Three Rivers Southeast Arkansas Study

Appendix A: Economics

THREE RIVERS SOUTHEAST ARKANSAS

Introduction

The Three Rivers Southeast Arkansas Feasibility Study (Three Rivers Study) is being conducted by the U. S. Army Corps of Engineers (USACE) to recommend modifications to the McClellan-Kerr Arkansas River Navigation System (MKARNS) that would provide long-term sustainable navigation and promote the continued safe and reliable economic use of the MKARNS.

Study Authority

Section 216, Flood Control Act of 1970 (Public Law 91-611) authorizes a feasibility study due to examine significantly changed physical and economic conditions in the Three Rivers study area. The study will evaluate and recommend modifications for long-term sustainable navigation on the MKARNS.

Study Purpose

There is a risk of a breach of the existing Soil Cement Structure near the entrance channel to the MKARNS on the White River. During high water events, Mississippi backwater can create significant head differentials between the Arkansas and White rivers. The existing Soil Cement Structure in the isthmus between the Arkansas and White rivers is subject to damaging overtopping, flanking and seepage flows that could result in a catastrophic breach and failure of the system. The uninhibited development of a breach, or cutoff, has the potential to create navigation hazards, increase the need for dredging, and adversely impact an estimated 200 acres of bottomland hardwood forest in the isthmus.

Based on the Section 216 authority, the study is investigating alternatives that would minimize the risk of cut off development, including reducing the cost of maintenance associated with preventing cutoff development, while minimizing impacts to the surrounding ecosystem.

Non-Federal Sponsor

The Arkansas Waterways Commission is the non-federal sponsor for the Three Rivers Southeast Arkansas Study. An amended feasibility cost-sharing agreement was executed in June 2015.

Recommended Plan

The recommended plan consists of a newly constructed 2.5-mile long containment structure at an elevation of 157 feet above mean sea level (ft msl) that would begin on natural high ground just south and west of the existing Melinda Structure located on the south side of Owens Lake. It would continue east and cross the Melinda head cut south of the existing Melinda Structure. From there, it would head northeast and connect to the existing Soil Cement Structure north of Jim Smith Lake. It continues to follow the existing Soil Cement Structure alignment terminating at the existing Historic Closure Structure. The recommended plan also includes a relief opening at the Historic Cutoff to an elevation 145 ft msl regardless of the width. In addition, the existing Melinda Structure would be demolished in place and the debris would be pushed into the deep scour hole at the top of the head cut. Finally, adding an opening in the existing Owens Lake Structure between Owens Lake and the White River would prevent water from backing up into Owens Lake, which would impact the bottomland hardwood forest. The opening would be designed to allow fish passage into Owens Lake.

PURPOSE OF APPENDIX

This appendix summarizes plan formulation and economic analysis for the Three Rivers Feasibility Study. Plan formulation considers existing conditions of the study area and identifies plans that address specified problems and opportunities, and the economic evaluation quantifies costs and benefits of plan alternatives with the objective of identifying the plan that maximizes National Economic Development (NED) benefits. The document:

1) Summarizes existing socioeconomic conditions in the study area;
2) Describes the future without projection condition; and
3) Compares alternatives in the context of NED benefits and alternative costs.

1. EXISTING CONDITIONS IN THE STUDY AREA

Section 2 inventories critical resources (physical, demographic, economic, social etc.) relevant to study problems and opportunities.

1.1 EXISTING NAVIGATION

The MKARNS was the largest civil works project ever undertaken by the U.S. Army Corps of Engineers at the time of its opening, and today, it ships about $3.4 billion (about 12 million tons) worth of commodities to and from Arkansas and Oklahoma each year.[1] The system is 445-miles long and includes the Verdigris, Arkansas and White Rivers. With 18 locks, it has an elevation differential of 420 feet from its beginning at mile 600 on the Mississippi River to the head of navigation near Tulsa. The MKARNS is a multi-beneficiary system that provides water supply, navigation, fish and wildlife, recreation, hydropower generation, and flood control (when considered as part of the Arkansas River Basin Project and its upstream reservoirs that control water flows). In May of 2015, the U.S. Department of Transportation upgraded the MKARNS from a “connector” system to “corridor” system as part of the Maritime Administration America’s Marine Highway Program. The upgrade in status brings the MKARNS into the same category as other major inland waterways such as the Mississippi and Ohio rivers.

[1] Unless otherwise stated, references to tonnage and commodity value are from the U.S. Army Corps of Engineers, Lock Performance Monitoring System, and the Corps’ Waterborne Commerce Statistics Center.

1.1.1 HISTORICAL AND EXISTING COMMODITY FLOWS

Before constructing the MKARNS, commercial navigation on the Arkansas River ranged between 0.5 million and one million tons a year. In 1970, after the MKARNS opened traffic grew rapidly through about 1978 to nearly 10 million tons per year. Traffic then declined slightly and stabilized for the next ten years at a level of about 8 million tons. Traffic again increased in the 1990's until the financial crisis of 2008 through 2009 when it dropped significantly. Since, 2011, volumes began to increase again to current levels of nearly 12 million tons per year (Figure 2). The annual compound growth rate over the historical period is 2.35 percent per annum. Today, about 80 percent of cargo on the MKARNs is outbound or inbound meaning that it flows through the Montgomery Point Lock and Dam to and from the Mississippi River (Table 1-1). Today, most internal shipments consist of sand and gravel for roads and construction.

