transport of large quantities of debris and sediment onto the refuge.
- One of the greatest water quality threats to aquatic species in this system is the increase in sedimentation. Increased sediment loads can adversely impact aquatic species and their associated habitats due to excessive deposition of fine sediments (e.g., siltation in substrates used as fish spawning habitat or in areas utilized as mussel beds).
- By the early 1980s, groundwater levels had declined from 60 to 90 feet in wells in the alluvial aquifer in the Grand Prairie and Cache River areas due to irrigation withdrawals, and water levels continue to decline in both areas at an average rate of about one-quarter and one-half foot per year, respectively. Water levels have generally declined throughout both areas except near rivers, an indication that, in a reversal of predevelopment conditions, surface water features are recharging the alluvial aquifer.

- In 2009, sections of Clay, Craighead, Cross, Green, Lee, Poinsett, and St. Francis Counties, Arkansas, on the western side of Crowley's Ridge, were designated as the Cache Critical Ground Water Area (CGWA) by the ANRC because groundwater levels had dropped below half of the original saturated thickness of the alluvial aquifer. Reduction in aquifer hydraulic pressure means that, in some areas, the hydraulic gradients have been reversed, particularly in the CGWA, and the rivers now typically recharge the alluvial aquifer rather than the aquifer recharging the rivers.
- Common sources of water quality impairment within the Cache River NWR RHI include: sedimentation and siltation; metals other than mercury (e.g., aluminum, zinc, and lead); low dissolved oxygen; and dissolved solids (e.g., chlorides and sulfates). The primary water quality problems experienced by the refuge are turbidity and siltation. While some of these problems originate from on-refuge land use activities (particularly farming and road/levee construction), the majority stem from non-point sources of erosion and runoff outside the refuge's boundaries.
- The Arkansas Department of Environmental Quality (ADEQ) identified several segments of the Cache River and Bayou DeView on the impaired waters 303(d) list. The causes (i.e., siltation/turbidity, lead or aluminum, total dissolved solids, chlorides, or unknown) of these designations have been identified as being associated with sources such as agriculture and municipal point sources.
- Beavers are a nuisance and pose a threat from the construction of dams and huts. These structures divert and pool water into areas that can cause damage. The damage often occurs to bottomland hardwoods and other species that cannot tolerate extended periods of flooding.
- Invasive species could potentially impact the aquatic biota resources on the refuge. For example, the northern snakehead (*Channa argus*) is an invasive fish species that was discovered in eastern Arkansas in 2008 and could have a potential adverse impact to native fish populations on the refuge. Northern snakeheads have been documented in waterbodies within the RHI, and it is likely only a matter of time before their presence is confirmed in refuge waters.

In the longer term, climate change impacts including increased temperatures and altered rainfall patterns could potentially compound the influences of other identified threats currently impacting the Cache subbasin and the refuge. Projected climate change impacts of particular relevance to the refuge include the following:

- Climate models project continued warming in the southeastern United States and an increase in the rate of warming through 2100. The projected rates of warming are more than double those experienced since 1975, with the greatest temperature increases projected to occur in the summer. By 2080, projected mean temperature increases range from about 4.5°F under a low carbon dioxide (CO_2) emissions scenario to 9°F (10.5°F in summer) under a higher CO_2 emissions scenario. In eastern Arkansas, the number of days per year with a peak temperature over 90°F is expected to more than double, from an average of around 60 days to more than 135 days by 2080.
- Increases in ambient temperature can increase water temperatures placing additional stress on the aquatic ecosystems within the Cache River Basin and subsequently on the refuge's aquatic resources.
- Warmer temperatures increase the rate of evaporation of water into the atmosphere. Potential evapotranspiration in the vicinity of the refuge is projected to increase, especially during the summer, which could lead to increased moisture stress for plants and decreased availability of water for management of the refuge's impoundments during the summer and fall.

- The frequency of extreme precipitation events has been increasing across the Southeast, particularly over the past two decades. This trend may be tied to a warming atmosphere which has a greater capacity to hold water vapor, therefore producing higher rates of precipitation. Any increases in runoff due to increased storm severity would cause additional scouring and river bank deterioration, and would augment impacts from nonpoint source pollution and sedimentation.

1.3 Needs and Recommendations

Water resource needs and recommendations for Cache River NWR identified in this WRIA are briefly summarized below. A more in-depth discussion of needs and recommendations is provided in the Assessment (Section 6) of this document.

Several of the identified needs and recommendations coincide with those found within other refuge planning documents, such as the Comprehensive Conservation Plan (CCP). Where appropriate, the CCP objectives and strategies (e.g., Cache River NWR Objectives 1-16, 2-4, 3-2 and 3-6) referencing issues and threats regarding the aquatic resources, hydrology, and water quality should be prioritized based on information contained within this WRIA.

Key needs and recommendations identified in this WRIA include:

- Research and outreach regarding Best Management Practices (BMPs), including both the correct implementation and evaluation of BMP effectiveness, are urgently needed to achieve reductions in sedimentation and excess nutrients/contaminants.
- Increase stream connectivity and restore the natural hydrology in areas where permissible. This would include continued coordination efforts for Phase 2 of the *Lower Cache River Restoration Project*.
- Develop design and installation standards for water control structures to facilitate increased flow, water dispersion, and fish passage in target areas, and when new construction projects are initiated, keep these as a guideline/template to follow and reference.
- Populate a complete road crossing location map. Identify areas that could be targeted for new structures or for replacing old structures and prioritize based on biological (e.g., aquatic species) and management needs.
- As identified as a strategy in the refuge CCP under *Cache River NWR Objective 2-4: Water Management*, the development of a detailed water management plan for the refuge should be considered. From a water resource management perspective, development of such a plan should be considered a high priority. The plan should inventory existing water management infrastructure and condition, assess existing and needed water management capabilities, quantify existing surface and groundwater use by the refuge, identify critical information gaps and monitoring needs, and analyze management options to restore a more natural hydrologic regime on the refuge. To assist with the development of such a document, information and technical support is available from the USFWS Regional Hydrologist, Refuge Inventory and Monitoring staff, and/or other partners (e.g., USGS).
- Develop an Inventory and Monitoring Plan (IMP) for the refuge. Surveys addressing the water and aquatic monitoring component of the IMP should consider: surface and groundwater level monitoring; monitoring of refuge water use for management purposes; water quality monitoring (water temperature, dissolved oxygen, turbidity, other parameters as appropriate); cross-section profiles to monitor channel incision and bank erosion; and possibly sedimentation rate

measurements at selected locations. Surveys to monitor the aquatic biota should be implemented to assess potential impacts from hydrologic alterations and other possible vectors (e.g., aquatic invasive species).

- Perhaps most importantly, the refuge should strengthen efforts to establish new partnerships and build upon existing partnerships with other federal, state, and local agencies, academic partners, and non-governmental organizations (NGOs). These collaborative efforts will assist in addressing other needs and recommendations. One such example where established partnerships and collaborative efforts would be advantageous for the refuge is in the evaluation of the aquatic resources. Biological monitoring for aquatic indicator species (e.g., mussels, aquatic insects, certain fish species, etc.) should be considered. By directly monitoring such species, links to water quality and management actions on the refuge can be evaluated.

2 Introduction

This Water Resource Inventory and Assessment (WRIA) Summary Report for Cache River National Wildlife Refuge (Cache River NWR or the refuge) inventories relevant hydrologic information, provides an assessment of water resource needs and issues of concern, and makes recommendations to address those needs and concerns. The information compiled as part of the WRIA process will ultimately be housed in an online WRIA database currently under development by the U.S. Fish and Wildlife Service (Service or USFWS) Natural Resources Program Center (NRPC). Together, the WRIA Summary Report and the accompanying information in the online WRIA database are intended to be a reference to help guide on-going and adaptive water resource management. This WRIA Summary Report was developed with input by refuge staff as well as internal and external partners with extensive knowledge about the Cache River Basin. The document incorporates existing hydrologic information compiled between April 2012 and December 2014. This WRIA was developed in conjunction with the Dale Bumpers White River NWR WRIA. The Region of Hydrologic Influence (RHI) containing the Cache River NWR is contained within the RHI for Dale Bumpers White River NWR. Greater regional context is provided in that report.

The WRIA database and summary reports provide a reconnaissance-level inventory and assessment of water resources on and adjacent to National Wildlife Refuges and National Fish Hatcheries nationwide. Achieving a greater understanding of existing refuge water resources will help identify potential concerns or threats to those resources and will provide a basis for wildlife habitat management and operational recommendations to refuge managers, wildlife biologists, field staff, Regional Office personnel, and Department of Interior managers. A national team composed of USFWS Water Resource staff, Environmental Contaminants biologists, and other Service employees developed the standardized content of the national interactive online WRIA database and summary reports.

The long-term goal of the National Wildlife Refuge System (NWRS) WRIA effort is to provide up-to-date, accurate data on NWRS water quantity and quality in order to acquire, manage, and protect adequate supplies of clean and fresh water. An accurate water resources inventory is essential to prioritize issues and tasks, and to take prescriptive actions that are consistent with the established purposes of the refuge. Reconnaissance-level water resource assessments evaluate water rights, water quantity and water quality issues, water management, potential water acquisitions, threats to water supplies, and other water resource issues for each field station.

WRIAs are recognized as an important part of the NWRS Inventory and Monitoring (I&M) initiative and are prioritized in the National I&M Operational Blueprint as Task 2a (USFWS 2010a). In addition, this WRIA work supports the Water Resources Inventory and Monitoring (WRIM) Operational Goal, as well as Objective WRIM 1.0, and Task WRIM 1.4 within the National I&M Seven Year Plan (USFWS 2013a). The seven-year plan outlines a strategic, focused, measureable and prioritized plan directly tied to the I&M Operational Blueprint. Hydrologic and water resource information compiled during the WRIA process can facilitate the development of other key documents for each refuge including Hydrogeomorphic Analyses (HGMs), Comprehensive Conservation Plans (CCPs), Habitat Management Plans (HMPs) and Inventory and Monitoring Plans (IMPs). In addition, water quality and pollutant source information compiled as part of this WRIA will help inform the Contaminant Assessment Process (CAP) for the refuge. A CCP for the Central Arkansas National Wildlife Refuge Complex, which includes Cache River NWR, was completed in 2009 (USFWS 2009). In 2002, a broad HGM analysis was performed for the White River Basin in the Delta Region (Foti et al. 2002). A similar but more narrowly focused analysis was completed for the 100-year floodplain of the Cache River in 2010 (Heitmeyer 2010). Although an HGM for Cache River NWR has not been initiated, hydrologic information collected during this WRIA project could be used to inform a refuge-specific HGM.

Preliminary water resource assessments conducted within Region 4 by the U.S. Fish and Wildlife Service beginning in 2007, as well as hydrologic and climate change vulnerability assessments conducted by the USFWS and USGS in 2009, identified Cache River NWR as one of six top priority sites within Region 4 recommended for detailed hydrologic characterization. A hydrologic and landscape database was published for Dale Bumpers White River NWR and Cache River NWR in 2012 (Buell et al. 2012). Following this work, the WRIA processes were initiated in 2012 and a formal kick-off meeting and refuge visit were held on May 23, 2013.

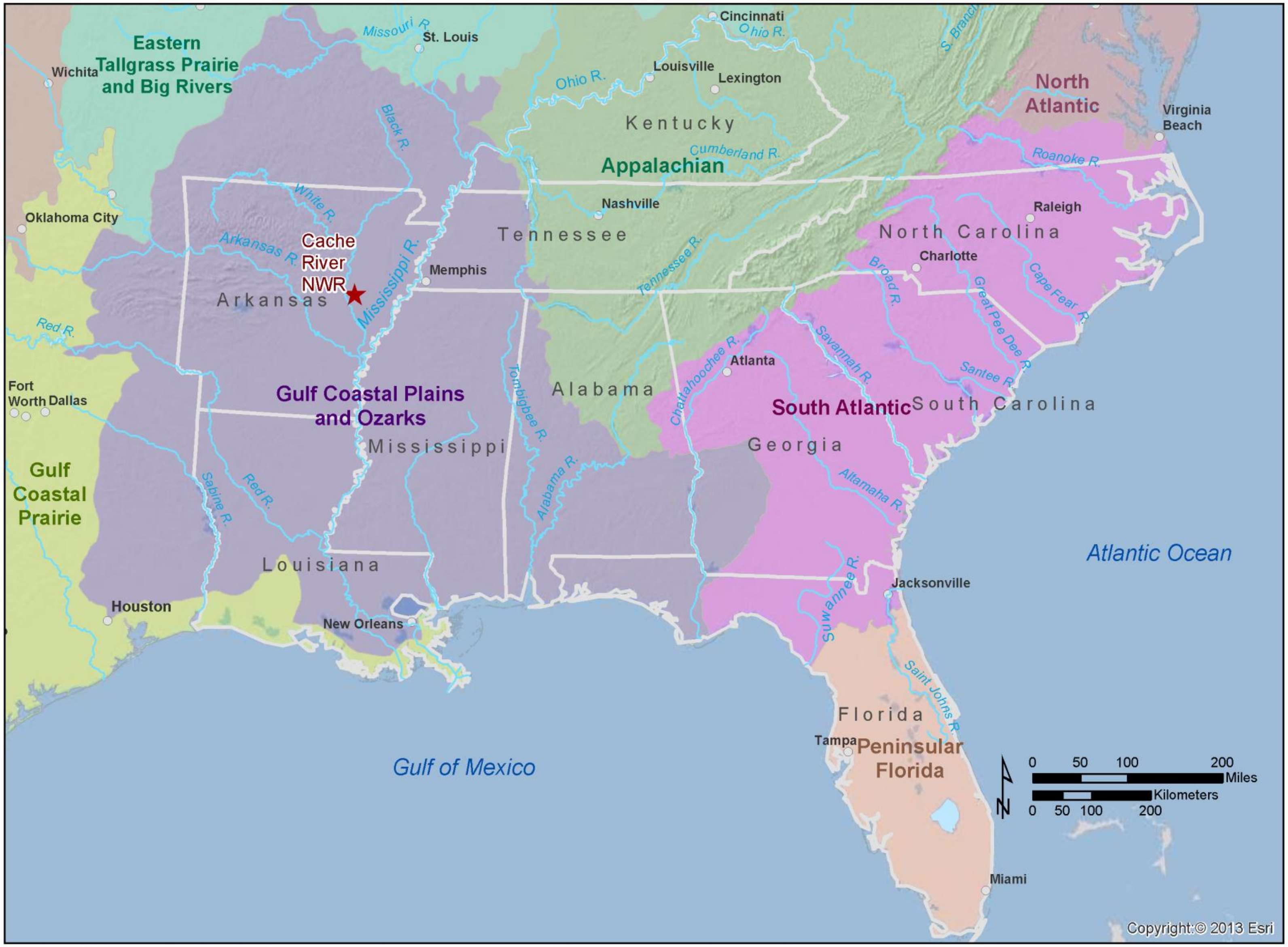
3 Facility Information

Cache River National Wildlife Refuge is located in east-central Arkansas, in Jackson, Monroe, Prairie and Woodruff Counties, Arkansas. The refuge's headquarters and administrative offices are located near the town of Augusta, Arkansas. The refuge is located in the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (GCPO LCC) (Figure 1). Cache River NWR was established June 16, 1986, under the authority of the Emergency Wetlands Resources Act of 1986 (USFWS 2009). The purpose of the refuge is "…the conservation of the wetlands of the Nation in order to maintain the public benefits they provide and help fulfill international obligations contained in various migratory bird treaties and conventions…" (16 U.S.C. 3901(b)) (USFWS 2009). Cache River NWR is administered as part of the Central Arkansas National Wildlife Refuge Complex, along with Bald Knob, Big Lake, and Wapanocca NWRs (USFWS 2009). Since the development of the CCP, two additional refuges have been added to the Complex, Holla Bend NWR and Logan Cave NWR.

The original title-fee acquisition area consisted of 1,395 acres. Cache River NWR currently encompasses 69,500[2] acres within an 185,574-acre approved acquisition area (USFWS 2009; Figure 2). The current acquisition boundary of the refuge runs along 70 miles of the Cache River floodplain. The refuge is in an active acquisition phase, with numerous isolated tracts scattered throughout the acquisition boundary (USFWS 2009). The USFWS has proposed to expand the current acquisition boundary to include an additional 102,000 acres surrounding the Cache River NWR, which would protect, restore and enhance up to a total of 287,574 acres east and west of the Cache River and Bayou DeView (USFWS 2012b). The refuge contains some of the largest remaining tracts of bottomland hardwood forest within the Mississippi Alluvial Valley (MAV) and is one of the few remaining areas in the Lower Mississippi River Valley not drastically altered by channelization and drainage (USFWS 2009).

Only one federally endangered species has been documented on the refuge: the ivory-billed woodpecker (*Campephilus principalis*), which was reportedly sighted in a cypress-tupelo swamp of Bayou DeView in 2004 and 2006. Other threatened or endangered species that have not been documented on the refuge but could potentially occur are the fat pocketbook mussel (*Potamilus capax*), interior least tern (*Sterna antillarum athalassos*), and piping plover (*Charadrius melodus*). Cache River NWR falls within the Lower Mississippi River Ecosystem (LMRE), which is the primary wintering habitat for mid-continent waterfowl populations and breeding and migrating habitat for neotropical migratory birds and resident songbirds (USFWS 2009).

[2] An additional parcel of 1,276 acres was acquired on June 26, 2105, while this document was in the review process (Keith Weaver, personal communication, June29, 2015). As such, this land is not included in quantitative accounts of resources on refuge-owned properties within this document.



Map Date: 8/28/2013 File: Fig1_R4_Overview.mxd Data Source: USFWS LCC Boundaries; Natural Earth 10m River and Lake Centerlines; ESRI Map Service.

Figure 1. Location of Cache River National Wildlife Refuge in relation to USFWS Region 4 Landscape Conservation Cooperative Boundaries.

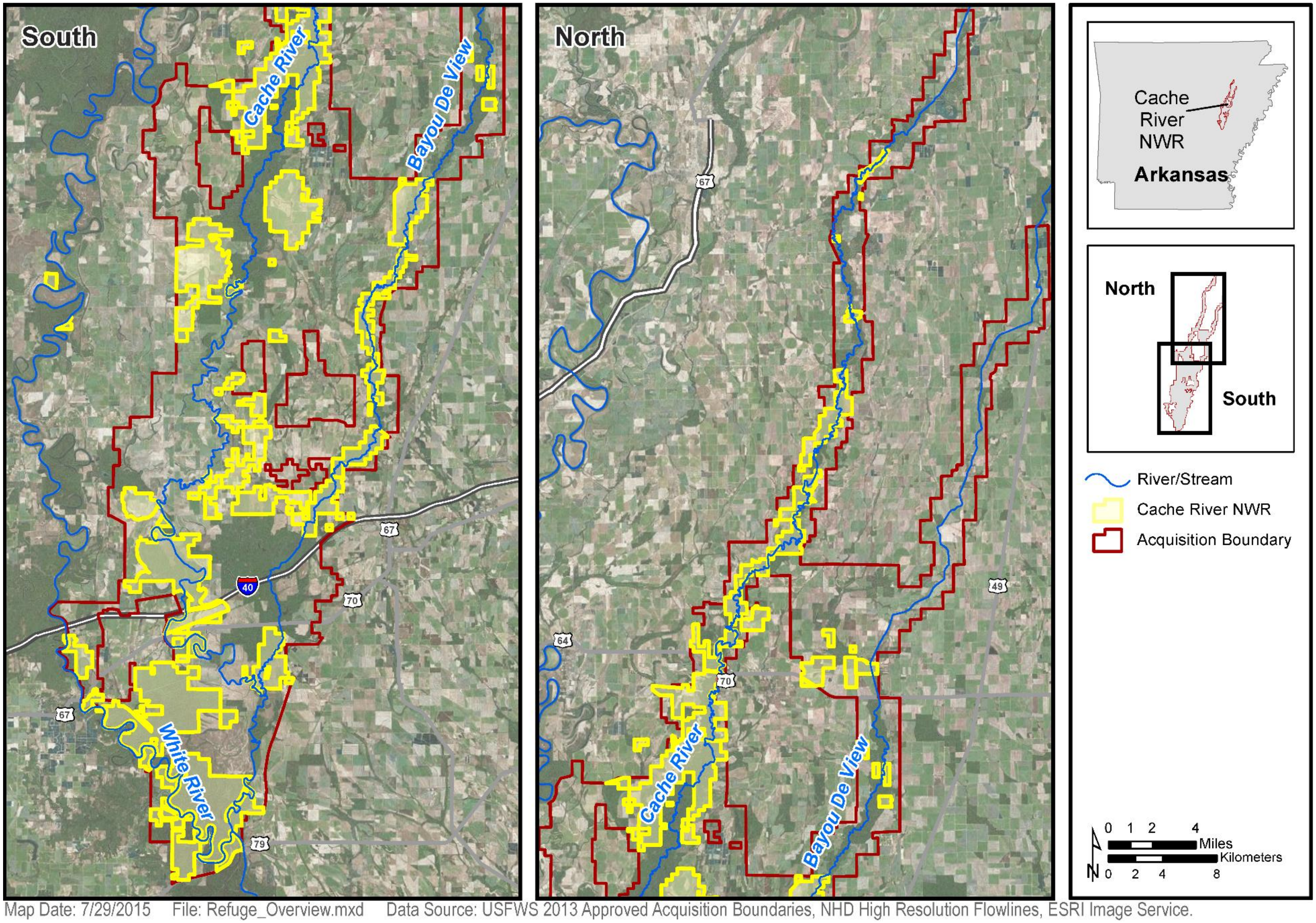


Figure 2. Refuge Overview, including acquired land within the 2013 approved acquisition boundary.

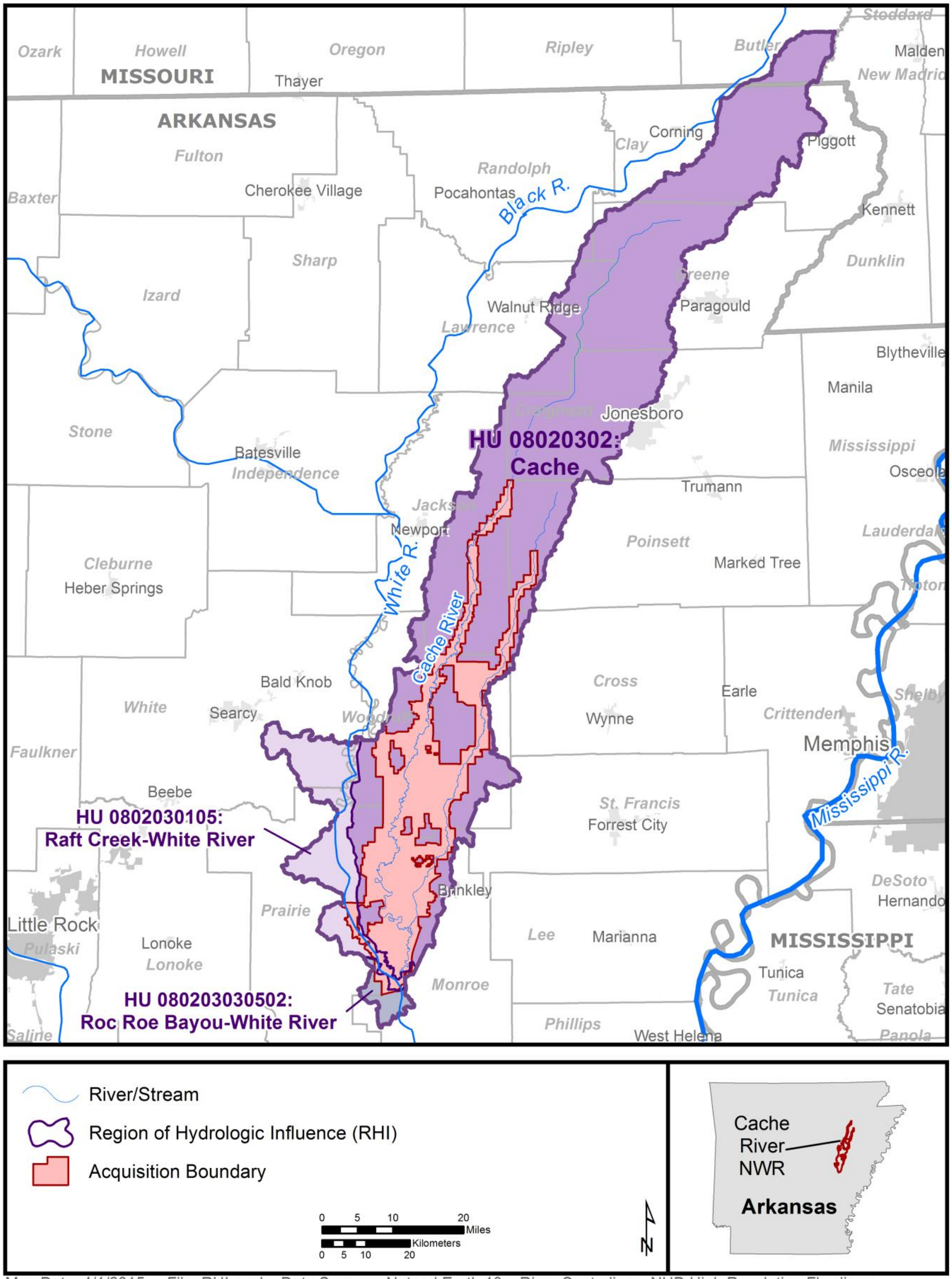
4 Natural Setting

4.1 Region of Hydrologic Influence (RHI)

This assessment focuses on water resources within the geographic extent of the refuge acquisition boundary, and more broadly on water resources within a Region of Hydrologic Influence (RHI) containing the refuge. The RHI describes some portion of the watershed – either the entire or partial watershed – upstream of the refuge that affects the condition of water resources on the refuge. This construct anchors the refuge in the greater watershed and thereby provides a reference for discussing the refuge within a watershed context. Because water travels down gradient, it is the activities occurring upstream of the refuge that will tend to most directly affect water quantity (e.g., diversions, withdrawals, land cover changes) or water quality (e.g., pollution from agricultural, urban, or industrial land uses) on the refuge itself. However, the low gradient of the MAV, in concert with numerous anthropogenic changes to the system and active management, has resulted in conditions where downstream areas with little direct hydrologic connection affect conditions upstream at the refuge. Accordingly, in addition to the upstream watershed, the RHI identified in this WRIA includes downstream areas containing features and management practices directly relevant to hydrologic conditions within Cache River NWR.

Geographic delineations for the RHI are drawn from the National Watershed Boundary Dataset (WBD), a hierarchical framework that divides the landscape into progressively smaller hydrologic units (HUs) and assigns specific numeric hydrologic unit code (HUC) identifiers. At the coarsest scale, the HUs are called hydrologic regions and assigned a unique 2-digit HUC. At progressively finer scales, 4-, 6-, 8-, 10-, and 12-digit HUs are called subregions, basins, subbasins, watersheds, and subwatersheds, respectively (Laitta et al. 2004).

The majority of Cache River NWR is located within the Cache subbasin (08020302). A small portion of the lower refuge is located outside this subbasin, within two subbasins associated with the White River. Water levels and conditions on the White River have a direct effect on the hydrology of the lower Cache River. These relationships will be discussed in further detail in Section 5.4. In order to inventory data which characterize these hydrologic relationships, two smaller hydrographic units are included with the Cache subbasin to define the RHI for the refuge. These units are the Raft Creek-White River watershed (0802030105), which extends along the White River upstream from the confluence of the White and Cache Rivers; and the Roc Roe Bayou-White River subwatershed (080203030502), which is downstream of the confluence along the White River, and which contains the southernmost portion of the refuge approved acquisition boundary (Figure 3). The RHI includes a total drainage area of 2,251 mi^2 (1,440,780 acres).



Map Date: 4/1/2015 File: RHI.mxd Data Sources: Natural Earth 10m River Centerlines, NHD High Resolution Flowlines and Waterbodies, National Watershed Boundary Dataset, ESRI Topo Service.

Figure 3. Region of Hydrologic Influence for Cache River National Wildlife Refuge.

4.2 Topography and Landforms

The Cache River Basin drains a portion of the relatively flat area of the Gulf Coastal Plain province to the south and east of the Ozarks. Elevation ranges from 500 feet above mean sea level (MSL) at the north end, near the Missouri state line, to 125 feet above MSL at the mouth of the White River (USFWS 2012b). The surface of the basin generally slopes gently southward. Major drainage systems in this area include the White, Cache, and Bayou DeView Rivers. The Ozark Escarpment, which acts as the fall line between the Gulf Coastal Plain and the Interior Highlands, trends from northeast to southwest, and occurs along the White River near Batesville, Arkansas.

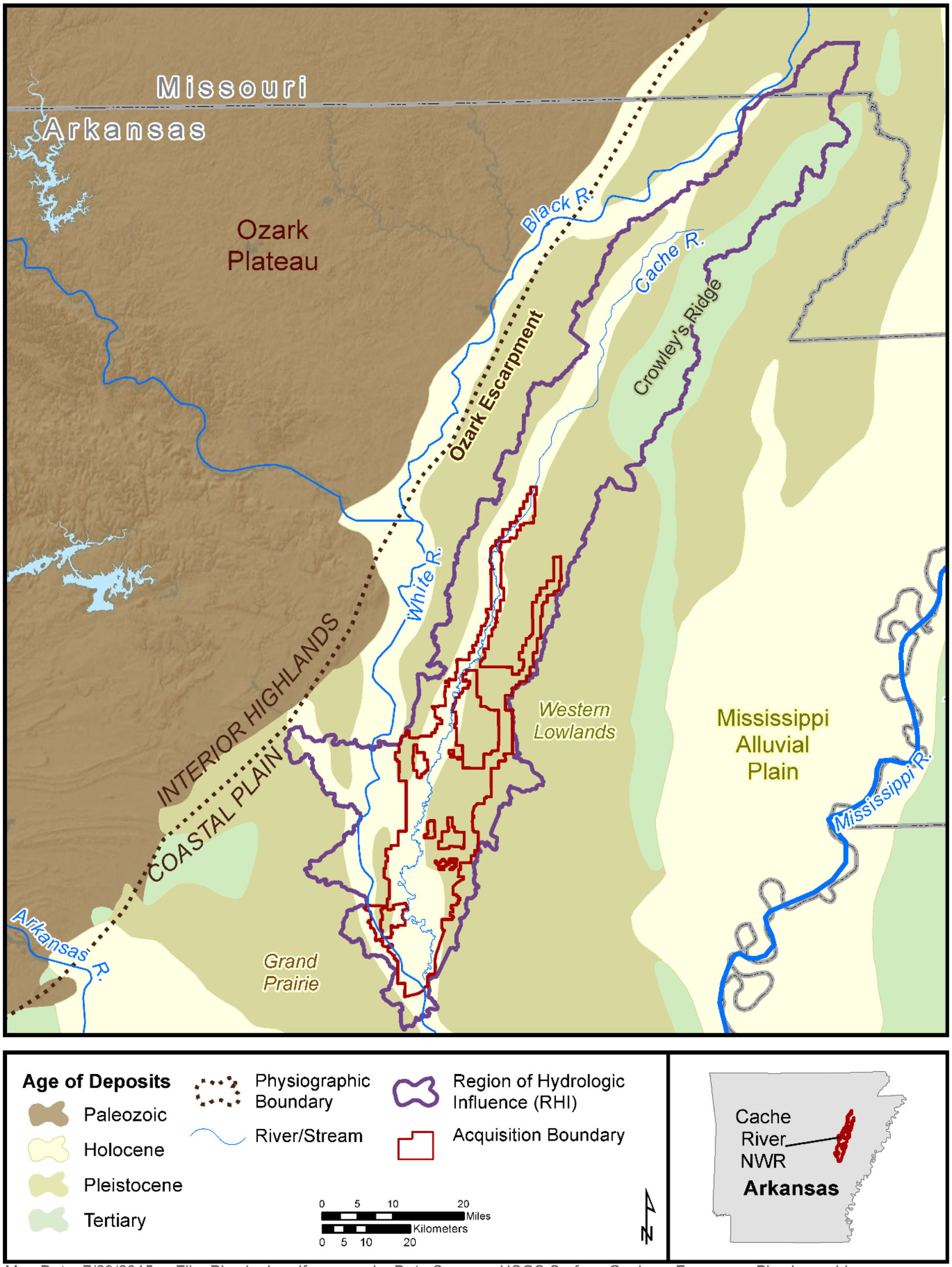
Cache River NWR is located in the broad, flat Mississippi River Alluvial Plain, a section of the Gulf Coastal Plain. This area is often alternatively referred to as the Mississippi Alluvial Valley, the Mississippi River Delta, and the Mississippi Embayment. All names generally refer to the low-lying area presently dominated by fluvial sediments of the Mississippi River. Figure 4 shows the location of the refuge in relation to important physiographic areas and features.

Throughout the larger MAV, eroded Tertiary remnants subdivide the area into lowlands, which are further subdivided into smaller units by ridges of Wisconsin or Holocene age (Saucier 1994). The most prominent topographic feature in the present-day MAV is Crowley's Ridge, a narrow erosional remnant of Tertiary strata, which runs north to south and bisects the northern portion of the alluvial plain (Figure 4). Crowley's Ridge is thought to be the remains of uplands that once separated the Mississippi River system to the west from the Ohio River system to the east. The ridge is similar in age and geology to the uplands bounding the MAV to the east (Saucier 1994). The southern half of the ridge is approximately 3 miles wide and rises 100 to 150 feet above the surrounding plain. The northern half of the ridge, which begins around Jonesboro, Arkansas, and extends north-northeast to the Missouri border, ranges from 10 to 12 miles wide, at an average elevation of 250 feet above the alluvial plain. Crowley's Ridge divides the Cache River and Lower White River Basins to the west from the St. Francis River Basin to the east.

A less prominent interfluve within the MAV is the Grand Prairie, which separates the Arkansas River Basin from the Lower White River Basin. The Grand Prairie is a low terrace which dates to the Sangamon Stage, an interglacial period approximately 125,000 years before present (B.P.). The terrace has a relatively constant width of around 25 miles. Elevation ranges from 20 to 40 feet higher than the adjacent White River lowlands (Saucier 1994).

Between Crowley's Ridge and the Grand Prairie is an area called the Western Lowlands, which roughly corresponds to the Lower White River Basin and the lower portion of the Upper White River Basin up to the Ozark Escarpment. This area of lowlands features local drainages that have formed narrow valleys and floodplains within early Wisconsin-age glacial outwash (Saucier 1994).

Within this greater context, Cache River NWR is located within the Western Lowlands of the Mississippi Alluvial Plain; the primary elements of relief are river terraces and natural levees. The topography is relatively flat and characterized by braided-stream terraces, meander belts and backswamps (USFWS 2009). Section 4.5 will address the dominant surface processes and landforms which characterize the present-day Cache River NWR.



Map Date: 7/29/2015 File: Physio_Landforms.mxd Data Sources: USGS Surface Geology, Fenneman Physiographic Boundaries, Natural Earth 10m River Centerlines, ESRI Topo Service

Figure 4. Physiographic divisions and major landforms in the vicinity of Cache River National Wildlife Refuge.

4.3 Geology and Hydrogeology

Beneath the Cache River system is Paleozoic bedrock located 1,000 to 4,000 feet below sea level. Overlaying the bedrock are strata of gravel and sand, supporting several aquifers, alternating with confining strata of silts and clays. Surface strata are composed of Quaternary deposits of alluvium and loess (USFWS 2009, Figure 5).

The Mississippi Embayment specifically refers to the underlying geologic structure beneath the MAV, an area of lowlands formed by a plunging syncline that extends from central Louisiana into southern Missouri and Illinois between the Appalachians to the east and the Ozark-Ouachita highlands to the north and west (Saucier 1994). The northernmost reaches of the embayment were flooded by waters from the Gulf of Mexico during the Cretaceous Period, more than 65 million years B.P. (Renken 1998).

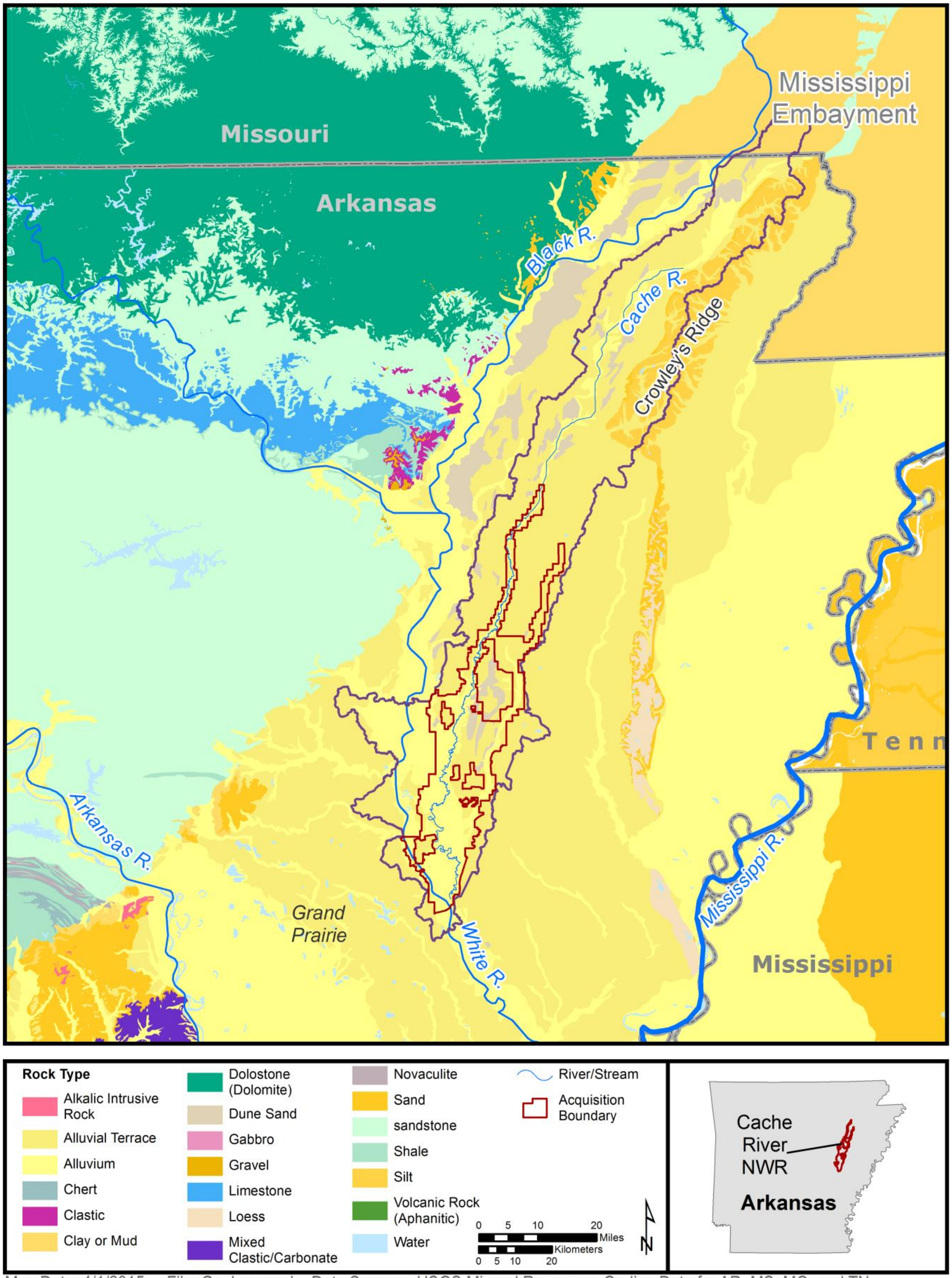
With the advent of continental glaciations during the Pleistocene, sea levels receded and the coastal shoreline retreated southward. The low area formed by the Embayment gradually filled with sediment. Layers of sands and gravels were deposited by the deltas of the ancestral Mississippi and other rivers. Clays, mud, marl, and shale were deposited during periodic marine invasions (Saucier 1994). At the conclusion of the Pleistocene epoch and the most recent (Wisconsin) glacial retreat, sea levels rose again. During glacial retreat, the MAV acted as the conduit for glacial meltwater and sediments. Deposits from this time occur in the form of braided stream terraces known as valley trains, as well as unconsolidated alluvium. Additional deposits of loess (wind-blown silt) also date to earlier periods of the Pleistocene (Saucier 1994).