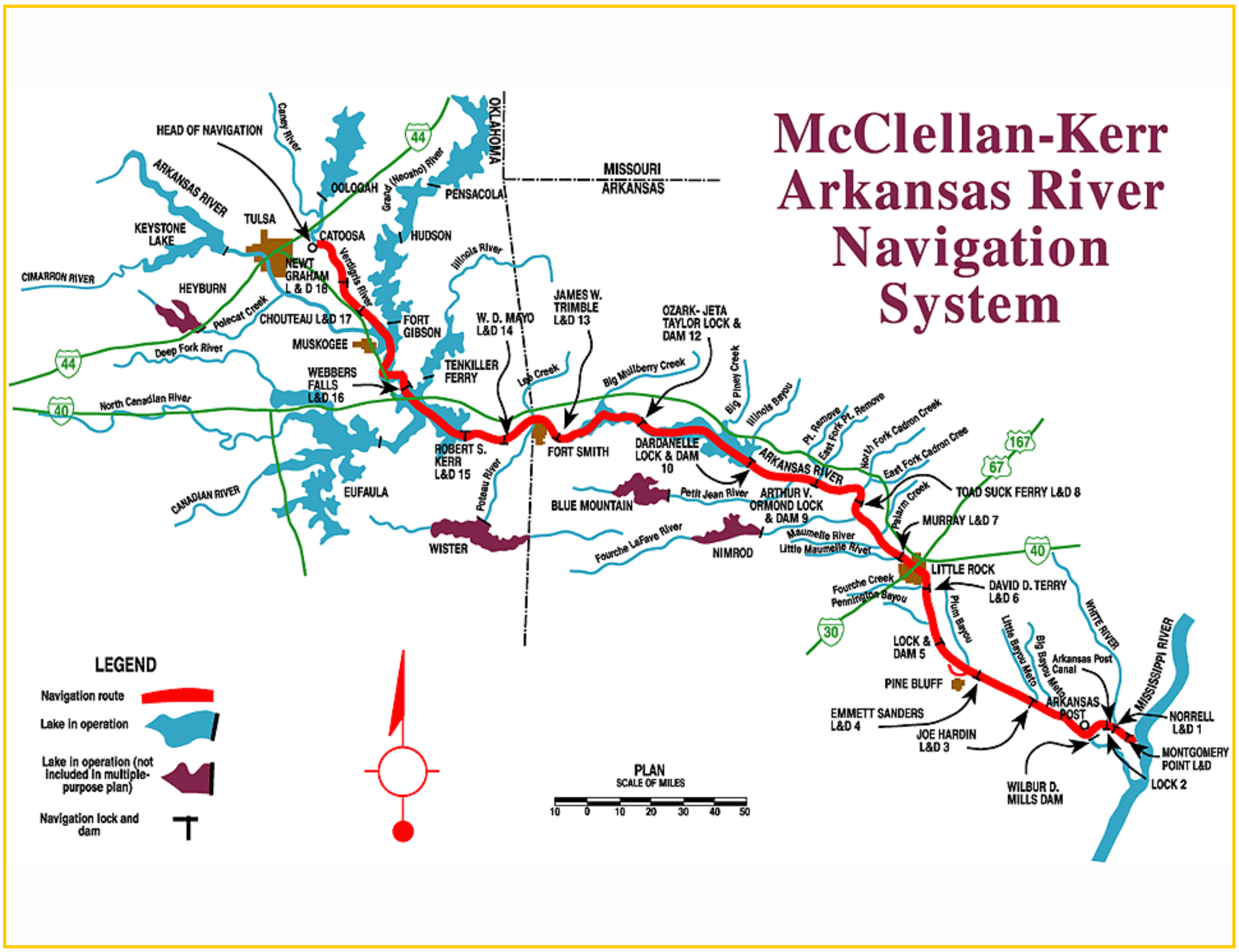

Figure 1. McClellan Kerr Arkansas River Navigation System

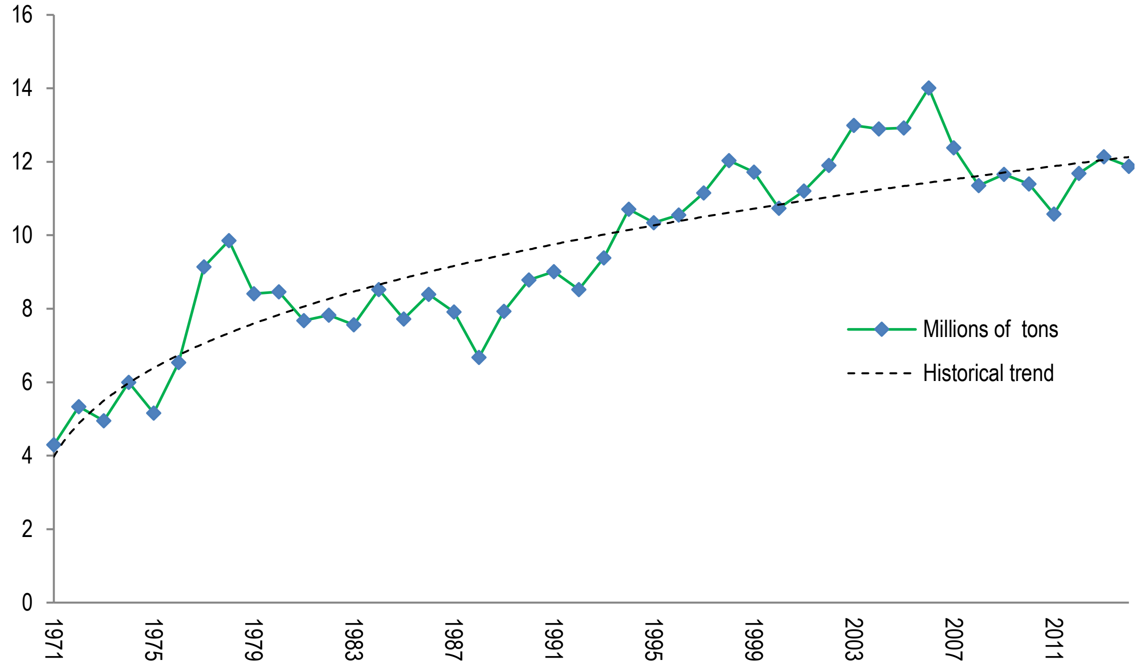

Figure 2. Historical Commodity Flows on the MKARNS (1971 to 2014, millions of tons)

Table 1-1
Historical and Current Commodity Flows through the Project Area by Direction (1971 through 2014, millions of tons)

Year	Total Tonnage	Inbound	Outbound	Internal	Total tonnage through project area (inbound and outbound)
1971	4.24	0.76	0.46	2.43	1.82
1972	5.67	1.17	1.03	3.46	2.21
1975	5.20	1.44	0.87	2.47	2.74
1976	7.08	1.99	1.66	3.03	4.05
1977	9.14	2.84	2.34	3.46	5.68
1978	10.22	2.60	3.90	3.17	7.05
1979	8.93	2.04	3.46	2.93	5.99
1980	5.13	1.80	0.66	2.67	2.46
1981	6.06	1.95	0.77	2.96	3.10
1982	5.20	1.44	0.87	2.46	2.74
1983	7.08	1.99	1.66	3.03	4.05
1984	9.14	2.84	2.34	3.46	5.68
1985	10.21	2.60	3.90	3.17	7.05
1986	8.93	2.04	3.46	2.93	5.99
1987	9.13	1.61	4.64	2.42	6.72
1988	9.45	1.56	5.68	1.74	7.71
1989	8.26	1.52	4.61	1.56	6.70
1990	8.02	1.91	3.91	1.90	6.11
1991	9.49	2.13	4.26	2.43	7.06
1992	8.33	2.10	3.19	2.52	5.81
1993	9.70	2.61	3.45	2.96	6.74
1994	8.89	2.13	3.35	2.75	6.13
1995	6.68	2.09	3.09	2.11	5.68
1996	7.93	2.17	3.84	1.91	6.45
1997	8.79	2.28	3.54	2.47	6.33
1998	9.01	2.25	4.29	2.20	7.02
1999	8.53	2.08	4.43	2.12	7.06
2000	9.38	2.42	4.24	2.56	7.18
2001	10.71	3.68	5.00	2.03	8.68
2002	10.35	3.68	5.18	1.49	8.86
2003	10.55	4.06	5.19	1.30	9.25
2005	10.33	3.83	5.05	1.45	8.88
2006	12.93	3.97	4.40	4.56	8.37
2007	14.01	4.35	5.25	4.41	9.60
2008	12.38	4.05	4.77	3.56	8.82
2009	11.35	2.92	4.84	3.59	7.76
2010	11.66	3.32	4.99	3.35	8.31
2011	11.39	3.71	4.84	2.84	8.55
2012	11.28	3.75	5.13	2.40	8.88
2013	11.70	4.23	5.39	2.08	9.62
2014	11.49	4.82	4.77	2.50	9.59

Source: U.S. Army Corps of Engineers Lock Performance Monitoring System

Accounting for about 90 percent of inbound tonnage, the top inbound commodities are:

- Fertilizer,
- Iron and steel,
- Distillate, residual and other fuel oils,
- Building materials and minerals,
- Food and other farm goods,
- Coal and coke; and,
- Manufacturing ores and chemicals.

Most fertilizer shipped into the MKARNs comes from manufacturers and distributors along the Gulf Coast, particularly in Louisiana and Southeast Texas. Since 2001, fertilizers deliveries to MKARNS ports have increased steadily despite a significant decline after the 2008 financial crisis (tables 1-2 and 1-3). On average, fertilizer shipments grew at an annual rate of 1.9 percent from 2001 through 2014. Growers in the Midwest use the majority of fertilizer products (primarily nitrogenous). Iron and steel products have followed the same general pattern as fertilizer increasing by about 2.9 percent per year since 2001. The primary consumers of iron and steel are manufacturers in Arkansas and Oklahoma.

Shipments of distillate fuel oils (primarily diesel fuel) have grown as well. From 2005 through 2007, diesel freight grew from nearly 99,000 to 302,000 tons (a 200 percent increase). The sharp rise corresponds to the development of the Fayetteville Shale, which is an unconventional gas reservoir that extends across northern Arkansas from the state's western edge throughout north central Arkansas. Southwestern Energy, Inc. began drilling in Fayetteville Shale in 2005 and gas production has steadily increased since. Most horizontal drillings rigs are powered with diesel fuel, and since they typically operate continuously the rigs consume substantial amounts of fuel.

Building materials that include products such as lumber, aggregate (sand and gravel) and Portland cement have grown at annual average rate of 5.4 percent since 2001, and like many other commodities dropped significantly in the years following the 2008 financial crisis but have since rebounded as the economy improved. Building materials support construction and maintenance of homes, businesses and roads in the region. Animal feed (including prepared feed and raw corn and grains), has grown at a rate of 2.3 percent since 2001 and supports livestock producers in the region including Arkansas’s poultry industry, which according to the USDA, ranks second in the nation in total pounds of chicken meat produced, and third in Turkey production.

Table 1-2: Historic and Current Inbound Commodities through Study Area (2001-2014, thousands of tons)

Commodity	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Share 2014	Annual Growth rate (2001-2014)*
Fertilizer	1,531	1,540	1,651	1,436	1,401	1,292	1,404	981	1,171	1,444	1,506	1,648	1,918	2,003	42.5%	1.9%
Iron and steel	749	907	945	1,076	989	1,215	905	690	677	625	800	804	867	1,114	21.9%	2.9%
Distillate fuel oils	87	65	65	87	99	183	302	294	199	220	129	161	279	446	8.8%	12.4%
Building materials and minerals	198	210	386	316	456	515	288	272	433	388	284	301	290	411	8.9%	5.4%
Animal Feed	202	93	110	96	114	111	121	194	252	288	257	220	238	276	5.6%	2.3%
Coal	153	192	178	181	232	422	582	126	148	213	217	196	204	116	2.5%	-2.0%
Iron Steel Waste and Scrap	142	58	97	40	40	37	38	32	45	91	81	85	92	98	2.1%	-2.6%
Industrial chemicals	201	171	189	167	182	144	141	105	77	107	98	104	115	158	3.4%	-1.7%
Dry sulfur; clay, and salt	14	19	48	39	90	56	59	89	95	180	105	86	87	81	1.8%	13.4%
Wheat and other grains	107	70	93	97	71	88	74	66	77	58	98	95	81	80	1.7%	-2.1%
Petroleum pitches and asphalt	183	214	183	218	237	241	104	55	115	55	68	30	57	15	0.3%	-16.4%
Equipment and Machinery	13	26	5	4	12	6	5	8	5	17	3	0	6	3	0.1%	-9.9%
Other	103	114	106	73	48	42	25	7	25	24	34	28	85	19	0.4%	-11.4%
Total	3,683	3,680	4,056	3,829	3,971	4,353	4,048	2,918	3,320	3,709	3,679	3,757	4,228	4,820	100.0%	1.9%

* Historical data provide a reference for study projections, and are based on the data from the USACE Lock Performance Monitoring System (LPMS). Historic data from the LPMS are used to analyze long-term trends and inter-annual variation in commodity flows; however, for the baseline in study projections discussed in subsequent sections of this appendix, the analysis relies on data from the Waterborne Commerce Statistics Center. The PDT recognizes that there are minor discrepancies between LPMS and WCSC data, and WCSC data are required for planning analyses that factor into derivation of cost benefit ratios.