At the beginning of the Holocene epoch, approximately 12,000 years B.P., water and sediment supplies from glacial outwash decreased, and the ancestral Mississippi River system transitioned from a braided outwash complex to an aggrading, meandering low-gradient channel. Cyclic changes in base level caused the channel to entrench into the valley fill, creating erosional terraces within the MAV. The Holocene alluvial plain is dominated by the meander belts of the Mississippi and Arkansas Rivers. Each is a low, broad ridge that is a mile to several miles wide, and 5 to 10 feet higher than the adjacent floodplain areas (Saucier 1994, “alluvial terraces,” as shown on Figure 5).

The Mississippi Embayment Aquifer System (MEAS) underlies the Mississippi Alluvial Plain section of the Gulf Coastal Plain province in Arkansas. It is composed of six aquifers in poorly consolidated to unconsolidated bedded sand, silt and clay (Renken 1998). In Arkansas, the extent of MEAS ranges from the upper northeast corner of the state to the lower southwest corner (Figure 6).

The uppermost unit of MEAS in the vicinity of the refuge and along the core of the Mississippi Embayment is the Mississippi River Valley alluvial aquifer, commonly referred to as the alluvial aquifer. The alluvial aquifer produced 94% of the groundwater withdrawn in Arkansas in 2010 (Kresse et al. 2014), and is primarily used for irrigation. Groundwater wells drawing from the alluvial aquifer can yield from 50 to more than 500 gallons per minute (Pugh 2008).

The alluvial aquifer is composed of unconsolidated Quaternary (Holocene and Pleistocene) alluvium overlying other aquifers and laterally adjacent to the confining units of the Mississippi Embayment. It contains two distinct lithologies: a clay and silt cap which varies in thickness and extent overlying coarse sand and gravel, which are often well-sorted and generally become finer in texture with proximity to the surface (Renken 1998). The hydraulic conductivity is greater at the bottom of the aquifer and decreases upward as the sediment size decreases (Mahon and Poynter 1993).



Map Date: 4/1/2015 File: Geology.mxd Data Sources: USGS Mineral Resources On-line Data for AR, MS, MO, and TN; Natural Earth 10m River Centerlines; ESRI Map Service

Figure 5. Surface geology within the Region of Hydrologic Influence (RHI) and Mississippi Embayment.

The alluvial aquifer underlies about 32,000 mi^2 and generally ranges from 50 to 125 miles in east to west extent and about 250 miles north to south, adjacent to the Mississippi River (Holland 2007). The thickness of the alluvial aquifer ranges from 60 to 140 feet, with an average of 100 feet. These estimates of measure include the clay/silt cap, which has an average thickness of 30 feet (Ackerman 1996), but which can exceed 60 feet in thickness throughout the Grand Prairie area (Renken 1998). The clay/silt cap acts as a confining unit throughout much of the aquifer. Saturated thickness is usually equal to the thickness of the aquifer, except for areas where groundwater pumping has caused cones of depression to develop.

Recharge for the alluvial aquifer comes from direct precipitation (in places where confining unit is absent), runoff from adjacent slopes, upward flow from underlying aquifers, and infiltration from streams during periods when water levels in surface features are higher than water levels in the aquifer. Within the Cache River and Lower White River Basins, the presence of clay soils at the surface prevents widespread recharge of the alluvial aquifer from surface waters (USFWS 2012a). However, recharge from induced stream infiltration may take place in areas where the clay/silt cap is thin enough to have been breached by stream channels, and where well withdrawals have lowered the adjacent water table below the stream level (Gonthier 1996; Wilbur et al. 1996). This condition exists along most of the length of the Cache River (Broom and Lyford 1981). Alternately, during dry periods, water may discharge from the alluvial deposits or adjoining aquifers into the streams, which contributes to baseflow (Renken 1998).

Groundwater enters the alluvial aquifer from the north and west and flows in a south and east direction toward major rivers. In areas of high groundwater withdrawal, groundwater flows towards cones of depression that are formed as a result of withdrawal activities.

The fine-textured loess of Crowley's Ridge acts as a major hydrologic interruption within the alluvial aquifer, bisecting the northern portion of the unit. Both the White and Arkansas Rivers penetrate the alluvial aquifer and also act as local hydrologic boundaries (Ackerman 1996).

Below the alluvial aquifer are deeper aquifers within geologic units ranging in age from late Cretaceous to middle Eocene (approximately 70 – 40 million years B.P.) (Table 1, Figure 6). These units consist of alternating beds of sand and clay with some interbedded silt, lignite, and limestone (Grubb 1984), and range from 60 to 600 feet in thickness. The Vicksburg-Jackson confining unit, which separates the alluvial aquifer from the lower strata, is present in parts of southeastern Arkansas but absent in the northeast. Thus, in northeastern Arkansas, the southward-dipping lower strata of the MEAS are hydraulically connected to the alluvial aquifer; however, the distinct differences in texture and permeability between the units can cause the lower MEAS strata to act as lower confining units for the alluvial aquifer (Renken 1998).

In the Cache River Basin, the most important of these deeper aquifers lie in the Sparta and Memphis sands of the Middle and Lower Claiborne aquifers. The Sparta aquifer is primarily found in portions of southeastern Arkansas, where it is hydraulically isolated from deeper aquifers by the Lower Claiborne confining unit. The Sparta aquifer consists of fine- to medium-grained sand near the top, grading to coarse-grained sand at the bottom with some interbedded clay. Maximum thickness of this unit is around 900 feet (Pugh 2008). North of latitude 35˚N (shown on Figure 6, corresponding to roughly the upper 2/3 of the refuge area), the Lower Claiborne confining unit is absent, and the connected aquifers of the Middle and Lower Claiborne units are collectively referred to as the Memphis aquifer (Ackerman 1996; Pugh 2008).

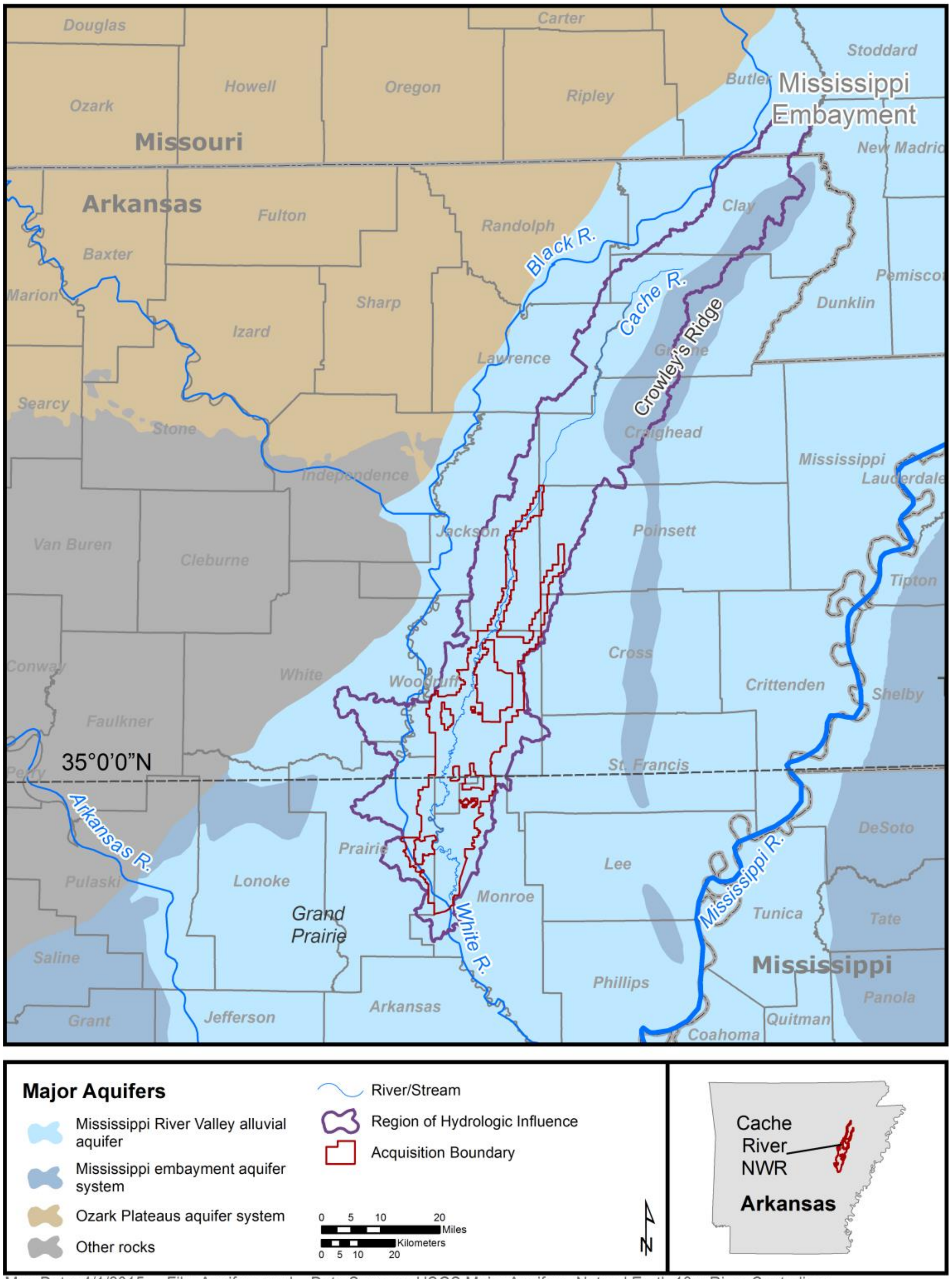
Both the Sparta and Memphis aquifers are primarily used for industrial and public water consumption. Water quality in these aquifers makes them more suitable for public consumption wells than the alluvial aquifer (US EPA 2009). The Sparta aquifer commonly yields 1,000 gallons per minute (Pugh 2008). Yields of as much as 2,000 gallons per minute may occur in the Memphis aquifer in areas of eastern Arkansas

(Renken 1998). Wells in the Middle Claiborne aquifers in Arkansas are reported to yield from 300 to 1,000 gallons per minute.

Water within the Claiborne aquifers would flow from the northwest to the southeast in natural conditions; however, large groundwater withdrawals in southern Arkansas and northern Louisiana have caused declines of the potentiometric surface and some changes in direction of regional predevelopment flow. Large withdrawal rates from the middle Claiborne aquifer have also induced downward leakage of water into the middle Claiborne aquifer from the upper Claiborne and the Mississippi River Valley alluvial aquifers (Renken 1998).

Table 1. Hydrogeologic Units in the vicinity of Cache River National Wildlife Refuge. [Source: Modified from Ackerman 1996.]

ERA	SYSTEM	SERIES	NORTHEASTERN ARKANSAS		SOUTHEASTERN ARKANSAS		HYDROSTRATIGRAPHIC UNITS	
CENOZOIC	QUATERNARY	HOLOCENE	Alluvium and terrace deposits		Alluvium and terrace deposits		Mississippi Embayment Aquifer System	Mississippi River confining unit
		PLEISTOCENE						Mississippi River Valley alluvial aquifer
	TERTIARY	OLGIOCENE	*not present*		*not present*			Vicksburg-Jackson Confining Unit
		EOCENE			Jackson Group	Undifferentiated		
			Claiborne Group	Cockfield Formation	Claiborne Group	Cockfield Formation		Upper Claiborne Aquifer
				Cook Mountain Formation		Cook Mountain Formation		Middle Claiborne confining unit
				Memphis Sand		Sparta Sand		Middle Claiborne Aquifer
						Cane River Formation		Lower Claiborne confining unit
						Carrizo Sand		Lower Claiborne-upper Wilcox aquifer



Map Date: 4/1/2015 File: Aquifers.mxd Data Sources: USGS Major Aquifers, Natural Earth 10m River Centerlines, ESRI Map Service

Figure 6. Extent of major aquifers within the Region of Hydrologic Influence (RHI) as related to the vicinity of Cache River National Wildlife Refuge.

4.4 Soils

Soils in the Cache subbasin formed in two different depositional environments, water-deposited alluvium and wind transported loess. The alluvium was deposited by the Mississippi River when it flowed in the channels now occupied by the Black and the Cache Rivers (TNC 2005). The wide range in textures of the alluvium in the watershed results from the differences in depositional sites.

Erosion and sedimentation are legacy effects of land use activities and current problems in the subbasin. Some soils in the subbasin are highly susceptible to erosion, especially those formed in loessal parent materials, such as those found in basins originating along Crowley's Ridge, while soils within the refuge acquisition boundary are not generally susceptible to erosion due to their geographic setting, slope, and texture. For instance, very few areas within the refuge are greater than gently sloping whereas slopes along Crowley's Ridge are much higher.

Soil texture plays a major role in erosion. The material most easily dislodged by runoff has a texture close to that of fine sand. Soils with finer silt/clay textures tend to be stickier, and thus it is more difficult for particles to become dislodged or entrained. Coarser material has heavy particles which can only be moved at higher fluid speed. As long as the flow is slow, it cannot erode. Gentle slopes within the refuge slow down the flow and reduce erosion. Fine clay and loam particles, once dislodged and entrained, are easily transported, even at low speeds, but in the case of anything coarser than fine sand, the distance from erosion site to sedimentation site is typically short.

When a river overflows it banks, its velocity immediately diminishes, leaving coarse sediment deposited in low ridges bordering the channel known as natural levees. As the water spreads out over the floodplain and the velocity becomes less, a greater amount of fine sediment is deposited. Within the refuge these low ridges are comprised of Beulah, Bosket, Dexter, and Dubbs soils. Finer sediment, with a higher percentage of silt, is deposited on the floodplains and soils such as the Commerce and Dundee are formed. Clay and finer size fractions are deposited in water that is left standing as shallow lakes or swamps once the flood water recedes. The Kobel and Jackport soils formed in this manner (TNC 2005). While no soil series on the refuge is highly erodible, erosion has occurred within some units. Loring, Grenada, Grubbs, Providence, and Wiville are susceptible to erosion. Bulltown, Loring, and Levee series have higher slopes, and thus, greater potential for erosion.

The refuge is dominated by nine soil series: Askew fine sandy loam, Foley-Bonn complex, Foley-Calhoun complex, Kobel silty clay loam, McCrory fine sandy loam, Mhoon soils, Sharkey soils, Tuckerman silty clay loam, and Yancopin silty clay loam. Table 2 summarizes characteristics of the major soil components which occupy at least one percent of the acquisition boundary of Cache River NWR. The distribution of individual soil series is problematic because individual counties were mapped over a one hundred year period and the same soil is called by different names in different counties (e.g., the Foley-Jackport-Crowley association component Jackport in Poinsett County is called Alligator in Cross County). For management and restoration purposes, emphasis should be placed on series in Table 2 with similar characteristics, rather than on differences in soil series nomenclature.

Broadly speaking, the southern portion of the refuge is dominated by Kobel-Commerce-Dubbs association and the northern portion of the refuge is dominated by the Foley-Jackport-Crowley association (USDA undated-a). Dundee-Sharkey-Bosket occupies a large portion of the center of the refuge, while Calloway-Henry-Grenada and Amagon-Dundee-Sharkey occupies smaller portions of the refuge.

The three major associations (Kobel-Commerce-Dubbs, Foley-Jackport-Crowley, and Dundee-Sharkey-Bosket) are characterized by broad, low, level areas in floodplains. Individual soil series occupy different geographic settings or locations (Table 2) within the floodplain, with different textures, and drainage classes that reflect their formation and govern their hydrologic function with respect to runoff, erosion, and groundwater recharge. Soil hydrologic processes include infiltration, storage, redistribution, drainage, evaporation, and transpiration. All soil hydrologic processes occur within soil pore space. Porosity describes the relative volume of void space between soil particles that may be filled with air or water. Soil porosity depends on the texture and structure of soil. Coarse-textured soils tend to have less pore space than fine-textured soils, although the relative size of pores in coarse-textured soils tends to be larger than in fine-textured soils. Coarse-textured soils tend to be more permeable, permitting quicker infiltration with greater potential for groundwater recharge.

The Kobel series consists of very deep, poorly drained and very poorly drained, very slowly permeable, level to nearly level soils that formed in clayey alluvium. Commerce and Yancopin soils are on similar landscape positions; they are in a fine-silty particle size class, do not have cambic horizons and are somewhat poorly drained. Dubbs soils are on adjacent higher terraces, are in a fine-silty particle size class, and are well drained. Commerce and Mhoon soils typically occur on low flood plains near the present channel and are in a fine-silty particle size class.

The Foley series consists of very deep, poorly drained, very slowly permeable soils that formed in silty material high in sodium on level to nearly level stream terraces. Amagon, Jackport, and Lafe occur on similar landscapes. Amagon and Jackport do not contain high amounts of exchangeable sodium cations. Lafe soils have exchangeable sodium cations nearer the soils surface. McCrory soils, which occur on lower terraces and floodplains, are in a fine-loamy particle-size class. The Crowley series consists of very deep, somewhat poorly drained, very slowly permeable soils on broad, nearly level coastal prairies, formed in clayey sediments on terraces. A large portion of the refuge contained by this association is mapped as the Tuckerman series. Tuckerman soils are on level to nearly level Holocene floodplains and low terraces, slightly lower than McCrory and Foley.

The Dundee series consists of very deep, somewhat poorly drained, level to gently sloping soils that formed in loamy alluvium. Dundee soils typically occur on higher parts of natural levees and in a fine-silty particle size class along former channels. The Sharkey series consists of very deep, poorly and very poorly drained, very slowly permeable soils that formed in clayey alluvium on floodplains and low terraces. Bosket and Dubbs soils are better drained and are on slightly higher positions than Sharkey and Dundee.

Table 2. Soil series found within the approved acquisition boundary of Cache River National Wildlife Refuge. Hydrologic Soil Groups are defined in Table 3. [Source: SSURGO undated].

Map Unit	Acres within Acquisition Boundary	Slope	Drainage	Hydric	Hydrologic Soil Group	Surface Texture	Subsurface texture	Location	Parent Material
Amagon	3842	level to very gently sloping	poorly drained	Partially hydric	C or D	silt loam	silty clay loam	low terraces; depressions, natural levees	stratified silty alluvium
Amagon and Forestdale	1930	level to gently undulating	poorly drained	Partially hydric	C	clay	clay	river valley, backswamp	N/A
Askew	7739	very gently sloping	moderately well drained	Partially hydric	C	fine sandy loam	silty clay loam, loam, fine sandy loam	low terraces	loamy alluvium
Bosket	4681	level to undulating	well drained	Partially hydric	B	fine sandy loam	fine sandy loam, sandy clay loam, loamy fine sand	natural levees along creeks and abandoned river channels	stratified beds of predominantly loamy sediment
Bulltown	1610	gently sloping	somewhat excessively drained	Partially hydric	B	loamy fine sand	fine sandy loam, sandy clay loam, fine sand	dunes on terraces	sandy eolian deposits
Calhoun	2404	level to very gently sloping	poorly drained	Partially hydric	C or D	silt loam	silty clay loam	low ridges	loess
Commerce	7706	level to gently undulating	somewhat poorly drained	Partially hydric	C	silt loam	silt loam to silty clay loam	natural levees	beds of stratified loamy alluvium
Crowley	1474	level to very gently sloping	poorly drained	Partially to all hydric	D	silt loam	silty clay, silty clay loam, silt loam		loess
Dubbs	10874	level to gently sloping	well drained	Partially hydric	B	loam, silt loam, and silty clay loam	fine sandy loam	river valley, natural levee	loamy alluvium
Dundee	4574	level to gently sloping	somewhat poorly drained	Partially hydric	C	silt loam, silty clay loam, and loam	sandy loam	river valley, natural levee	loamy alluvium
Foley-Bonn complex	10898	level	poorly drained	Partially to all hydric	D	silt loam with redoximorphic features	silt loam, silty clay loam, and silt with rexodimorphic features	terraces	loamy material high in exchangable sodium
Foley-Calhoun complex	14427	level	poorly drained	Partially hydric	D	silt loam	silt loam to silty clay loam	broad flats	silty sediment
Foley-Calhoun-Bonn complex	3770	level	poorly drained	Partially hydric	D	silt loam	silt loam to silty clay loam	broad flats in areas of wind-deposited sediments	loess

Map Unit	Acres within Acquisition Boundary	Slope	Drainage	Hydric	Hydrologic Soil Group	Surface Texture	Subsurface texture	Location	Parent Material
Foley-Calhoun-McCrory complex	4322	level	poorly drained	Partially hydric	D	silt loam	silt loam to silty clay loam	broad flats, lower parts of natural levees	N/A
Forestdale	3766	level to gently sloping	poorly drained	All hydric	D	silty clay loam	silty clay to silty clay loam	river valley, stream terrace	clayey alluvium
Grenada	5585	level to gently sloping	moderately well drained	Partially hydric	C	silt loam	silt loam to silty clay loam, fragipan	tops and side slopes of low ridges	loess
Grubbs	4496	gently sloping	somewhat poorly drained	Partially hydric	D	silt loam	silty clay loam		clayey sediments
Jackport	9147	level	poorly drained	Partially to all hydric	D	silty clay loam	clay, silty clay, and silty clay loam	abandoned backswamps	predominantly clayey sediments
Kobel	42968	level	poorly drained	Partially to all hydric	D	silty clay loam	clay, silty clay loam, and clay loam	floodplains and back swamps	clayey alluvium
Lafe	2210	level	somewhat poorly drained	Partially hydric	D	silt loam	silty clay loam, silt loam, fine sandy loam	terraces	eolian or alluvial loamy sediments
McCrory	10463	level	poorly drained	Partially hydric	D	fine sandy loam	fine sandy loam, loamy fine sand	terraces	loamy alluvial sediments
Mhoon	7891	level	poorly drained	All hydric	D	silt loam	silt loam, silty clay loam	floodplains	stratified beds of loamy sediments
Overcup	5142	level to very gently sloping	poorly drained	Partially hydric	D	silt loam	clay, silty clay, and silty clay loam	river valley, stream terrace	clayey alluvium
Sharkey	37525	level	poorly drained	Partially hydric	D	clay	clay	broad flats	thick beds of fine-textured slackwater deposits
Teksob	12673	level to gently sloping	well drained	Partially hydric	B	loam	loam, sandy clay loam, fine sandy loam, fine sand	terraces	loamy alluvium
Tichnor	3626	level to very gently sloping	poorly drained	Partially to all hydric	C or D	silt loam	silty clay loam to silt loam	upland, flood plain	loamy alluvium
Tuckerman	26146	level to very gently sloping	moderately well drained	All hydric	C	silty clay loam	silty clay to silty clay loam	floodplains of the White River	loamy alluvium
Wiville	4573	level to gently sloping	well drained	Partially hydric	B	fine sandy loam	fine sandy loam, sandy clay loam, fine sand	sand dunes on stream terraces	loamy eolian deposits

Map Unit	Acres within Acquisition Boundary	Slope	Drainage	Hydric	Hydrologic Soil Group	Surface Texture	Subsurface texture	Location	Parent Material
Yancopin	11943	level to gently sloping	somewhat poorly drained	Partially hydric	C	silty clay loam to silt loam	sandy loam	river valley, floodplain	N/A

The Natural Resources Conservation Service (NRCS) defines a hydric soil as "soil that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part." The concept of hydric soils includes soils developed under sufficiently wet conditions to support the growth and regeneration of hydrophytic vegetation. Soils that are sufficiently wet because of artificial measures are included in the concept of hydric soils. Also, soils in which the hydrology has been artificially modified are hydric if the soil, in an unaltered state, was hydric. Some series, designated as hydric, have phases that are not hydric depending on water table, flooding, and ponding characteristics. NRCS maintains a national list of hydric soil components (USDA undated-b). Within the Soil Survey Geographic (SSURGO) Database, "hydric soils" include all map units in which the majority of soil components meet hydric criteria. "Partially hydric soils" may have some hydric components within a larger matrix of non-hydric components (SSURGO undated). Using these criteria, 55% of soils within the acquisition boundary of Cache River NWR are classified as all hydric, and 42% of soils are partially hydric. Only about 4% of soils can be classified as not hydric (USDA undated-a).

NRCS also assigns a hydrologic group to each map unit as an indicator of the runoff (and indirectly, recharge) potential for the soil unit when thoroughly wet. There are four groups, ranging from A (high infiltration/low runoff) to D (very slow infiltration/high runoff). If a soil is assigned to a dual hydrologic group, the first letter is for drained areas and the second letter is for undrained areas. The majority (83%) of soils within the acquisition boundary of Cache River NWR fall into hydrologic groups C and D, which are characterized by slow infiltration and high runoff potential (Table 3). Figure 7 depicts soils characterized by hydrologic group.

Table 3. Acres of refuge soils by hydrologic group. [Source: USDA 2013].

Hydrologic Group	**Description**	**Acres within acquisition boundary**	**Percent of total area**
None assigned		12,358	4
A	High infiltration, low runoff	--	--
B	Moderate infiltration, moderately low runoff	35,859	13
C	Slow infiltration, moderate runoff	75,384	26
C/D	Slow infiltration, moderate runoff/ Very slow infiltration, high runoff	91	Less than 1
D	Very slow infiltration, high runoff	162,189	57
Total		***172,443***	***100***

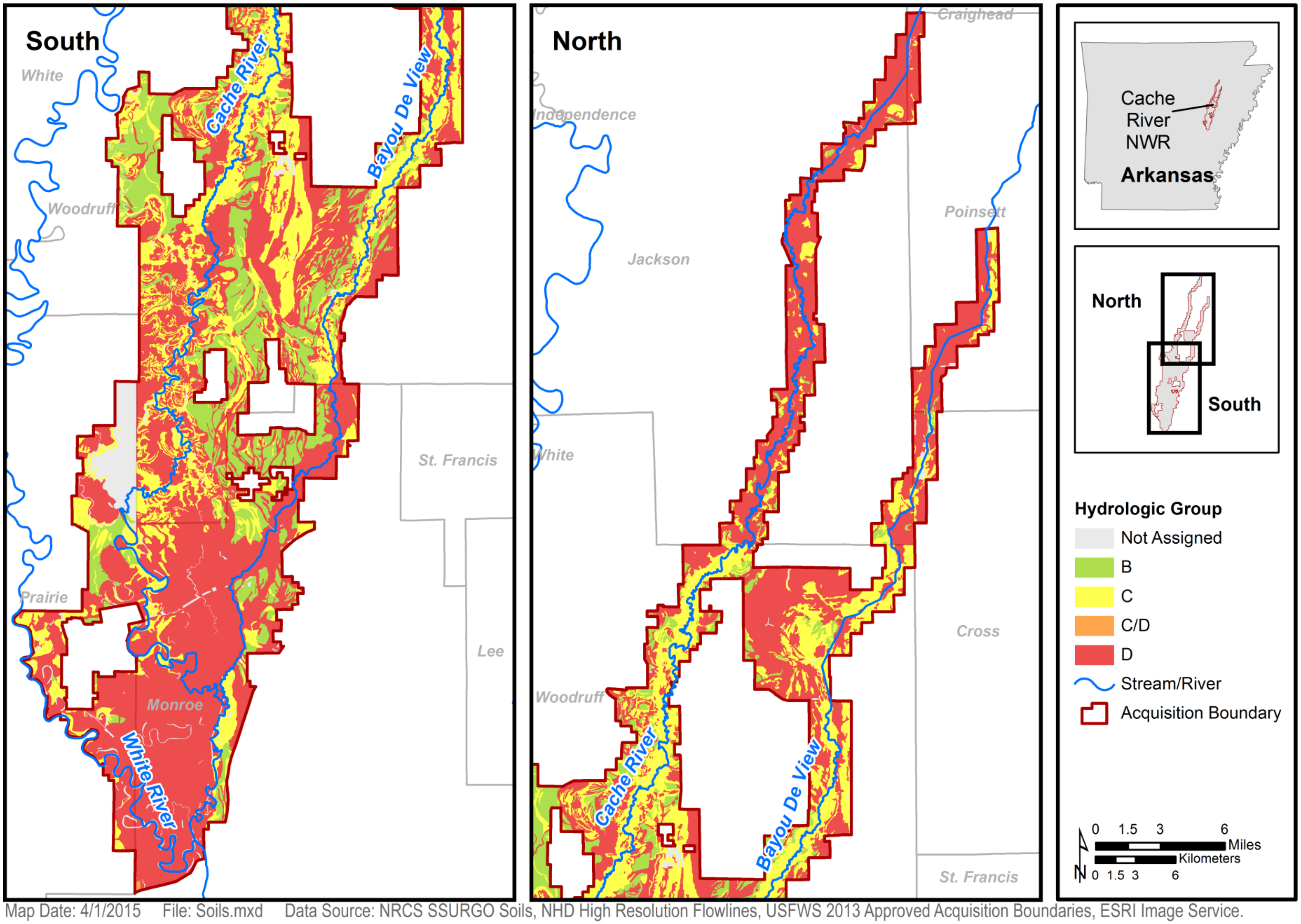


Figure 7. Soil hydrologic groups within the approved acquisition boundary of Cache River National Wildlife Refuge. Runoff properties range from group A (high infiltration/low runoff) to group D (very slow infiltration/high runoff).

4.5 Hydrology and Geomorphology

The Cache subbasin (08020302) consists of 1.26 million acres within Arkansas and a small portion of southern Missouri (CAST 2006), totaling 1,291,400 acres overall (Coastal Environments 1977). The primary stream within the Cache subbasin is the Cache River. The Cache River originates in Butler County, Missouri, and flows approximately 203 river miles through portions of eleven Arkansas counties before joining the White River in Clarendon, Arkansas (USFWS 2009). Much of the original meandering channel has been straightened and channelized to expedite runoff; eighty-nine (89) miles of the upper Cache River were channelized through combined efforts of private landowners and local authorities in the early portion of the twentieth century (Mauney and Harp 1979, USACE 1994). The lower section of the Cache River above the confluence with the White River was channelized by the USACE in the early 1970s from a length of 10.5 miles to 6.7 miles (Bowman and Wright 1998). Plans to restore natural meanders within the lower Cache River are discussed in Section 5.4.4.1.

The major tributary to the Cache River is Bayou DeView, which begins on Crowley's Ridge north of Jonesboro, Arkansas. Bayou DeView flows through five counties for a total length of 107 miles. The upper 65 miles have been channelized for flood control (Mauney and Harp 1979).

Both the Cache River and Bayou DeView are underfit streams, meaning that current hydrologic conditions within the watershed result in stream discharges that are too small to have eroded the surrounding valleys and meanders. The present-day channels are thought to occupy abandoned historic channels of the Black and St. Francis Rivers (Walton et al. 1996).

The entire Cache subbasin is generally characterized by low relief, with a difference of about one foot in elevation between the 2-year and 10-year floodplains. With the exception of the channelized reaches of the lower Cache River, the lower portion of the Cache subbasin is exemplary of the anastomosing/anabranching or braided backswamp-floodplain drainage pattern which characterized the entire system prior to anthropogenic disturbance. In these areas, stream channels are sinuous and poorly defined; surface features may become hydrologically connected or disconnected in response to slight changes in river stage. In the middle portion of the subbasin, the river is confined to the most recent, relatively narrower floodplain of the lowest terrace. Streams in the upper portions of the subbasin have been impacted by straightening and channelization. Hydrology in this portion of the subbasin is influenced by extensive ditching in upland areas (Coastal Environments 1977).

Flooding along the White River results in backwater flooding of the lower Cache subbasin to a point approximately 25 miles upstream on the Cache River from the confluence with the White River (Coastal Environments 1977). There are no major levees within the RHI; however, hydrology has been greatly altered by the cumulative effects of many small, privately-constructed levees and other anthropogenic modifications. These and other hydrologic alterations are discussed in detail in section 5.4.

4.6 Anthropogenic Landscape Changes

There is evidence of prehistoric Indian occupation dating back to 10,000 B.C., with most sites occurring on natural levees, low-lying terraces and low sandy knolls with highly fertile sandy soils (Spears et al. 1975, USFWS 2009). Prehistoric human occupation along the Cache River appears to have been relatively intense, possibly due to the Cache River being a larger stream during that time.

Anthropogenic changes within the Cache River Basin share many activities with changes within the White River Basin (Holt and Hunt 2015) and the larger MAV (Gardiner and Oliver 2005). Land clearing and conversion to agriculture, flood control, and more recent afforestation activities all are important factors in the broader region with local variations in the Cache River Basin. Afforestation (establishing forest cover in areas having non-forest land cover) and reforestation (replanting forest after logging, fire, or storm damage) are management priorities for both Cache River NWR and Dale Bumpers White River NWR (USFWS 2009, 2012a).

The earliest historic European settlement known to occur in the Cache River Basin was in 1816 at the site of present-day Clarendon, Arkansas, formerly known as “Mouth of the Cache.” Prior to the Civil War, settlement occurred primarily on Crowley’s Ridge, with lowland communities restricted to landings along the Cache River or Bayou DeView, or at major road crossings. Intensive settlement and farming in lowland areas did not occur until after the Civil War (House 1975). The refuge contains several cemeteries dating to the late 1800s, as well as remnants of the railroads that facilitated logging of the forests, including spurs, an old railroad tram and a steam-powered water pump (USFWS 2009).

Prior to flood control work beginning in the early 1900s, waters of the neighboring White, Black, and St. Francis Rivers overflowed into the basin during extreme events (Heitmeyer 2010), effectively turning the shallow, meandering Cache River and Bayou DeView into floodplain channels of the neighboring streams. Longstanding effects of flood control on the geomorphology, vegetation communities, and soils of the basin may be, for all practical purposes, irreversible (Klimas et al. 2009).

A tight-knit cycle of land clearing and hydrologic alteration has been the dominant influence, increasing in scale and intensity from European settlement through most of the 20th century. Large (e.g., channelization) and small (e.g., field ditches and spoil pile levees) scale alterations have set the stage for current conditions within the larger context of climate change. Past land use activities continue to affect landscape dynamics including groundwater levels, soil infiltration capacity, and evapotranspiration rates due to shifts in vegetation community structure along with the alteration of magnitude, timing, frequency, duration, and rate of change in flow regime.

The construction of the levee system on the Mississippi River and tributaries such as the White River following the “Great Flood” of 1927 accelerated conversion of bottomland hardwoods to agricultural production. Extensive conversion occurred in the Cache River/Lower White River Basin from the 1940s through the mid-1970s as land protected by the levees was cleared for cultivation. Areas within the Cache River/Bayou DeView portion of the basin were cleared to the riverbanks (USFWS 2012a). Between 1940 and 1960, land clearing for rice farming expanded in the Lower Mississippi Alluvial Valley (LMAV), particularly in the Cache River Basin. A total of 22% of the land remaining in forest at the beginning of World War II was cleared by 1960. A spike in soybean prices, combined with improved flood control, drainage, and technology that made larger areas suitable for agriculture, caused unprecedented clearing of forests in the 1960s and 1970s (LMVJV 2007). By the 1980s, the forested area of the LMAV had been reduced to 20% of the original total, occurring in small and finely dispersed fragments with larger fragments centralized along the major river systems (Creasman et al. 1992, Haynes 2004, Twedt and Loesch 1999, cited in LMVJV 2007). In Arkansas, losses were more dramatic; approximately 15% of the original 8 million acres remain, with most fragmentation on drier areas (e.g., natural levees) and the largest tracts remaining in lowlands (Rudis 1995, cited in Klimas et al. 2004).

In the late 1980s, Congress passed Farm Bill legislation that introduced “swampbuster” provisions to slow wetland conversion, which was followed by the Wetland Reserve Program and other private land conservation programs that encouraged restoration of bottomland forests. Collectively these programs were intended to replant over 7 million acres of forest on marginal agricultural lands (i.e., afforestation) in the LMAV (King and Keeland 1999, cited in Hanberry et al. 2012) and reforest hundreds of thousands of acres of degraded wetland areas (King et al. 2005, cited in Hanberry et al. 2012). As of 2005, the estimated coverage of afforested land in the LMAV was approximately 479,000 acres. Deforestation has nearly halted and forest restoration is the dominant land use change in the LMAV, but ongoing effects of agricultural activities, altered hydrologic regimes and other factors continue to degrade forests (Gardiner and Oliver 2005).