Table 1-3. Current Distribution of Primary Inbound Commodity Flows from the MKARNs by Origin and Destination

Commodity	Primary shipping state(s)	Share of tonnage	Receiving state	Shares of tonnage
Building materials and minerals	Kentucky	6%	Arkansas	0%
			Oklahoma	100%
	Louisiana	31%	Arkansas	46%
			Oklahoma	54%
	Missouri	46%	Arkansas	76%
			Oklahoma	24%
	Mississippi	8%	Arkansas	0%
			Oklahoma	100%
Chemical fertilizers	Louisiana (posts of New Orleans and Baton Rouge)	93%	Arkansas	16%
			Oklahoma	84%
	Mississippi (Bayou Casotte)	5%	Arkansas	6%
			Oklahoma	94%
Coal (lignite and coke)	Louisiana (posts of New Orleans and South LA)	93%	Arkansas	44%
			Oklahoma	56%
	Kentucky	7%	Arkansas	0%
			Oklahoma	100%
Food and other farm goods (primarily animal feed)	Iowa	9%	Arkansas	0%
			Oklahoma	100%
	Illinois	12%	Arkansas	0%
			Oklahoma	100%
	Louisiana	76%	Arkansas	16%
			Oklahoma	84%
Iron and steel	Alabama	28%	Arkansas	41%
			Oklahoma	59%
	Illinois	6%	Arkansas	44%
			Oklahoma	56%
	Indiana	5%	Arkansas	92%
			Oklahoma	8%
	Kentucky	10%	Arkansas	16%
			Oklahoma	84%
	Louisiana	47%	Arkansas	67%
			Oklahoma	33%
Manufacturing ores and chemicals	Louisiana	98%	Arkansas	50%
			Oklahoma	50%
Petroleum products (primarily distillate fuels)	Louisiana	99%	Arkansas	98%
			Oklahoma	2%

Source: Generated based on 2014 data from the USACE Waterborne Commerce Statistics Center.

Accounting for about 90 percent of outbound tonnage, the top outbound commodities are:

- Soybeans and wheat;
- Iron and steel;
- Fertilizers;
- Coal (lignite and coke);
- Petroleum products (distillate, residual and other fuel oils); and,
- Building materials and minerals.

About one half of outbound tonnage from the MKARNS is wheat and soybeans shipped primarily to the ports of South Louisiana and New Orleans for export to global markets. From 2001 through 2014, soybean freight grew at a rate of 9.8 percent. According to the USDA Economic Research Service, main export destinations for U.S. oilseeds, oilseed meal, and vegetable oil include China, the European Union, Japan, Mexico, and Taiwan.[2] Other important markets−including Indonesia, South Korea, and Thailand. Canada, Mexico, the Philippines, and several Latin American countries also import significant quantities of U.S. oilseed meals.

Exports of wheat from the system dropped between 2001 through 2012 from a high of 1.32 million tons in 2001 to 0.6 million in 2012. The decline was probably more related to domestic wheat production trends rather than global demand. Harvested acreage of U.S. wheat has dropped off nearly 30 million acres, or nearly one-third, from its peak in 1981 because of declining returns compared with other crops and changes in government programs that allow farmers more planting flexibility.[3] But since 2011, in response to increasing global demand, wheat exports from the MKARNs have rebounded significantly.

Iron and steel scrap metal is another important outbound commodity on the system

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[2] Unless otherwise stated, discussion of crop markets and production are based on information and analysis prepared by the USDA's Economic Research Service. Available online at: http://www.ers.usda.gov/topics/crops/.aspx

[3] Authorization of the Conservation Reserve Program (CRP) in the 1985 Farm Act, followed by planting flexibility provisions in the 1990 Farm Act, provided wheat farmers with other options for use of their acreage. Under the 1990 Act, farmers participating in commodity programs could plant up to 25 percent of their base wheat acreage to crops other than wheat without losing base acreage.[3] Thus, farmers had an incentive to grow crops with higher returns or to earn rental payments from idling land under the CRP. Planting flexibility facilitated expansion of soybeans, corn, and other crops in traditional wheat areas, hence the steady increases in soybean and corn exports on the MKARNS.

(nine percent of outbound tonnage). Since, 2001 shipments have risen on average by 8.9 percent per annum. Most iron and steel consists of scrap and re-melting ingot used by domestic steel producers along the Lower Mississippi River. According to the U.S. Geologic Survey (USGS), steel scrap consumption by domestic steel mills revealed that two key trends have emerged during the last few decades.[4] First, steelmakers have increased use of electric arc furnaces, which primarily use scrap as a charge material to produce raw steel. Second, steel producers have increased continuous casting−a more efficient forming technology than ingot casting that has increased mill yields.

Today, coal makes up about eight percent of outbound tonnage from the MKARNS. Outbound lignite coal goes to terminals near New Orleans and is transferred to ships for distribution to domestic electricity producers along the Gulf Coast. Domestic processors along the Gulf Coast also import coke from the MKARNS. These firms treat coke to produce calcined petroleum coke, which ultimately finds its way into the primary aluminum and steel industry. Other uses include the production of titanium dioxide, which is used as a pigment for paint, plastics, sunscreens, and food coloring.

Like coal, outbound fertilizer shipments comprise about eight percent of MKARNs exports, primarily for domestic consumption. Outbound shipments of distillate, residual and other fuel oils (mostly diesel fuel) flow to Louisiana deep draft ports for export to foreign consumers. According to the U.S. Energy Information Administration (EIA), the largest importers of U.S. distillate fuel are Mexico, Chile, the Netherlands and Brazil. There was a significantly large increase in late 2012 and 2013 that was, in large part, due to a steep increases in world demand over the last several years. According to the EIA, in 2010, U.S. exports totaled about 239 million barrels, and by the end of 2015, this had increased to 433 million barrels.[5] The reason for the sharp decline in MKARNS exports of distillate fuel in 2014 is not clear.

Tables 1-4 and 1-5 summarize the origins and destinations of MKARNS commodities by state and waterway based on 2014 WCSC data. With the exception of outbound agricultural crops, which are shipped to deep draft ports in Louisiana for foreign world export, the bulk of goods shipped on the MKARNS flow to and from domestic producers and consumers; although some may be processed into value added goods and ultimately exported.

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[4] Brown, R.E. "Iron and Steel Scrap Statistical Compendium." U.S. Department of Interior, U.S. Geologic Survey. Accessed online at: http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel_scrap/stat/

[5] Unless otherwise stated, data regarding consumption and trade of energy commodities including distillate fuel and coal (excluding waterborne traffic) are from the U.S. Energy Information Administration. Available at: https://www.eia.gov/.

Table 1-4. Historic and Current Outbound Commodities through Study Area (2001-2014, thousands of tons)

Commodity	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Share 2014	Annual rate (2001-2014)*
Soybeans	361	399	575	486	659	742	754	830	1,086	1,364	898	907	835	1,334	28.9%	9.8%
Wheat	1,324	1,407	1,319	1,418	799	726	656	676	417	467	618	975	1,389	1,283	23.4%	-1.4%
Iron and steel	127	158	177	280	217	305	287	299	281	604	736	540	600	517	9.0%	8.9%
Fertilizer	444	603	579	487	301	464	328	382	412	302	455	543	424	431	8.7%	-0.7%
Aggregates	1,858	1,494	1,185	1,355	1,230	2,129	1,708	1,601	1,868	751	281	233	170	370	8.0%	-10.9%
Coal (lignite and coke)	79	66	164	170	168	154	150	263	310	502	515	608	546	345	6.4%	9.9%
Rye, Rice, Sorghum and Oats	396	615	697	412	603	471	332	231	228	299	206	186	204	88	1.9%	-10.2%
Distillate fuel oils	28	25	25	28	42	36	144	101	69	86	196	181	230	78	1.7%	7.6%
Corn	10	3	7	7	14	8	61	77	13	53	97	219	234	71	1.5%	15.0%
Petroleum pitches and asphalt	110	127	70	44	39	31	112	77	73	63	83	50	101	55	1.2%	-4.8%
Forest Products	73	71	33	79	96	26	21	20	42	36	41	40	0	42	0.9%	-3.9%
Building mat. and minerals	26	71	91	50	30	38	81	154	52	175	35	50	109	62	0.8%	3.5%
Pulp, Waste Products	6	4	0	59	73	57	73	46	39	46	57	24	40	29	0.6%	11.9%
Industrial chemicals	4	10	25	75	45	6	33	11	33	40	57	46	102	21	0.5%	12.6%
Equipment and Machinery	12	23	10	4	13	10	0	19	25	18	34	23	31	14	0.2%	-2.0%
Other	139	102	236	97	68	45	31	57	36	35	155	505	378	37	0.8%	-9.0%
Total	4,999	5,178	5,193	5,049	4,396	5,248	4,771	4,843	4,986	4,842	4,465	5,129	5,393	4,777	94.6%	-1.0%

* Historical data provide a reference for study projections, and are based on the data from the USACE Lock Performance Monitoring System (LPMS). Historic data from the LPMS are used to analyze long-term trends and inter-annual variation in commodity flows; however, for the baseline in study projections discussed in subsequent sections of this appendix, the analysis relies on data from the Waterborne Commerce Statistics Center. The PDT recognizes that there are minor discrepancies between LPMS and WCSC data, and WCSC data are required for planning analyses that factor into derivation of cost benefit ratios.

Table 1-5. Current Distribution of Primary Outbound Commodity Flows from the MKARNs by Origin and Destination

Commodity	Primary shipping state	Shares of tonnage	Receiving state(s)	Shares of tonnage
Building materials and minerals	Arkansas	52%	Illinois	20%
			Louisiana (primarily terminals on Lower Miss.)	27%
			Mississippi	6%
			Tennessee	21%
			Texas	15%
	Oklahoma	48%	Illinois	21%
			Louisiana (primarily river terminals)	57%
			Minnesota	6%
			Texas	5%
Coal (lignite)	Arkansas	14%	Louisiana (Port of Plaquemines)	100%
	Oklahoma	86%	Louisiana (Port of Plaquemines)	90%
Coal (coke)	Arkansas	5%	Kentucky	100%
	Oklahoma	95%	Louisiana (Lower Mississippi river)	36%
			Texas (Intra-coastal Waterway terminals)	55%
Iron and steel	Arkansas	40%	Alabama	17%
			Arkansas (Lower Mississippi river terminals)	54%
			Kentucky	16%
			Tennessee	5%
	Oklahoma	60%	Alabama	10%
			Arkansas (Lower Mississippi river terminals)	40%
			Kentucky	9%
			Louisiana	17%
			Tennessee	10%
			Texas	6%
Soybeans	Arkansas	50%	Louisiana (ports of Plaquemines and South Louisiana)	100%
	Oklahoma	50%	Louisiana (ports of Plaquemines and South Louisiana)	98%
Wheat	Arkansas	10%	Louisiana (ports of Plaquemines and South Louisiana)	97%
	Oklahoma	90%	Louisiana (ports of Plaquemines and South Louisiana)	85%

Source: Generated based on annual 2014 data from the USACE Waterborne Commerce Statistics Center.

1.2 PROJECT AREA DEMOGRAPHICS AND ECONOMY

The study area comprises portions of Arkansas and Desha counties in Southeastern, Arkansas, and with the exception of a few small nearby communities, the study area is sparsely populated and the nearest communities are at least several miles from the current project area where existing control structures reside, and include Watson (Desha County) and Gillette (Arkansas County).

Data from the 2010 Census, the U.S. Bureau of Labor Statistics, and the 2013 American Community Survey for population, employment, were used to summarize socioeconomic conditions in these counties. As shown in Table 6, both Arkansas and Desha counties have small populations relative to other areas of the state (15,341 and 20,749 respectively), and in both counties population has fallen significantly since the 2000 Census – a 20 percent reduction in Desha County and a 10 percent decrease in Arkansas County. The nearest population centers to the project site are the City of Gillette (Arkansas County) and the City of Watson. Gillette is roughly 15 miles away (straight line distance), and Watson is about 11 miles (straight line distance). Both are sparsely populated, and have also seen their numbers declines since year 2000.

Table 1-6. Existing Population Levels and Trends in Project Area

Region	2000 Population	2010 Population	2014 Population	Population percent change (2010-2014)	Population density (persons per square mile)
State of Arkansas	2,673,400	2,872,684	2,933,369	2.1%	51
Desha County, Arkansas	15,341	13,008	12,264	-20%	20
Arkansas County, Arkansas	20,749	19,019	18,594	-10%	21
Gillette (Arkansas County)	288	211	197	-32%	na
Watson (Desha County)	819	692	687	-16%	na

“na” = not available. Source: U.S. Census Bureau: 2014 American Community Survey.

Key income indicators (per capita income and median household income) for counties in the project area vary with lower values characteristic of rural counties and higher values for urban counties (Table 1-7). With exception Arkansas County, median household incomes and per capita incomes in each area are lower than state level values. The distribution of employment by occupation category in most counties tends to follow national and state allotments.

Table 1-7. Existing Employment and Income in Project Area

County	Per capita income	Median household income	Total civilian workforce	Distribution of workforce by sector				
				Management, business, science, and arts	Natural resources, construction, and maintenance	Production and transportation	Sales and office workers	Service
United States	$28,155	$53,046	141,864,697	36%	18%	25%	9%	12%
State of Arkansas	$22,170	$40,768	1,245,432	31%	17%	24%	11%	17%
Desha County, Arkansas	$19,882	$28,680	4,960	28%	17%	20%	14%	20%
Arkansas County Arkansas	$23,045	$39,633	8,681	28%	17%	20%	11%	24%
Gillette (Arkansas County)	$16,913	$25,500	49	22%	27%	6%	22%	22%
Watson (Desha County)	$19,222	$35,624	289	37%	7%	26%	18%	12%

Source: U.S. Census Bureau: 2014 American Community Survey.

Executive Order 12898, entitled "Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations," addresses potential disproportionate human health and environmental impacts that a project may have on minority or low-income communities. Thus, the environmental effects of the Project on minority and low-income communities or Native American populations must be disclosed, and agencies must evaluate projects to ensure that they do not disproportionally impact any such community. If such impacts are identified, appropriate mitigation measures must be implemented.

To determine whether a project has a disproportionate effect on potential environmental justice communities (i.e., minority or low income population), the demographics of an affected population within the vicinity of the Project must be considered in the context of the overall region. Guidance from the Council on Environmental Quality (CEQ) states that "minority populations should be identified where either: (1) the minority population of the affected areas exceeds 50 percent, or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis (CEQ 1997)."

Table 1-8 displays Census data summarizing racial, ethnic and poverty characteristics of areas adjacent to construction sites (loops and compressor stations). The purpose is to analyze whether the demographics of the affected area differ in the context of the broader region; and if so, do differences meet CEQ criteria for an Environmental Justice community. With the exception of Desha County, minority populations do not exceed reference by significant amount, and are not greater than 50 percent. In Desha County, Black or African American citizens make up 47.8 percent of the population at the county level; however, most of the county's residents live in communities along State Highway 165, which runs along the western boundary of the county and are approximately 15 to 20 miles from the project site. As a result, it is very unlikely that the project would impacts these communities. Table 6 also displays the number of children adjacent to Project areas. The purpose of the data is to assess whether the project disproportionally affects the health or safety risks to children as specified by Executive Order (E.O.) 13045 - Protection of Children from Environmental Health Risks and Safety Risks (1997). Overall, it does not appear that the Project would disproportionally affect children.

Table 1-8. Racial Composition, Number of Children and Poverty Indictors in the Upper White River Basin (percent)

Region	Racial composition						Poverty indicators		
	White	African American	Native American or Indian	Asian	Hispanic or Latino	Other or two or more races	Percent Unemployed	Percent below poverty line	Percent under age 17
United States	56.1	12.6	0.9	4.8	16.3	9.3	6.2	15.4	23.7
State of Arkansas	70.6	15.4	0.8	1.2	6.4	5.6	5.1	15.8	24.2
Desha County,	43.5	47.8	3.0	0.3	4.4	1	14.2	31.2	25.9
Arkansas County	69.1	24.5	0.2	0.5	2.7	3	8.2	16.3	23.7
Town of Gillette	66.8	29.9	0.0	0.0	1.2	2.1	0.0	21.7	7.6
Town of Watson	81.2	15.2	0.3	1.0	1.6	0.7	2.0	23.8	19.5

Source: U.S. Census Bureau: 2014 American Community Survey

1.3 RECREATIONAL RESOURCES

A substantial amount of the project area resides on state and federal properties including the Dale Bumpers White River National Wildlife Refuge operated by the U.S. Fish and Wildlife Service (USFWS) and the Trusten Holden Wildlife Management Area operated by the Arkansas Game and Fish Commission (AGFC) in conjunction with the Corps and the USFWS. In addition, some acreage of the project area is on private property owned by the Anderson Tully Timber Company. Recreation (primarily hunting and fishing) is common in each of these land holdings.

Dale Bumpers White River National Wildlife Refuge was established in 1935 for the protection of migratory birds. It is one of the most important areas for wintering waterfowl in North America. The refuge is also home to the only population of native black bear in the State of Arkansas and is designated as a Wetland of International Importance. According to the USFWS, Dale the refuge attracts about 455,000 visits each year including hunters, anglers, bird watchers and others.[6] The refuge lies mostly in the floodplain of the White River, near where the confluence of the White and Mississippi River.

Purchased in 1973, the Trusten Holder WMA contains approximately 10,268 acres. Consisting primarily of bottomland hardwoods, the area provides excellent wetlands habitat for native wildlife and migrating waterfowl. The State of Arkansas purchased the area to protect prime bottomland hardwood tracts which had been dwindling in eastern Arkansas in the early 1970s because of increased farming activities. The property is located near Norrell Lock and Dam No. 2 on the White River. Official visitation estimates are not available; however, a 2008 study (and survey of property managers) by the Arkansas Nature Conservancy estimates that 600 people visited the site in 2005.[7]

Anderson Tully Lumber Co. operates a hardwood lumber operation in the project area, and leases land to hunting clubs that in turn sub-leases land to members. Visitation estimates for the property are not available.