Buell (2012) conducted land cover change analysis for the Cache River Basin based on National Land Cover Dataset (NLCD) land cover data from 1992 to 2001, using the Land Cover Change Retrofit product. Fifteen (15) separate land cover classes were delineated for USGS 8-digit units in the basin, although land cover change was calculated for seven classes (water, urban, barren, forest, grassland, agriculture, and wetland). Buell found small (1.3%) changes to the basin as a whole between 1992 and 2001. That trend has continued with approximately a 0.6% change between 2001 and 2006 (Fry et al. 2011). After a 6% drop in agricultural land use from 1992 to 2001, the agriculture classification remained essentially unchanged from 2001 to 2006. All counties in the basin lost population from 2000 to 2010 with the exception of Greene, Craighead, and White Counties (UALR 2011).

Table 4 compares the 1992 and 2011 NLCD land use of each watershed and subwatershed within the RHI. Over this time period, the agriculture classification has declined throughout the RHI, while the water, urban, and wetland classifications have increased in area. Increases in the water classification may be due to an increase in surface water impoundments that are used to cultivate rice and other crops, and thereby may not accurately reflect the decreases and increases for the agriculture and water classifications, respectively. Forested areas appear to be decreasing in the upper portions of the RHI, and increasing in the lower areas, possibly as a result of refuge restoration efforts.

Table 4. Percent of 1992 and 2011 National Land Cover Database (NLCD) land use by watershed area within the Cache River National Wildlife Refuge Region of Hydrologic Influence (RHI). [Source: Jin et al. 2013, Vogelmann et al. 2001].

NHD Watershed/ Subwatershed	Water		Urban		Barren		Forest		Grassland		Agriculture		Wetland	
	1992	**2011**	**1992**	**2011**	**1992**	**2011**	**1992**	**2011**	**1992**	**2011**	**1992**	**2011**	**1992**	**2011**
0802030201	0.38	0.90	0.30	4.95	0.20	0.04	19.52	17.51	--	0.08	78.49	73.54	1.00	2.87
0802030202	0.38	0.96	0.42	4.06	0.19	0.04	16.31	12.76	--	0.11	82.05	77.82	0.55	4.13
0802030203	0.45	0.91	0.37	4.57	0.08	0.05	9.82	6.78	--	0.15	88.80	83.96	0.47	3.57
0802030204	1.25	1.89	0.43	4.47	0.01	0.03	1.55	0.93	--	0.01	84.96	79.73	11.79	12.93
0802030205	1.37	2.81	3.28	9.92	0.50	0.13	19.90	18.44	--	0.15	66.88	59.04	8.04	9.48
0802030206	1.36	2.09	0.31	4.53	0.00	0.05	1.02	0.66	--	0.00	89.42	84.43	7.86	8.22
0802030207	1.46	0.89	0.79	4.60	0.00	0.02	1.53	2.50	--	0.01	73.32	68.28	22.91	23.70
0802030208	1.36	1.62	0.24	3.99	0.00	0.00	1.07	2.84	--	0.01	72.19	64.43	25.14	27.11
0802030105	6.12	7.34	0.62	3.91	0.01	0.19	9.54	11.33	--	0.14	59.35	50.04	24.34	27.02
080203030502	4.44	3.99	0.09	2.74	0.00	0.01	16.64	20.15	--	0.41	28.71	25.75	49.88	46.71
RHI	***1.86***	***2.34***	***0.69***	***4.77***	***0.10***	***0.06***	***9.69***	***9.39***	***0.00***	***0.11***	***72.42***	***66.70***	***15.20***	***16.58***

4.7 Climate

4.7.1 Historical Climate

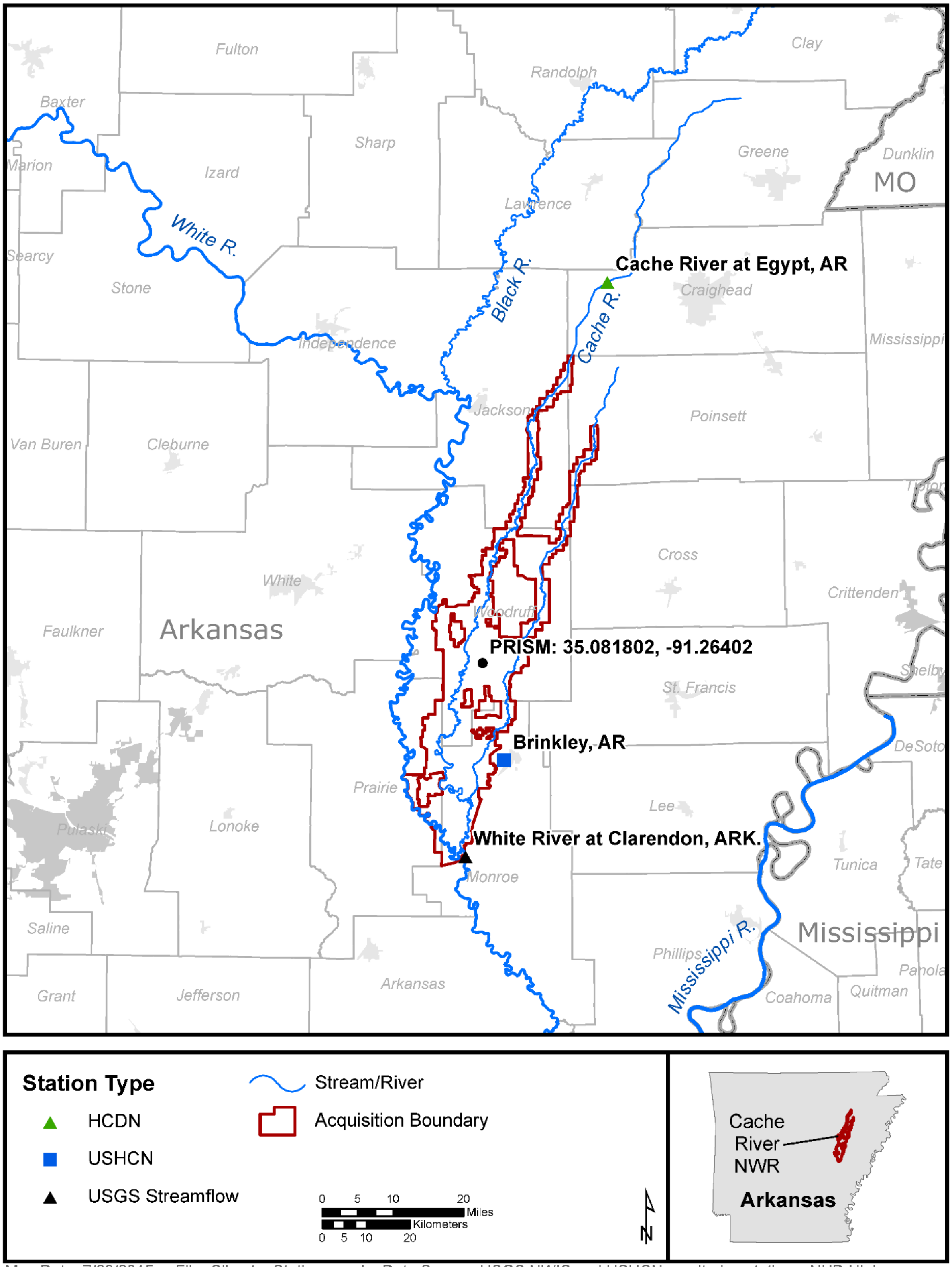
Climatic information presented in this WRIA comes from the U.S. Historical Climatology Network (USHCN) of monitoring sites maintained by the National Weather Service (NWS) (Menne et al. undated) and the PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping service, which is the U.S. Department of Agriculture's (USDA) official source of climatological data. The period of record for the USHCN data is 1895 – 2012, while the PRISM data represent 1971 – 2000 climatological normals. The closest USHCN station to the Cache River NWR is located in Brinkley, Arkansas, which is to the east of the southern portion of the refuge and approximately 17 miles southeast of the refuge's geographic center. For the PRISM data, a central point within the refuge was selected (35.081802, –91.264020) and used to access the PRISM Data Explorer (PRISM 2010). Figure 8 shows the locations of climate monitoring stations cited within this report, as well as the location used to access PRISM data.

4.7.1.1 Temperature

The climate of central and eastern Arkansas is mild and moderately humid with average monthly temperatures in the vicinity of the refuge ranging from approximately 40°F (4.4°C) to 80°F (26.7°C) (Figure 9). Mean monthly temperatures exhibit the greatest year-to-year variability in fall through early spring (October through March) and the least variability in the spring and summer (April through August) (Figure 10). The PRISM dataset shows average minimum and maximum temperatures in the vicinity of the refuge ranging from approximately 30°F (-1.1°C) in January to 92°F (33.3°C) in July (Table 5). Analysis of the average daily maximum, mean, and minimum temperature by water year reveals what appears to be an increasing trend in the mean and minimum annual temperature since about 1980. There is a weaker indication of an increasing trend since 1980 for the maximum annual temperature (Figure 10).

4.7.1.2 Precipitation

The region receives an average of 50 inches of precipitation annually with mean monthly precipitation ranging roughly from 3 to 5 inches (Table 5, Figure 11). Precipitation is somewhat seasonal with nearly one-third of the annual rainfall occurring from March to May and less than one-fifth of the annual rainfall occurring from July to September (USFWS 2009). April receives the greatest amount of precipitation at an average of 5.42 inches, whereas August receives the least at an average of 2.64 inches (Table 5). Data suggest that from approximately 1905 to 1930 the region experienced an extended period of above average precipitation, and from approximately 1990 to 2005 the region experienced an extended period of below average precipitation (Figure 12). In addition, while they were of short duration, the below average precipitation from 1939 to 1943, and the above average precipitation from 1919 to 1922 and 1942 to 1944 are noteworthy, as all three periods represent a substantial deviation from the annual average (Figure 12). While short and extended periods at either extreme do occur throughout the period of record, there does not appear to be any clear and consistent increasing or decreasing trends in annual precipitation.



Map Date: 7/29/2015 File: Climate_Stations.mxd Data Source: USGS NWIS and USHCN monitoring stations, NHD High Resolution Flowlines, ESRI Topo Service.

Figure 8. Locations of climate stations considered for the Cache River National Wildlife Refuge WRIA.

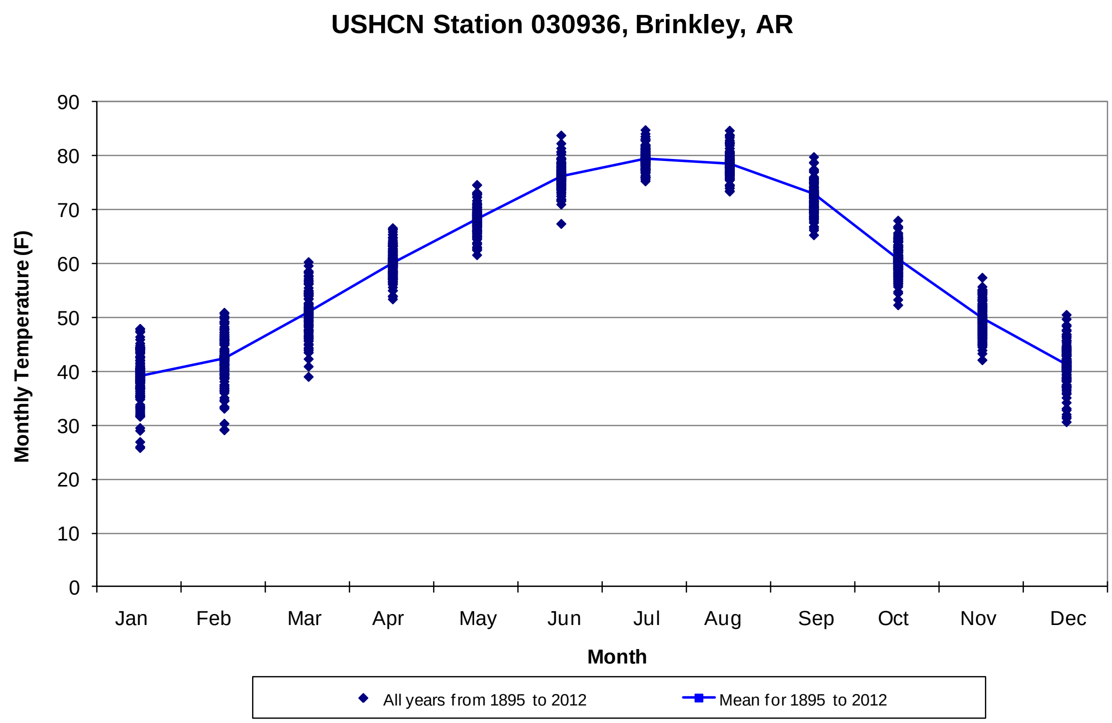


Figure 9. Mean and distribution of monthly temperature for 1895 – 2012 for USHCN Station 030936 at Brinkley, Arkansas. [Source: Menne et al. undated].

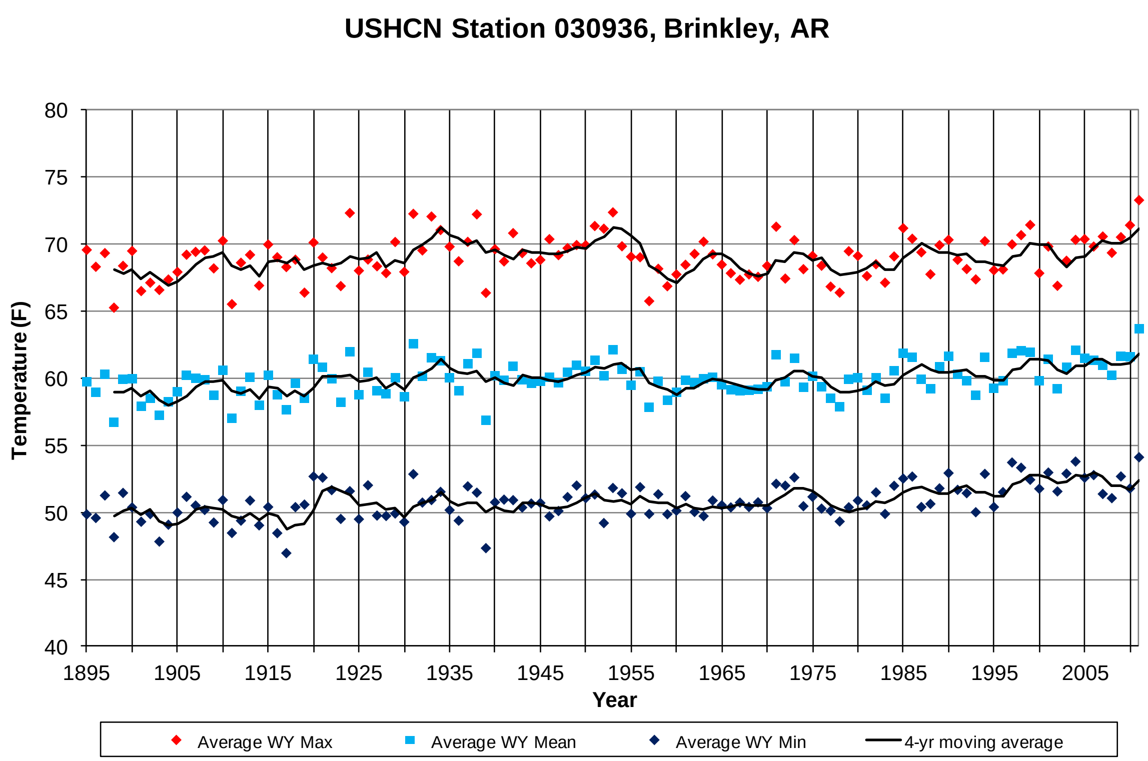


Figure 10. Average daily maximum, mean, and minimum temperature by water year (1895 – 2012) at Brinkley, Arkansas (USHCN Station 030936). [Source: Menne et al. undated].

Table 5. PRISM Monthly Normals (1971-2000) for precipitation and maximum and minimum temperature at Cache River National Wildlife Refuge. [Source: PRISM 2010].

Month	Precipitation (In)	Max Temperature (F)	Min Temperature (F)
January	3.69	47.88	29.91
February	3.69	54.32	33.98
March	5.22	63.21	42.30
April	5.42	72.54	50.32
May	5.14	80.65	59.52
June	4.06	88.39	67.64
July	3.20	92.23	71.26
August	2.64	91.04	68.99
September	3.39	84.49	61.72
October	3.78	75.11	50.14
November	5.27	61.39	41.31
December	4.86	51.24	33.24
Total Precipitation	**50.35**		
Mean Temperature		**71.87**	**50.86**

1971-2000 Normals for –91.264020, 35.081802. Downloaded 6/19/13 from http://prismmap.nacse.org/nn/. Copyright 2010. PRISM Climate Group, Oregon State University.

Across the Southeast, annual precipitation decreased by 6.0% between 1901 and 2008, with seasonal changes being the greatest in the fall (27.4% increase) and summer (4.0% decrease). In recent decades (1970-2008), annual precipitation has decreased by 7.7%, with significant decreases in winter (9.6%) and spring (29.2%) partially offset by a 3.6% increase in summer precipitation (Karl et al. 2009).

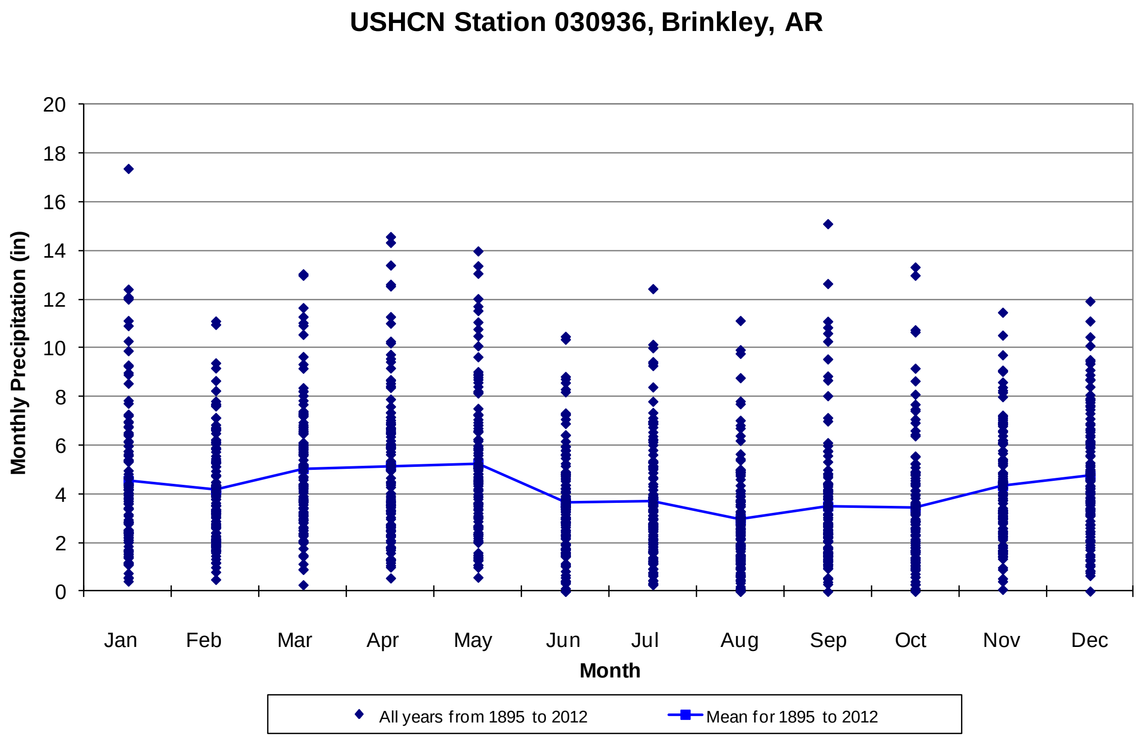


Figure 11. Mean and distribution of monthly precipitation for 1895 – 2012 for USHCN Station 030936 at Brinkley, Arkansas. [Source: Menne et al. undated].

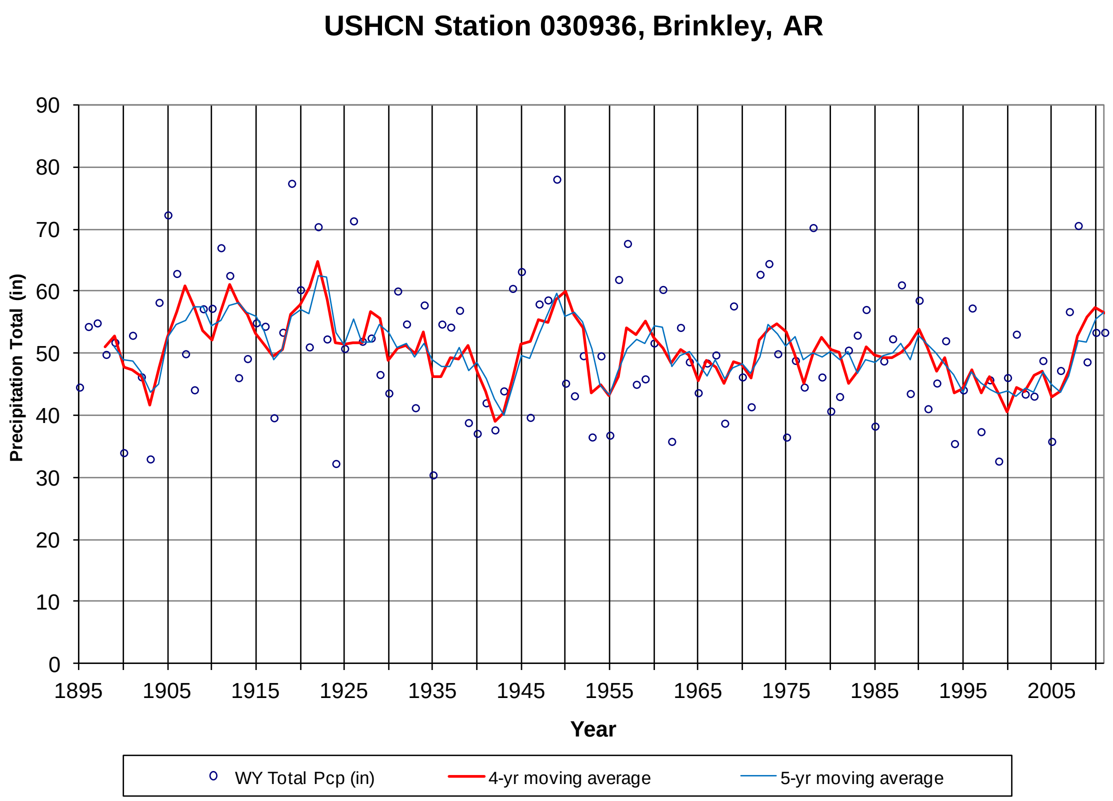


Figure 12. Total annual precipitation by water year (1895 – 2012) at Brinkley, Arkansas (USHCN Station 030936). [Source: Menne et al. undated].

4.7.1.3 *Streamflow*

Within the Cache subbasin, streamflow is linked to precipitation, as well as upstream surface water flows and groundwater contributions. The Hydro-Climatic Data Network (HCDN) is a network of USGS stream gaging stations that are considered well suited for evaluating trends in stream flow conditions. Sites in the network have periods of record that exceed 20 years and are located in watersheds that are relatively undisturbed by surface water diversions, urban development, or dams. The closest HCDN gage to the Cache River NWR is located on the Cache River at Egypt, Arkansas (07077380) (Figure 8). General trends for the Cache River, based on the USGS gage at Egypt, Arkansas, are summarized for the period of record (1964 – 2012) in Figure 13 and Figure 14. The average annual discharge over the period of record is 875 cubic feet per second (cfs). The average monthly discharge is highest between December and May and lowest between June and November. Streamflow on the Cache River at Egypt, Arkansas, is highly variable; however, 2007 – 2012 was a period of consistently above average streamflow, while predominantly below average streamflow occurred from 1967 – 1972 and 1980 – 1981 (Figure 14), which corresponded to two drought periods (see Section 4.7.1.4). While short and extended periods of above and below the average discharge did occur throughout the period of record, there are no apparent trends in the average annual discharge. The hydrograph shows that water levels at the Egypt, Arkansas, gage respond rapidly to precipitation events, a characteristic that is typical of headwater portions of watersheds but also reflective of the effects of upstream channelization (TNC 2005). Additionally, Wilber et al. (1996) found that climatic variation (e.g., drought conditions, storm frequency and intensity) is the primary influence on Cache River flows and explained almost three-fourths of the variation in flows observed at the Patterson gage (middle Cache River Basin) between the 1930s and 1980s.

4.7.1.4 *Drought Conditions*

According to USGS (1991), Arkansas has never had a major drought that significantly lowered water levels in deep regional aquifers. In contrast, shallow aquifers in the western and southeastern parts of the state (e.g., alluvial aquifer) have experienced significant declines during drought periods. State-wide, moderate intensity (recurrence interval of 10 to >25 years) droughts occurred in 1954 – 1956, 1963 – 1967 and 1970 – 1972 (USGS 1991). These periods are reflected in the water year precipitation trends in Figure 12. The streamflow record on the Cache River at Egypt, Arkansas (USGS Gage ID# 07077380) shows annual flow dropped below the long-term average during the droughts that occurred over the gage's period of record (Figure 14). More recently, Arkansas experienced severe to exceptional drought conditions in the summer of 2012, during one of the most severe droughts in U.S. history. The drought was mitigated by the use of irrigation, which is used for a large percentage of field crops in Arkansas (Kemper et al. undated); however, overpumping of groundwater for irrigation during droughts can cause significant water level declines, as occurred during the early 1980s drought in northern Arkansas (USGS 1991). During the summer of 2012, the lowest stage on the Cache River near Patterson, Arkansas, occurred in May (2.82 feet NGVD29) (USACE undated); however, the lowest stage on the White River at Clarendon, Arkansas, occurred in August. Thus, it appears that drought impacts are less pronounced on the Cache River, likely as a result of rice farmers releasing their floodwaters during August and September. Section 5.4.4.5 contains more information on agricultural and surface water relationships.

4.7.1.5 *Storm Frequency and Intensity*

Storm frequencies, intensities and duration greatly influence the hydrology within Arkansas and, more specifically, within the Cache subbasin. Subsequently, these storm related issues lead to seasonal flooding and continuously variable hydrological regimes within the Cache River and on the refuge. Flooding in Arkansas is generally widespread in winter, where it lasts for several days, whereas during summer, flooding is generally local and of short duration. State-wide, a major flood (recurrence interval of 10 to

>100 years) occurred in 1927 (USGS 1991). Locally, the Cache River near Patterson, Arkansas, reached its highest recorded stage of 16.0 feet NGVD29 in 1927. More recently, substantial floods occurred on the Cache River in 2008 and 2011. The Cache River near Patterson, Arkansas, reached 11.37 feet NGVD29 in April 2008; however, this stage has been exceeded numerous times over the period of record (USACE undated) so it does not seem that the 2008 flood had a profound effect on the Cache River. In 2011, late spring runoff and record snowmelt from the Upper Mississippi River Valley, combined with heavy precipitation, led to record floods throughout most of Arkansas in April and May. The Cache River near Patterson, Arkansas, peaked at 12.87 feet NGVD29 in May 2011, the highest recorded stage height since 1937 (USACE undated). Some of these trends are reflected in the precipitation and streamflow records depicted in Figure 13 and Figure 14, respectively, which depict discharge trends from the USGS gage on the Cache River at Egypt. The Egypt gage is featured in the hydroclimate section of this WRIA because it has a consistent record of discharge data, whereas the Cache River near Patterson, Arkansas only has a consistent record of stage data.

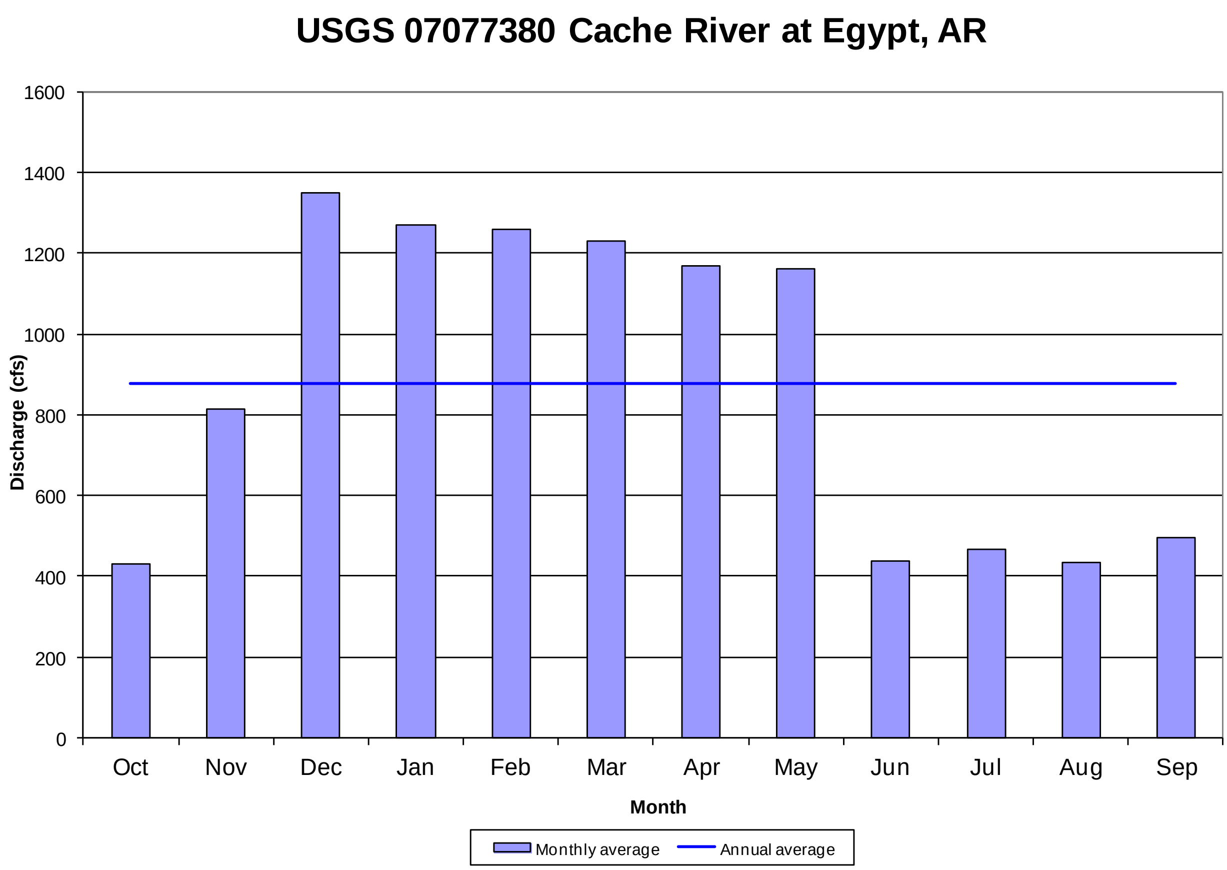


Figure 13. Average monthly discharge from the Cache River at USGS site 07077380 at Egypt, Arkansas. From data collected from 1964 to 2012. [Source: USGS 2013].

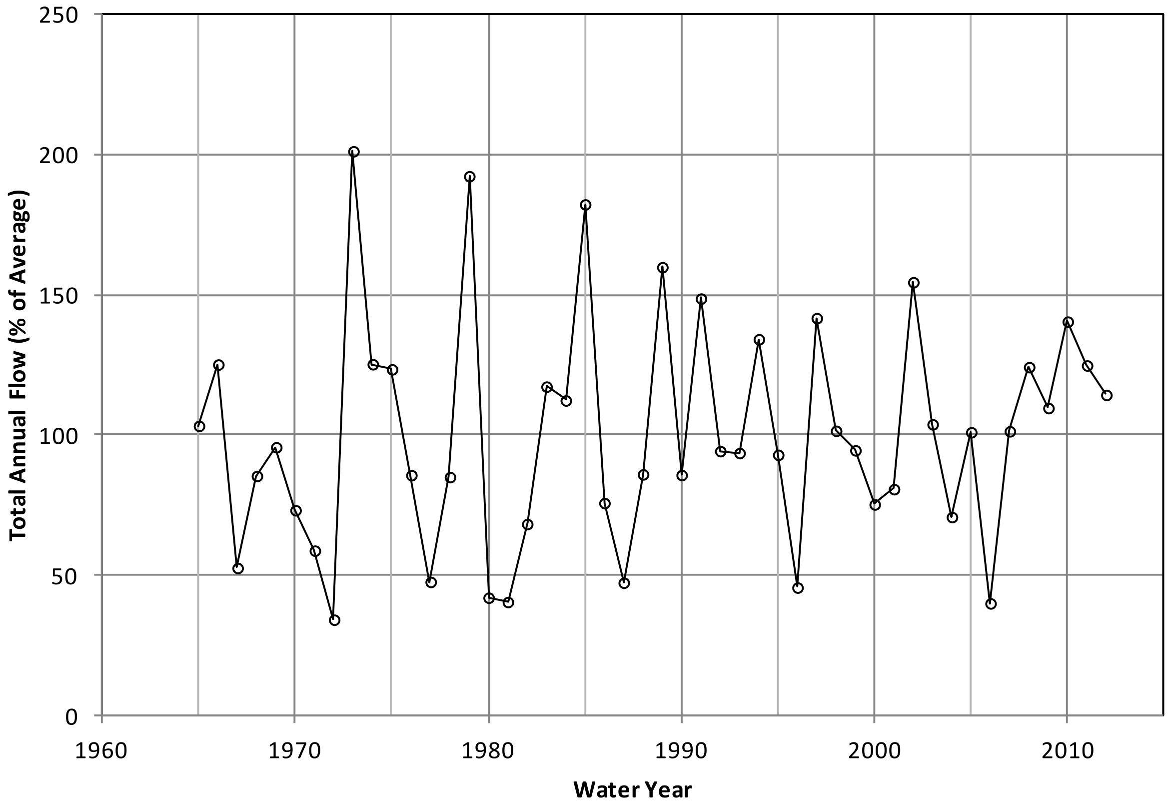


Figure 14. Percent of average annual flow on Cache River near Egypt, Arkansas: 1964-2012. Average annual flow from the period of record is 875 cubic feet per second (cfs). 1 cfs = 448.8 gallons per minute. [Source: USGS 2013].

4.7.2 Climate Change Projections

Ingram et al. (2013) synthesized a large body of scientific information composed of numerous peer-reviewed scientific assessments. Information from this effort projects water supply stress to increase significantly in the region by 2050 due to a combination of continued warming and increased water use, with the most severe impacts in the summer. Runoff and soil erosion potential are projected to increase in parts of the region due to changes in rainfall that either increase rainfall erosivity or decrease vegetative cover. Inland water temperature is projected to increase as air temperature increases, which may adversely impact some aquatic species (Ingram et al. 2013).

Spatial and temporal changes in temperature and rainfall patterns will add substantial complexity to management planning on Cache River NWR. In the eastern United States, documented seasonal warming patterns, extended growing seasons, high spring stream flow, decreases in snow depth, and increased drought frequency are projected to continue (Scott et al. 2008). Although the specific impacts climate change will have on the Cache River ecosystem are uncertain, these regional changes to the quantity and timing of available water are likely to magnify the influences of other identified threats and challenges currently impacting the system.

4.7.2.1 Temperature

By the last decade of the 21st century, global average surface temperature is projected to rise by 2.8 °C (5.0 °F) (likely range: 1.7-4.4 °C and 3.1-7.9 °F) under the A1B (moderate) emissions scenario and 3.4 °C (likely range: 2.0-5.4 °C and 3.6-9.7 °F) under the A2 (high) emissions scenario relative to a 1980-1999 baseline (IPCC 2007). In the southeastern United States, climate models project continued warming and an increase in the rate of warming through 2100. By the end of the 21st century, the interior of the region is projected to warm by as much as 9 °F, with the greatest temperature increases projected to occur in the summer and the frequency of maximum temperatures exceeding 95 °F expected to increase across the Southeast (Ingram et al. 2013). In eastern Arkansas, the number of days per year with a peak temperature over 90 °F is expected to double, from an average of around 60 days to more than 135 days by 2080 (Karl et al. 2009).

4.7.2.2 Precipitation

As summarized by Karl et al. (2009), CCSP (2008), Ingram et al. (2013), and NOAA (2013), changes in annual precipitation for the Southeast do not exhibit any strong trends, although projections for the near-term (present day to 2040) show notable seasonal variations, with a decrease in precipitation during summer months, and an increase(1-2%) in the fall. It should be noted that there is considerable disagreement between the various climate models on the magnitude and direction of changes in precipitation. For future time periods (2021-2050; 2040-2070; 2070-2099), both low (B1) and high (A2) emissions scenarios yield both increases and decreases in projected annual mean precipitation.

4.7.2.3 Storm Severity

The frequency of extreme precipitation events has been increasing across the Southeast, particularly over the past two decades (NOAA 2013). This trend in more intense precipitation events is also seen in other places around the world (IPCC 2007), and may be tied to a warming atmosphere which has a greater capacity to hold water vapor, therefore producing higher rates of precipitation (NOAA 2013). The increase in extreme precipitation, coupled with increased runoff due to the expansion of impervious surfaces and urbanization, has led to an increased risk of flooding in urban areas of the region (Shepherd et al. 2011; NOAA 2013). Across the Southeast, for all regional climate model simulations and emissions scenarios, the average annual number of days with precipitation exceeding 1 inch increases, with the largest increases across the Appalachian Mountains (NOAA 2013).

Increases in storm severity will exacerbate existing problems caused by runoff from nearby agricultural lands. Increased run off leads to unnaturally high peak flows and velocities, decreasing the stability of the sand and gravel substrates that many species of mussels and fish depend on. Any additional increases in runoff from a climate change-based increase in storm severity would cause additional scouring and river bank deterioration, compounding impacts from nonpoint source pollution and sedimentation.