2. FUTURE WITHOUT PROJECT CONDITION

Section 2 lays out the future without project condition in terms of expected costs associated with operating and maintaining containment structures in the project area, and the potential impacts of a cut-off forming between the Arkansas and White Rivers. Thus, estimated costs and impacts are benefits (i.e., avoided costs) in the with-project future condition. Some material including the data and methodology for determining the probability of existing containment structures failing, and future maintenance, operation

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[6] U.S. Fish and Wildlife Service, Dale Bumpers White River National Wildlife Refuge online factsheet. Last Updated: Apr 22, 2014 at: http://www.fws.gov/refuge/White_River/about.html.

[7] Nature Conservancy of Arkansas, “The Impacts on Endangered Species from Recreation on Public Lands in the Big Woods of Arkansas,” October 2008.

and rehabilitation of existing structures come from the Ark-White Cutoff Study (2009).[8] Costs have been updated to FY2018 prices levels. Projections of future commodity flows have also been developed based recent data and macroeconomic conditions in the region, the U.S. and on a global level.

2.1 OVERVIEW OF MODEL AND ASSUMPTIONS

Project benefits stem from a comparison of without project condition costs to construction and OMRR&R[9] costs associated with alternative plans. Differences between the economic costs of an alternative and the economic costs of the without project condition will be either a positive cost savings (if costs of an alternative is less than the cost of the without project condition), or a negative cost savings (if costs of an alternative is more than the cost of the without project condition).

Two types of economic costs are in the analysis. Some occur regardless of whether or not a cut-off forms and some costs are realized only if a cut-off forms. New containment structures, and repairs and rehabilitation to existing structures will take place whether or not a cutoff forms given that the analysis assumes the Corps will continue to keep the rivers separated in the same manner as it has in the past (i.e., the business as usual scenario). Remaining costs occur only if a cutoff forms and consist of:

1) Costs associated with restrictions in commercial navigation through the project area;
2) Costs of the District's emergency contingency plan to repair a breach and resultant cut-off;
3) Increased dredging costs due to sediment deposition near the cut-off; and,
4) Costs to repair damaged infrastructure at the Montgomery Point Lock and Dam.

Similar to flood risk management analyses, costs associated with a cutoff are stochastic in nature. Thus, an important component of the study involved estimating the probability of a cutoff occurring in the future. This probability is based on a joint probability analysis using both an expert panel of hydrologists and engineers, and empirical hydrologic data for the Arkansas and White rivers. In addition, the methodology includes an analysis of risk and uncertainty inherent in civil works projects. For the Three Rivers Study, this is important because there is a significant amount of uncertainty in the future without

[8] Arkansas White River Cutoff Study: General Re-evaluation Report." USACE Little Rock District and U.S. Fish and Wildlife Service, May 2009.
[9] Operations, Maintenance, Repair, Replacement, and Rehabilitation

project condition. Economic analysis for the study relies on historical data, engineering estimates, and expert knowledge to evaluate all possible outcomes, which results in a probabilistic range of costs and benefits. Ranges (i.e., statistical confidence intervals) are generated using frequency distribution fitting tools and Monte Carlo simulation software (@Risk), which is proprietary software approved and certified by the Corps for use risk and uncertainty analysis.

The without-project condition represents the current state of the project under the assumption that the Corps continues to perform ad hoc repairs as they have in the past, and build new small scale structures to prevent cut-offs from progressing. This assumption is based on the possibility that if conditions in the area deteriorate, a cut-off between the two rivers would develop. If this cutoff forms, it is very likely that hydrologic conditions would disrupt navigation for extended periods. Additional assumptions include:

1) If a new cutoff forms, it would be approximately the same size as the historic cutoff;

2) A new cutoff would have a streambed elevation equal to that of the White and Arkansas rivers;

3) If a cutoff occurs, the Corps would close the cutoff with a structure made of sheet pile, stone and soil cement;

4) A cutoff channel would be open for 220 days after a breach occurs until the Corps could survey and evaluate conditions in the area, and then design, and implement a project to close the cut-off;

5) During the closure, conditions would be intermittently un-navigable due to cross currents and draft constraints caused by uncontrolled flows to the Arkansas River;

6) The Corps will not allow existing containment structures to degrade to less than 70 percent of their designed integrity; and,

7) The Corps will reconstruct existing containment structures when structure integrity decreases to 70 percent.

The above assumptions apply when calculating without project costs and are discussed in more detail elsewhere in this document.

The period of analysis runs through 2075 under the following assumptions:

1) A feasibility study start date of June 2015 and an end date of June 2018;
2) Project design commences 2018 and requires 2.5 years to complete;
3) Project authorization occurs in 2019; and,
4) Construction requires three years and the period of analysis is 50 years.

Thus, the base year in which project benefits begin to accrue is 2025. Also, to avoid duplication of effort and plan under the Corps SMART planning paradigm, some material used to estimate the future without project condition including data and methods for determining the probability of existing containment structures failing, and future maintenance, operation and rehabilitation of existing structures come from the Ark-White Cutoff Study.

The remainder of Section 2 discusses methods for estimating the:

1) Probability of a cutoff occurring;
2) Future costs of rehabilitating and repairing existing structures (i.e., Melinda and Jim Smith structures);
3) Costs of constructing new structures;
4) Costs of contingency repairs and damages to Montgomery Point Lock and Dam in the event of a cutoff; and,
5) NED costs of lost navigation in the event of a cutoff.

2.2 PROBABILITY OF CUTOFF

The probability of a cutoff occurring is based on expert elicitation, and a joint probability model using hydrologic frequencies developed by SWL Hydrology and Hydraulics engineers (SWL H&H). The expert opinion elicitation (EOE) process was incorporated into USACE risk protocol in the late 1990's and was developed to assist in producing best estimate probabilities for complex engineering problems such as engineering reliability analysis for dams and levees, navigation locks and hydropower facilities. For the 3-Rivers Feasibility Study, the expert panel consisted of seven scientists and engineers who were selected based on:

1) Strong relevant expertise through academic training (engineering, hydrology, geology and geochemistry), professional accomplishment and experiences, and peer-reviewed publications;
2) Familiarity and knowledge of various aspects related to the study area and the problem;

3) Willingness to acts as proponents or impartial evaluators;
4) Availability and willingness to commit needed time and effort; and
5) Specific related knowledge and expertise of issues of interest.

Attachment A at the end of this document provides a biographical sketch for panel members.

The expert elicitation took place at the Corps Little Rock District office, and included a technical facilitator, several observers and the expert panel. Prior to the workshop, SWL staff provided experts with background materials including fact sheets, a historical overview of the study area including past damages to containment structures, engineering design materials for existing containment structures, and other studies or information related to head cutting and hydrologic and geologic issues related to the study. These included a contract study completed in 2000 by FTN Associates entitled the "Arkansas-White River Cutoff Analysis," which modeled and analyzed historic flow regimes (discharge elevation frequency) in the study area using hydraulic models.

The workshop lasted three days with the first day focusing on discussions of background materials and study objectives, a description of the study area including hydrology and geomorphic processes affecting head-cutting and containment structures, and the overall elicitation process. The group also discussed potential sources of bias such as overconfidence, wanting to influence decisions and funding allocations, or preconceived notions that they would be evaluated by superiors as a result of their answers. Day 2 consisted of a field trip to the study area where the panel inspected the Jim Smith, Owens Lake and Melinda structures and observed and discussed other geophysical and hydrologic conditions in the study area.

The elicitation, which involved an undisclosed (blind) tally, took place on the third day of the workshop. Before providing estimates, the facilitator led a technical discussion of the issue such as the condition of containment structures, head-cutting in the isthmus (past, present and expected), head differential and duration frequencies for the Arkansas and White rivers, and hydrologic events that impact the Mississippi River in conjunction with the Arkansas and White. The panel were also given the assumptions that: 1) more than one cutoff would not occur in any given year, 2) any cutoff that formed would be 1,100 feet wide with a bottom elevation of 110 feet (mean sea level), and 3) containment structures were in a fully rehabilitated and repaired state. Then, matrices showing head differentials and duration combinations were provided to the panel, who then provided conditional probabilities of a breach of containment structures, and subsequent cut-off formation. Presenting the elicitation in terms of conditional probabilities had the benefit of simplifying the question by decomposing the problem. Experts were also asked to provide their level of confidence in their estimates, and each had high confidence in their respective values. Results for the panel were aggregated across all head differential and duration combinations to arrive a baseline (i.e., year 1 of the period of analysis) probability estimate along with descriptive statistics (mean, median, standard deviation, maximum, and minimum). Descriptive statistics were reviewed and discussed, and the panel was given an opportunity to revise their initial estimates.

Panel members provided their estimates (i.e., educated best guess) of the probability of a cutoff occurring given a predetermined set of hydrologic conditions for the Arkansas and White rivers. Specially, the panel applied expert judgment to determine the probability given different combinations of head differentials between the two rivers, and the duration of each head differential represented by the expression P(B|H&D) where:

H = Head differential between two rivers in feet,
D = Duration of the head differential in days,
B = Cutoff occurring; and,
P = Probability of cutoff occurring under conditional on head differential and duration.

Historical data generated by SWL Hydrology and Hydraulics (H&H) provided estimates regarding the frequency at which head differentials and durations occur. These estimates were then combined with the expert panel's probability estimates of a cutoff developing– a process that incorporates the law of total probability and Bayes' rule, which in a general framework states:

$S = B_1 \cup B_2 \cup ... \cup B_k$ and $B_i \cap B_j = 0$ for $i \neq j$ and where S is the sample space.