4.7.2.4 Impacts to Wetlands and Waterfowl Species

Migrations of numerous bird species, supported by refuges, may become asynchronous with changing seasons, native nuisance species and non-native invasive species will likely extend their range, and vegetation types may shift to plant communities that are inappropriate for refuge trust species (Scott et al. 2008). Changes in the migration patterns of waterfowl could have a significant impact on how refuges manage their woodlands and water resources throughout the year. In an unpublished analysis of waterfowl inventory data, climate data, crop production data and other related factors, Bednarz et al. (cited in Strickland 2011) found that warmer winters equated to more ducks in northern states (Minnesota, Illinois, Iowa and Ohio) and fewer ducks in the South, including Arkansas. Warmer winters could create the conditions ducks need (ice-free wetlands and plenty of food) in northern states, such that they would not need to migrate south (Strickland 2011). Additionally, untimely flooding could change flood zones in bottomland forests, affecting tree regeneration and survival, as well as waterfowl populations (Browne and Humburg 2010).

5 Inventory Summary and Discussion

5.1 Water Resources

This section briefly summarizes and discusses important aspects of the water resources inventory (both surface water and groundwater) for Cache River NWR, including important physical water resources, water resources related infrastructure and monitoring, water quantity, and water quality conditions. Online historical and current streamflow and groundwater data are available from the USACE (undated) and USGS (2013).

5.1.1 Streams

An inventory of named streams was compiled from the National Hydrography High-Resolution (1:24000) Dataset (NHD) for the RHI, using the flowline feature dataset. The RHI for the Cache River NWR includes a total of 5,356 miles of streams: 985 miles of named streams and 4,371 miles of unnamed streams (USGS 2013). Within the refuge acquisition boundary, there are 33 named streams, totaling 349 miles, as well as 851 miles of unnamed streams (Table 6, Figure 15a-c). The Cache River flows within the refuge approved acquisition boundary for 136 miles.

5.1.2 Canals and Drainage Ditches

The NHD assigns a feature type of Canal/Ditch to linear features that serve as an "Artificial open waterway constructed to transport water, to irrigate or drain land, to connect two or more bodies of water, or to serve as a waterway for watercraft" (USGS 2015). Under this designation, the NHD includes 1,193 miles of canals and drainage ditches within the RHI for the Cache River NWR, including 44 miles within the refuge acquisition boundary and 8 miles on the refuge (USGS 2013). The majority of these features are unnamed. There are seven named features which share names with features classified as streams, are less than 0.2 miles long, and only total a sum of 0.5 miles. It is likely that the named features are an artifact of the data production process, rather than an attempt to assign names to artificial features. As such, it is noteworthy that according to the feature definitions outlined in the NHD, the channelized portions of the Cache River fall within the Stream/River class and are not distinguished from artificial features.

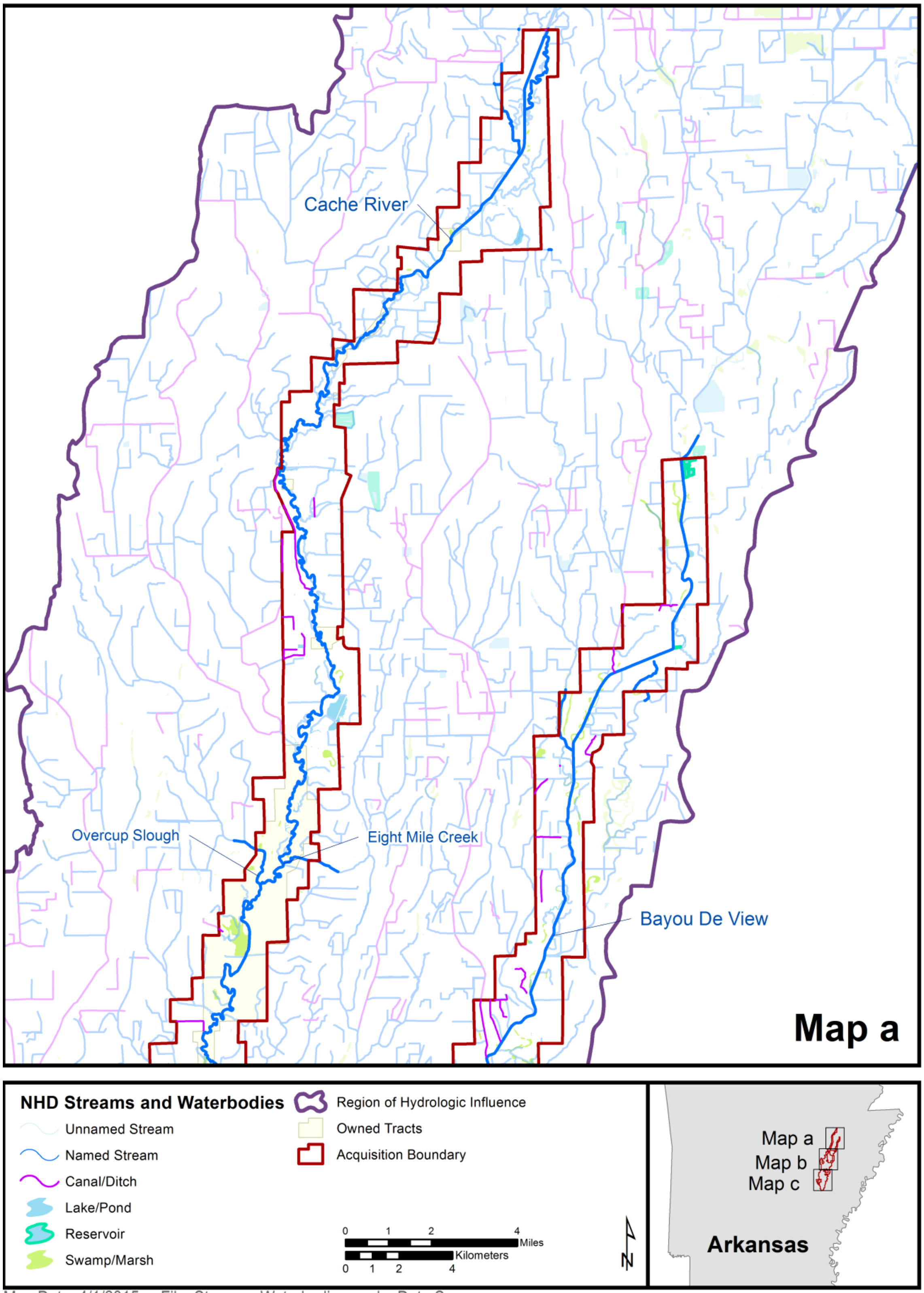
5.1.3 Lakes and Ponds

The NHD inventories a total of 32,479 acres of unnamed lakes and ponds and 4,380 acres of named lake and ponds within the RHI. Within the refuge acquisition boundary there are 19,922 acres of named and unnamed lakes or ponds, of which 5,705.4 acres have been acquired. Named lakes and ponds on the refuge are shown on Figure 15a-c and listed in Table 7.

According to the CCP, the refuge contains 87 bodies of water and 1,010 acres of surface water (oxbows, bayous, and rivers) (USFWS 2009). The acquisition boundaries for Cache River NWR at time of the drafting of the CCP were described as the lands within the 10-year floodplain of the lower and middle Cache River Basin, including Bayou DeView. This would indicate that most waterbodies are hydrologically dependent on flooding from the rivers; as such, surface water feature acreage would be highly variable both seasonally and from year to year.

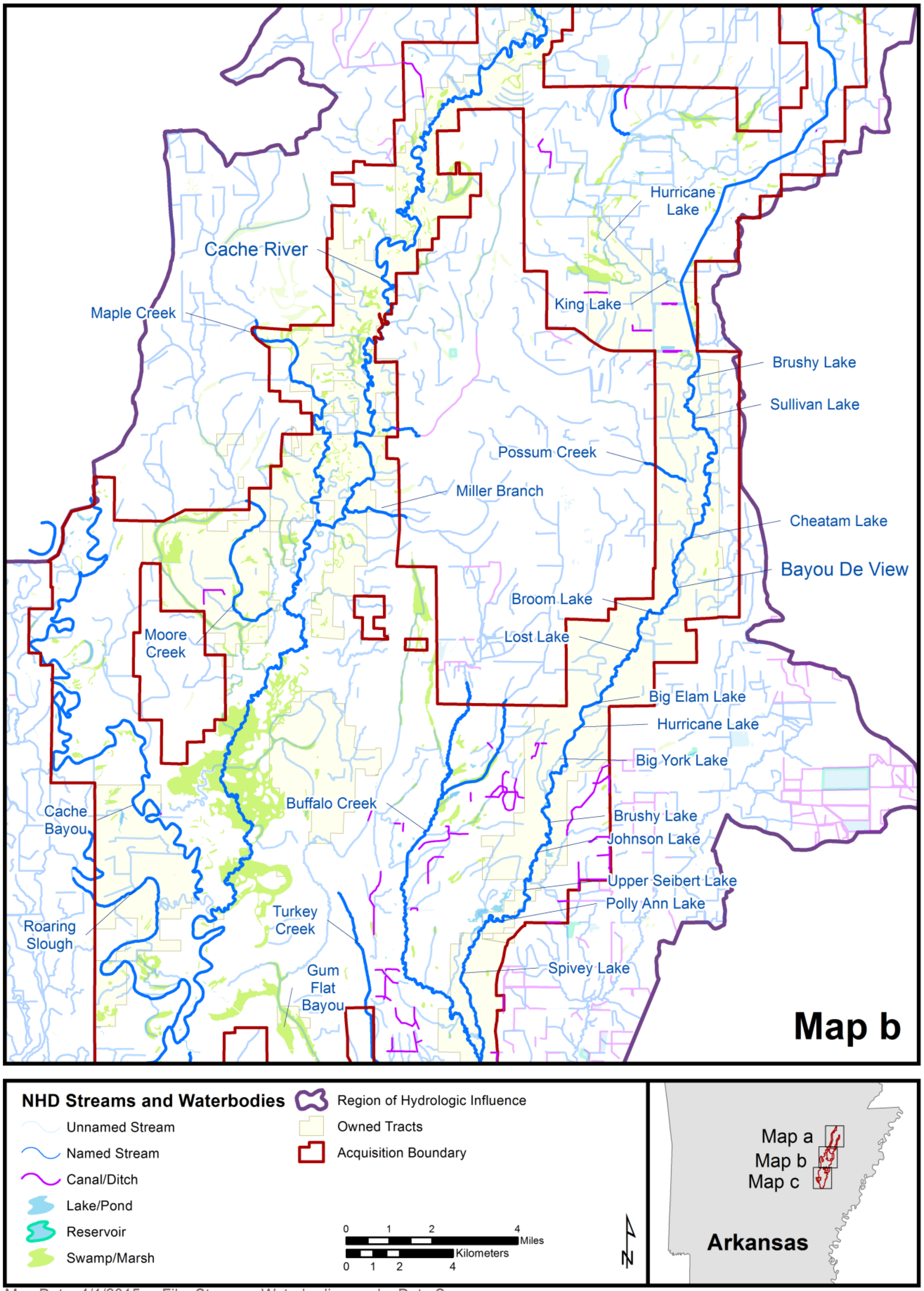
Table 6. National Hydrography Dataset (NHD) named streams within Cache River National Wildlife Refuge. [Source: USGS 2013].

Name	**Miles Within Acquisition Boundary**	**Miles on Refuge**
(unnamed)	850.5	179.5
Bayou DeView	72.5	24.2
Bear Slough	1.0	--
Beaver Bayou	5.5	--
Benson Slash Creek	3.2	Less than 1
Buffalo Creek	12.1	1.5
Cache Bayou	23.8	4.8
Cache River	136.1	45.3
Caney Creek	1.1	--
Culotches Bay Slough	9.1	Less than 1
Deep Slough	1.5	--
Ditch Number 1	4.7	Less than 1
Eight Mile Creek	Less than 1	--
Fish Slough	Less than 1	Less than 1
Gum Flat Bayou	6.9	3.0
Hill Bayou	1.0	--
Jackson Bayou	3.7	Less than 1
Little Cow Lake	1.5	--
Locust Slough	3.0	--
Maloy Bayou	Less than 1	--
Maple Creek	7.2	6.0
Mill Ditch	Less than 1	Less than 1
Miller Branch	1.5	Less than 1
Moore Creek	4.4	4.1
Old Channel Cache River	2.6	--
Old Forked Slough	1.3	--
Overcup Slough	1.1	1.1
Possum Creek	Less than 1	Less than 1
Roaring Slough	9.5	5.4
Roc Roe Bayou	6.4	3.8
Sevenmile Bayou	2.0	1.0
Threemile Creek	1.5	--
Turkey Creek	5.8	Less than 1
White River	16.7	Less than 1
Total	***1199.6***	***285.3***



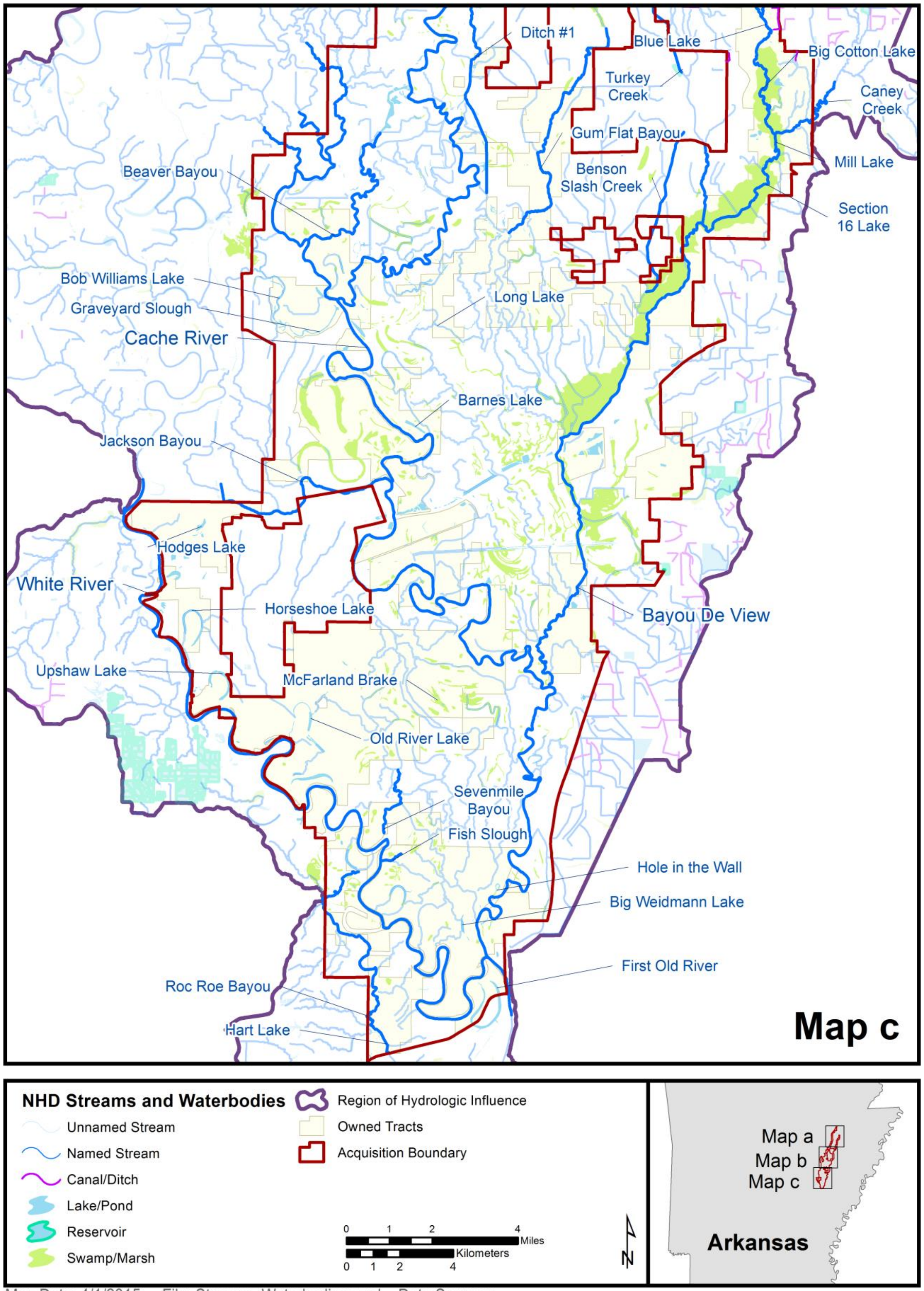
Map Date: 4/1/2015 File: Streams_Waterbodies.mxd Data Sources:
NHD High Resolution Flowlines and Waterbodies, ESRI Topo Service.

Figure 15a. National Hydrography Dataset (NHD) streams, canals/ditches, lakes/ponds, reservoirs and swamp/marsh within Cache River National Wildlife Refuge.



Map Date: 4/1/2015 File: Streams_Waterbodies.mxd Data Sources:
NHD High Resolution Flowlines and Waterbodies, ESRI Topo Service.

Figure 15b. National Hydrography Dataset (NHD) streams, canals/ditches, lakes/ponds, reservoirs, and swamp/marsh within Cache River National Wildlife Refuge.



Map Date: 4/1/2015 File: Streams_Waterbodies.mxd Data Sources:
NHD High Resolution Flowlines and Waterbodies, ESRI Topo Service.

Figure 15c. National Hydrography Dataset (NHD) streams canals/ditches, lakes/ponds, reservoirs and swamp/marsh within Cache River National Wildlife Refuge.

Table 7. National Hydrography Dataset (NHD) named lakes and ponds within Cache River National Wildlife Refuge. [Source: USGS 2013].

LakePond Name	Acres within Acquisition Boundary	Acres on Refuge	LakePond Name	Acres within Acquisition Boundary	Acres on Refuge
(unnamed)	*18069.3*	*5137.5*	Horseshoe Lake	55.2	52.2
Barnes Lake	19.6	19.6	Hurricane Lake	6.3	5.7
Beard Lake	1.4	--	Ingram Lake	10.6	--
Beaver Lake	1.3	--	Jackson Lake	14.9	--
Big Brushy Lake	6.0	6.0	Jake Williams Lake	13.2	13.1
Big Buck Lake	8.3	--	Johnson Lake	19.7	7.1
Big Cotton Lake	3.7	3.7	King Lake	16.8	8.2
Big Elam Lake	9.6	--	Little Brushy Lake	less than 1	less than 1
Big Jack Lake	4.1	--	Little Buck Lake	2.7	--
Big Robe Bayou	72.7	--	Little Clear Lake	15.6	--
Big Twin Lake	11.7	2.8	Little Cotton Lake	3.0	3.0
Big Weidmann Lake	13.5	13.5	Little Elam Lake	2.3	--
Big York Lake	2.2	2.2	Little Jack Lake	less than 1	--
Bird Lake	4.0	--	Little Reddon Lake	less than 1	--
Blue Hole	2.5	2.5	Little Twin Lake	8.4	4.4
Blue Lake	2.3	2.3	Little Weidmann Lake	less than 1	less than 1
Bob Williams Lake	68.5	31.0	Little York Lake	1.9	1.9
Broom Lake	10.1	--	Long Lake	7.7	4.6
Brushy Lake	9.4	5.7	Loshita Branch	88.0	--
Bull Lake	20.9	6.4	Lost Lake	5.6	--
Buzzard Lake	2.2	less than 1	Lower Seibert Lake	5.7	5.3
Chambers Lake	less than 1	--	McFarland Brake	39.4	39.4
Cheatam Lake	14.2	--	Mill Lake	7.0	--
Crosslay Slough	17.9	--	Miller Lake	42.0	35.1
Crosspond Bayou	1.3	less than 1	Morrison Lake	12.7	3.4
Cypress Swamp	192.1	--	Old River Lake	31.6	13.7
Dodson Lake	5.8	3.7	Otter Lake	less than 1	less than 1
Dupree Lake	6.5	--	Polly Ann Lake	4.3	4.3
First Old River	91.1	43.4	Reddon Lake	less than 1	--
Fish Lake	12.6	--	Robinson Lake	25.9	--
Graveyard Slough	27.5	27.5	Roc Roe Lake	25.1	14.1
Gregory Lake	2.8	--	Round Pond	3.8	--
Grindle Lake	2.4	--	Section 16 Lake	8.7	8.7
Gum Flat Bayou	497.7	104.1	Spivey Lake	5.7	5.7
Hale Lake	22.1	--	Straight Lake	5.3	--
Halls Lake	18.7	--	Sullivan Lake	2.5	--
Hammond Lake	28.1	1.3	Upper Old River	26.0	26.0
Hart Lake	9.3	9.3	Upper Seibert Lake	9.0	5.8
Heifer Lake	2.6	--	Upshaw Lake	51.4	13.2
Hickson Lake	13.0	--	Walker Lake	2.4	--
Hodges Lake	14.1	--	White Lake	7.7	--
Hole in the Wall	5.7	5.7	***Total***	***19922.2***	***5705.4***

5.1.4 Springs and Seeps

There are no springs within the refuge acquisition boundary; however, springs are abundant in the Upper White Basin, particularly within the Salem and Springfield Plateau sections of the Ozark Plateaus physiographic province. Losing streams (streams that recharge the groundwater system) are also present in this region. There is moderate surface-groundwater interaction in portions of the MAV. Water levels at some locations within the alluvial aquifer are known to fluctuate with streamflow (Albin et al. 1967, Lamonds et al. 1969, cited in Adamski et al. 1995; See Figure 23 in Section 5.4.2). Within the RHI, springs are known to occur in Clay, Craighead and Greene Counties. The NHD lists 124 springs and seeps within the RHI; most are clustered between the towns of Piggott, Arkansas, and Corning, Arkansas, in northern Clay County. One named spring, Bettis Spring, is located in southern Greene County at the western edge of Crowley's Ridge.

5.1.5 Wetlands

The National Wetland Inventory (NWI) was established by the U.S. Fish and Wildlife Service in 1974 to provide information on the extent of the nation's wetlands (Tiner 1984). The NWI produces maps of wetland habitat as well as reports on the status and trends of the nation's wetlands. Using the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al. 1979) wetlands have been inventoried and classified for approximately 90% of the conterminous United States and approximately 34% of Alaska. Cowardin's classification places all wetlands and deepwater habitats into 5 "systems": marine, estuarine, riverine, lacustrine, and palustrine. Most of the wetlands in the United States are either estuarine or palustrine (Tiner 1984). The predominant wetland systems at Cache River NWR are defined in Cowardin et al. (1979) as either, Palustrine, Lacustrine, or Riverine, with each being described as:

> *Palustrine:* The Palustrine System includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below 0.5% (e.g., inland marshes, bogs, fens, and swamps).
>
> *Lacustrine:* The Lacustrine System includes wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30% areal coverage; and (3) total area exceeds 8 ha (20 acres). Similar wetland and deepwater habitats totaling less than 8 ha are also included in the Lacustrine System if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 2 meters (6.6 feet) at low water. Lacustrine waters may be tidal or nontidal, but ocean derived salinity is always less than 0.5%.
>
> *Riverine:* The Riverine System includes all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts in excess of 0.5%. A channel is "an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water" (Langbein and Iseri 1960).

The different systems can be broken down into subsystems, classes and hydrologic regimes based on the wetland's position in the landscape, dominant vegetation type, and hydrology.

Within Cache River NWR, wetlands are primarily palustrine, with freshwater forested/shrub comprising the dominant habitat type (Table 8). Wetland habitat delineated by the NWI identifies over 93,900 acres of freshwater forested/shrub wetland (i.e., moist and wet bottomland forests and swamp forests) within the acquisition boundary, and over 40,904 acres within areas owned by the USFWS. Using NWI data, 60% of the owned areas are considered wetlands, as compared to 36% of the area within the acquisition boundary (Table 8, Figure 16).

Table 8. Wetland habitat delineated by the National Wetland Inventory (NWI) inside the Cache River National Wildlife Refuge acquired and acquisition boundaries. [Source: USFWS undated].

Wetland Type	**Acres within Acquisition Boundary**	**Percent of Total**	**Acres on Refuge**	**Percent of Total**
Freshwater Emergent Wetland	2,027.7	less than 1	388.7	less than 1
Freshwater Forested/Shrub Wetland	93,900.5	32.2	40,904.5	55.9
Freshwater Pond	1,439.0	less than 1	367.7	less than 1
Lake	1,478.8	less than 1	520.6	less than 1
Riverine	5,105.1	1.7	1,438.2	less than 1
Upland/Unclassified	187,971.6	64.4	29,601.1	40.4
All Wetlands	*103,951.0*	*35.6*	*43,619.7*	*59.6*
Total	***291,922.6***	***100.0***	***73,220.8***	***100.0***

The NHD also maps wetland features, although not in the same level of detail as the NWI. According to the NHD definition of features, the feature type “Swamp/Marsh” addresses any “Noncultivated, vegetated area that is inundated or saturated for a significant part of the year. The vegetation is adapted for life in saturated soil conditions” (USGS 2015). Data within the NHD appear to severely underestimate the area of wetland around Cache River NWR, classifying 17,168 acres within the acquisition boundary (6%) and 6,379 acres on the refuge (6%) as Swamp/Marsh. NHD wetlands are shown on Figure 15a - c as “Swamp/Marsh” features.

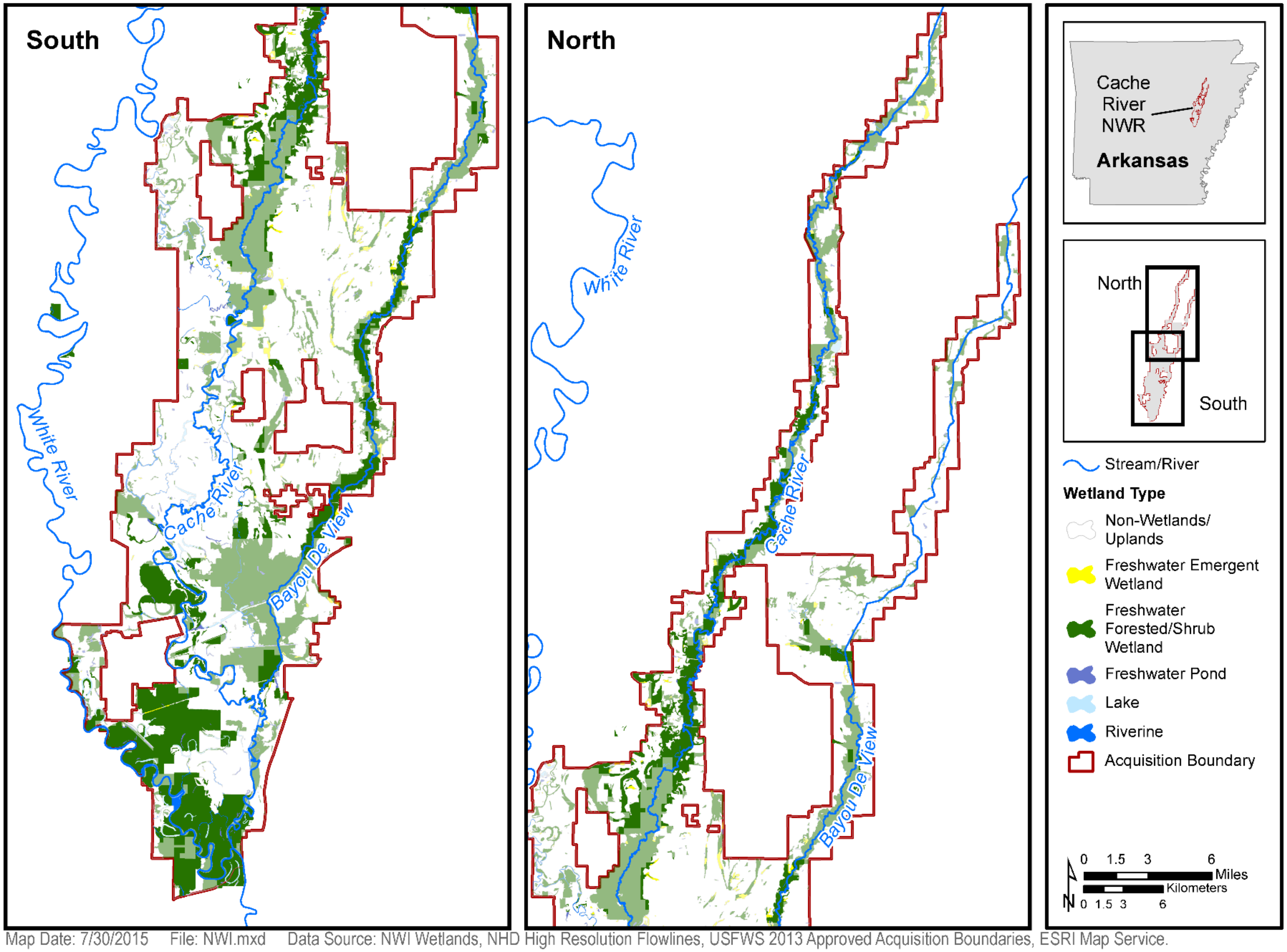


Figure 16. National Wetland Inventory wetlands within the Cache River National Wildlife Refuge acquisition boundary. Darker shades indicate wetlands on tracts owned by U.S. Fish and Wildlife Service.

5.2 Infrastructure

Refuge management activities focus on water, waterfowl, wetland, cropland and forestry programs and providing compatible wildlife-dependent recreation. While this section focuses on the first four management areas (water, waterfowl, wetland, and cropland), refuge staff also manage forest resources, according to the 2007 Forested Habitat Management Plan, which includes reforestation of cleared lands to connect forested tracts and silvicultural management to improve forest stand quality (USFWS 2009).

5.2.1 Impoundments

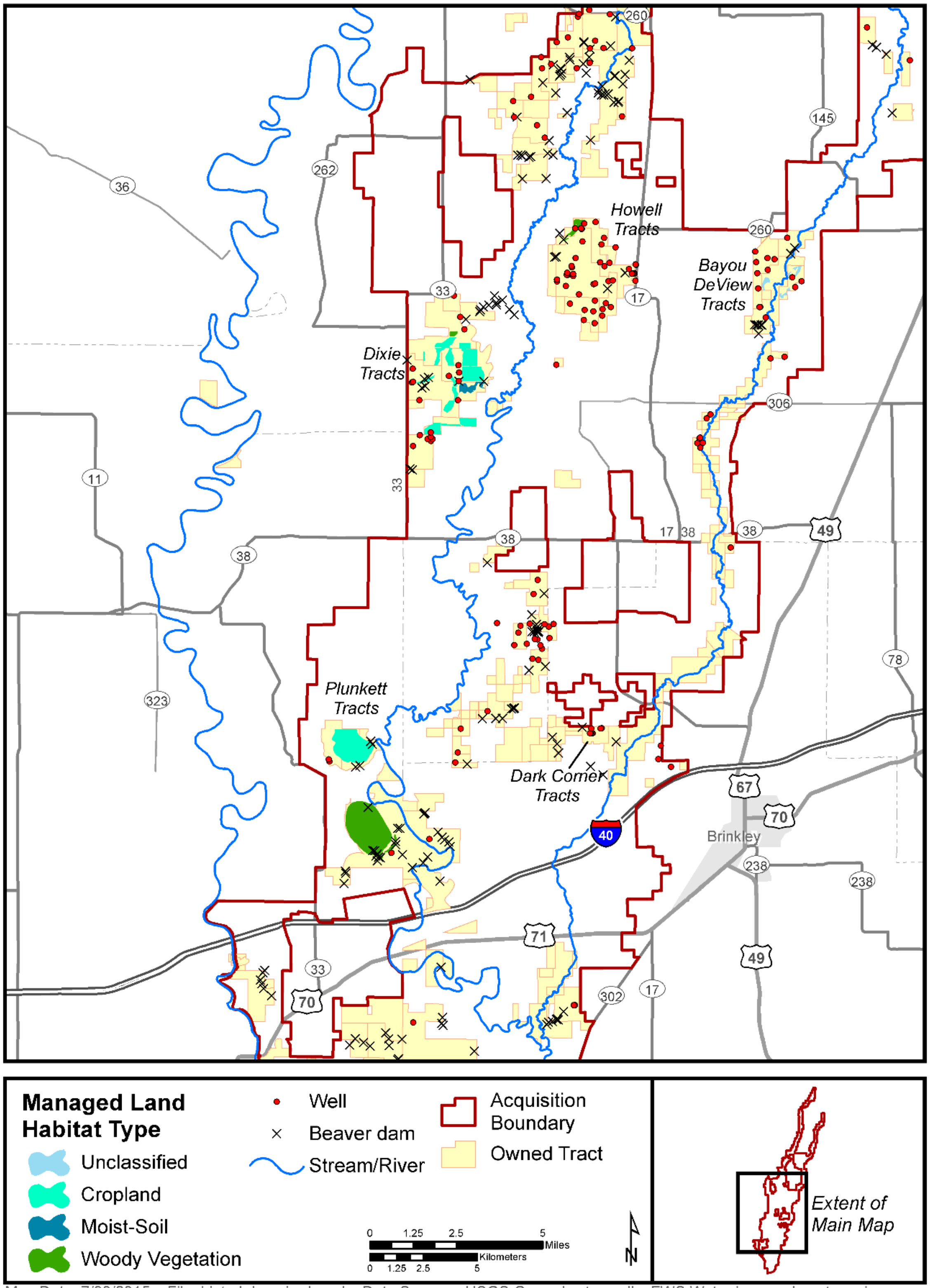
Cache River NWR has 2,605 acres of constructed and managed impoundments, cropland, woody wetlands, and moist-soil units. Many of these managed lands are dependent on rainwater; some are gravity-fed from the Cache River. There are a number of impoundments at the Dixie, Plunkett, Bayou DeView LTD, and Howell tracts that can be flooded by ground water from wells. According to data (i.e., GIS shapefiles) provided by refuge staff, 54% of managed lands have complete water control capabilities, while 46% have partial water control capabilities. The habitat types and locations of managed land units with proximity to known wells are shown on Figure 17.

The refuge has two cooperative farming units that are managed to provide habitat and food for waterfowl and migrating shorebirds: the Dixie Farm Unit (2,768 acres) and the Plunkett Farm Unit (1,081 acres). Rice, milo, soybeans, Japanese millet and occasionally corn are grown on a rotating basis utilizing cooperative farming. Moist-soil units are where water levels are managed to propagate moist-soil plants that produce natural seeds for duck consumption. Moist-soil management is most effective in impoundments that are relatively flat and have water control structures and adjacent wells that can be used for irrigation and/or fall flooding. A total of twenty-two of the refuge's impoundments possess these characteristics. Moist-soil units can be managed to provide a diversity of habitats in succession, such as mudflats for shorebirds, annual grasses and sedges for waterfowl and perennial vegetation for marshbirds. The refuge has also acquired Wetland Reserve Program (WRP) lands (e.g., Howell, Revel and Dark Corner tracts) that contain numerous moist-soil impoundments that are actively managed as waterfowl and shorebird habitat (Figure 17). These tracts are considered the most suitable for shorebird use because they offer a diversity of water depths as well as mud bottoms (USFWS 2009; Richard Crossett, written communication, July 15, 2015).

Drawdown is achieved via releases through water control structures (Richard Crossett, written communication, July 15, 2015). The timing of drawdown depends on habitat objectives and the amount of water in adjacent drainage ditches. The refuge partnered with Ducks Unlimited and the North American Wetlands Conservation Council to restore over 1,000 acres of waterfowl habitat in the two farm units by improving levees and adding new water control structures (Ducks Unlimited undated) and continues to work with its partners to improve water/habitat management for wetland dependent species. The refuge has plans to develop more detailed water management plans for all units (USFWS 2009). Refuge staff have not mapped the locations or types of water control structures on the refuge.

5.2.2 Roads

The refuge maintains 144 miles of gravel roads for management access and wildlife-dependent recreation (e.g., hunting, fishing, and hiking). Very few of these roads are thought to impound or restrict the flow of water; however, a detailed analysis of the effects of roads on refuge hydrology has not been conducted (Richard Crossett, personal communication, July15, 2015). Additionally, there are numerous abandoned roads, logging trails and game trails that are accessible to hikers (USFWS 2009).



Map Date: 7/30/2015 File: Listed_Impaired.mxd Data Sources: USGS Groundwater wells; FWS Water Impoundments and Managed Lands; NHD High Resolution Flowlines; ESRI Map Service.

Figure 17. Managed lands, beaver dams, and other infrastructure known to affect hydrology on Cache River National Wildlife Refuge.

5.2.3 Dikes and Levees

Refuge water management includes annual maintenance of levee systems and ditches. Small-scale levees surround the moist-soil units and green tree reservoirs found throughout the refuge. Many of the adjacent farms throughout the refuge acquisition boundary have small levees as well. Although these are rarely continuous or large in scale, their effects on hydrology and vegetation communities can be substantial due to the flat topography within area.

5.2.4 Dams

There are no major dams (i.e., dams used for hydropower, navigation, etc.) present in the RHI. The Arkansas Natural Resources Commission (ANRC) lists 44 small dams within the RHI. None of these inventoried dams are on the refuge; most are located at the base of Crowley's Ridge near Jonesboro, Arkansas, or to the west of the White River. Most dams consist of small reservoirs or ponds that may capture runoff and affect in-stream hydrology during drier seasons, but likely do not have a major effect on flood events.

Refuge staff have made efforts to record and monitor the locations of persistent beaver dams that affect hydrology. At the time of this writing, 236 individual dams have been inventoried. Some of these locations are shown on Figure 17.

5.2.5 Water supply wells

The refuge uses a well on the Plunkett Farm unit, one well on Bayou DeView LTD, two wells on the Howell tract, and nine wells on the Dixie Farm unit for water management. The exact well coordinates and pumping capacities are unknown. There is also a large re-lift pump located on the Dixie farm unit that can be used to pump water out from the farm into Cache Bayou (Richard Crossett, personal communication, July 15, 2015).

5.2.6 Other infrastructure

Other infrastructure on the refuge includes public use areas consisting of 36 boat ramps (including concrete, gravel and primitive ramps) and associated parking areas (USFWS 2009).

5.3 Water Monitoring

This section summarizes known aquatic monitoring activities and data on and in the vicinity of the refuge, including water quantity and elevation, water quality, and aquatic habitat (including biological sampling for water quality or habitat quality assessment). Gage readings and estimates of surface water coverages for habitat and species management are conducted by the refuge biologist on managed impoundments and data is maintained in a MS ACCESS database; however, the specific locations of monitoring activities undertaken by the refuge have not been explicitly mapped, or information was not readily accessible during the development of this document.

5.3.1 Surface Water

This section presents information on federal and state surface water quantity and water quality monitoring locations and parameters monitored within the Cache River NWR RHI. Sections 5.4 and 5.5 address historic monitoring and trends for water quantity and quality at the RHI scale.

5.3.1.1 Hydrography

The USGS maintains monitoring stations that measure discharge and stage along the Cache River upstream of the refuge, as well as along the downstream rivers that contribute to water levels on the refuge via backwater flooding. There are 16 USGS surface water quantity monitoring sites (stream and lake gages and sites that were periodically measured for water levels) within the RHI. Fifteen active and historic sites are within 20 miles of the Cache River NWR acquisition boundary; seven of these sites are located within the acquisition boundary (Table 9, Figure 18). The gages at Morton (07077700; Site #7 in Table 9, Figure 18) and Patterson (07077500, Site #6 in Table 9 Figure 18) have a period of record beginning in 1951 and extending into 2013.

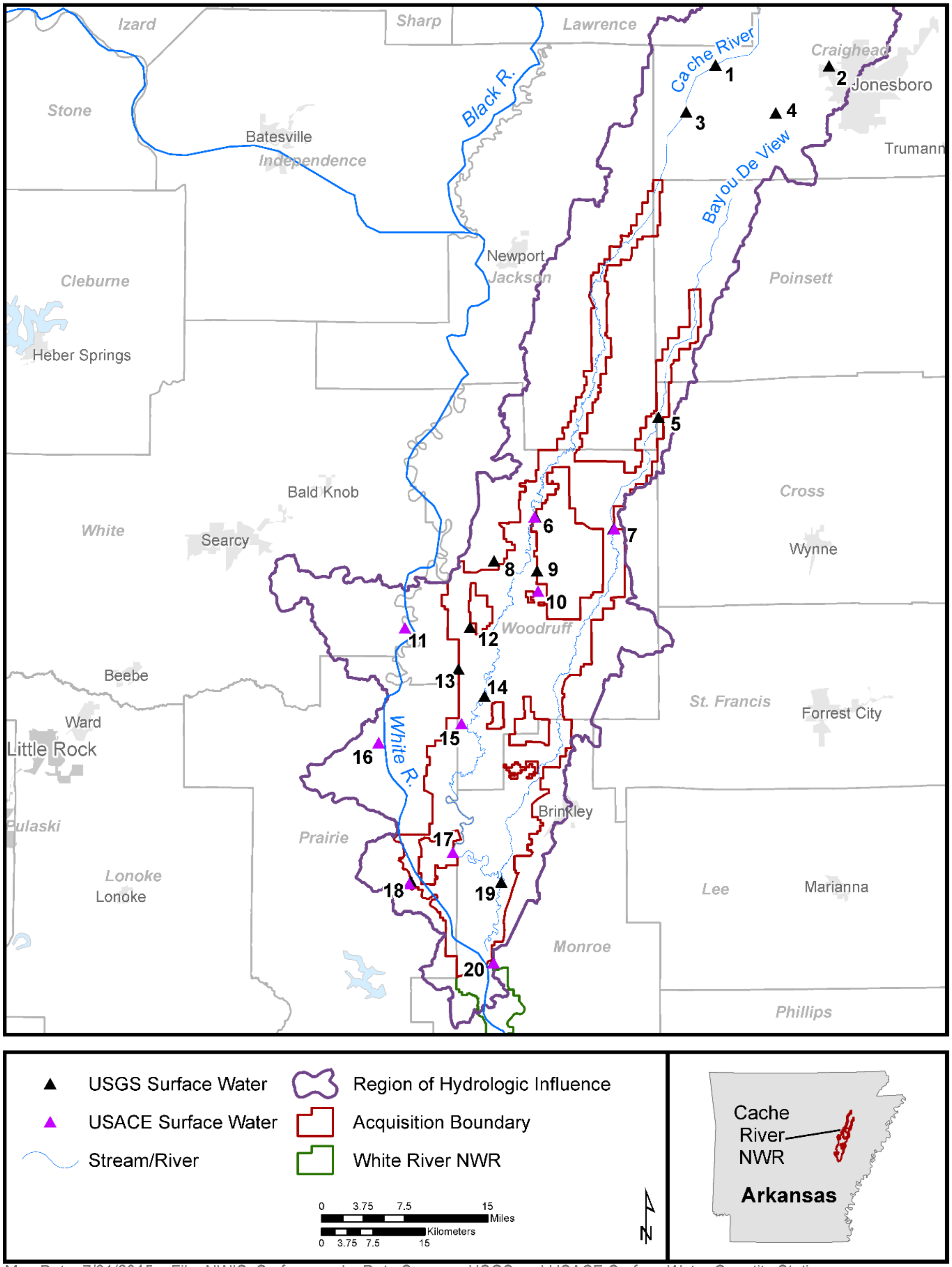
The USACE web site RiverGages.com lists the locations of nine active sites which measure water quantity (Stage, Precipitation, or Pool Level) within the RHI (USACE undated). Four of these sites overlap with current or historic USGS surface water stations, due to a history of shared management duties between the two agencies. Generally, the USACE gages have longer periods of record than the USGS sites for stage.

Table 9 and Figure 18 show the USACE stations within the Cache River NWR RHI. Information available on RiverGages.com includes flood stage elevation and record high stage information for each site. USACE and USGS use different datums for many of the co-managed stations; as such, data values may not be directly comparable.

Table 9. U.S. Geological Survey (USGS) and U.S. Army Corps of Engineers (USACE) surface water quantity monitoring stations near Cache River National Wildlife Refuge. Duplicate numbers on Figure 18 indicate stations which are co-located or in close proximity. [Source: USGS 2013; USACE undated).

# on Figure 18	Site ID	Name	Agency	Type	Begin	End
1	07077380	Cache River at Egypt, AR	USGS	Discharge	10/1/1964	Current
2	07077650	Big Creek near Jonesboro, AR	USGS	Discharge	9/28/1960	10/5/1988
3	07077400	CACHE RIVER NEAR CASH, ARK.	USGS	Discharge	4/9/1974	7/31/1984
4	07077660	Bayou Deview near Gibson, AR	USGS	Discharge	4/9/1974	9/26/1989
5	07077682	BAYOU DEVIEW NR HICKORY RIDGE, ARK.	USGS	Discharge	10/27/1965	7/25/1966
6	CR113	CACHE RIVER AT PATTERSON, AR.	USACE	Stage	1911	Current
6	07077500	Cache River at Patterson, AR	USGS	Discharge	10/1/1927	Current
7	BD111	Bayou DeView At Morton, AR	USACE	Stage	1911	Current
7	07077700	Bayou DeView near Morton, AR	USGS	Discharge	1/16/1951	5/9/2013
8	07077520	MOORE CREEK NEAR GRAYS,AR.	USGS	Discharge	4/21/1987	6/7/1988
9	07077510	MILLER BRANCH NEAR GRAYS,AR.	USGS	Discharge	5/27/1987	5/24/1989
10	n/a*	White River near Augusta	USACE	Stage	1911	Current
11	n/a*	White River at Georgetown	USACE	Stage	1911	Current
12	07077530	CACHE BAYOU NEAR GREGORY, AR.	USGS	Discharge	6/10/1987	6/7/1988
13	07077545	ROARING SLOUGH AT DIXIE, AR.	USGS	Discharge	4/21/1987	6/7/1988
14	07077555	Cache River near Cotton Plant, AR	USGS	Discharge	4/3/1987	Current
15	CR115	Cache River at Little Dixie, AR	USACE	Stage	2012	Current
16	WR114	White River At Des Arc, AR	USACE	Stage	1911	Current
17	CR114	Cache River At Brasfield, AR	USACE	Stage	1911	Current
18	WR115	White River At De Valls Bluff, AR	USACE	Stage	1909	Current
18	07077000	White River at DeValls Bluff, AR	USGS	Discharge	10/1/1949	Current
19	07077790	CACHE RIVER AT 100 YDS BELOW DREDGING, AR	USGS	Discharge	8/31/1977	3/19/1980
20	WR116	WHITE RIVER AT CLARENDON, AR	USACE	Stage	1886	Current
20	07077800	WHITE RIVER AT CLARENDON, ARK.	USGS	Discharge	10/1/1928	9/30/1993

* Gages managed by the USACE Little Rock District do not have a Site ID



Map Date: 7/31/2015 File: NWIS_Surface.mxd Data Sources: USGS and USACE Surface Water Quantity Stations, NHD High Resolution Flowlines and Waterbodies, National Watershed Boundary Dataset, ESRI Map Service.

Figure 18. Surface water quantity monitoring near Cache River National Wildlife Refuge. Information for numbered sites is presented in Table 9.

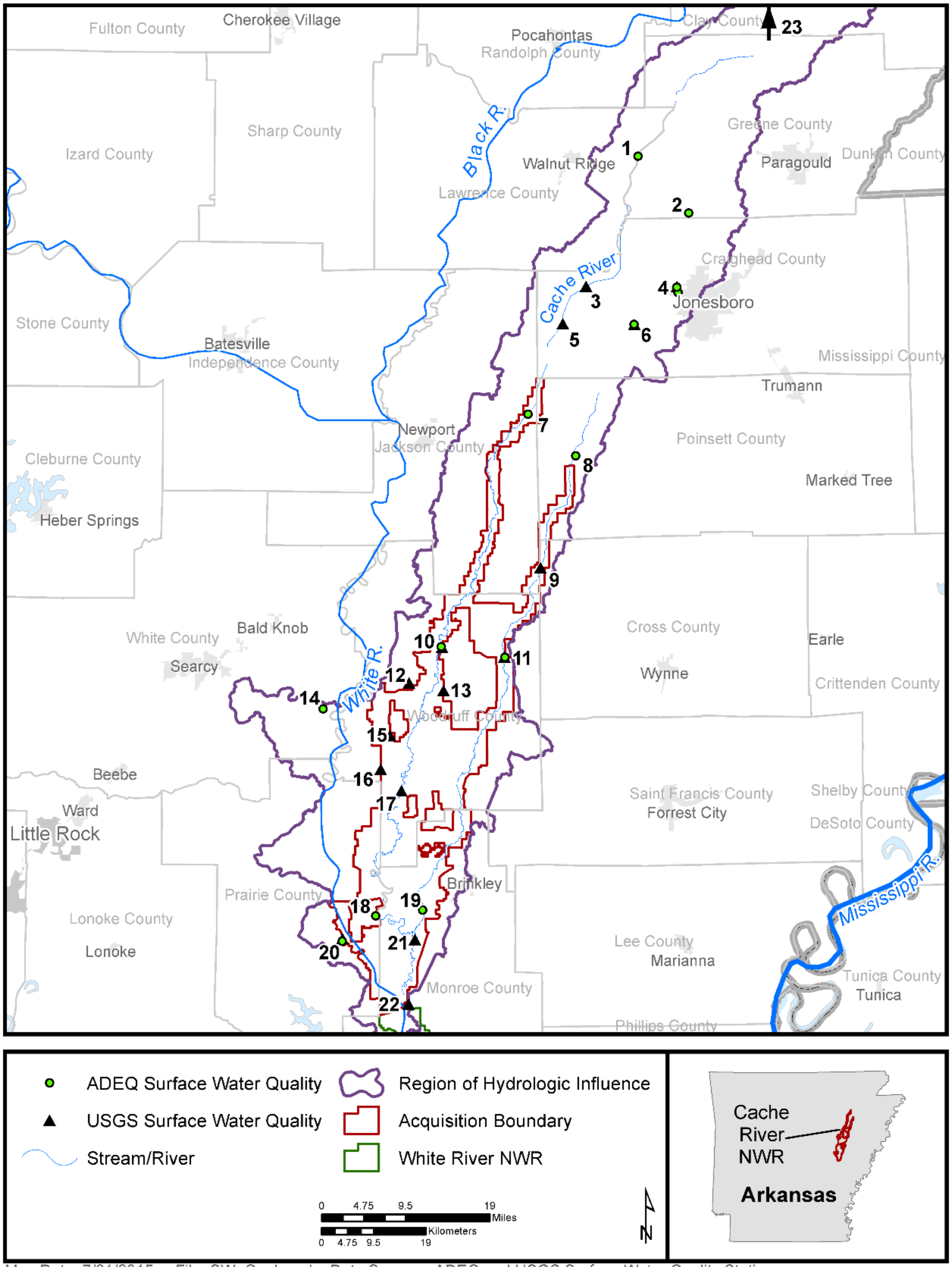
5.3.1.2 Water quality monitoring

Multiple agencies conduct surface water quality monitoring within the RHI. The USGS has collected water quality data at 16 active and historic surface water sites within the RHI (USGS 2013). There are three active water quality sites on different rivers within the refuge acquisition boundary. Site 07077000 (White River at DeValls Bluff, Arkansas) has a period of record beginning in 1945 (Site #20 in Table 10 and Figure 19). It has been monitored for a variety of water quality parameters, including temperature, specific conductance, dissolved oxygen, pH, phosphorous, and dissolved solids. Site 07077500 (Cache River at Patterson, Arkansas) has a period of record beginning in 1951 (Site #10 in Table 10 and Figure 19). From 1987 to 1993, suspended sediment discharge (in tons per day) and concentration (in milligrams per liter) were collected on a daily basis at this site. Turbidity measurements (an indicator related to sediment concentration) have been collected periodically over the entire period of record at this site. Additional parameters, such as specific conductance, dissolved oxygen, pH, phosphorus, and dissolved solids, are also currently monitored. Site 07077700 (Bayou DeView near Morton, Arkansas) was also activated in 1951 (Site #11 in Table 10 and Figure 19). Water quality parameters monitored at this site include pH, nitrate, ammonia, total nitrogen, phosphate, organic carbon, mercury, lead and other various metals. Detailed water quality monitoring data for these sites is available online through the USGS National Water Information (NWIS) web interface.

The Arkansas Department of Environmental Quality's (ADEQ) Water Quality Monitoring Program includes the monitoring of the chemical parameters in the water of streams within the State. Statewide, the monitoring network of streams includes over 160 ambient stations that are sampled monthly, over 100 stations that are sampled on a bi-monthly or quarterly schedule, and an additional 30-50 stations that are intensively sampled over a short period of time for special purposes. Within the RHI, there are 16 surface water sampling locations with the following types: channelized stream, reservoir, and river/stream (Table 10, Figure 19). Three of these sampling sites are co-located with the three USGS sites mentioned above: site WHI0031, White River at DeValls Bluff, Arkansas; site UWCHR02, Cache River at Hwy. 64 at Patterson, Arkansas; and site UWBDV02, Bayou DeView at Hwy. 64 four miles east of McCrory, Arkansas (#20, #10, and #11 in Table 10 and on Figure 19, respectively). Each has been sampled on a monthly basis since 1990 for a variety of parameters, including turbidity, pH, dissolved oxygen, phosphorus, and temperature. Data for the ADEQ stations listed in Table 10 can be obtained by searching the ADEQ Surface Water Quality Monitoring Data Search Page (ADEQ 2013).

Table 10. U.S. Geological Survey (USGS) and Arkansas Department of Environmental Quality (ADEQ) surface water quality monitoring stations near Cache River National Wildlife Refuge. Duplicate numbers indicate stations which are co-located or in close proximity. [Source: USGS 2013, ADEQ 2012].

# on Figure 19	Station ID	Name	Agency	Start	End
1	UWCHR04	Cache River at Hwy, 412, 6 1/2 mi. E. of Walnut Ridge, AR	ADEQ	6/1/1994	
2	LWHI002A	Lake Frierson - mid. pt. of trans. fm. ramp parallel to dam	ADEQ	10/21/1989	
3	07077380	Cache River at Egypt, AR	USGS	10/5/1965	9/1/1998
4	WHI0172	Lost Creek at Lacy Drive	ADEQ	7/25/2002	
4	WHI0196	Big Creek ditch at Hwy. 63B	ADEQ	6/25/2008	
4	07077650	Big Creek near Jonesboro, AR	USGS	9/28/1960	10/5/1988
5	07077400	Cache River near Cache, AR.	USGS	4/9/1974	9/26/1983
6	WHI0026	Bayou DeView west of Gibson, AR	ADEQ	4/8/1974	
6	07077660	Bayou Deview near Gibson, AR	USGS	4/9/1974	9/20/1994
7	UWCHR03	Cache River at Hwy. 18 near Grubbs, AR	ADEQ	6/1/1994	
8	LWHI001A	Lake Hogue - NW of Waldenburg - close to S. levee.	ADEQ	10/21/1989	
9	07077682	Bayou DeView near Hickory Ridge, AR	USGS	10/27/1965	7/25/1966
10	UWCHR02	Cache River at Hwy. 64 at Patterson, AR	ADEQ	6/1/1994	
10	07077500	Cache River at Patterson, AR	USGS	1/16/1951	current
11	UWBDV02	Bayou Deview at Hwy. 64, 4 mi. E. of McCrory, AR	ADEQ	6/1/1994	
11	07077700	Bayou DeView near Morton, AR	USGS	1/16/1951	current
12	07077520	Moore Creek near Grays, AR	USGS	4/21/1987	6/7/1988
13	07077510	Miller Branch near Grays, AR	USGS	5/27/1987	5/23/1990
14	WHI0197B	Bayou Des Arc at Hwy. 367	ADEQ	12/22/2009	
15	07077530	Cache Bayou near Gregory, AR	USGS	6/10/1987	6/7/1988
16	07077545	Roaring Slough at Dixie, AR	USGS	4/21/1987	6/7/1988
17	07077555	Cache River near Cotton Plant, AR	USGS	4/3/1987	4/9/2002
18	WHI0032	Cache River near Brasfield, AR	ADEQ	4/3/1974	
19	WHI0033	Bayou DeView at Hwy. 70	ADEQ	4/3/1974	
20	WHI0031	White River at DeValls Bluff, AR	ADEQ	3/25/1974	
20	07077000	White River at DeValls Bluff, AR	USGS	11/6/1945	current
21	07077790	Cache River at 100 yards below Dredging, AR	USGS	8/31/1977	3/19/1980
22	07077800	White River at Clarendon, AR	USGS	10/1/1947	7/1/1986
23	07077080	Little Cache River Ditch No. 1 near McDougal, AR	USGS	10/4/1972	7/30/1975



Map Date: 7/31/2015 File: SW_Qual.mxd Data Sources: ADEQ and USGS Surface Water Quality Stations; NHD High Resolution Flowlines and Waterbodies, National Watershed Boundary Dataset HU-6 Boundaries, ESRI Map Service.

Figure 19. Surface water quality monitoring near Cache River National Wildlife Refuge. Information for numbered sites is presented in Table 10.

5.3.1.3 Aquatic habitat and biota

Anthropogenic stressors and practices have drastically changed the landscape and impacted the aquatic habitat and biota within the Cache River subbasin. However, unique delta ecosystems are still present in areas, some of which occur exclusively within the boundaries of Cache River NWR. These habitats primarily consist of lotic systems (i.e., streams) such as the Cache River and Bayou DeView. In addition to the lotic habitats, abandoned channel scars in the form of oxbow lakes or forested brakes provide most of the permanent lentic habitats. Many of these habitats are seasonally connected to the river during flood events. During large flood events, much of the bottomland hardwood forests found throughout the refuge serve as temporary habitat for many aquatic species. Many fish and herpetofuana species use the flooded forests, sloughs, and lakes as reproductive and/or nursery habitat. In addition, many aquatic taxa (i.e., fishes, molluscs, amphibians, etc.) inhabit the rivers, bayous, and lakes year round (USFWS 2008).

The aquatic habitats adjacent to, and within, the Cache River NWR support a large diversity of species. Several popular game (sport) fish species found within these systems include: white crappie (*Pomoxis annularis*), black crappie (*P. nigromaculatus*), largemouth bass (*Micropterus salmoides*), spotted bass (*M. punctulatus*), bluegill (*Lepomis macrochirus*), flathead catfish (*Pylodictis olivaris*), and blue catfish (*Ictalurus furcatus*). Many non-game and commercial fishes are also found in the various aquatic systems of the refuge. Freshwater mussels are found throughout the refuge in flowing waters and to a lesser degree in permanent backwater sloughs and lakes. Other invertebrate species (e.g., crayfish, snails, aquatic insects, etc.) also inhabit the varying aquatic habitats within the refuge. Specific information on the abundance, species richness and distribution of molluscs and other invertebrate species within the refuge is limited mostly to studies of the Cache River. The floodplain forests and isolated wetland habitats of Cache River NWR are also suitable for numerous species of reptiles and amphibians. Various species of snakes, lizards, frogs, toads, salamanders, and turtles occupy the refuge (USFWS 2008).

Biological Inventories

At least 50 species of fishes have been documented from the Cache River, Bayou DeView, and associated backwaters (Mauney and Harp 1979; Killgore and Baker 1996). Killgore and Baker (1996) documented 29 species of larval fish in the forested floodplains throughout the Cache River Basin. Available data is limited for adult and larval fishes within refuge-specific aquatic habitats. However, it is likely that many species occur at multiple life stages throughout waters found on the Refuge (USFWS 2008). For example, The Fishes of Arkansas (Robison and Buchanan 1988) describes 215 species of fish found within the state and includes information for species occurrences within the Cache River (and associated tributaries).

Very few mussel surveys have been conducted in waters exclusively on the Cache River NWR. Surveys were conducted in the Cache River during the early-mid 1990s. Christian et al. (2005) surveyed the lower 42 miles of the Cache River and confirmed the presence of 26 mussel species, four (*Ellipsaria lineolate*, *Lasmigona complanata*, *Ligumia recta*, and *Truncilla donaciformis*) of which had not been previously documented in the Cache River. The documentation of these additional four species, coupled with documented occurrences from previous studies (Wheeler 1914; Gordon et al. 1980; Ecological Consultants 1983; Jenkinson and Ahlstedt 1988), provides a total record of 39 mussel species for the Cache River watershed (Christian et al. 2005). In 2007, preliminary mussel survey efforts in Bayou DeView and within the Cache River NWR boundary were initiated. However, at this time, there are no comprehensive studies characterizing the mussels of Bayou DeView, other tributaries of the Cache River, and floodplain lakes located within the refuge boundaries (USFWS 2008).

Information for other invertebrate species (e.g., crayfish, snails, aquatic insects, etc.) potentially occurring on the refuge is extremely limited or no-existent. However, efforts are currently being conducted to describe crayfish taxa within Arkansas (Brian Wagner, personal communication, December 10, 2013) and will hopefully include information for taxa identified within the Cache River and associated tributaries.

<u>The Amphibian and Reptiles of Arkansas</u> (Trauth et al. 2004) provides comprehensive records for known occurrences and distributions of salamanders, frogs, toads, turtles, snakes, lizards, and alligators within the state and includes documentation of species within areas encompassed by the Cache River Basin. Although, to date, no thorough herpetological population or occurrence surveys have been conducted on Cache River NWR specific property, a 1985 species list (species known or expected to occur) for the adjacent Dale Bumpers White River NWR included 47 species of reptiles and 20 species of amphibians. This list lends perspective to the potential diversity of the herpetological resources for Cache River NWR. Also, reptiles and amphibians were surveyed by University of Arkansas Monticello personnel in the mid and late 1980's on Black Swamp Wildlife Management Area and on lands eventually purchased for the refuge, as part of an overall research project of the Waterways Experiment Station in Vicksburg. Of the taxa potentially on Cache River NWR, two species, the mole salamander (*Ambystoma talpoideum*) and western chicken turtle (*Deirochelys reticularia miaria*) have been recognized as Species of Greater Conservation Need by the State of Arkansas (AWAP 2006).

Comprehensive survey records compiled and available from the Arkansas Natural Heritage Commission (ANHC) document historic and current aquatic species accounts throughout Arkansas. These inventory records include information for the Cache River Basin and assist in inventorying “aquatic elements of special concern”, including state and federally listed threatened or endangered taxa. For all other aquatic taxa, various species observational records comprise most of the information available. Examples of this type of information would include species accounts reported by the public and recorded observations from biologists conducting other routine field work.

<u>Biological Monitoring</u>

The delta ecosystems found throughout the Cache River Basin provide researchers an opportunity to collect information and study the aquatic habitats and biota that are somewhat unique to eastern Arkansas, and the larger White River Basin. The “White River Comprehensive Report” (Hoover et al. 2009) was a thorough summary of studies and surveys within the White River Basin and includes some limited information for the Cache River. In this report, the fisheries resources of the basin, sensitivity to environmental disturbances, and means of conserving and enhancing fish populations were discussed and summarized.

USFWS and Arkansas Game and Fish Commission (AGFC) biologists periodically sample for various aquatic biota within the White River Basin, including the Cache River and associated tributaries. Recent efforts have included monitoring for invasive species, sampling for species of concern, or reporting on the status and distribution of rare, threatened, or endangered species. For example, USFWS and AGFC have collaboratively been monitoring alligator gar (*Atractosteus spatula*) within the lower White River and in other basins where the species historically occurred. Monitoring efforts for aquatic invasive species, such as northern snakehead (*Channa argus*), are on-going since the initial confirmation of this species in 2008 in eastern Arkansas. Additional aquatic invasive species known to be established in waters adjacent to, and potentially in, refuge waters include: silver carp (*Hypophthalmichthys molitrix*), bighead carp (*H. noblis*), grass carp (*Ctenopharyngodon idella*), and common carp (*Cyprinus carpio*).

An effort to restore some of the natural hydrology of the lower Cache River has been initiated. In summer of 2014, the USACE completed Phase 1 of The *Lower Cache River Restoration Project*. In an effort to assess the changes to the hydrology and effects on aquatic communities, a component of the restoration project included pre- and post-assessment of fish and macro-invertebrate communities within the channelized and historic meanders of the river. The second half of the project (Phase 2) includes the remaining portion of the river (i.e., below the Phase 1 area to the confluence of the White River), which is bordered by the Cache River NWR. Efforts have been initiated to collect pre-assessment data for the fish and macro-invertebrate communities for Phase 2. Results of these sampling and monitoring efforts will be provided to TNC and available once the project is complete and as additional information becomes available in subsequent survey years.

Cache River NWR participated in the USFWS Abnormal Amphibians Study (Reeves et al. 2013) to document amphibian abnormalities in refuge populations. A 3-year sampling period was initiated in 2006. The initial survey conducted in 2006 by refuge staff did not indicate any amphibian abnormalities on Cache River NWR. However, additional information from the study did indicate that the Cache River Basin was in proximity to "hot-spot" clusters of higher predicted amphibian abnormality prevalence (percent of frogs abnormal) (Reeves et al. 2013).

Threatened and Endangered Species

While no specific federally-listed (threatened or endangered) aquatic species have been identified or documented in the Cache River or on the refuge, six federally-listed aquatic species have been historically or are currently documented in the Lower White River Basin and include four mussel taxa (*Potamilus capax* fat pocketbook; *Lampsilis abrupta* pink mucket; *Quadrula cylindrical cylindrical* rabbitsfoot; *Leptodea leptodon* scaleshell), one fish taxon (*Scaphirhynchus albus* pallid sturgeon), and one plant taxon (*Lindera melissifolia* pondberry). These six federally-listed aquatic taxa of the Lower White River Basin represent one quarter of such species documented within Arkansas.

Several of the aforementioned federally-listed taxa have been documented in proximity to the Cache River NWR boundary or waters connected to the Cache River. Thus, the likelihood exists that refuge waters could contribute to the life history needs for some, or all, of these taxa. For example, single pink mucket (*Lampsilis abrupta*) specimens were documented in the main stem of the lower White River at RM 99 (Clarendon, Arkansas) and RM 63.5 (Lambert's Landing Bend) (Christian 1995). This indicates that a relict population might exist within this reach of the White River which begins immediately downstream of the confluence with the Cache River and is also near the southern end of the Cache River NWR boundary. Rabbitsfoot (*Quadrula cylindrical cylindrical*) is one of the most recent mussel taxa to be listed (USFWS 2013b) and has been documented throughout much of the main stem of the White River (Harris et al. 1997: Figure 14) that flows adjacent to Cache River NWR boundaries. Additionally, in 2010, the USFWS had a final rule and determined it necessary to list shovelnose sturgeon (*S. platorynchus*) as threatened due to similarity of appearance with pallid sturgeon (*S. albus*) (USFWS 2010b). This ruling applies to known sympatric waters for the two species. Recent efforts to track and monitor pallid sturgeon indicates that the species uses the lower, undammed reach of the Arkansas River and potentially inhabits a portion of the St. Francis River. As additional studies are conducted and additional species accounts are documented, this ruling may eventually apply directly to the lower White River and associated tributaries, including the Cache River, thereby directly affecting the Cache River NWR.

Of all aquatic taxa, mussels comprise most of the statewide federal listings, with at least fourteen species. However, one of these, turgid blossom (*Epioblasma turgidula*), is considered extirpated from the state (Bill Posey, personal communication, January 3, 2014) and most likely extinct throughout its historic range (Haag 2012: Table 10.1 pg. 333). Two major threats to mussel species include sedimentation and chemical runoff from agriculture. Sedimentation is created by a number of sources including agricultural runoff, headcutting in fields and drainage tributaries, stream bank erosion, and stream channel instability and degradation. A wide variety of chemicals are used in modern agriculture including pesticides, herbicides, defoliants, and fertilizers. Some of these chemicals can be detrimental to mussels, fish and aquatic wildlife if they accumulate in large enough quantities in streams and other water bodies. Malacologists generally agree that contaminants are partially responsible for the decline of freshwater mussels.

ANHC identifies 59 “special concern” aquatic taxa as occurring in, or as being reported from, the Lower White River Basin (Table 11). The “special concern” status indicates that these species are listed as federally threatened or endangered, state threatened or endangered, or of conservation concern and warrant active inventory efforts. These species include 21 fish taxa, 18 mussel taxa, 7 crustacean taxa, 6 amphibian taxa, 5 reptile taxa, 1 insect taxon, and 1 plant taxon (Table 11).

Table 11. Aquatic Elements of Special Concern, Lower White River Watersheds. [Source: ANHC 2014].

Scientific Name	Common Name	Federal Status	State Status	Global Rank	State Rank
Animals-Invertebrates					
Allocrangonyx hubrichti	Hubricht's long-tailed amphipod	-	INV	G2G3	S1?
Caecidotea brevicauda	an isopod	-	INV	GNR	S1
Caecidotea foxi	an isopod	-	INV	GNR	S1
Crangonyx obliquus	an amphipod	-	INV	G5	S3?
Cyprogenia aberti	western fanshell	-	INV	G2G3Q	S2
Lampsilis abrupta	pink mucket	LE	SE	G2	S2
Lampsilis siliquoidea	fatmucket	-	INV	G5	S3
Leptodea leptodon	scaleshell	LE	SE	G1G2	S1
Ligidium elrodii	an isopod	-	INV	G4G5	S2
Ligumia recta	black sandshell	-	INV	G4G5	S2
Lirceus louisianae	an isopod	-	INV	GNR	S1
Macrobrachium ohione	Ohio shrimp	-	INV	G4	S1?
Obovaria jacksoniana	southern hickorynut	-	INV	G2	S2
Obovaria olivaria	hickorynut	-	INV	G4	S3
Pleurobema cordatum	Ohio pigtoe	-	INV	G4	S1
Pleurobema rubrum	pyramid pigtoe	-	INV	G2G3	S2
Potamilus alatus	pink heelsplitter	-	INV	G5	S1
Potamilus capax	fat pocketbook	LE	SE	G2	S1
Quadrula apiculata	southern mapleleaf	-	INV	G5	S2
Quadrula cylindrica cylindrica	rabbitsfoot	LT	SE	G3G4T3	S2
Quadrula metanevra	monkeyface	-	INV	G4	S3S4
Somatochlora ozarkensis	Ozark emerald	-	INV	G3	S1
Toxolasma lividum	purple lilliput	-	INV	G3Q	S2
Uniomerus declivis	tapered pondhorn	-	INV	G5Q	S2
Uniomerus tetralasmus	pondhorn	-	INV	G5	S2
Villosa lienosa	little spectaclecase	-	INV	G5	S3
Animals-Vertebrates					
Acipenser fulvescens	lake sturgeon	-	INV	G3G4	S1
Ambystoma talpoideum	mole salamander	-	INV	G5	S3
Ammocrypta clara	western sand darter	-	INV	G3	S2?
Anguilla rostrata	American eel	-	INV	G4	S3
Atractosteus spatula	alligator gar	-	INV	G3G4	S2?
Chrysemys dorsalis	southern painted turtle	-	INV	G5	S3
Crystallaria asprella	crystal darter	-	INV	G3	S2?
Cycleptus elongatus	blue sucker	-	INV	G3G4	S2
Deirochelys reticularia miaria	western chicken turtle	-	INV	G5T5	S3
Desmognathus conanti	spotted dusky salamander	-	INV	G5	S1
Erimyzon sucetta	lake chubsucker	-	INV	G5	S2?
Etheostoma fusiforme	swamp darter	-	INV	G5	S2?
Etheostoma parvipinne	goldstripe darter	-	INV	G4G5	S2
Hiodon alosoides	goldeye	-	INV	G5	S2?
Hyla avivoca	bird-voiced treefrog	-	INV	G5	S3
Lethenteron appendix	American brook lamprey	-	INV	G4	S2?
Lithobates areolatus circulosus	northern crawfish frog	-	INV	G4T4	S2
Moxostoma pisolabrum	pealip redhorse	-	INV	G5	S2?

Scientific Name	Common Name	Federal Status	State Status	Global Rank	State Rank
Mugil cephalus	striped mullet	-	INV	G5	S1?
Nerodia cyclopion	Mississippi green watersnake	-	INV	G5	S3
Notropis maculatus	taillight shiner	-	INV	G5	S3
Notropis sabinae	sabine shiner	-	INV	G4	S2?
Noturus flavus	stonecat	-	INV	G5	S1
Phenacobius mirabilis	suckermouth minnow	-	INV	G5	S1
Platygobio gracilis	flathead chub	-	INV	G5	S1?
Polyodon spathula	paddlefish	-	INV	G4	S2?
Pseudacris illinoensis	Illinois chorus frog	-	INV	G5T3	S1
Regina grahamii	Graham's crayfish snake	-	INV	G5	S2
Regina rigida sinicola	gulf crayfish snake	-	INV	G5T5	S3
Scaphiopus holbrookii	eastern spadefoot	-	INV	G5	S2
Scaphirhynchus albus	pallid sturgeon	LE	SE	G2	S1
Umbra limi	central mudminnow	-	INV	G5	SH
Plants-Vascular					
Zannichellia palustris	horned-pondweed	-	INV	G5	S2S3

5.3.2 Groundwater

5.3.2.1 Groundwater level monitoring

Groundwater levels are monitored by a variety of agencies including USGS and ANRC. A very large number of irrigation wells have been sampled since concerns about the long-term sustainability of the alluvial aquifer first arose in the mid-20th century. As a result, the USGS lists 10,302 wells within the RHI that have been or potentially could be sampled for groundwater levels. Well names are derived from the Public Land Survey System (PLSS) Section-Township-Range location of the well plus additional letter and number identifiers which subdivide the sections into increasingly specific quarters. For example, well 08S02W01CBA1 is located in section 1 of township 8 south, range 2 west. “CBA1” means that the well is the first well within the southwest (“C”) quarter of section 1, which is further subdivided into quarter-quarters (“B” = southeast), each of which are further subdivided into quarter-quarter-quarters (“A” = northeast). Figure 20 depicts the quarter naming conventions within sections.

There are 1,465 wells located within the refuge acquisition boundary; 352 are located on lands currently owned by the refuge. Of those, the USGS has measured groundwater levels at 35 sites since 1957 (Table 12, Figure 21).

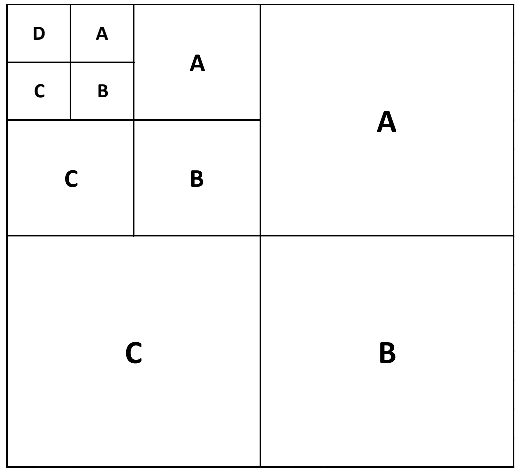


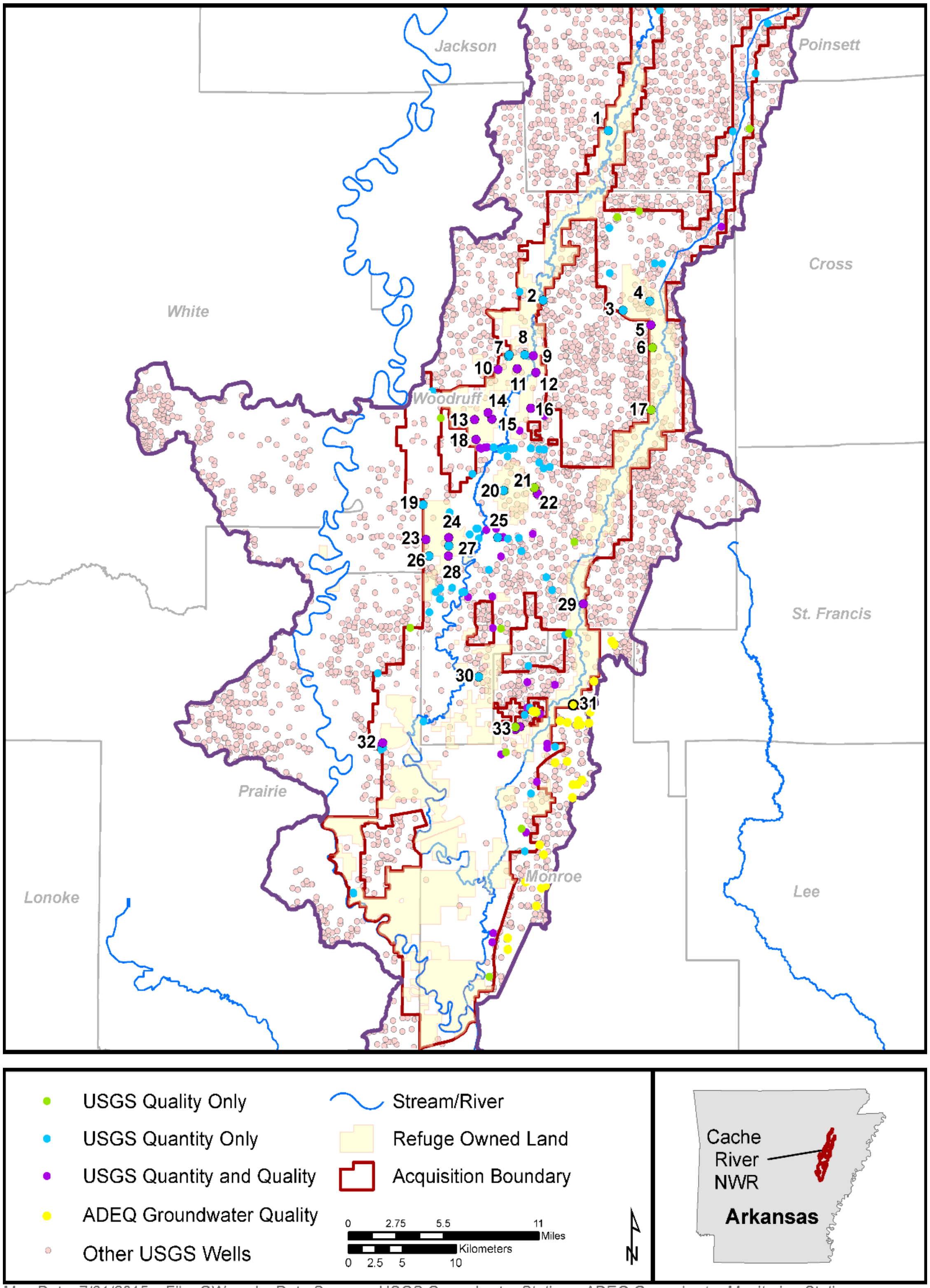
Figure 20. Illustration of naming conventions for section areal subunits.