Assuming $B_1, B_2, \ldots, B_k$ is a partition of S such that $P(B_i)>0$, for i = 1, 2,…,k then:

$$P(B_j \mid A) = \frac{P(A \mid B_j)P(B_j)}{\sum_{i=1}^{k} P(A \mid B_i)P(B_i)}$$

The frequency (i.e., probability) at which head differentials have occurred in the project area is represented by P(H). Most observed head differentials in the historical record presented with a differential of zero feet (85 percent of the time).[10] The Arkansas River had a higher water surface elevation than the White less than five percent of the time, and the most frequent observation was a one foot head differential, and the least frequent observation was a differential of 25 feet. Remaining observations indicate that

[10] For the purposes of this study, a head differential of zero indicates the water surface elevations of the rivers are equal or neither river has a water surface elevation that is high enough to overtop existing containment structures.

the White River's surface elevation was greater than the Arkansas' about 10 percent of the time with the high and low frequencies being head differentials of two and 25 feet, respectively.

In addition to head differentials, historical data provided the duration frequency of each differential - P(D|H). For example, the probability that the relatively rare and extreme event in which the Arkansas was 25 feet higher than the White lasted one to two days was 100 percent. The frequency or probability that it lasted longer than 2 days was zero. In other words, it has not lasted more than two days based on the historical record. Table 2-1 shows different P(H) and P(D|H) combinations.

Table 2-1
Frequency of Head Differentials between the Arkansas and White Rivers, and Frequency of Duration

Head differential (feet) *	Frequency of head differential P(H)	Frequency of duration of head differential P(D|H)											
		1-2 Days	2-3 Days	3-4 Days	4-5 Days	5-6 Days	6-7 Days	1-2 Weeks	2-3 Weeks	3-4 Weeks	1-2 Months	2-3 Months	3+ Months
-25 or more	0.02%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
-20 to -25	0.23%	43.93%	16.67%	11.83%	9.17%	7.50%	6.34%	4.57%	0.00%	0.00%	0.00%	0.00%	0.00%
-15 to -20	0.31%	49.56%	11.33%	8.04%	6.24%	5.10%	4.31%	15.42%	0.00%	0.00%	0.00%	0.00%	0.00%
-10 to -15	0.78%	34.38%	12.11%	8.59%	6.66%	5.44%	4.60%	20.70%	7.50%	0.00%	0.00%	0.00%	0.00%
-5 to -10	0.77%	27.07%	14.48%	10.27%	7.97%	6.51%	5.50%	24.75%	3.46%	0.00%	0.00%	0.00%	0.00%
-4 to -5	0.39%	48.08%	15.68%	11.13%	8.63%	7.05%	5.96%	3.48%	0.00%	0.00%	0.00%	0.00%	0.00%
-3 to -4	0.60%	37.32%	15.14%	10.74%	8.33%	6.81%	5.76%	15.89%	0.00%	0.00%	0.00%	0.00%	0.00%
-2 to -3	0.69%	31.12%	16.99%	12.05%	9.35%	7.64%	6.46%	16.39%	0.00%	0.00%	0.00%	0.00%	0.00%
-1 to -2	0.99%	31.33%	12.41%	8.80%	6.83%	5.58%	4.72%	21.21%	9.12%	0.00%	0.00%	0.00%	0.00%
0	85.27%	22.64%	12.15%	8.62%	6.69%	5.46%	4.62%	20.77%	12.15%	6.90%	0.00%	0.00%	0.00%
1 to 2	1.49%	27.12%	11.30%	8.01%	6.22%	5.08%	4.29%	19.31%	11.30%	7.38%	0.00%	0.00%	0.00%
2 to 3	1.66%	28.64%	10.71%	7.60%	5.89%	4.81%	4.07%	18.30%	10.71%	9.28%	0.00%	0.00%	0.00%
3 to 4	1.28%	20.92%	14.25%	10.11%	7.84%	6.41%	5.42%	24.35%	10.71%	0.00%	0.00%	0.00%	0.00%
4 to 5	1.03%	33.88%	13.44%	9.54%	7.40%	6.04%	5.11%	22.98%	1.61%	0.00%	0.00%	0.00%	0.00%
5 to 6	1.15%	10.86%	16.36%	11.61%	9.00%	7.36%	6.22%	27.97%	10.63%	0.00%	0.00%	0.00%	0.00%
6 to 7	1.50%	19.88%	12.38%	8.78%	6.81%	5.57%	4.71%	21.16%	12.38%	8.34%	0.00%	0.00%	0.00%
7 to 8	1.02%	30.42%	8.93%	6.34%	4.91%	4.02%	3.39%	15.27%	8.93%	7.86%	9.94%	0.00%	0.00%
8 to 9	0.40%	45.01%	12.52%	8.88%	6.89%	5.63%	4.76%	16.30%	0.00%	0.00%	0.00%	0.00%	0.00%
9 to 10	0.06%	57.69%	13.50%	9.58%	7.43%	6.07%	5.13%	0.60%	0.00%	0.00%	0.00%	0.00%	0.00%
10 to 15	0.18%	34.97%	11.24%	7.97%	6.18%	5.05%	4.27%	19.21%	11.10%	0.00%	0.00%	0.00%	0.00%
15 to 20	0.18%	8.01%	11.57%	8.21%	6.36%	5.20%	4.40%	19.77%	11.57%	10.17%	14.75%	0.00%	0.00%
20 to 25	0.01%	72.22%	13.00%	9.22%	5.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
25 or more	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

* Head differentials are measured from White to Arkansas. Source: Generated from historical data by the Hydraulics and Hydrology Section, Corps of Engineers Little Rock District.

From the information in Table 2-1 once can determine the probability of having both the amount of head and the duration of that head − P(H&D). For example, the probability of the White River being 20 to 20 to 25 feet below the Arkansas for one to two days is 0.02 percent multiplied by 100 percent or 0.10 percent − P(H) x P(D|H), or the probability of the Arkansas being lower than the White by 5 to 6 feet for 1 to 2 weeks is 0.32 percent. The sum of all probabilities is 100 percent hence the law of total probability. Table 2-2 shows different P(H) x P(D|H) combinations.

Table 2-2
Probability of Head Differentials Given a Specific Duration

Head differential (feet) *	1-2 Days	2-3 Days	3-4 Days	4-5 Days	5-6 Days	6-7 Days	1-2 Weeks	2-3 Weeks	3-4 Weeks	1-2 Months	2-3 Months	3+ Months
-25 or more	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
-20 to -25	0.10%	0.04%	0.03%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
-15 to -20	0.15%	0.04%	0.03%	0.02%	0.02%	0.01%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%
-10 to -15	0.27%	0.09%	0.07%	0.05%	0.04%	0.04%	0.16%	0.06%	0.00%	0.00%	0.00%	0.00%
-5 to -10	0.21%	0.11%	0.08%	0.06%	0.05%	0.04%	0.19%	0.03%	0.00%	0.00%	0.00%	0.00%
-4 to -5	0.19%	0.06%	0.04%	0.03%	0.03%	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
-3 to -4	0.22%	0.09%	0.06%	0.05%	0.04%	0.03%	0.09%	0.00%	0.00%	0.00%	0.00%	0.00%
-2 to -3	0.21%	0.12%	0.08%	0.06%	0.05%	0.04%	0.11%	0.00%	0.00%	0.00%	0.00%	0.00%
-1 to -2	0.31%	0.12%	0.09%	0.07%	0.06%	0.05%	0.21%	0.09%	0.00%	0.00%	0.00%	0.00%
0	19.30%	10.36%	7.35%	5.70%	4.66%	3.94%	17.71%	10.36%	5.88%	0.00%	0.00%	0.00%
1 to 2	0.40%	0.17%	0.12%	0.09%	0.08%	0.06%	0.29%	0.17%	0.11%	0.00%	0.00%	0.00%
2 to 3	0.48%	0.18%	0.13%	0.10%	0.08%	0.07%	0.30%	0.18%	0.15%	0.00%	0.00%	0.00%
3 to 4	0.27%	0.18%	0.13%	0.10%	0.08%	0.07%	0.31%	0.14%	0.00%	0.00%	0.00%	0.00%
4 to 5	0.35%	0.14%	0.10%	0.08%	0.06%	0.05%	0.24%	0.02%	0.00%	0.00%	0.00%	0.00%
5 to 6	0.12%	0.19%	0.13%	0.10%	0.08%	0.07%	0.32%	0.12%	0.00%	0.00%	0.00%	0.00%
6 to 7	0.30%	0.19%	0.13%	0.10%	0.08%	0.07%	0.32%	0.19%	0.13%	0.00%	0.00%	0.00%
7 to 8	0.31%	0.09%	0.06%	0.05%	0.04%	0.03%	0.16%	0.09%	0.08%	0.10%	0.00%	0.00%
8 to 9	0.18%	0.05%	0.04%	0.03%	0.02%	0.02%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%
9 to 10	0.03%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10 to 15	0.06%	0.02%	0.01%	0.01%	0.01%	0.01%	0.04%	0.02%	0.00%	0.00%	0.00%	0.00%
15 to 20	0.01%	0.02%	0.02%	0.01%	0.01%	0.01%	0.04%	0.02%	0.02%	0.03%	0.00%	0.00%
20 to 25	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
25 or more	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

* Head differentials are measured from White to Arkansas. Source: Generated from historical data by the Hydraulics and Hydrology Section, Corps of Engineers Little Rock District.