Table 12. Groundwater monitoring within and near Cache River National Wildlife Refuge. Sites with the same identifying location number on Figure 21 are in close proximity. [Sources: ADEQ 2013; USGS 2013].

# on Figure 21	Site ID	Name	Agency	Quality Period of Record	Quality Samples	Quantity Period of Record	Quantity Measure -ments
1	352420091100001	09N02W14CAA1	USGS	--	0	8/24/1984 - 4/21/1992	16
2	351611091141101	08N02W31DDD1	USGS	8/13/1990 - 8/4/1992	3	12/3/1986 - 4/16/2013	61
2	351611091141102	08N02W31DDD2	USGS	--	0	12/11/1989 - 9/20/1992	35
3	351537091091701	07N02W01DBB1	USGS	--	0	9/14/1989 - 9/21/1992	29
4	351602091073901	07N01W05BBB1	USGS	--	0	9/14/1989 - 9/21/1992	31
5	351453091073601	07N01W08BCB1	USGS	8/14/1974	1	2/1/1973 - 4/17/1976	10
6	351347091073201	07N01W17CBA1	USGS	7/19/1973	1	--	0
7	351330091162101	07N03W23AAB1	USGS	--	0	11/17/1987 - 9/22/1992	46
7	351334091161901	07N03W23AAA1	USGS	--	0	9/22/1987 - 8/25/1992	45
8	351333091152201	07N03W24AAB1	USGS	--	0	11/15/1988 - 9/21/1992	40
9	351330091145001	07N02W19BAB1	USGS	2/8/1989	1	11/15/1988 - 9/21/1992	40
10	351300091170201	07N03W23CDB1	USGS	7/18/1988	1	10/23/1986 - 9/22/1992	49
11	351253091155001	07N03W24CDA1	USGS	2/8/1989	1	11/15/1988 - 9/22/1992	38
12	351241091144201	07N02W19CDD1	USGS	2/9/1989	1	11/16/1988 - 9/21/1992	38
13	351020091201101	06N03W04DAA1	USGS	7/19/1988	1	10/21/1986 - 9/22/1992	47
14	351047091174001	06N03W03ABD1	USGS	7/19/1988	1	9/22/1987 - 9/22/1992	46
14	351047091174002	06N03W03ABD2	USGS	8/2/1988, 2/8/1989	2	11/17/1987 - 9/22/1992	46
15	351028091172601	06N03W03DAA1	USGS	2/8/1989	1	11/15/1988 - 9/22/1992	39
16	351058091150301	07N02W31CCD1	USGS	2/9/1989	1	11/16/1988 - 9/21/1992	39
17	351046091074101	07N01W32CCD1	USGS	8/19/1998 - 6/29/2010	5	--	0
18	350930091182601	06N03W10CBB1	USGS	2/8/1989	1	11/15/1988 - 9/22/1992	39
19	350623091214401	06N03W31BCB1	USGS	--	0	9/17/1957 - 4/16/2013	30
20	350700091164701	06N03W26ACB2	USGS	7/18/1991, 8/4/1992	2	--	0
20	350700091164801	06N03W26ACB1	USGS	--	0	11/16/1988 - 9/21/1992	39
21	350707091145501	06N02W30BD1	USGS	7/20/1995	1	--	0
22	350649091144401	06N02W30ACC1	USGS	2/9/1989	1	11/16/1988 - 9/21/1992	40
23	350445091213301	05N03W07BBA1	USGS	7/19/1988	1	9/22/1987 - 9/22/1992	39

# on Figure 21	Site ID	Name	Agency	Quality Period of Record	Quality Samples	Quantity Period of Record	Quantity Measure -ments
24	350446091201201	05N03W05DCC1	USGS	7/19/1988	1	9/22/1987 - 9/22/1992	42
24	350446091201202	05N03W05DCC2	USGS	8/2/1988, 2/7/1989	2	11/13/1987 - 9/22/1992	46
25	350441091171201	05N03W02CDC1	USGS	--	0	12/14/1989 - 9/21/1992	35
26	350342091214501	05N03W07CDC1	USGS	--	0	10/21/1986 - 9/21/1992	44
27	350422091201201	05N03W08ACC1	USGS	--	0	1/25/1990 - 9/22/1992	28
28	350353091201401	05N03W08CDD1	USGS	2/7/1989	1	11/15/1988 - 9/22/1992	39
29	350127091120201	05N02W27CBA1	USGS	7/14/1961	1	7/14/1961 - 7/14/1961	1
30	345800091183001	04N03W15BCA1	USGS	--	0	10/12/1961 - 12/12/1961	2
31	MON905*	Monroe County Irrigation Well 905	ADEQ	2003	1	--	0
32	345453091242501	04N04W34DDC1	USGS	7/18/1974	1	1/15/1973 - 9/26/1973	6
33	345526091161901	04N03W36BAC1	USGS	--	0	1/16/1973 - 5/27/1994	29
33	345526091162101	04N03W36BBD1	USGS	8/12/1983	1	10/13/1983 - 10/13/1983	1
33	345533091160201	04N03W36ABB1	USGS	8/12/1983	1	10/13/1983 - 10/13/1983	1
33	345533091161901	04N03W36BAB1	USGS	7/29/1983	1	--	0

*Note: There are four ADEQ wells located within the acquisition boundary; only MON905 is located on refuge land.



Map Date: 7/31/2015 File: GW.mxd Data Sources: USGS Groundwater Stations; ADEQ Groundwater Monitoring Stations; NHD High Resolution Flowlines and Waterbodies, National Watershed Boundary Dataset HU-6 Boundaries, ESRI Map Service.

Figure 21. Groundwater monitoring on and near Cache River National Wildlife Refuge. Numbered locations are detailed in Table 12.

5.3.2.2 Groundwater quality monitoring

On the refuge, groundwater quality samples have been collected by USGS at 26 wells (Table 12, Figure 21).

ADEQ's groundwater quality monitoring includes ambient monitoring and research-oriented monitoring, such as investigations of pesticides in groundwater in eastern Arkansas, nutrient and bacteria transport in shallow aquifer systems in northwest Arkansas, and saltwater intrusion into shallow aquifers in south-eastern Arkansas. The ambient groundwater monitoring program was developed in order to document existing groundwater quality in various aquifers throughout the state. The monitoring program currently consists of 195 well and spring sites in 12 different monitoring areas within the state. Each area of the state is sampled every three years. The refuge is located closest to the Brinkley Monitoring Area, which encompasses the town of Brinkley and surrounding areas in northern Monroe County. The Brinkley Monitoring Area was last sampled in 2011 (ADEQ 2012). A full suite of inorganic parameters is analyzed for the samples, including all major cations, anions, and trace metals. In addition, semi-volatile and volatile organic analyses are performed on samples in areas with industry, landfills, and other facilities which store, manufacture or dispose organic chemicals. Areas with row-crop agriculture commonly include pesticide analyses. Within the RHI, there are 44 well monitoring sites. Of these sites, 4 sampling sites are located at wells within the refuge acquisition boundary: MON182, MON 183, and MON909 are located at public water supply wells, and MON905, which is on land owned by the refuge, is located at an irrigation well (Site#31, Table 12, Figure 21). It is noteworthy that although these sites should be sampled every three years according to program guidelines, MON909 does not have any sampling data and there is only one sample date (from 2011) listed for each of the other wells in the ADEQ online database.

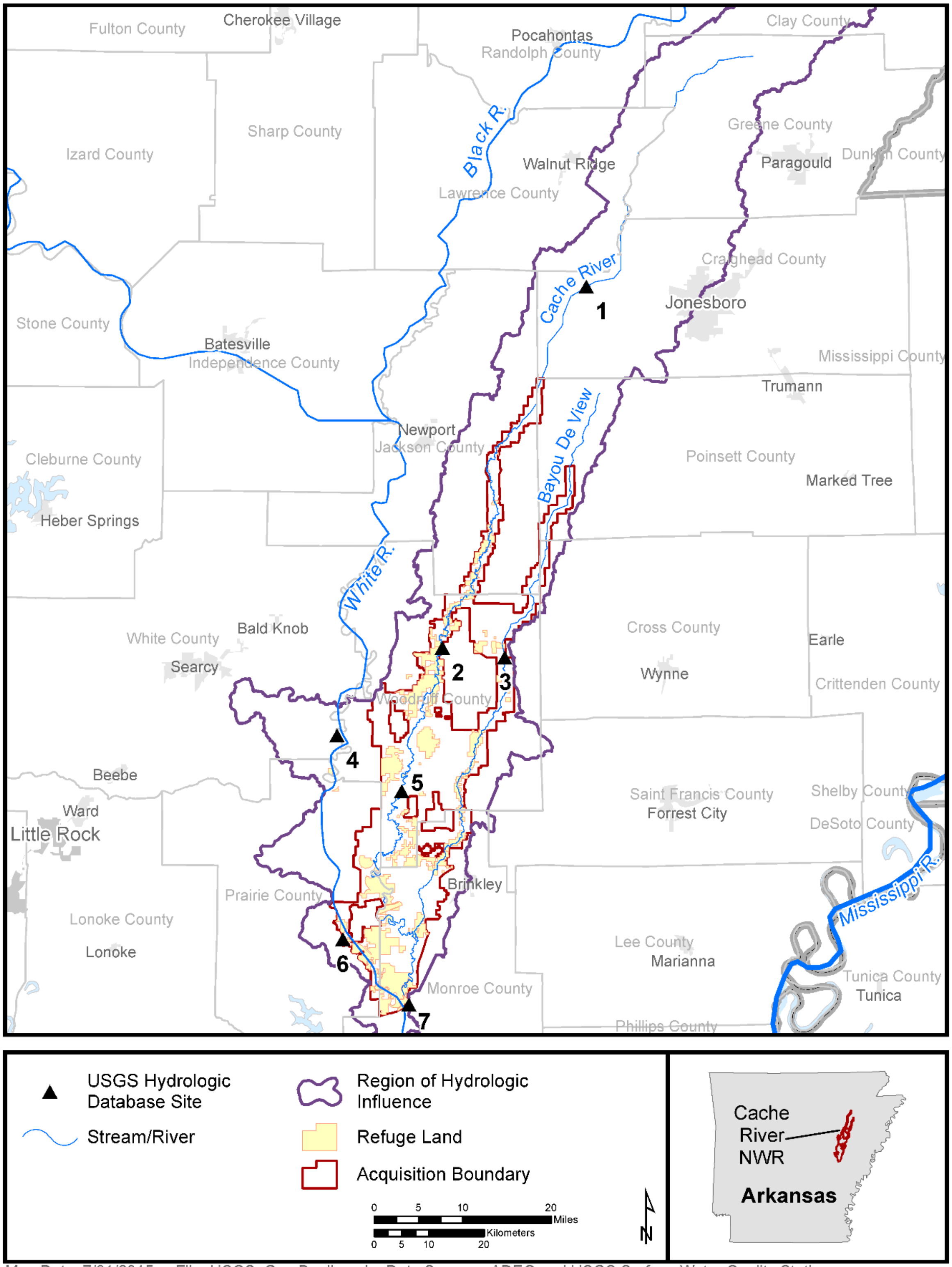
5.4 Water Quantity and Timing

5.4.1 Historical Streamflows

The Hydro-Climatic Data Network (HCDN) is a network of USGS stream gaging stations that are considered well suited for evaluating trends in streamflow conditions. Sites in the network have periods of record that exceed twenty years and are located in watersheds that are relatively undisturbed by surface water diversions, urban development, or dams. The closest HCDN gage to the refuge is located on the Cache River in Egypt, Arkansas. Historical streamflow data from this station are presented in Section 4.7.1.3.

In 2012, the USGS constructed a hydrologic database containing detailed streamflow information and analysis for 26 gage sites in contributing watersheds for Cache River NWR and Dale Bumpers White River NWR. Seven of these gages are within the Cache River NWR RHI; none are on refuge land, but three are within the acquisition boundary. (Figure 22, Table 13; Buell et al. 2012). Historic streamflow for site #1, Cache River at Egypt, Arkansas (07077380), is discussed in section 4.7.1.3.

The hydrologic-data derivatives include statistical-summary data and hydrologic metrics as well as the Indicators of Hydrologic Alteration (IHA) parameters and Environmental-Flow Components (EFCs) (Richter et al. 1996; TNC 2009). The IHA software package was developed by Richter and The Nature Conservancy (TNC) to provide a tool for calculating the characteristics of natural and altered hydrologic regimes. This is accomplished through a series of statistics that are organized into parameter groups, which include the following categories: magnitude of monthly water conditions (I1), magnitude and duration of annual extreme water conditions (I2), timing of annual extreme water conditions (I3),



Map Date: 7/31/2015 File: USGS_GaryBuell.mxd Data Sources: ADEQ and USGS Surface Water Quality Stations; NHD High Resolution Flowlines and Waterbodies, National Watershed Boundary Dataset HU-6 Boundaries, ESRI Map Service.

Figure 22. Gage Sites compiled in the U.S. Geological Survey (USGS) hydrologic database for Cache River and Dale Bumpers White River National Wildlife Refuges. Numbered sites are detailed in Table 13.

Table 13. U.S. Geological Survey (USGS) surface water quantity monitoring sites within the region of hydrologic influence (RHI) used in USGS hydrologic database. Sites are shown on Figure 22. Sites indicated with an asterisk (*) were evaluated for significant hydrologic trends using the Indicators of Hydrologic Alteration (IHA) and Environmental Flow Components (EFC) analyses. [Source: Buell et al. 2012].

# on Figure 22	USGS Station Number	Station Name	Drainage Area (mi^2)	Period of Record
1	07077380	Cache River at Egypt, AR*	701	Gage Height: 1974 - 2009 Discharge: 1965 - 2009
2	07077555	Cache River nr Cotton Plant, AR*	1040	Gage Height: 1987 - 2009 Discharge: 1987 - 2009
3	07077700	Bayou DeView near Morton, AR*	421	Gage Height: 1987 - 2009 Discharge: 1939 - 2009
4	07076750	White River at Georgetown, AR	22400	Discharge: 1928 - 2009
5	07077500	Cache River at Patterson, AR*	1170	Gage Height: 1987 - 2009 Discharge: 1928 - 2009
6	07077000	White River at DeValls Bluff, AR	23400	Gage Height: 1987 - 2009 Discharge: 1950 - 2009
7	07077800	WHITE RIVER AT CLARENDON, ARK.*	25555	Gage Height: 1886 - 2009 Discharge: 1929 - 1993

frequency and duration of high and low pulses (I4), and rate and frequency of water condition changes (I5). There are also five EFC groups that relate hydrologic patterns to ecological function: monthly low flows (E1), extreme low flows (E2), high-flow pulses (E3), small floods (E4), and large floods (E5). Each parameter group category contains one or more statistical parameters. The hydroecological-flow characterization process, background and development of ecological-flow methodologies, and commonly used assessment techniques, including IHA and its application in this analysis, are discussed in detail in Richter et al. (1996) and TNC (2009).

The IHA and EFCs data for five stations in close proximity to Cache River NWR and with at least 20 years of discharge record were examined in greater detail to provide a summary of the issues affecting the refuge within a regional context. These stations are indicated with asterisks in Table 13. In this analysis, stream discharge and gage height hydrologic data were used when available.

No significant trends exist over the period of record for the gage at Cache River near Cotton Plant, Arkansas. Table 14 summarizes IHA and EFC results for stream discharge at the four stations with statistically significant trends within the RHI. The table reports the IHA and EFC parameters exhibiting a significant trend over the period of record and the direction of each trend, as well as ecological influences associated with each flow parameter and more information on how each parameter is calculated. A p-value of 0.025 was deemed significant (John Faustini, personal communication, September 19, 2013).

When significant trends exist, all trends for discharge agree in direction for the sites within the Cache River NWR acquisition boundary. For example, analysis of the magnitude of monthly water conditions indicates significant upward trends for discharge in August for all four sites. While the IHA method allows “estimation of the magnitude of impacts but does not enable strong inferences regarding the cause” (Richter et al. 1996), higher discharge in August could be the result of unseasonal runoff of surplus water from irrigation. Some areas within the MAV (particularly the Cache subbasin) suffer from unseasonal surplus drainage from agricultural fields during what historically would have been the driest time of the year (Jason Phillips, USFWS, personal communication, May 23, 2013).

In most cases, trends within the RHI also agree in direction with significant trends from the gage on the White River at Clarendon, Arkansas, which is just outside the RHI; however, there are instances where significant trends within the RHI differ in direction from trends on the larger White River system. For example, the gages on the mainstem Cache River exhibit significant decreasing trends for the 1-day, 3-day, and 7-day minimum flows, meaning that the lowest flows are getting lower over time. However, these three measures all show an increasing trend on the White River, which could be the result of upstream management of large impoundments which may enable higher minimum flows. This divergence of trends between the Cache and White River systems is also evidenced by increasing EFC Extreme Low Flow Frequency on the Cache River, and decreasing Low Flow Frequency on the White River.

Both the Cache and White River systems show significant increasing trends in the number of reversals, and the Cache River and Bayou DeView gages indicate significant increasing trends in both high and low pulse counts. These trends may have negative implications for plant and animal communities that rely on extended seasonal periods of consistently high or low water.

Table 14. Significant trends at select U.S. Geological Survey (USGS) hydrologic database stations within the Cache River National Wildlife Refuge Region of Hydrologic Influence (RHI). [Source: Buell et al. 2012].

Parameter Group	Ecosystem Influences	Parameter	Calculation	Cache River @ Egypt	Cache River @ Patterson	Bayou de View @ Morton	White River @ Clarendon
IHA I	Habitat availability for aquatic organisms; soil moisture availability for plants; availability of water for terrestrial animals; availability of food/cover for fur-bearing mammals; reliability of water supplies for terrestrial animals; access by predators to nesting sites; influences water temperature, oxygen levels, photosynthesis in water column	Magnitude of Flow: August	Mean or median value for calendar month	increasing	increasing	increasing	increasing
IHA II	Balance of competitive, ruderal, and stress-tolerant organisms; creation of sites for plant colonization; structuring of aquatic ecosystems by abiotic vs. biotic factors; structuring of river channel morphology and physical habitat conditions; soil moisture stress in plants; dehydration in animals; anaerobic stress in plants; volume of nutrient exchanges between rivers and floodplains; duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments; distribution of plant communities in lakes, ponds, and floodplains; duration of high flows for waste disposal, aeration of spawning beds in channel sediments	1-day Minimum	Annual minima, 1-day mean	decreasing	decreasing	--	increasing
		3-day Minimum	Annual minima, 3-day means from a moving average	decreasing	decreasing	--	increasing
		7-day Minimum	Annual minima, 7-day means from a moving average	decreasing	decreasing	--	increasing
		Base Flow Index	7-day minimum flow/mean flow for year	decreasing	decreasing	--	increasing

Parameter Group	Ecosystem Influences	Parameter	Calculation	Cache River @ Egypt	Cache River @ Patterson	Bayou de View @ Morton	White River @ Clarendon
IHA IV	Frequency and magnitude of soil moisture stress for plants; frequency and duration of anaerobic stress for plants; availability of floodplain habitats for aquatic organisms; nutrient and organic matter exchanges between river and floodplain; soil mineral availability; access for waterbirds to feeding, resting, and reproduction sites; influences bedload transport, channel sediment textures, and duration of substrate disturbance (high pulses)	Low Pulse count	Number of low pulses within each water year; a day is classified as a low pulse if it is less than a specified threshold (default = flows less than the median minus 25%)	increasing	increasing	increasing	--
		High Pulse Count	Number of high pulses within each water year; a day is classified as a high pulse if it is greater than a specified threshold (default = flows greater than the median plus 25%)	increasing	increasing	increasing	--
IHA V	Dessication stress on low-mobility stream edge (varial zone) organisms	Number of Reversals	Calculated by dividing the hydrologic record into "rising" and "falling" periods which end with a change of sign in the rate of change; number of reversals is the number of times the sign changes in a water year.	increasing	increasing	increasing	increasing

Parameter Group	Ecosystem Influences	Parameter	Calculation	Cache River @ Egypt	Cache River @ Patterson	Bayou de View @ Morton	White River @ Clarendon
EFC Monthly Low Flow	Provide adequate habitat for aquatic organisms; maintain suitable water temperatures, dissolved oxygen, and water chemistry; maintain water table levels in floodplain, soil moisture for plants; provide drinking water for terrestrial animals; keep fish and amphibian eggs suspended; enable fish to move to feeding and spawning areas; support hyporheic organisms (living in saturated sediments)	August Low Flow	Mean or median value of low flow for calendar month; default low flow is a flow that is below 50% of daily flows for the period.	increasing	increasing	--	increasing
EFC Extreme Low Flow	Enable recruitment of certain floodplain plant species; Purge invasive, introduced species from aquatic and riparian communities; Concentrate prey into limited areas to benefit predators	Extreme Low Frequency	Frequency of extreme lows during each water year or season; default is a flow that is below 10% of daily flows for the period	increasing	increasing	--	decreasing
EFC High-Flow Pulses	Shape physical characteristics of river channel; determine size of streambed substrates; prevent riparian vegetation from encroaching into channel; restore normal water quality conditions after prolonged low flows; aerate eggs in spawning gravels, prevent siltation	High Flow Frequency	Frequency of extreme highs during each water year or season; default is a flow that exceeds 75% of daily flows for the period. Begins when flow increases by more than 25%. A pulse includes all high flows with a peak flow less than a 2-year return interval event	increasing	increasing	increasing	--
		High Flow Fall Rate	Average, median or all negative changes in consecutive daily values following a high flow pulse	--	decreasing	decreasing	--

5.4.2 Historic Groundwater

Ackerman (1996) developed a hydrologic budget and predevelopment regional potentiometric surface information for the alluvial aquifer. Model simulations indicate that, prior to development and the advent of pumping, groundwater in the alluvial aquifer generally followed the land surface slope southward down the Mississippi River Valley, and toward major rivers. Based on this model, surface water features such as rivers would have received most of the predevelopment outflow from the alluvial aquifer.

Pumping of groundwater from the alluvial aquifer for the cultivation of rice began in the Grand Prairie and Cache River areas in the early twentieth century. Throughout the aquifer, pumping rates have generally increased, with large increases in the early 1950s and between 1973 and 1982 (Ackerman 1996), and from the early 1990s to 2000 (Schrader 2006; Clark and Hart 2009).

By the early 1980s, water levels had declined from 60 to 90 feet in wells in the alluvial aquifer in the Grand Prairie and Cache River areas (Ackerman 1996; Renken 1998). These areas most likely saw earlier and larger well drawdowns as compared to other areas within the MAV due to a combination of sustained history of groundwater extraction and the local thickness of the confining unit (Ackerman 1996). Water levels generally declined throughout both areas except near rivers, an indication that, in a reversal of predevelopment conditions, surface water features were recharging the alluvial aquifer. Figure 23 shows close agreement between hydrographs from stream gages on the White (A) and Cache (B) Rivers and those taken from nearby wells, indicating linkage between surface water features and the alluvial aquifer in these areas. Hydrograph (C) on Figure 23, from the Cache River at Egypt, Arkansas, is a location where the potentiometric surface of the alluvial aquifer has declined below the riverbed and there is little connection between groundwater and river levels (Ackerman 1996).

As demand from the alluvial aquifer increased and yields decreased, the deeper Sparta aquifer was increasingly used for irrigation. Like the alluvial aquifer, lows in the predevelopment potentiometric surface were located only in areas of natural groundwater discharge. The location of potentiometric lows has changed and now depressions are in areas with large withdrawals from wells. Water now tends to flow to the southwest, toward major pumping in the Grand Prairie area (Renken 1998). Additionally, large withdrawal rates from the middle Claiborne aquifer have induced downward leakage of water into the middle Claiborne aquifer from the upper Claiborne and the Mississippi River Valley alluvial aquifers (Renken 1998). Holt and Hunt (2015: Appendix E) includes groundwater modeling results for the alluvial and Middle Claiborne aquifers which detail locations of potentiometric (i.e. water level) lows.

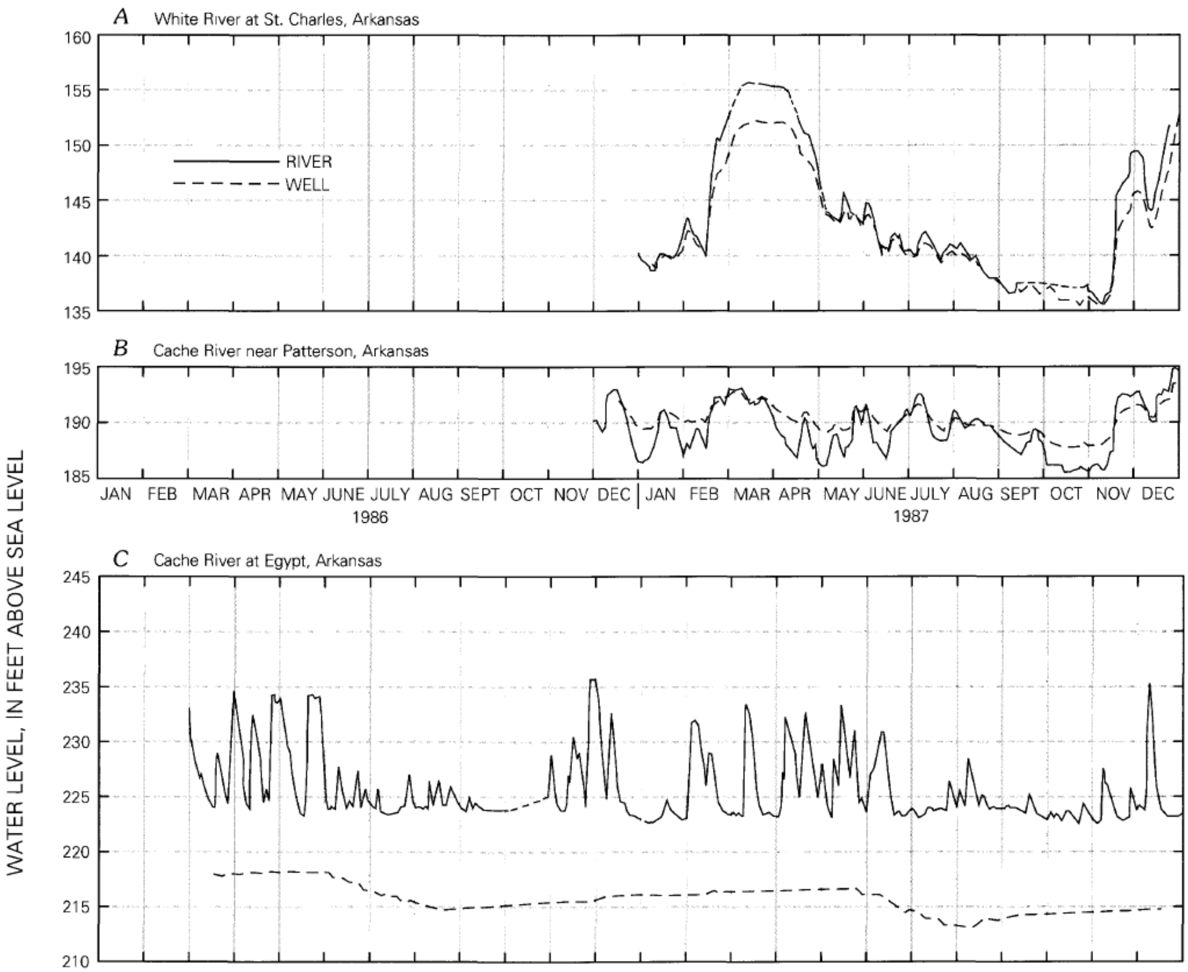


Figure 23. Hydrographs showing water levels for wells within the alluvial aquifer and nearby rivers within the Region of Hydrologic Influence (RHI). [Source: Modified from Ackerman 1996, Figure 5].

5.4.3 Current and Projected Future Groundwater Resources

Each year, according to the requirements of the Arkansas Ground Water Protection and Management Act of 1991, Arkansas Code Annotated 15-22-906, the ANRC prepares Groundwater Protection and Management reports. The 2014 report covers water level data from 505 wells (255 in the alluvial aquifer, 201 from the Sparta/Memphis aquifer) from spring 2013 to spring 2014 and also evaluates water level trends over the past 10 years (ANRC 2015). The refuge lies within the Grand Prairie and Cache River study areas

Of the wells monitored in the alluvial aquifer, 44.3% showed declines in static water levels over the reporting period. The data in the 2014 report shows relatively stable water levels in all study areas within the alluvial aquifer for the one year averages, due to higher than average annual precipitation in 2013. However, declines due to over-use still exist and are apparent in the 10-year averages as well as the period of record. Of 303 alluvial aquifer wells monitored in both 2009 and 2014, 179 (59.1%) had declining static water levels. Over a 10-year period of time from 2004 to 2014, 265 of 359 wells (73.8%) monitored showed declines in the alluvial aquifer. The 5-year average change over the entire aquifer was -1.01 feet, and the 10-year average change was -3.72 feet (ANRC 2015). Average declines in the alluvial aquifer for counties encompassing the refuge are listed in Table 15. The average ten-year decline in the Grand Prairie study area was -2.33 feet; in the Cache River study area, the average decline was -4.97 feet (Table 15).

The 2014 ANRC Groundwater Report indicates that significant cones of depression exist in the alluvial aquifer, especially in the Grand Prairie and in the Cache River Study Areas located adjacent to the southwest of the southern end of the RHI and west of Crowley's Ridge, respectively (Figure 24). Wells showing the greatest decline in the Cache River study area are generally located at the base of Crowley's Ridge and in portions of the study area furthest from the major rivers, indicating that the rivers may be locally recharging the aquifer.

In the Sparta/Memphis aquifer, 48.6% of the wells sampled showed declines. The average change over the entire aquifer during the 2013-2014 monitoring period was +0.64 feet. During the monitoring period from 2009 to 2014, 229 wells were monitored for water-level change, with 95 of these wells (41.5%) showing a decline in static water levels. During the 10-year monitoring period, 187 wells were monitored with 82 (43.9%) of these wells showing declines (ANRC 2015). Average declines in the Sparta/Memphis aquifer for counties encompassing the refuge are listed in Table 15. The average ten-year decline in the Grand Prairie study area was -1.70 feet; in the Cache River study area, the average decline was -3.90 feet (Table 15).

Table 15. Average Change (2004-2014) in Water Level in the Alluvial Aquifer and Sparta/Memphis Aquifer. [Source: ANRC 2015].

		Alluvial Aquifer	**Sparta/Memphis Aquifer**
County	**Study Area**	**Avg Change (feet)**	**Avg Change (feet)**
Jackson	Cache	-2.45	Not assessed
Monroe	Cache	-2.32	-4.81
Prairie	Grand Prairie	-1.79	-1.83
Woodruff	Cache	-0.76	-3.16
	Cache Average	***-4.97***	***-3.90***
	Grand Prairie Average	***-2.33***	***-1.70***

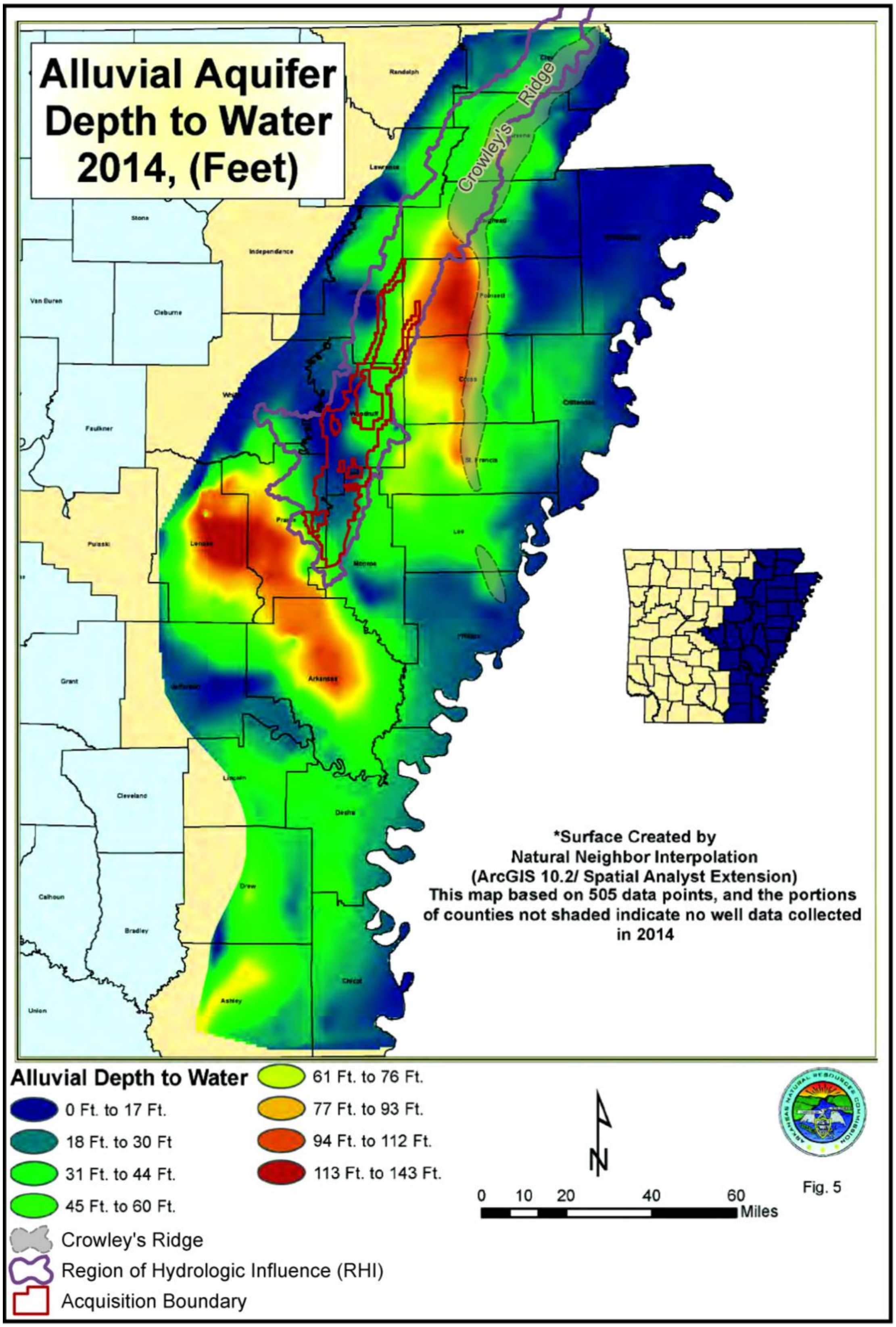


Figure 24. Depth to water in the alluvial aquifer, 2014. [Source: Modified from ANRC 2015].

In accordance with Act 1051 of 1985, all wells in Arkansas that have the capacity to produce 50,000 gallons per day must be registered with the ANRC. Domestic wells are exempt. The quantity used must be reported by March 1st of the following year. In 2014, an estimated 8,302.81 million gallons per day (Mgal/d) of water were reported to be withdrawn from the State's aquifers. The greatest reported volume is pumped from the alluvial aquifer and used primarily for irrigation. The reported statewide estimated groundwater use from the alluvial aquifer during 2012 was 8036.01 Mgal/d (ANRC 2015). Table 16 lists the 2014 number of registered wells and reported groundwater withdrawals from the alluvial aquifer and Sparta/Memphis aquifer for each of the counties surrounding Cache River NWR. Jackson County reported withdrawals of nearly 473 Mgal/d from the alluvial aquifer, which represents the 3rd greatest rate of withdrawal in the state (Table 16). Counties near the refuge are much more reliant on the alluvial aquifer over the Sparta/Memphis aquifer for groundwater withdrawals, as evidenced by both the total number of wells and the amounts withdrawn from each aquifer.

Based on 2012 water use data, only approximately 42% of the current alluvial aquifer withdrawal of 8036.01 Mgal/d, and 55% of the Sparta/Memphis aquifer withdrawal of 159.45 Mgal/d, is projected to be sustainable (Holland 2004, ANRC 2015). Table 16 lists the percent of 2012 groundwater withdrawals from the alluvial aquifer that are considered sustainable for each of the counties surrounding Cache River NWR. Prairie County, along the southeastern portion of the refuge containing the White River, has the lease sustainable groundwater consumption rates from the alluvial aquifer, with a percent sustainable rating of just under 27%.