Figures in Table 2-2 form one half of the equation to estimate the probability of a cutoff, and the second half are the estimates from the expert panel. The expression P(B|H&D) defines the cutoff probability (referred to herein as the joint breach probability). In other words, the probability of cutoff occurring P(B) given the probability of head and different combinations (H&D). Figure 3 illustrates the process. Tables 2-3 through 2-9 display cutoff probabilities for each panel member in the without project condition, and the sum of all cells in each table is the total probability that a cutoff could happen in the second year of the analysis period. As explained in subsequent discussion, the probability changes over the planning period as containment structures deteriorate and are rehabilitated.

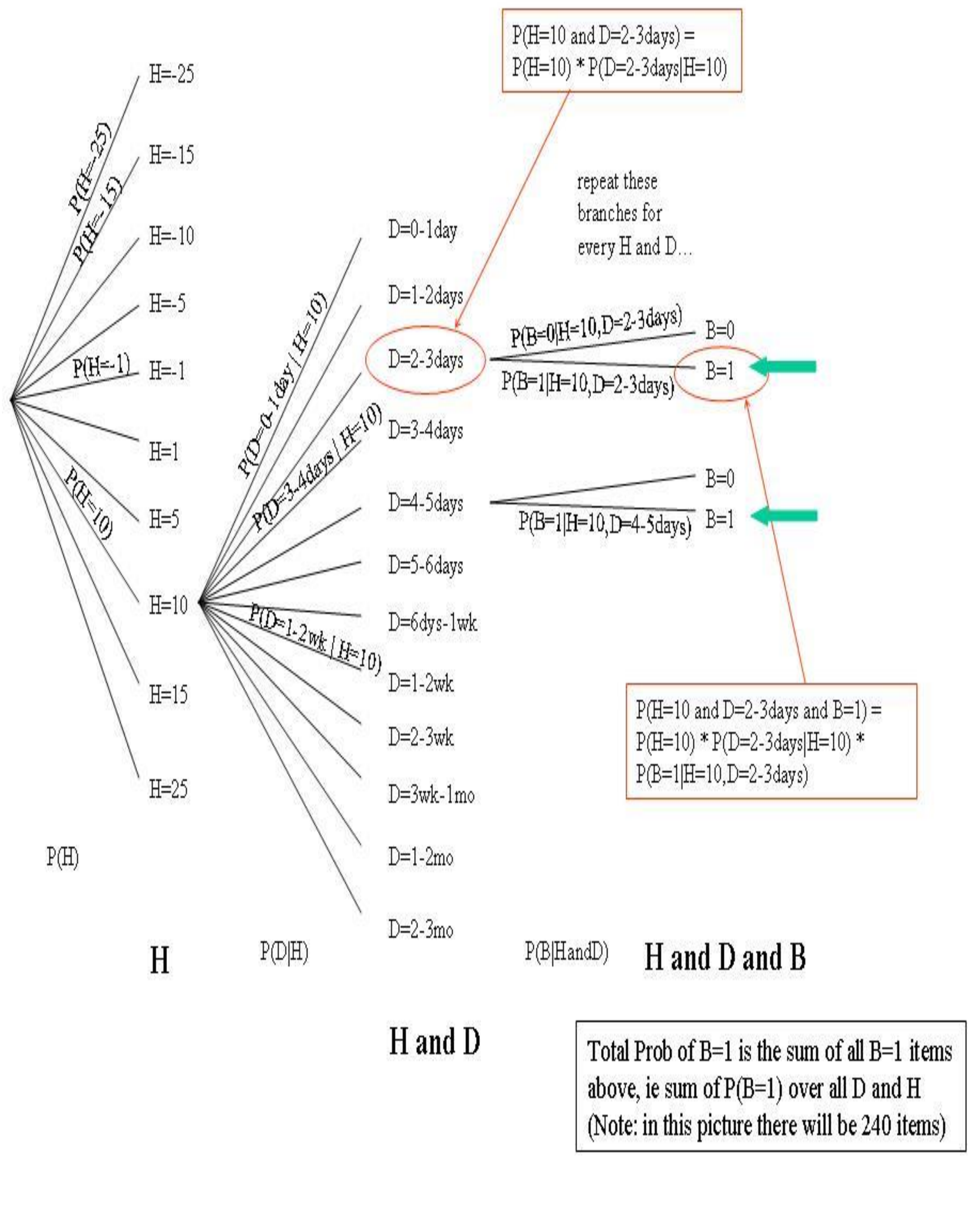

Figure 3. Illustration of Joint Probability Analysis for the Future without Project Condition

Table 2-3
Joint Breach Probability Estimates for Expert Panel Member Dr. Leroy Arnold
(Future without Project Condition)

Head differential (feet) *	1-2 Days	2-3 Days	3-4 Days	4-5 Days	5-6 Days	6-7 Days	1-2 Weeks	2-3 Weeks	3-4 Weeks	1-2 Months	2-3 Months	3+ Months
-25 or more	0.012%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-20 to -25	0.041%	0.019%	0.016%	0.015%	0.017%	0.015%	0.011%	0.000%	0.000%	0.000%	0.000%	0.000%
-15 to -20	0.046%	0.012%	0.010%	0.010%	0.010%	0.011%	0.048%	0.000%	0.000%	0.000%	0.000%	0.000%
-10 to -15	0.027%	0.019%	0.017%	0.016%	0.017%	0.018%	0.097%	0.059%	0.000%	0.000%	0.000%	0.000%
-5 to -10	0.002%	0.006%	0.008%	0.009%	0.010%	0.011%	0.057%	0.009%	0.000%	0.000%	0.000%	0.000%
-4 to -5	0.002%	0.003%	0.006%	0.006%	0.005%	0.004%	0.003%	0.000%	0.000%	0.000%	0.000%	0.000%
-3 to -4	0.002%	0.001%	0.001%	0.001%	0.001%	0.001%	0.005%	0.000%	0.000%	0.000%	0.000%	0.000%
-2 to -3	0.002%	0.001%	0.001%	0.006%	0.005%	0.005%	0.017%	0.000%	0.000%	0.000%	0.000%	0.000%
-1 to -2	0.003%	0.001%	0.001%	0.001%	0.003%	0.005%	0.042%	0.023%	0.000%	0.000%	0.000%	0.000%
0	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
1 to 2	0.004%	0.002%	0.002%	0.001%	0.004%	0.006%	0.057%	0.042%	0.033%	0.000%	0.000%	0.000%
2 to 3	0.005%	0.002%	0.002%	0.010%	0.008%	0.008%	0.046%	0.018%	0.023%	0.000%	0.000%	0.000%
3 to 4	0.003%	0.003%	0.002%	0.002%	0.002%	0.002%	0.016%	0.014%	0.000%	0.000%	0.000%	0.000%
4 to 5	0.003%	0.007%	0.015%	0.013%	0.011%	0.010%	0.047%	0.006%	0.000%	0.000%	0.000%	0.000%
5 to 6	0.001%	0.009%	0.013%	0.015%	0.017%	0.018%	0.096%	0.043%	0.000%	0.000%	0.000%	0.000%
6 to 7	0.003%	0.003%	0.002%	0.010%	0.013%	0.011%	0.064%	0.074%	0.075%	0.000%	0.000%	0.000%
7 to 8	0.003%	0.001%	0.001%	0.008%	0.010%	0.010%	0.062%	0.050%	0.056%	0.086%	0.000%	0.000%
8 to 9	0.002%	0.005%	0.005%	0.005%	0.008%	0.008%	0.032%	0.000%	0.000%	0.000%	0.000%	0.000%
9 to 10	0.003%	0.001%	0.001%	0.001%	0.001%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
10 to 15	0.006%	0.004%	0.004%	0.003%	0.004%	0.004%	0.021%	0.020%	0.000%	0.000%	0.000%	0.000%
15 to 20	0.004%	0.007%	0.006%	0.006%	0.006%	0.006%	0.037%	0.021%	0.019%	0.027%	0.000%	0.000%
20 to 25	0.002%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
25 feet or more	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
					Joint breach probability = 2.30%							

* Head differentials are measured from White to Arkansas. Source: Generated from historical data by the Hydraulics and Hydrology Section, Corps of Engineers Little Rock District and expert panel convened for the study.