The USGS and other agencies conduct research to predict the effects of sustained pumping on aquifer yields and groundwater movement, as well as simulations to model the effects of changes in pumping rates and locations. The percent sustainable rates described here are a product of such a simulation. Detailed information on groundwater modeling for both the alluvial and Sparta/Memphis aquifers is summarized in Section 5.4.3 of the Dale Bumpers White River NWR WRIA (Holt and Hunt 2015).

Table 16. 2012 Reported withdrawals of groundwater from registered wells by aquifer for counties containing Cache River National Wildlife Refuge. [Source: ANRC 2015, from Czarnecki et al. 2003 and Holland 2007].

	Alluvial Aquifer			**Sparta-Memphis Aquifer**	
County	**Mgal/day**	**# of wells**	**% Sustainable**	**Mgal/day**	**# of wells**
Jackson	472.91	2,765	43.5	0.40	1
Monroe	309.16	2,323	58.2	0.83	5
Prairie	411.1	1,786	26.8	11.84	57
Woodruff	164.36	1,958	100	1.63	10

5.4.4 Hydrologic Alterations

Land use in the Cache River Basin has fundamentally altered the historical flooding patterns which formed the basin. Channelization, ditching, and stream straightening, in conjunction with the conversion of forests to agriculture lands, have led to increase flashy stream flows. Flashy flow is characterized by rapid rates of flow increase and decrease during runoff events, high peak discharges, low base flows, and often high concentrations of nonpoint source pollutants. Rapid flow rates have increased headcutting and bank collapse. Additionally, debris can collect at the confluence of straightened and natural channels due to different flow rates resulting in blockages and further alterations to the flow regime. These land use impacts on the natural hydrologic system are discussed in further detail in the following subsections.

5.4.4.1 Channelization

Beginning in the early 1900s and continuing until the early 1930s, local drainage districts channelized the upper portion of the Cache River Basin, from Grubbs, Arkansas, at the north end of the refuge acquisition boundary, to the river's headwaters (USFWS 2009). In total, 89 miles of the upper Cache River and 65 miles of upper Bayou DeView have been channelized (Jason Phillips, USFWS, personal communication, May 23, 2013). The Flood Control Act of 1950 authorized the USACE to implement the Cache River Basin Project. The project plan included clearing, realignment and enlargement of 140 miles of the Cache River channel and 91 miles of tributary streams, including Bayou DeView, to facilitate agricultural drainage and prevent flooding. Construction began on the lower Cache River near the confluence of the White River in the 1970s, but was stopped due to local opposition; however, by that time approximately seven miles of the lower Cache River had already been channelized, a portion of which lies within the Cache River NWR boundary (USFWS 2009). In this area, plugs were placed in upstream openings of at least six meanders, converting them from lotic to lentic habitats by isolating them from upstream riverine flow and causing them to experience the accumulation of deep fine sediment. Dredged material was deposited along the channelized reaches (USACE 2011). The completed portion of the project did not affect flooding of the BLH forest and very little clearing occurred (USACE 2011).

USACE and TNC have proposed to restore a portion of the channelized reach of the lower Cache River. The project involves removing the aforementioned plugs from the upstream end of the upper three meanders to reconnect the channel to the meanders and using closure weirs to divert flow from the channel into the meanders (USACE 2011). This project is intended to improve habitat for aquatic species, such as freshwater mussels, and help restore hydrologic function of the landscape and Cache River/White River drainage (USFWS 2009). A construction contract for the first phase of the project was awarded in March 2013 (USACE 2013). Phase 1 was completed in the summer of 2014. Phase 2 awaits funding and has not been scheduled.

5.4.4.2 Channel Blockage at Grubbs

Accelerated flows in the channelized reach of the upper Cache River along with land use changes have caused debris to accumulate near Grubbs, Arkansas. The blockage, which extends for 0.8 mile is located where the channelized reach, which is wide, straight, and higher gradient, ends and encounters the natural meandering river channel, which is narrower and lower gradient, and hence has reduced conveyance capacity (Heitmeyer 2010; ADEQ 2013). The reduced conveyance causes woody debris to accumulate, further reducing conveyance and causing local water levels to rise and flooding to occur. High water levels have resulted in a shift to "wetter-type" species in the nearby BLH forest, as well as flooding of nearby farmland (Heitmeyer undated) and upstream erosion. Flood damage reduction on the Cache River is authorized under the uncompleted Cache River Basin flood control project described above (USACE 2008). Accordingly, the Willow Slough Drainage District has initiated the removal of approximately 18,000 cubic yards of logs and debris from the river (ADEQ 2013); however, this is a temporary solution that does not address the causes of the blockage. While the impacts of the blockage are reduced downstream, the refuge's CCP noted that blockage removal could lead to modifications in the natural river channel, release of large amounts of sediment and debris downstream and possible reformation of a blockage on the refuge (USFWS 2009).

5.4.4.3 *Ditching*

In addition to channelization of the mainstem Cache River and Bayou DeView, many of the tributary streams in the basin have been converted to ditches for flood control and agricultural drainage. Ditching is particularly extensive in the northern half of the Cache River Basin, which is characterized by straight and shallow ditches with few or no pools. These streams are so deeply incised that they no longer access their floodplain during high water events and they quickly route runoff from the land surface to the mainstem Cache River during rainfall events, increasing both the total amount of runoff and the flashiness of the river. They often have eroding banks, unstable bed structures and high suspended sediment concentrations (TNC 2005, USFWS 2009). Downstream of Grubbs, Arkansas, the direct impacts of channelization decrease. TNC (2005) found that the degree of channel incision decreases from the upper to the lower portions of the watershed, with stream reaches in the middle and lower portions of the watershed exhibiting profiles more typical of naturally-formed alluvial channels, though still degraded.

5.4.4.4 *Levees*

There are no major levees within the RHI; however, surface hydrology is affected by the cumulative impacts of many small private levees related to rice production and agriculture. The magnitude of these impacts is poorly understood and has not been studied on a large scale (Richard Crossett, written communication, July 15, 2015).

The release of surface water impounded by private levees for the cultivation of rice within the RHI affects the timing and magnitude of low streamflows in the summer. Rice water is released from irrigated fields generally at least two weeks before harvest which can range from late July to late September (Richard Crossett, written communication, July 15, 2015). This flush of warm water at what is typically the driest time of year may impact species that rely on varying water levels and dry periods to complete their life cycles.

The CCP (USFWS 2009) documents several recommended actions to restore connectivity between rivers and floodplain lakes and/or forests, most of which involve removing or breaching several existing levees, including those along Jackson Bayou and the Bayou DeView Ltd Tract.

5.4.4.5 *Agricultural Withdrawal of Surface Water*

A continuing hydrologic alteration is the increasing withdrawal of surface and alluvial aquifer water for irrigation (Heitmeyer 2010). Individual withdrawals can be small and scattered but total withdrawals are substantial. In 2009, the sections of Clay, Craighead, Cross, Green, Lee, Poinsett, and St. Francis Counties on the western side of Crowley's Ridge, were designated as the Cache Critical Ground Water Area (CGWA) by the ANRC because groundwater levels had dropped below half the saturated thickness of the alluvial aquifer (ANRC 2011). The portions of those counties containing the Cache River Basin are designated current critical areas (ANRC 2013; shown on Figure 25). The alluvial aquifer beneath the Cache River Basin in Poinsett and Cross Counties is also identified as having one of the largest decreases in groundwater elevation in the state since 2011. Sustained heavy pumping from multiple wells for extensive periods has led to substantial, widespread groundwater-level declines in several portions of eastern Arkansas. In some areas, declines of water levels have resulted in partially air filled upper parts of the aquifer, reductions in hydraulic pressure, saturated thickness, stored water, lateral flow within the alluvial aquifer, and baseflow to streams throughout most of the aquifer's extent in Arkansas. Accompanying the decreased groundwater levels in the southern portion of the basin, there are areas of salt water intrusion from deeper layers into the alluvial aquifer (US EPA 2009). Excessive levels of salt water now occur near Brinkley, Arkansas, and in nearby Bald Knob, Arkansas (Heitmeyer 2010). Reduction in aquifer hydraulic pressure means that, in some areas, the hydraulic gradients have been reversed, particularly in the CGWA, and the rivers now typically recharge the alluvial aquifer rather than vice-versa (Reed 2003). Currently portions of the Cache River have low base flows. Bayou DeView and northern portions of the Cache River have little to no flow during summer months (Heitmeyer 2010).

Increasing surface water withdrawals for agricultural irrigation constitute a relatively recent form of hydrologic modification in the Cache River Basin. These withdrawals occur on individual farms, and while singularly may be quite small, collectively they produce a cumulative effect on streamflow throughout the basin (USFWS 2009). In 2005, an estimated 41% of irrigation withdrawals in Prairie County came from surface water (89.64 Mgal/d), which is up from 36% (82.40 Mgal/d) in 2000 and 27% in 1991 (Holland et al. 1993, Holland 2004, 2007). By contrast, the other counties encompassing the refuge (Jackson, Monroe and Woodruff) continue to rely heavily on groundwater, with surface water withdrawals consistent at 5 to 9% of total irrigation withdrawals (Holland 2004, 2007).

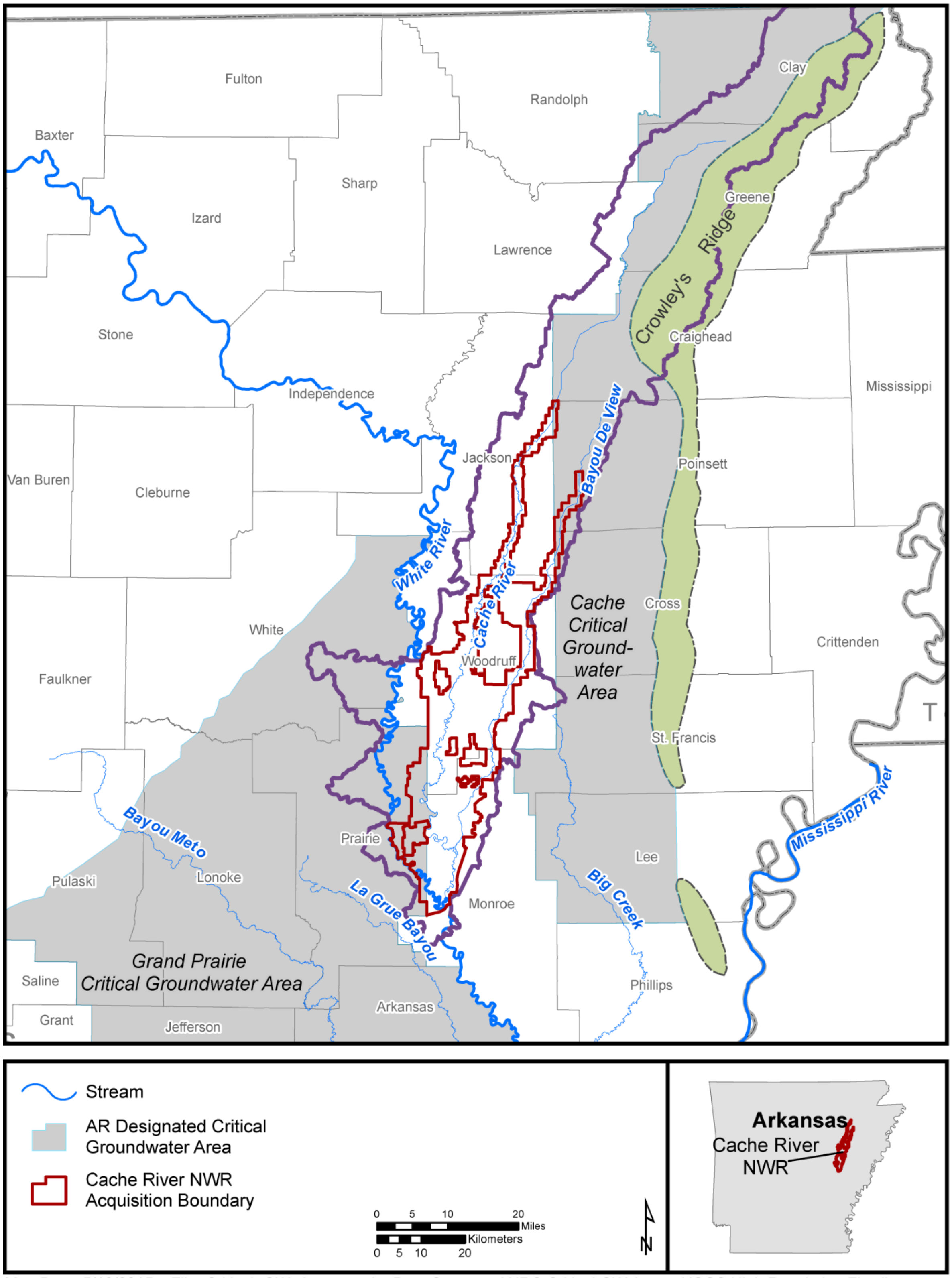
5.4.5 Arkansas Minimum Flows and Levels

Minimum flow in a river is generally defined as the minimum (not the most desirable) flow amount or lake level necessary to protect the fish and wildlife habitat, aquatic life, water quality, recreation, aesthetic beauty, navigation or transportation. As defined by ANRC (2009) minimum flow in Arkansas is "the quantity of water required to meet the largest of the following instream flow needs as determined on a case by case basis: 1) aquifer recharge, 2) fish and wildlife, 3) interstate compacts, 4) navigation, and 5) water quality" (ANRC 2009). Minimum flow is usually measured in elevation (feet above MSL) at a gage. During periods of water shortage, minimum stream flows may take priority over other uses and needs. However, minimum stream flow levels (elevations) do not ensure a specific stream flow (cfs) or compel flow augmentation from reservoirs, impoundments, or any other sources (ANRC 2009). Section 5.6 contains more detailed information on water law in Arkansas, including definitions of riparian rights and excess surface water, as well as how these laws may impact Cache River NWR.

Instream flow, which is synonymous with environmental or ecological flow, includes the concept that a regime of varying water flows and levels is necessary for aquatic ecosystems to function properly (Poff et al. 1997; Richter et al. 2003). The term may also be used specifically in law to denote water which is expressly dedicated to remain in the stream channel and which should not be diverted for other purposes. Optimum flow is used by some states and groups to describe a targeted "best" flow if environmental and habitat issues were the priority concern (SARP 2013).

Arkansas is in the process of updating its water plan with the possibility of addressing limitations in its current water allocation strategies by adopting an environmental flow approach. The ANRC is currently working with AGFC, TNC, USGS and other agencies to replace the Arkansas Method with the Environmental Limits of Hydrologic Alteration (ELOHA) approach (Poff et al. 2010) to establishing statewide environmental flows. Research intended to provide the scientific foundation for the environmental flow standards is currently underway; however, it will likely take ten or more years before empirical, risk-based flow and associated ecological impact relationships are known and available statewide (Fish and Wildlife Flows Subgroup 2013).

Overall, the allocation of flows for fish and wildlife remains a low priority. According to the most recent information available, in 2010, water withdrawals for agricultural irrigation, livestock, and aquaculture accounted for 80% of water use in Arkansas (Maupin et al. 2014).



Map Date: 5/18/2015 File: Critical_GW_Areas.mxd Data Sources: ANRC Critical GW Areas; USGS High Resolution Flowlines and Waterbodies, National Watershed Boundary Dataset HU-6 Boundaries, ESRI Topo Service.

Figure 25. Critical Groundwater Areas in Arkansas. Critical Groundwater Areas digitized from ANRC undated.

5.5 Water Quality

5.5.1 Federal and State Water Quality Regulations

5.5.1.1 Designated Uses

The Cache River and Bayou DeView are designated by the Arkansas Pollution Control and Ecology Commission (APC&EC) for the following uses: propagation of fish and wildlife; primary and secondary contact recreation; domestic, agricultural and industrial water supply; and perennial Delta fishery (ADEQ 2012). A portion of the Cache River from the northern end of the state-owned Black Swamp Wildlife Management Area (south of Patterson, Arkansas) to the mouth of Cache Bayou (northwest of Cotton Plant, Arkansas) is designated as an Extraordinary Resource Water (ERW) (FTN Associates, Ltd. 2012). In Arkansas, ERWs warrant extra protection due to their scenic beauty, aesthetics, scientific values, broad scope recreation potential, and intangible social values (APCEC 2011).

5.5.1.2 Water Quality Standards

ADEQ Water Division is responsible for implementing water quality regulations and Clean Water Act (CWA) reporting. Arkansas' surface water quality standards, established under Regulation No. 2 of the Arkansas Water and Air Pollution Control Act, include designation of uses for all waters, development of narrative or numeric criteria designed to prevent impairment of the designated uses, and an anti-degradation policy (APCEC 2011). Water quality standards must be reviewed and updated at least every three years; the most recent triennial review took place in 2013.

5.5.1.3 NPDES

As authorized by the CWA, the National Pollutant Discharge Elimination System (NPDES) permit program regulates point sources that discharge pollutants into waters of the United States. NPDES permits are required for operation and sometimes construction associated with domestic or industrial wastewater facilities or activities (e.g., wastewater treatment facilities, mines, etc.). In Arkansas, the U.S. Environmental Protection Agency (EPA) has delegated administration of the NPDES permit program to ADEQ.

5.5.1.4 Groundwater Regulations

Groundwater is protected by laws at both the federal and state levels. The EPA is responsible for groundwater protection through the Safe Drinking Water Act (SDWA), which was intended to protect the quality of ground water serving as a source for public water supply wells through the requirement of maximum contaminant level standards for drinking water. SDWA established the Underground Injection Control, Wellhead Protection, and Source Water Protection Programs, which are administered by the Arkansas Department of Health (ADH).

The Clean Water Act is primarily a surface water program; however, the EPA recommends that states apply 15% of CWA Section 106 grant monies (for point-source contamination) toward developing and implementing groundwater protection programs. CWA section 319 funds (non-point sources) may also be used for groundwater protection projects (US EPA 2009).

Arkansas has no permit system to specifically protect ground water quality. Responsibility for administration of groundwater regulations is divided among several state agencies. As previously mentioned, protection of groundwater wells primarily used for public supply falls to the Arkansas Department of Health (ADH). ANRC is responsible for investigation of potential contaminant sources, and for any follow-up investigation of verified sources of contamination. ADEQ conducts groundwater studies and oversees the cleanup of contaminated sites.

5.5.1.5 Antidegradation Policy

The antidegradation policy, adopted by the Arkansas Pollution Control and Ecology Commission in 2011, requires that existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected. Where water quality exceeds levels necessary to support propagation of fish, shellfish and wildlife, and recreation in and on the water, the quality shall be maintained and protected unless the State finds that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. In allowing such degradation or lower water quality, the State shall assure water quality adequate to protect existing uses fully.

Where high quality waters constitute an outstanding state or national resource, such as those waters designated as ERW, ecologically sensitive or natural and scenic waterways, those uses and water quality for which the outstanding waterbody was designated shall be protected by water quality controls, maintenance of natural flow regime, protection of instream habitat, and encouragement of land management practices that protect the watershed.

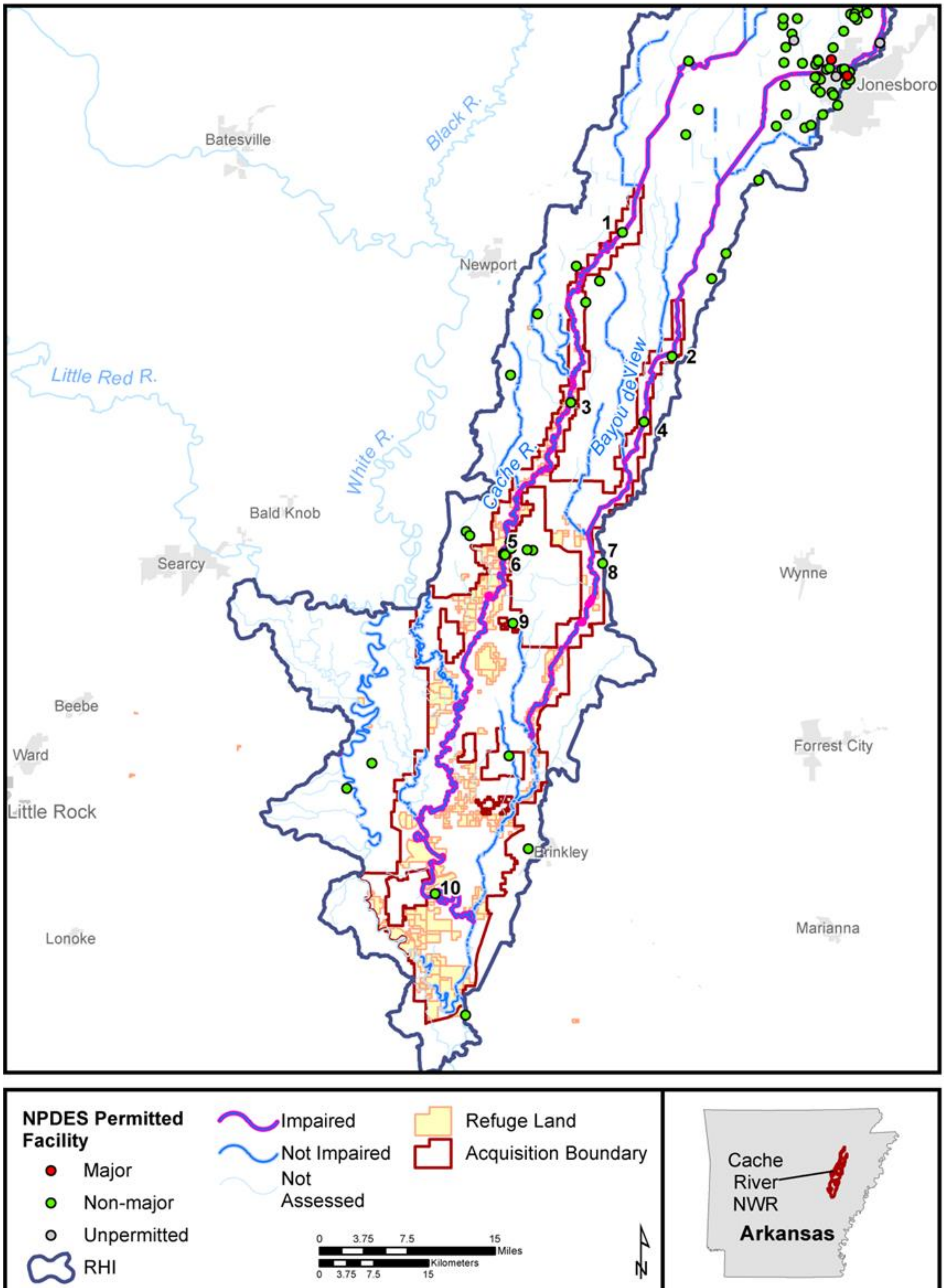
5.5.1.6 Impaired Waters and TMDLs

In order to meet CWA requirements, the six major river basins within the state have been categorized into 38 water quality planning segment groups based on hydrological characteristics, human activities, and geographic characteristics. For the purposes of this WRIA, the 2008 Integrated Water Quality Monitoring and Assessment Report is being used, as the 2010 and 2012 list have yet to be EPA-approved and may not be approved until the 2014 list is published. The primary database for the 2008 Integrated Water Quality Monitoring and Assessment Report is from the ADEQ Ambient and Roving Water Quality Monitoring Networks. The networks include the AWQMN (Ambient Water Quality Monitoring Network) stations that are sampled monthly and the RWQMN (Roving Water Quality Monitoring Network) stations that are sampled bi-monthly. The RWQMN Stations are divided into five groups geographically and are sampled for two years on a rotating schedule.

The RHI for Cache River NWR falls within one of the six major ADEQ basins: the White River Basin (Basin 4). Common sources of impairment within the Cache River NWR RHI include: sedimentation and siltation (as measured and associated by turbidity); total metals other than mercury (aluminum, zinc, and lead); low dissolved oxygen; and dissolved solids (chlorides and sulfates).

Impaired waters and waterbodies within or near the Cache River NWR acquisition boundary are shown in Figure 26. In 2008, Cache River and Bayou DeView did not meet Fisheries (Aquatic Life) designated use due to concentrations of lead and sedimentation in the surface water. Non-point sources (e.g., agriculture practices) were identified as the primary contributors to increased sedimentation. These increased levels of sedimentation result in increased accumulation of heavy metals (i.e., lead) as the lead is bound to the sediment loads (US EPA 2009).

The ANRC designated the Cache River watershed as a priority watershed for the first time in the 2011-2016 Nonpoint Source (NPS) Pollution Management Plan. In 2012, several segments of the Cache River and Bayou DeView were listed because of lead contamination (ADEQ 2012). These impaired streams were assigned a low priority for TMDL development. There are several permitted facilities that discharge into the Cache River and Bayou DeView within the refuge acquisition boundary, including the cities of Cotton Plant, Grubbs, Patterson, Amagon and Beedeville, Arkansas. These facilities are discussed further in section 5.5.1.7. There are currently no waterbodies with existing TMDLs within the Cache River Basin.



Map Date: 5/20/2015 File: Listed_Impaired.mxd Data Sources: 2008 EPA-RAD 305b, 303d, and TMDL lines; US EPA NPDES Sites; NHD High Resolution Flowlines; ESRI Map Service.

Figure 26. 2008 listed impaired waters and National Pollutant Discharge Elimination System (NPDES) permits near the Cache River National Wildlife Refuge. Numbered NPDES permit locations are detailed in Table 17.

5.5.1.7 NPDES

Within the Cache River RHI there are a total of 115 NPDES permitted facilities (US EPA 2015). Two of the permitted facilities are considered "major," which are defined as either:

> Publicly Owned Treatment Works (POTWs) with design flows ≥1 MGD or that serve a population ≥10,000 or cause significant water quality impacts, or
>
> Non-POTW discharges surpassing a point threshold based on criteria such as toxic pollutant potential, flow volume and water quality factors such as impairment of receiving water or proximity of discharge to coastal waters (US EPA 2013).

The two major NPDES-permits are associated with City of Jonesboro City Water & Light facilities, located in Jonesboro, Arkansas, in the upper portion of the RHI (Figure 26). One of the facilities is a wastewater treatment plant; the second permit may be relict of an old facility location or permit software system conversion, as it does not appear to be associated with a facility that actively releases water.

Of the remaining NPDES facilities in the Cache River NWR RHI, 107 are classified as "non-major" dischargers because they do not meet the above criteria, or are facilities that discharge without an NPDES permit. The 5 remaining facilities are classified as NPDES Unpermitted.

There are 10 NPDES facilities within the Cache River NWR acquisition boundary; three of these facilities are on refuge land (Figure 26, Table 17). All facilities within the acquisition boundary are non-major permits.

Table 17. NPDES Permitted facilities within the Cache River National Wildlife Refuge acquisition boundary. Facilities are shown on Figure 26. Asterisks (*) indicates a facility on refuge land. [Source: US EPA 2015]

# on Figure 26	EPA Registry ID	System ID	Name
1	110025120116	AR0034614	GRUBBS, CITY OF
2	110010066677	AR0022446	FISHER, CITY OF
3	110010063732	AR0049603	BEEDEVILLE, CITY OF
4	110010066427	AR0034720	HICKORY RIDGE, CITY OF
5*	110009006896	AR0039837	PATTERSON, CITY OF
6*	110006786031	AR0044954	MCCRORY, CITY OF
7	110011376144	ARG640050	MORTON PLANT
8	110011376144	ARG640049	MORTON PLANT
9	110046324287	ARR000950	WOODRUFF COUNTY TRANSFER STATION
10*	110022550372	ARR00C291	CROP PRODUCTION SERVICES INC.-CLARENDON

5.5.2 Other Surface Water Quality Information

The Mississippi River Basin Health Watershed Initiative Project (MRBI) is a voluntary program that provides financial and technical assistance to agricultural producers for addressing water quality concerns in the Middle Cache River Watershed that includes: Skillet Ditch-Overcup Ditch, Browns Creek-Overcup Ditch, Cyprus Creek-Overcup Ditch, Overcup Slough-Overcup Ditch and Town of Gourd-Overcup Ditch (USDA 2012).

The NRCS, in partnership with Jackson County Conservation Service District, may allocate funding to landowners in portions of Craighead, Jackson, Poinsett and Woodruff Counties. The effort encompasses approximately 122,000 acres with the objective of improving water quality through the reduction of sediment and nutrient loads entering the watershed and the Cache River NWR. The initiative will also focus on wetland enhancement, the improvement of fish and wildlife habitat, and reduction of aquifer groundwater mining.

A study undertaken to measure turbidity values throughout the Cache subbasin during high flow events identified seven subwatersheds as contributing the most total (mass) suspended sediment to the Cache River system (TNC 2005). An analysis (TNC 2009) of non-point source pollution data in the subbasin collected in that study identified Swan Pond Ditch (080203020205), which straddles Crowley's Ridge, as the most severe of sediment contributors to the Cache River and the most in need of Total Suspended Sediment (TSS) abatement. The analysis also identified Culotches Bay (080203020805), which intersects the refuge, as the second highest priority subwatershed for TSS abatement largely because the reach of the Cache River to which Culotches Bay drains has the lowest allowable TSS levels for both base and storm flow values considered in the study (APCEC 2004).

5.5.3 Groundwater Quality

Saltwater intrusion into the alluvial aquifer near Brinkley, Arkansas, was documented as early as 1946. In the 1970s and 1980s, the USGS and Arkansas Geological Commission conducted a study of saltwater intrusion in this area and found that a 56 mi^2 area of the aquifer had elevated chloride concentrations, indicating saltwater intrusion. The highest concentrations were centered near Brinkley, Arkansas. The principal cause identified by the study was upward movement of saltwater from the underlying Sparta aquifer through the thinned or absent Jackson confining unit in response to pumping based on the finding of similar chemical compositions between the alluvial and Sparta aquifers in contaminated areas (Morris and Bush 1986).

ADEQ identified saltwater intrusion from deeper layers into the alluvial aquifer in the southeast part of the state, related to heavy drawdown of water, irrigation practices, and area hydrogeology (ADEQ 2004). Saltwater intrusion in areas of northeast Monroe County and southern Woodruff County has rendered the water no longer suitable for irrigation (USFWS 2012c).

5.5.4 Land Use Activities Affecting Water Quality

Longstanding effects on the geomorphology, vegetation communities, and soils of the entire Cache River Basin affect water quality. The conversion of forest to agriculture over the last century has left a residue of nutrients and pesticides in more readily erodible soils. Changes in stream geomorphology resulting from efforts to drain wetted land for agriculture purposes, exposes widened channels to increased risk of bank erosion. Removal of stream buffers in agriculture fields allows for erosion from field disturbing activities (e.g., disking) to reach the stream network.

The primary water quality problems experienced by the refuge are turbidity and siltation (USFWS 2013c). While some of these problems originate from on-refuge land use activities (particularly farming and road/levee construction), the majority stem from non-point sources of erosion and runoff outside the refuge's boundaries. While less prevalent, water quality impacts on Cache River NWR also include metals other than mercury, suspended solids, and low dissolved oxygen. Additionally, septic discharge is considered a minor problem, and oil and gas development in adjacent counties, along with pipeline construction, have the potential to affect water quality.

The primary source of water quality pollutants entering the refuge are from the Cache River and Bayou DeView, whose watersheds are composed primarily of agricultural areas. The majority of waterways within the region form a network of extensively channelized drainage ditches. Government programs have been used to develop this highly productive agricultural land. However, many of the practices utilized in making this land more productive actually impair water quality. Once a natural stream has been channelized, only those organisms which do not require in-stream cover and can exist in highly turbid waters will survive (ADEQ 2012). Of primary concern to the refuge are increases in sedimentation rates and pesticides (USFWS 2012c). There is reasonable likelihood for continued exposure of fish-eating birds, predatory fish, and mammals to persistent, bioaccumulative compounds on the refuge. Perhaps the more certain current water quality threat to aquatic species is the potential for increased sedimentation. Point source discharges (i.e., wastewater treatment plants) and septic discharges are considered a minor problem.

Future irrigation needs, in light of climate change, threaten increases in salt water intrusion into shallow aquifers in response to further reductions in groundwater levels. Lowered groundwater levels would in turn lead to lower baseflow, which would contribute to flashier streamflow and further risk of gully and stream bank erosion. Assuming negligible population growth in the basin, point source and septic system pollution should not present much of a threat.

5.6 Water law/water rights

In 2014, the U.S. Department of the Interior Office of the Solicitor prepared a memo on state water laws in Region 4 (Brown-Kobil 2014), which is the basis for much of the information presented in this section.

5.6.1 State Water Law Overview

The ANRC (formerly known as the Arkansas Soil and Water Conservation Commission) registers surface and groundwater withdrawals, which requires that users report their water use for the past year. Owners of wells capable of producing at least 50,000 gallons per day are required to register with the state and pay an annual registration fee (ADEQ 2012). The ANRC issues permits for non-riparian surface water use (i.e., power plants, industries, large-scale irrigation projects). There is no permit system to protect groundwater quality (US EPA 2009).

Water law in Arkansas has developed from General Assembly legislation, state agency regulatory programs, and case law developed by the courts (ANRC 2011). Water is regulated under the Arkansas Water Resources Development Act (Ark. Code Ann. § 15-22-6); Arkansas Groundwater Protection and Management Act (Ark. Code Ann. § 15-22-9); the Arkansas Water and Air Pollution Control Act (Ark. Code Ann. § 8-4); the Arkansas Irrigation, Drainage and Watershed Improvement District Act (Ark. Code Ann. §§ 14-117-101 to -427); and the Regional Water Distribution District Act (Ark. Code Ann. § 14-116-101 to -406). Arkansas is a riparian reasonable use state with use of surface water considered a property right as long as use does not unreasonably harm another riparian landowner's use. Groundwater use follows similar logic in that a landowner may use groundwater from a well on their land as long as the use does not unreasonably harm another landowner's groundwater use (Rowan et al. 2013). Laws governing water in the state are closely tied to the type of water involved. For example, surface water and groundwater are governed under different rules as are waters in a reservoir vs. free-flowing water.

5.6.1.1 Public Trust Doctrine

Lands under navigable waters in the state of Arkansas are held in trust for the people. This follows the English common law doctrine in which the sovereign held title to the beds of navigable and tidal waters as a trustee for the benefit of the people. Upon admission to the Union in 1836, the state of Arkansas gained title to the beds of navigable lakes and streams (ARNC 2011). In 1980, the Arkansas Supreme Court expanded the definition of "navigable" to include not only commercial use but recreational use (e.g., fishing in flatbottom boats, canoeing, floating, etc.) as well (268 Ark. 227 1980).

5.6.1.2 Riparian Water Rights

Technically, "riparian" refers to streams, while "littoral" refers to lakes, but the term "riparian rights" includes streams and lakes. The only way to obtain riparian rights is to purchase riparian property. On navigable waters, a riparian landowner owns to the ordinary high water mark (OHWM)—a point indicated by vegetation and the nature of the soil —and the state owns the stream bed (ARNC 2011). The OHWM is defined in the Arkansas code as "the line delimiting the bed of a stream from its bank, that line at which the presence of water is continued for such length of time as to mark upon the soil and vegetation a distinct character" (Ark. Code Ann. § 15-22-202). If the water is non-navigable, the riparian owner has rights to the center of the stream.

5.6.1.3 Navigable Waters

The Cache River is not classified as navigable water by the USACE. As such, the riparian owner's rights extend to the middle thread or center of the stream unless the deed by which the property was acquired described the boundaries in some other, more specific way (ANRC 2011).

For navigable waters, the public has the right to use the water and beds "for the purposes of bathing, hunting, fishing, and the landing of boats" in addition to navigation and commerce (Craig 2007- *Anderson v. Reames,* 161 S.W.2d 957, 960-61 [Ark. 1942]). Even if one part of the streambed in a navigable stream is owned by the state and the remainder is private property, a person has a right to be anywhere on that stream, provided that person remains afloat and does not wade onto the privately-owned portion of the streambed without the landowner's permission. For non-navigable waters, the public rights to use the water and streambeds are less clear and tend to be heavily contested by respective landowners that encounter perceived trespass issues.

5.6.1.4 Transfer of Surface Water

Non-riparian landowners can apply to the ARNC for surface water rights. Before approving a non-riparian application, the ARNC has to calculate "excess surface water" to determine if the water resources are available. Excess surface water was defined by the General Assembly in 1985 as 25% of the amount of water left over after calculating the amount of water required for specific needs which include existing riparian rights as of June 28, 1985; water needs of federal water projects existing on June 28, 1985; the firm yield of all reservoirs in existence on June 28, 1985; maintenance of minimum stream flows for fish and wildlife, water quality, aquifer recharge requirements and navigation; and future water needs of the basin of origin as projected in the Arkansas Water Plan (Ark. Code Ann. § 15-22-304). In 1995, the definition of excess surface water was amended for the White River Basin only, such that "a transfer shall not exceed on a monthly basis an amount which is fifty percent of the monthly average of each individual month of excess surface water" (Ark. Code Ann. § 15-22-304(e)) (Perkins 2002). The 1990 Arkansas Water Plan included calculations of excess surface water for the five major water basins of the state taking into account projected riparian uses, minimum streamflow requirements for fish and wildlife, and navigation needs to the year 2030. When the ARNC evaluates a non-riparian permit for water rights, the proposed use is evaluated against the figures calculated in 1990 to make sure excess surface water levels have not been exceeded (ARNC 2011). The 2014 Arkansas Water Plan is currently under development and will evaluate projected water needs to the year 2050. On December 11, 2014, ANRC approved taking the 2014 Arkansas Water Plan Update through rulemaking. Most recently, the ANRC has proposed a new rule based upon the recommendations contained in the 2014 Update. Public meetings and an open public comment period occurred in summer 2015.

Examples of reasons for obtaining a surface water transfer permit include irrigation, hydrologic fracturing of natural gas wells, municipal water supply, industrial cooling water, and mining. The largest project to date is the Grand Prairie Irrigation Project. The greatest growth in non-riparian intra-basin transfer permits has resulted from development of the Fayetteville Shale from the petroleum industry. As of March 3, 2010, the Commission had received 726 applications from gas companies (ARNC 2011).

5.6.1.5 Allocation of Surface Water

In times of shortage, the ANRC may on its own initiative, or on the petition of any person claiming to be affected by such shortage of water, after a notice and hearing, allocate the available water among the users affected by the shortage in a manner that each may obtain an equitable portion of the available water (138 C.A.R.R. 003 § 307.1). There are uses that are excluded from an allocation process including "…water stored in federal impoundments" (ANRC Rules § 307.2). There are also reserved water uses that are excluded from an allocation process such as domestic and municipal-domestic, minimum streamflow, and federal water rights. Minimum streamflow is the "quantity of water necessary to support interstate compacts, navigation, fish and wildlife, water quality, and aquifer recharge" (Ark. Code Ann. § 15-22-202). Federal water rights are not defined in the Arkansas code; however, the ANRC rules state that "there may be some water over which the United States has a preemptive right that is superior to the rights of others" (ANRC Rules § 307.7). The water uses considered in this rule were for uses such as interstate compacts and navigation. As of 2011, the ANRC had not declared a shortage or initiated allocation procedures (ANRC 2011).

5.6.1.6 Surface Water Withdrawals

As summarized by Brown-Kobil (2014): The Arkansas Soil and Water Conservation Commission regulates water in the state which follows the riparian rule of reasonable use. Any person who diverts water from any stream, lake, or pond, except those natural lakes or ponds in the exclusive ownership of one person, shall register with the Commission or with his/her local conservation district (Ark. Code Ann. § 15-22-215(a)). Once registered, the Commission will issue a certificate of registration (Id. at § 15-22-215(e)). A "person" is defined as any natural person, partnership, firm association, cooperative, municipality, county, public or private corporation, and any state or local government agency (Ark. Code Ann. § 15-22-202(8); Arkansas Groundwater Protection Act, Ark. Code Ann. § 15-22-903(10)). While these statutory definitions do not include federal agencies in the definition of a person, state regulations do include federal agencies in the definition of a person (138 C.A.R.R.003 § 301.3(DD)).

Non-riparian users are required to obtain a water use permit, regardless of the volume of water proposed for use. The ANRC, in cooperation with the USGS, collects and compiles reported monthly water use (surface water and groundwater) data for several categories, including irrigation and livestock use, in its Aggregated Water-Use Data System (AWUDS; ANRC and USGS 2014). Water-use data for domestic (self-supplied) and livestock (stock) are not required to be reported to ANRC.

5.6.1.7 Groundwater Withdrawals

As summarized by Brown-Kobil (2014): The 1991 Arkansas Groundwater Protection Act, Ark. Code Ann. § 15-22-901 to 914, authorizes the Commission to designate critical groundwater areas (Id. at § 15-22-903(6)). The statute's purpose declares that conservation of groundwater may require limit of withdrawals in critical groundwater areas through the issuance of water rights (Id. at § 15-22-902). After public notice and hearing, the Commission has the power to declare a critical groundwater area and to allocate water rights (Id. at § §15-22-908, 909). If the Commission "declares" an area to require water rights, no one may withdraw groundwater or construct a new well without first obtaining a water right (Id. at §15-22-909).

Under the 1991 Arkansas Groundwater Protection Act, no regulation of groundwater resources occurs until a critical area is designated. The ANRC has designated three critical groundwater areas to date; however, the ANRC has never regulated these areas (ANRC 2013). The Cache Critical Ground Water Area encompasses most of the area between Crowley's Ridge and the southern portion of the RHI as well as most of the northern portion of the RHI. The Grand Prairie Critical Ground Water Area occupies a small portion of the southwestern part of the RHI and an extensive area west of the White River south of the Cache River NWR (Figure 25). As described above, reported groundwater use for several categories is available by county or HUC in ANRC's AWUDS (ANRC and USGS 2014). If the ARNC issued a declaration of necessity and followed procedures to do so, a regulatory program could be initiated and water rights issued (ANRC 2011).

5.6.1.8 Diffused Surface Water

Water law and regulation in Arkansas is tied to the type of the water involved (e.g., watercourses, streams, and lakes) and the location of the landowner who wishes to use the resource (e.g., riparian landowner, non-riparian landowner). Water that has not become part of a natural channel, lake, or pond is considered "diffused surface water." Arkansas code defines "diffused surface water" as "water occurring naturally on the surface of the ground other than in natural channels, lakes, or ponds" (Ark. Code Ann. § 15-22-202). Arkansas case law has developed rules for determining liability for landowners' actions to manage diffused surface water, whether the landowner takes steps to prevent it from coming onto low lying land or whether removing excess water from land by filling and/or draining (ARNC 2011).

5.6.2 Legal or Regulatory Issues Potentially Affecting the Refuge

The refuge does not have formal water rights or filed permit applications (USFWS 2009). As described in Section 5.2.5, the refuge has 13 + irrigation wells for groundwater withdrawals. As noted above, the refuge is located near the Cache Critical Ground Water Area; however, the ANRC has not yet begun to regulate groundwater resources in the designated areas. As noted in Section 5.6.1.5, in times of shortage ANRC may allocate water among users, although such allocation would exclude any water stored in federal impoundments. Regardless, state law specifically acknowledges that Federal Reserve water rights have priority over other uses and needs (Brown-Kobil 2014).

With respect to groundwater, most of the refuge and the area within the refuge acquisition boundary lies outside of the existing Critical Groundwater Areas (Figure 25), which in any event the ANRC has never yet regulated (ANRC 2013). However, in the event that ANRC were to begin regulating groundwater use and expand the Cache and/or Grand Prairie Critical Groundwater Areas or designate a new Critical Groundwater Area, the refuge could be affected. It would be prudent to document existing groundwater use by the refuge and be prepared to submit a water right application should ANRC initiate groundwater regulation. Brown-Kobil (2014) notes that groundwater rights are only issued for a beneficial use. "Beneficial use" means the use of water in such quantity as is economical and efficient and which use is for a purpose and in a manner which is reasonable, not wasteful, and is compatible with the public interest. This should include groundwater used for wildlife and habitat.

6 Assessment

In this section, the focus will be to highlight and briefly discuss the perceived major threats or issues of concern related to the water resources on the refuge, and then briefly discuss corresponding needs and recommendations to address those threats and issues. The primary drivers of these threats are the anthropogenic and environmental stressors occurring within the Cache River NWR Region of Hydrologic Influence (including the Cache River and Bayou DeView) and influences from the White River, which is located at the southern portion of the refuge. For discussion and context purposes, the perceived threats or issues of concern are identified by two temporal categories: 1) urgent/immediate issues (those for which impacts have already manifested) and, 2) long-term issues (currently not an immediate threat but if current practices continue, then impacts are likely). Similarly, Needs and Recommendations are classified as immediate (urgent needs that should be addressed as soon as practicable) or long-term (important but less immediate needs, or those that will require long-term efforts to address).

6.1 Water Resource Issues of Concern

The Region of Hydrologic Influence (RHI) primarily focuses on upstream basin conditions, with the addition of downstream areas containing features and management practices directly relevant to hydrologic conditions within Cache River NWR. The low gradient of the Mississippi Alluvial Valley (MAV), in concert with numerous anthropogenic changes to the system and active management, has resulted in conditions where downstream areas with little direct hydrologic connection affect conditions upstream at the refuge. The refuge's location within the RHI leads to a multitude of perceived threats and issues of concern that can directly or indirectly impact the water resources. The majority of Cache River NWR is located within the hydrologic unit identified as the Cache subbasin (08020302). A small portion of the lower extent of the refuge is located outside this subbasin but is within two hydrologic units associated with the White River; these units are the Raft Creek-White River watershed (0802030105), which extends along the White River upstream from the confluence of the White and Cache Rivers, and the Roc Roe Bayou-White River subwatershed (080203030502), which is downstream of the confluence along the White River, and which contains the southernmost portion of the refuge approved acquisition boundary. Water levels and conditions on the White River have a direct effect on the hydrology of the lower Cache River. Thus, in order to inventory data which characterize these hydrologic relationships, the two smaller hydrologic units are included with the Cache subbasin to define the RHI for the refuge. The RHI includes a total drainage area of 2,251 mi^2 (1,440,780 acres).

Many of the threats and issues of concern within the RHI are largely related to anthropogenic changes and most are associated with water quantity and water quality issues. Anthropogenic alterations, such as stream channelization, groundwater withdrawals for agriculture practices, and conversion of bottomland hardwoods to agricultural fields, greatly influence the hydrology within the RHI and ultimately on the refuge. These generalized changes ultimately lead to more specific and common issues on the refuge such as: seasonal water quality issues (e.g., high temperatures, low dissolved oxygen, etc.), alteration of the natural flow regime (e.g., timing, magnitude, and duration of floods or low flows), channel incision or sedimentation, and water rights issues. Unfortunately, concerns have been expressed that many of these longstanding changes and effects on the geomorphology, vegetation communities, and soils of the basin may be, for all practical purposes, irreversible (Klimas et al. 2009).

The greatest threat to the Cache River NWR biotic communities results from alterations to the hydrologic regime occurring in the Cache River basin beyond the refuge acquisition boundary. The refuge comprises the largest remaining bottomland hardwood (BLH) tract in the MAV while most BLH habitat in the basin today is highly fragmented (Heitmeyer 2010). The one-percent chance excedance (or 100-year floodplain) of the Cache River basin contains about 270,000 acres of agricultural land, 4,000 acres of stream channel, and approximately 100,000 acres of forested wetlands (USFWS 2009). Ditches and land leveling have reduced ponding and floodwater retention and have increased surface runoff and the flashiness of the Cache River and its tributaries. The basin as a whole retains only about 25% of its original forested area (Klimas et al. 2009). Species native to a very different basin struggle in the face of these changes and nuisance species threaten to outcompete.

To further assist in assessing any perceived resource threats or issues of concern on the refuge, a *Needs Assessment* was conducted in May 2013 (USFWS 2013c). Within the *Needs Assessment*, refuge staff identified the top three environmental threats that currently impact the Cache River NWR resources as: 1) water quantity and quality conditions, 2) changes in disturbance regime, and 3) human use/disturbance. When specifically asked to identify the top issues or concerns regarding threats to the refuge's water (quantity) supply, the following were identified: 1) minimum flows in Cache River and Bayou DeView, 2) surface and groundwater extraction, and 3) alterations to hydrologic conditions. When specifically asked to identify the top issues or concerns regarding threats to the refuge's water quality, the following were identified: 1) erosion, 2) sedimentation, and 3) agricultural run-off (in regards to nutrient and chemical introductions).

6.1.1 Urgent/Immediate Issues

6.1.1.1 Water Quantity

Threats or issues of concern include alterations to the availability of surface and groundwater on a seasonal scale and how anthropogenic and environmental changes disturb or alter those water resources.

<u>Surface Water</u>

- Inundation along the White River results in backwater flooding of the lower Cache River to a point approximately 25 miles upstream from its confluence with the White River during high water stages (Coastal Environments 1977). There are no major levees within the RHI; however, hydrology has been altered by the cumulative effects of many small, privately-constructed levees and other anthropogenic modifications.
- Channelization, ditching, and stream straightening, in conjunction with the conversion of forested areas to agriculture fields, have worked together to increase flashy stream flows. Flashy flow is characterized by rapid rates of flow increase and decrease during runoff events, high peak discharges, low baseflows, and often high concentrations of nonpoint source pollutants. Additionally, some areas within the Cache subbasin suffer from unseasonal surplus drainage from agricultural fields during what historically would have been the driest time of the year. This surplus drainage combined with the rapid flow rates have increased headcutting and bank collapses in many areas. Additionally, debris collects at the confluence of straightened and natural channels due to different flow rates resulting in blockages and further alterations to the flow regime.
- Analyses of land cover data reveal that agriculture land use has declined throughout the RHI in recent decades (at least since 1992), and that water, urban, and wetland classes have increased in area. Agricultural practices remain a major influence within the RHI, and potential impacts of agriculture on water resources (including the aforementioned alteration of surface water flows, water quality impacts, and aquatic habitat impacts) are still of great concern. The increases in water and wetland classes identified by recent landcover analyses is most likely due to an increase in surface water impoundments that are used to cultivate rice and other crops and flooding of

agriculture fields to promote waterfowl use for recreational/commercial hunting activities. The observed increase in urban landcover reflects continued urban development and population growth of cities (e.g., Jonesboro, Paragould, and Searcy, Arkansas) located within or adjacent to the RHI. Furthermore, forested areas appear to be decreasing in the upper portions of the Cache subbasin but increasing in the lower areas of the RHI, possibly as a result of refuge restoration efforts.

- Arkansas state government does not currently provide much enforcement on minimum flow requirements during times of shortage. With the development of a revised state water plan (publishing of draft rules and an open comment period is anticipated for 2015), efforts to monitor and maintain minimum flows might become of interest. Generally, in the Delta Region of the state, there is no strong political push to take action because of the economic value of the agriculture industry, often resulting in little to no emphasis on fish and wildlife resources.
- Overall, the allocation of flows for fish and wildlife remains a low priority. According to the most recent information available, in 2010, water withdrawals for agricultural irrigation, livestock, and aquaculture accounted for 80% of water use in Arkansas (Maupin et al. 2014).

Groundwater

- Land use activities continue to affect landscape dynamics including groundwater levels, soil infiltration capacity, and evapotranspiration rates due to shifts in vegetation community structure, contributing to altered surface water flow regimes.
- Pumping of groundwater from the alluvial aquifer for the cultivation of rice (and other agricultural practices) began in the Grand Prairie and Cache River areas in the early twentieth century. Throughout the aquifer, pumping rates have generally increased, with large increases in the early 1950s and between 1973 and 1982 (Ackerman 1996), and from the early 1990s to 2000 (Schrader 2006; Clark and Hart 2009).
- By the early 1980s, water levels had declined from 60 to 90 feet in wells in the alluvial aquifer in the Grand Prairie and Cache River areas (Ackerman 1996; Renken 1998). These areas most likely saw earlier and larger well drawdowns as compared to other areas within the MAV due to a combination of sustained history of groundwater extraction and the local thickness of the confining unit (Ackerman 1996). Water levels have generally declined throughout both areas except near rivers, an indication that, in a reversal of predevelopment conditions, surface water features were recharging the alluvial aquifer.
- Alteration of water levels, flow, and availability is an issue that impacts groundwater as well as surface water. Due to the political interests and agricultural ties associated with the Delta Region of the state, little enforcement authority exists that regulates the impacts to the associated aquifers. This is unlikely to change until, and unless, groundwater availability becomes an issue that impacts agricultural practices.
- Excessive groundwater pumping can cause streams to lose water through infiltration into the aquifer once the aquifer has been dewatered below the water level in the stream. Documentation shows that wells in proximity to the refuge are starting to fail. This indicates that the aquifer is being depleted (i.e., groundwater use is occurring at an unsustainable rate) and the water table is decreasing over time (Bill Prior, AGS, personal communication, May 22, 2013).

- Groundwater enters the alluvial aquifer from the north and west and flows in a south and east direction toward the major rivers. Thus, water would flow naturally from the northwest to the southeast; however, large groundwater withdrawals in southern Arkansas and northern Louisiana have caused declines of the potentiometric surface and some changes in direction of flow. Additionally, recharge from induced stream infiltration may take place in areas where the clay/silt cap is thin enough to have been breached by stream channels, and where well withdrawals have lowered the adjacent water table below the stream level (Gonthier 1996; Wilbur et al. 1996). This condition exists along most of the length of the Cache River (Broom and Lyford 1981). Conversely, during dry periods, water may discharge from the alluvial deposits or adjoining aquifers into the streams (Renken 1998).
- In 2009, sections of Clay, Craighead, Cross, Green, Lee, Poinsett, and St. Francis Counties, Arkansas, on the western side of Crowley's Ridge, were designated as the Cache Critical Ground Water Area (CGWA) by the ANRC because groundwater levels had dropped below half of the original saturated thickness of the alluvial aquifer (ANRC 2011). The portions of those counties containing the Cache River Basin are designated current critical areas (ANRC 2013). The alluvial aquifer beneath the Cache River Basin in Poinsett and Cross Counties is also identified as having one of the largest decreases in groundwater elevation in the state since 2011. Sustained heavy pumping from multiple wells for extensive periods has led to substantial, widespread groundwater-level declines in several portions of eastern Arkansas. In some areas, declines of water levels have resulted in: partially air-filled upper parts of the aquifer, reductions in hydraulic pressure, saturated thickness, stored water, lateral flow within the alluvial aquifer, and baseflow to streams throughout most of the aquifer's extent in Arkansas.
- Sustained heavy pumping from multiple wells for extensive periods has led to substantial, widespread groundwater-level declines in several portions of eastern Arkansas. Declines in water levels have resulted in reductions in hydraulic pressure and lateral flow within the alluvial aquifer in some areas and reduced baseflow to streams throughout most of the aquifer's extent in Arkansas. Reduction in aquifer hydraulic pressure means that, in some areas, the hydraulic gradients have been reversed, particularly in the CGWA, and the rivers now typically recharge the alluvial aquifer rather than the aquifer recharging the rivers (Reed 2003).
- If overdraft of an aquifer continues for an extended time, the capacity of the aquifer to store and release water could be permanently decreased. As the aquifer is depleted, compaction causes loss in porosity that may be partially or wholly irreversible, leading to a permanent reduction in the ability of the aquifer to store and transmit water. This has probably already occurred to some degree in the vicinity of the refuge.
- Accompanying the decreased groundwater levels in the basin, there are areas of salt water intrusion from deeper layers into the alluvial aquifer (US EPA 2009). Excessive levels of salt water now occur near Brinkley, Arkansas, and in nearby Bald Knob, Arkansas (Heitmeyer 2010).

6.1.1.2 Water Quality

- Common sources of impairment within the Cache River NWR RHI include: sedimentation and siltation; metals other than mercury (e.g., aluminum, zinc, and lead); low dissolved oxygen; and dissolved solids (chlorides and sulfates). The primary water quality problems experienced by the refuge are turbidity and siltation (USFWS 2013c). While some of these problems originate from on-refuge land use activities (particularly farming and road/levee construction), the majority stem from non-point sources of erosion and runoff outside the refuge's boundaries.

- A study undertaken to measure turbidity values throughout the Cache subbasin during high flow events identified seven subwatersheds calculated as contributing the most total (mass) suspended sediment to the Cache River system (TNC 2006). An analysis of non-point source pollution data in the subbasin collected in that study identified Swan Pond Ditch (080203020205), which straddles Crowley's Ridge, as the most severe of sediment contributors to the Cache River and the most in need of Total Suspended Sediment (TSS) abatement. The analysis also identified Culotches Bay (080203020805), which intersects the refuge, as the second highest priority subwatershed for TSS abatement. This was prioritized largely because the reach of the Cache River to which Culotches Bay drains has the lowest allowable TSS levels for both base and storm flow for considered areas in the study (APCEC 2004).
- One of the greatest water quality threats to aquatic species in this system is the increase in sedimentation. Current rates of sedimentation throughout the basin are unknown but may be lower than in previous decades when land conversion was at its peak. However, gully and bank erosion has increased particularly in areas with highly erodible soils and relatively steep topography. Increased sediment loads can adversely impact aquatic species and their associated habitats (e.g., mussel beds, fish spawning substrate, etc.) due to excessive deposition of fine sediments.
- In 2008, Cache River and Bayou DeView did not meet fisheries use designations due to concentrations of lead and elevated suspended sediment levels. Non-point sources (e.g., agriculture practices) were identified as the primary contributors to increased sedimentation. These increased levels of sedimentation result in increased accumulation of heavy metals (i.e., lead) as the lead is bound to the sediment loads (US EPA 2009).
- The ANRC designated the Cache River watershed as a priority watershed for the first time in the 2011-2016 Non-Point Source (NPS) Pollution Management Plan. In 2012, several segments of the Cache River and Bayou DeView were listed because of lead contamination (ADEQ 2012). There are several permitted facilities that discharge into the Cache River and Bayou DeView within the refuge acquisition boundary, including the cities of Cotton Plant, Grubbs, Patterson, Amagon, and Beedeville, Arkansas.
- Within the Cache River NWR RHI there are a total of 115 NPDES permitted facilities. Three of the permitted facilities are considered "major" (i.e., Publicly Owned Treatment Works [POTWs] with design flows ≥1 MGD, or those that serve a population ≥10,000, or cause significant water quality impacts). These are associated with the CWL Wastewater Treatment Plant and the City of Jonesboro City Water & Light facilities, all located in Jonesboro, Arkansas, in the upper portion of the RHI. Additionally, major non-POTW discharges are those surpassing a point threshold based on criteria such as toxic pollutant potential, flow volume, and water quality factors such as impairment of receiving water or proximity of discharge to coastal waters (US EPA 2013). Of the remaining NPDES facilities in the RHI, none are classified as "major" non-POTW dischargers, while 107 are classified as "non-major" dischargers because they do not meet the above criteria, or are facilities that discharge without an NPDES permit. The five remaining facilities are classified as NPDES Unpermitted.
- Excess nutrient loads as related to agriculture and municipality discharges in the Cache subbasin are a concern. ADEQ monitors water quality for environmental contaminants throughout the state and has identified waters for the 303(d) list of impaired streams and determined the TDMLs for several waterbodies within the watershed (ADEQ 2008). In addition, ADEQ identified several segments of the Cache River and Bayou DeView on the impaired waters 303(d) list. These areas

were either identified as an Impaired Waterbody with Completed TMDLs (Category 4a) or as Water Quality Limited Waterbodies (Category 5). The causes (i.e., siltation/turbidity, lead or aluminum, total dissolved solids, chlorides, or unknown) of these designations have been identified as being associated with sources such as agriculture and municipal point sources. (ADEQ 2008).

- In areas with little to no flow, low dissolved oxygen concentrations can impact fish and mussel communities during the warm summer months. Fish communities often experience dies-offs in July and August because of low dissolved oxygen concentrations and high water temperatures that are commonly associated with the shallow lakes and backwater areas found throughout the RHI and on the refuge. Occasional kills can also sometimes be attributed to point source releases of anoxic water from agricultural fields and irrigation ditches.

6.1.1.3 Geomorphology

- Longstanding effects on the geomorphology, vegetation communities, and soils of the entire Cache River Basin affect water quality. The conversion of forested areas to agriculture fields over the last century has left a residue of nutrients and pesticides in more readily erodible soils. Removal of stream buffers in agriculture fields has allowed for soil from field-disturbing activities (e.g., disking) to reach the stream network.
- Erosion and sedimentation are major issues and are related to the many landscape alterations and geomorphological changes. The construction of small levees and road systems throughout the basin and on the refuge have also helped facilitate these impacts. When the water is diverted or redirected from the natural hydrology, impacts downstream can potentially be magnified. This is easily seen in areas where channel incision, bank/head cutting, and collapse are prominent. Due to the anthropogenic manipulation of the system throughout the Cache subbasin, it is difficult to accurately determine how much of the sediment load is naturally versus artificially created.
- Near Grubbs, Arkansas, upstream channelization and associated impacts have led to the formation of numerous log jams and debris fields within the mainstem Cache River. As a result, the Willow Slough Drainage District has initiated the removal of approximately 18,000 cubic yards of logs and debris from the river (ADEQ 2013); however, this is only a temporary solution and will not permanently address the cause(s) of the blockage. Additionally, as noted in the refuge's CCP, blockage removal to temporarily alleviate upstream issues could have adverse effects downstream. The blockage removal could lead to: modifications in the natural river channel, release of large amounts of sediment and debris downstream, and possible reformation of similar blockages on the refuge (USFWS 2009).
- In addition to channelization of the mainstem Cache River and Bayou DeView, many of the tributary streams in the basin have been converted to ditches for flood control and agricultural drainage. Ditching is particularly extensive in the northern half of the RHI, which is characterized by straight and shallow ditches with few or no pools. These streams are so deeply incised that they no longer access their floodplain during high water events and they immediately discharge rainfall as runoff. They often have eroding banks, unstable bed structures and high suspended sediment concentrations (TNC 2005, USFWS 2009).

6.1.1.4 Invasive and Native Nuisance Species

- Current invasive or native nuisance species posing a threat to refuge resources (terrestrial and aquatic) include: feral pigs, beaver, European or Chinese privet, Japanese honeysuckle, mimosa, chinaberry, kudzu, Phragmites, and Asian carp (silver and bighead carp). Most of these have been inventoried and/or are being monitored on the refuge. At this time, beaver have been identified as one of the greatest threats to the refuge's aquatic resources (USFWS 2013c).
- Beavers are a nuisance and pose a threat from the construction of dams and huts. These structures divert and pool water into areas that can cause damage. The damage is often to the bottomland hardwoods and other species that cannot tolerate extended periods of flooding. Also, the structures add to the hydrological alterations and thereby complicate resource management practices.
- Additional threats exist that could potentially impact the aquatic biota resources on the refuge. For example, the northern snakehead is an invasive fish species that was discovered in eastern Arkansas in 2008. As the species expands its distribution within the Arkansas Delta, the northern snakehead could have a potential adverse impact to native fish populations in the Cache subbasin and more specifically, on the refuge. Northern snakeheads have been documented in waterbodies within the RHI, and it is most likely only a matter of time before their presence is confirmed in refuge waters.

6.1.2 Long-term Issues

6.1.2.1 Impacts Related to Climate Change

- Although the specific impacts climate change will have on aquatic resources within the RHI and on the refuge are not known with certainty, issues related to climate change (e.g., altered rainfall patterns and amount, extended periods of drought, etc.) could potentially magnify the influences of other identified threats (e.g., agriculture practices) and challenges currently impacting the Cache subbasin.
- Climate models project continued warming in the southeastern United States and an increase in the rate of warming through 2100. The projected rates of warming are more than double those experienced since 1975, with the greatest temperature increases projected to occur in the summer. By 2080, projected mean temperature increases range from about 4.5°F under a low CO_2 emissions scenario to 9°F (10.5°F in summer) under a higher CO_2 emissions scenario (Karl et al. 2009).
- In eastern Arkansas, the number of days per year with a peak temperature over 90°F is expected to more than double, from an average of around 60 days to more than 135 days by 2080 (Karl et al. 2009).
- Any additional increases in runoff from a climate change-based increase in storm severity would cause additional scouring and river bank deterioration, along with impacts from non-point source pollution and sedimentation.
- Changes in rainfall amounts provide evidence that the water cycle is already altered, including a 20% increase of rainfall over the past 50 years associated with the more intense storm events (USGCRP 2009).

- Increases in ambient temperature can increase water temperatures placing additional stress on the aquatic ecosystems within the Cache subbasin and subsequently on the refuge's aquatic resources.
- Warmer temperatures increase the rate of evaporation of water into the atmosphere, in effect increasing the atmosphere's capacity to "hold" water (USGCRP 2009) and potentially drying out some areas while providing increased precipitation to other areas. Potential evapotranspiration in the vicinity of the refuge is projected to increase, especially during the summer, which could lead to increased moisture stress for plants and decreased availability of water for management of the refuge's impoundments during the summer and fall.
- Arkansas has been identified as experiencing increased drought conditions, with the Delta Region identified as having a significant trend of increased drought (USGCRP 2009).
- Wilber et al. (1996) found that climatic variation is the primary influence on Cache River flows and explained almost three-fourths of the variation in flows observed at the Patterson gage (middle Cache River Basin) between the 1930s and 1980s. Data suggest that from approximately 1900 to 1930 the region experienced an extended period of above average precipitation, and from approximately 1990 to 2003 the region experienced an extended period of below average precipitation. While short and extended periods at either extreme do occur throughout the period of record, it is difficult to definitively confirm any obvious increasing or decreasing trends in annual precipitation.

6.1.2.2 Agriculture

- Future irrigation needs, in light of climate change, threaten increases in salt water intrusion into shallow aquifers in response to further reductions in groundwater levels. Lowered groundwater levels would in turn lead to lower baseflow, which would contribute to flashier streamflow and further risk of gully and stream bank erosion.
- Commodity markets and the overall economy greatly dictate the types and quantities of crops being produced annually, thereby, potentially requiring more water for production of certain crops (e.g., rice). During such increases and fluctuations in the types of crops being produced, increase in water demands (surface and ground) should be expected.

6.1.2.3 Groundwater

- Groundwater level declines due to over-use are apparent in recent monitoring data as well as over the entire period of record. Of 303 alluvial aquifer wells monitored in both 2009 and 2014, 179 (59.1%) of these had declining static water levels. Over a 10-year period (from 2004 to 2014), 265 of 359 wells (73.8%) monitored showed declines in the alluvial aquifer. Interestingly, during the 2010-2011 monitoring period, the average change over the entire aquifer was +0.16 feet. During the 5-year average that encompassed these years, the change was -1.01 feet, and the respective 10-year average change encompassing these years was -3.72 feet (ANRC 2015). The average ten-year decline in the Grand Prairie study area was -2.33 feet; in the Cache River study area, the average decline was -4.97 feet.
- The 2014 ANRC Groundwater Report indicates that significant cones of depression exist in the alluvial aquifer, especially in the Grand Prairie and in the Cache study area west of Crowley's

Ridge. Wells showing the greatest decline in the Cache study area are generally located at the base of Crowley's Ridge and in portions of the study area furthest from the major rivers, indicating that the rivers may be locally recharging the aquifer.

6.2 Needs/Recommendations

Several of the identified needs and recommendations coincide with those found within other refuge planning documents, particularly the CCP. Where appropriate, the associated CCP objectives and strategies as related to aquatic resources and hydrology should be prioritized based on information contained within this WRIA and as is practical for refuge implementation/operations.

6.2.1 Immediate

- To improve hydrological flows on the refuge, identify constriction points and barriers (e.g., culverts) and consider/evaluate for alternative replacements (e.g., low-water crossings or complete removal).
- Increase stream connectivity and restore the natural hydrology in areas where permissible. This would include continued coordination efforts for Phase 2 of the *Lower Cache River Restoration Project*.
- Develop design and installation standards for water control structures to facilitate increased flow, water dispersion, and fish passage in target areas, and when new construction projects are initiated, keep these as a guideline/template to follow and reference.
- Populate a complete road crossing location map. Identify areas that could be targeted for new structures or for replacing old structures and prioritize based on biological (e.g., aquatic species) and management needs.
- Research and outreach regarding Best Management Practices (BMPs), including both the correct implementation and evaluation of BMP effectiveness, are urgently needed to achieve reductions in sedimentation and excess nutrients/contaminants.
- Work with partners to acquire accurate aquatic species lists for the refuge. These species lists will provide valuable insight and assist with monitoring of aquatic resources on the refuge. Additionally, once baseline species lists are confirmed, management actions and associated impacts can be more accurately assessed.

6.2.2 Long-term

Recommendations to begin addressing potential impacts include: 1) Identify species that are most likely to be negatively impacted by effects of climate change, as well as generalist species that may benefit from changes; 2) Increase contiguity of footprint of NWR lands; 3) Establish decision-making processes that place individual refuges within a system context, and coordinate local actions with regional/national objectives and respective partners. Efforts to identify and monitor the environmental impacts associated with the introduction of non-native invasive species should also be considered.

6.2.2.1 Partnerships

Many agencies and citizen groups are active partners in conservation, management and sustainability of the Cache River Basin. In order to most effectively manage and protect this basin, efforts to continue, enhance, and expand future support of these and other partnerships is critical. Establishing new partnerships with agencies and entities where previous coordination and collaboration did not exist is also imperative. These partnership opportunities can potentially provide additional resources and perspectives on issues regarding the aquatic resources within the watershed and on the refuge. One such recommendation would be to work with the Arkansas Geological Survey (AGS), Arkansas Natural Resources Commission (ANRC), and U.S. Geological Survey (USGS) regarding groundwater issues.

Continue to work with the USACE and TNC to acquire funding for Phase 2 of the *Lower Cache River Restoration Project*. This effort is an excellent example of how partnerships can help make changes to the landscape that will potentially benefit the aquatic resources and ultimately, the Cache River NWR.

6.2.2.2 Water Quantity Information

Critical data are needed for the refuge, documenting the magnitude, frequency, timing, and duration of stream flows required throughout the year to support desired aquatic biota communities. As part of this data need, it is recommended that current USGS gages in the vicinity of the refuge be maintained, and an analysis of critical data gaps in gage data (for both surface water and groundwater) be completed in order to evaluate the need for additional gages and monitoring wells. Additional surface water and groundwater information can be obtained from various state and federal agencies, including ADEQ, AGS, USGS, and USACE.

6.2.2.3 Groundwater Information

Additional research is needed to further document and evaluate groundwater contributions to surface flow (and vice-versa) in the Cache River and Bayou DeView throughout the year. Analysis of aquifer hydrogeology and vulnerability to contamination for the physiographic region is also needed.

As agricultural land use practices continue in the watershed and climate change influences aspects of both surface water and groundwater recharge and discharge, the need for long-term groundwater information will increase. Continued monitoring of active wells within the watershed should be maintained and supplemented by additional monitoring where needed throughout the basin. Efforts should be made to collaborate with state and federal partners to effectively identify issues and assess how adverse long-term impacts to aquifers could affect the aquatic resources on the refuge.

6.2.2.4 Water Quality Monitoring

Evaluation of TMDLs in the watershed and monitoring of those associated impaired streams should continue over time. In addition, potential research could focus on biological monitoring, as well as nutrient and sediment modeling for those impaired streams within the watershed, providing information useful for species restoration efforts.

Specific water monitoring objectives for the refuge should be developed and implemented, either as part of the Inventory and Monitoring Plan (IMP) for the refuge, or as a stand-alone document. Water monitoring efforts are tied to critical baseline information needs in the adaptive management framework; targeting ecological integrity while meeting refuge, Regional, and National level Water Resources Inventory and Monitoring Goals and Objectives (USFWS 2010a; USFWS 2013c). Specific tasks should ideally supplement existing water monitoring work already being conducted in the watershed and in proximity to the refuge (e.g., ADEQ monitoring sites and efforts). Given projected mean temperature increases of 4.5 to 9 °F by 2080, additional water temperature monitoring to establish baseline conditions and detect future trends that could impact aquatic species should be considered. This work is already being facilitated by the use of stream temperature loggers deployed in Bayou DeView. However, additional sites need to be identified and monitored.

Quantification of sediment loads (e.g. total suspended solids [TSS], bedload transport, and turbidity recorded for varied discharges) is especially needed. This would help identify and assess adverse effects from agriculture practices within the RHI and climate change influences (e.g., increased runoff from severe storm events). It could also help to evaluate impacts associated with the removal of the debris field at Grubbs, Arkansas.

Additionally, to further evaluate the water quality on the refuge, biological monitoring for indicator species should also be explored and based on Richter et al. (2003) information. Directly linked to biological monitoring is a critical data need for taxonomic research and basic natural history research (especially life histories and flow dependencies) for species in the Cache River and associated tributaries, such as Bayou DeView.

6.2.2.5 Infrastructure and Barriers

Efforts to restore the hydrologic connectivity and fish passage can be accomplished by altering/removing levees, low water crossings, beaver dams, and other structures. The likely effectiveness of installing more fish passage "friendly" structures in lieu of galvanized steel culverts on the refuge should be evaluated. Additionally, specific areas and actions to provide better stream-floodplain connectivity to promote and restore the natural hydrology, such as those referenced in the *Bald Knob and Cache River National Wildlife Refuges Wildlife and Habitat Management Biological Review* (USFWS 2008) should be identified, where practical. This would potentially allow access to spawning and nursery habitats for large riverine fish species (e.g., alligator gar and paddlefish) and provide additional habitat for other aquatic species. Various aquatic species require and utilize backwater and inundated areas seasonally and during various aspects of their life history.

Emphasis should be on restoration of natural drainage and passive management. A primary goal for the refuge should be to provide for and encourage natural patterns of overbank flooding and drainage along naturally occurring flow paths, such as sloughs, side channels, swales, and meander valley networks. Water control structures should be constructed and maintained only in sites and units where intensive management is desired and possible, such as areas with moist-soil or greentree reservoir impoundments (USFWS 2009).

6.2.2.6 Long-term Planning

As identified as a strategy in the refuge CCP under *Cache River NWR Objective 2-4: Water Management*, the development of a detailed water management plan for the refuge should be considered. From a water resource management perspective, development of such a plan should be considered a high priority. The plan should include the following information:

- Inventory existing water management infrastructure and condition (e.g., water control structures, culverts, levees, groundwater wells, irrigation ditches, etc.) and develop a detailed georeferenced database/map for which information on these structures is readily accessible;
- Assess existing and needed/desired water management capabilities, including the effects of roads on refuge hydrology and any constraints that their presence may place on water management capabilities;
- Document and quantify existing surface water and groundwater use on the refuge to the extent known or readily determined;
- Identify critical information gaps and monitoring needs; and

- Analyze management options with respect to inundation frequency and impacts to resources affected. Any actions that can be taken to facilitate improvements to the hydrological regime on the refuge, including subsequent drainage of inundated areas as appropriate, should be identified.

Additionally, an IMP is needed for Cache River NWR. The IMP will allow for better planning in identifying appropriate surveys to inventory and monitor resources (including aquatic habitat and biota) on the refuge. Surveys for the IMP to specifically address water and aquatic habitat monitoring needs should consider the following elements:

- Surface water level monitoring in managed impoundments, greentree reservoirs, bottomland hardwood tracts, and other areas of management concern;
- Groundwater level monitoring in the alluvial aquifer;
- Refuge water use for management purposes from surface and groundwater sources;
- Water quality monitoring, including water temperature, dissolved oxygen, turbidity, toxic heavy metals, and pesticides;
- Cross-section profiles to monitor channel incision, bank erosion, and deposition (particularly in the vicinity of the Grubbs channel blockage);
- Sedimentation rate measurements at selected locations.

Development of a protocol for removing/installing barriers (culverts, abandoned water control structures, etc.) would be helpful in addressing fish passage and restoring the natural hydrology as much as possible. Work with USFWS internal partners such as Inventory and Monitoring, Fisheries, and Ecological Services to identify and prioritize areas for consideration of such restoration/construction projects.

Refuge staff should stay informed on the status of the Arkansas State Water Plan. Once the plan is completed, staff should review the plan and evaluate whether there are additional actions that can be taken based on information it contains to better address water resource issues on the refuge. As appropriate, the refuge should work with partners (e.g., ANRC) to identify minimum flow needs for Cache River and Bayou DeView.

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