Table 2-4
Joint Breach Probability Estimates for Expert Panel Member Dr. David Biedenharn
(Future without Project Condition)

Head differential (feet) *	1-2 Days	2-3 Days	3-4 Days	4-5 Days	5-6 Days	6-7 Days	1-2 Weeks	2-3 Weeks	3-4 Weeks	1-2 Months	2-3 Months	3+ Months
-25 or more	0.002%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-20 to -25	0.005%	0.004%	0.007%	0.009%	0.012%	0.015%	0.011%	0.000%	0.000%	0.000%	0.000%	0.000%
-15 to -20	0.000%	0.002%	0.003%	0.005%	0.006%	0.009%	0.048%	0.000%	0.000%	0.000%	0.000%	0.000%
-10 to -15	0.000%	0.000%	0.003%	0.008%	0.011%	0.014%	0.113%	0.059%	0.000%	0.000%	0.000%	0.000%
-5 to -10	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.010%	0.003%	0.000%	0.000%	0.000%	0.000%
-4 to -5	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-3 to -4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-2 to -3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-1 to -2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
0	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
1 to 2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
2 to 3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
3 to 4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
4 to 5	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%
5 to 6	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.016%	0.012%	0.000%	0.000%	0.000%	0.000%
6 to 7	0.000%	0.000%	0.000%	0.000%	0.000%	0.004%	0.032%	0.037%	0.038%	0.000%	0.000%	0.000%
7 to 8	0.000%	0.000%	0.000%	0.000%	0.002%	0.003%	0.031%	0.027%	0.040%	0.071%	0.000%	0.000%
8 to 9	0.000%	0.000%	0.000%	0.001%	0.002%	0.004%	0.019%	0.000%	0.000%	0.000%	0.000%	0.000%
9 to 10	0.000%	0.000%	0.000%	0.000%	0.001%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
10 to 15	0.000%	0.000%	0.001%	0.002%	0.002%	0.003%	0.025%	0.020%	0.000%	0.000%	0.000%	0.000%
15 to 20	0.000%	0.001%	0.002%	0.003%	0.004%	0.006%	0.037%	0.021%	0.019%	0.027%	0.000%	0.000%
20 to 25	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
25 or more	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
					Joint breach probability = 0.87%							

* Head differentials are measured from White to Arkansas. Source: Generated from historical data by the Hydraulics and Hydrology Section, Corps of Engineers Little Rock District and expert panel convened for the study.

Table 2-5
Joint Breach Probability Estimates for Expert Panel Member Mr. Mitch Eggburn
(Future without Project Condition)

Head differential (feet) *	1-2 Days	2-3 Days	3-4 Days	4-5 Days	5-6 Days	6-7 Days	1-2 Weeks	2-3 Weeks	3-4 Weeks	1-2 Months	2-3 Months	3+ Months
-25 or more	0.004%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-20 to -25	0.025%	0.010%	0.014%	0.011%	0.009%	0.011%	0.008%	0.000%	0.000%	0.000%	0.000%	0.000%
-15 to -20	0.039%	0.009%	0.013%	0.010%	0.008%	0.010%	0.036%	0.000%	0.000%	0.000%	0.000%	0.000%
-10 to -15	0.027%	0.009%	0.017%	0.013%	0.021%	0.027%	0.121%	0.044%	0.000%	0.000%	0.000%	0.000%
-5 to -10	0.000%	0.006%	0.008%	0.006%	0.005%	0.021%	0.095%	0.013%	0.000%	0.000%	0.000%	0.000%
-4 to -5	0.000%	0.000%	0.002%	0.002%	0.001%	0.006%	0.003%	0.000%	0.000%	0.000%	0.000%	0.000%
-3 to -4	0.000%	0.000%	0.000%	0.000%	0.002%	0.003%	0.009%	0.000%	0.000%	0.000%	0.000%	0.000%
-2 to -3	0.000%	0.000%	0.000%	0.000%	0.000%	0.002%	0.006%	0.000%	0.000%	0.000%	0.000%	0.000%
-1 to -2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
0	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
1 to 2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.005%	0.000%	0.000%	0.000%
2 to 3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.009%	0.008%	0.000%	0.000%	0.000%
3 to 4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.016%	0.007%	0.000%	0.000%	0.000%	0.000%
4 to 5	0.000%	0.000%	0.000%	0.000%	0.000%	0.003%	0.012%	0.001%	0.000%	0.000%	0.000%	0.000%
5 to 6	0.000%	0.000%	0.000%	0.000%	0.004%	0.004%	0.016%	0.030%	0.000%	0.000%	0.000%	0.000%
6 to 7	0.000%	0.000%	0.000%	0.005%	0.004%	0.004%	0.079%	0.093%	0.094%	0.000%	0.000%	0.000%
7 to 8	0.000%	0.000%	0.003%	0.003%	0.002%	0.009%	0.078%	0.068%	0.080%	0.101%	0.000%	0.000%
8 to 9	0.000%	0.002%	0.002%	0.001%	0.006%	0.009%	0.048%	0.000%	0.000%	0.000%	0.000%	0.000%
9 to 10	0.002%	0.000%	0.000%	0.001%	0.002%	0.002%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
10 to 15	0.003%	0.001%	0.004%	0.003%	0.007%	0.006%	0.035%	0.020%	0.000%	0.000%	0.000%	0.000%
15 to 20	0.001%	0.002%	0.004%	0.009%	0.007%	0.006%	0.037%	0.021%	0.019%	0.027%	0.000%	0.000%
20 to 25	0.001%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
25 or more	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
					Joint breach probability = 1.71%							

* Head differentials are measured from White to Arkansas. Source: Generated from historical data by the Hydraulics and Hydrology Section, Corps of Engineers Little Rock District and expert panel convened for the study.

Table 2-6
Joint Breach Probability Estimates for Expert Panel Member Dr. Steve Haase
(Future without Project Condition)

Head differential (feet) *	1-2 Days	2-3 Days	3-4 Days	4-5 Days	5-6 Days	6-7 Days	1-2 Weeks	2-3 Weeks	3-4 Weeks	1-2 Months	2-3 Months	3+ Months
-25 or more	0.004%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-20 to -25	0.025%	0.010%	0.007%	0.011%	0.013%	0.011%	0.008%	0.000%	0.000%	0.000%	0.000%	0.000%
-15 to -20	0.000%	0.000%	0.000%	0.000%	0.004%	0.003%	0.012%	0.000%	0.000%	0.000%	0.000%	0.000%
-10 to -15	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-5 to -10	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-4 to -5	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-3 to -4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-2 to -3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-1 to -2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
0	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
1 to 2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
2 to 3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
3 to 4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
4 to 5	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
5 to 6	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
6 to 7	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
7 to 8	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.025%	0.000%	0.000%
8 to 9	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
9 to 10	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
10 to 15	0.000%	0.000%	0.000%	0.003%	0.002%	0.002%	0.018%	0.015%	0.000%	0.000%	0.000%	0.000%
15 to 20	0.000%	0.005%	0.004%	0.006%	0.007%	0.006%	0.027%	0.021%	0.019%	0.027%	0.000%	0.000%
20 to 25	0.002%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
25 or more	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
					Joint breach probability = 0.30%							

* Head differentials are measured from White to Arkansas. Source: Generated from historical data by the Hydraulics and Hydrology Section, Corps of Engineers Little Rock District and expert panel convened for the study.

Table 2-7
Joint Breach Probability Estimates for Expert Panel Member Mr. Elmo Webb
(Future without Project Condition)

Head differential (feet) *	1-2 Days	2-3 Days	3-4 Days	4-5 Days	5-6 Days	6-7 Days	1-2 Weeks	2-3 Weeks	3-4 Weeks	1-2 Months	2-3 Months	3+ Months
-25 or more	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-20 to -25	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-15 to -20	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-10 to -15	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%
-5 to -10	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-4 to -5	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-3 to -4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-2 to -3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-1 to -2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
0	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
1 to 2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
2 to 3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
3 to 4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
4 to 5	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
5 to 6	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
6 to 7	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
7 to 8	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
8 to 9	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
9 to 10	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
10 to 15	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
15 to 20	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%	0.000%	0.000%
20 to 25	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
25 or more	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
					Joint breach probability = 0.005%							

* Head differentials are measured from White to Arkansas. Source: Generated from historical data by the Hydraulics and Hydrology Section, Corps of Engineers Little Rock District and expert panel convened for the study.

Table 2-8
Joint Breach Probability Estimates for Expert Panel Member Mr. Nick Mitchell
(Future without Project Condition)

Head differential (feet) *	1-2 Days	2-3 Days	3-4 Days	4-5 Days	5-6 Days	6-7 Days	1-2 Weeks	2-3 Weeks	3-4 Weeks	1-2 Months	2-3 Months	3+ Months
-25 or more	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-20 to -25	0.000%	0.000%	0.000%	0.000%	0.000%	0.003%	0.004%	0.000%	0.000%	0.000%	0.000%	0.000%
-15 to -20	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.005%	0.000%	0.000%	0.000%	0.000%	0.000%
-10 to -15	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-5 to -10	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-4 to -5	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-3 to -4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-2 to -3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-1 to -2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
0	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
1 to 2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
2 to 3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
3 to 4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
4 to 5	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
5 to 6	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
6 to 7	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.025%	0.000%	0.000%	0.000%
7 to 8	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.009%	0.016%	0.061%	0.000%	0.000%
8 to 9	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.006%	0.000%	0.000%	0.000%	0.000%	0.000%
9 to 10	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
10 to 15	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%	0.007%	0.006%	0.000%	0.000%	0.000%	0.000%
15 to 20	0.000%	0.000%	0.000%	0.000%	0.001%	0.002%	0.015%	0.011%	0.019%	0.027%	0.000%	0.000%
20 to 25	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
25 or more	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
					Joint breach probability = 0.22%							

* Head differentials are measured from White to Arkansas. Source: Generated from historical data by the Hydraulics and Hydrology Section, Corps of Engineers Little Rock District and expert panel convened for the study.

Table 2-9
Joint Breach Probability Estimates for Expert Panel Member Mr. Glen Raiable
(Future without Project Condition)

Head differential (feet) *	1-2 Days	2-3 Days	3-4 Days	4-5 Days	5-6 Days	6-7 Days	1-2 Weeks	2-3 Weeks	3-4 Weeks	1-2 Months	2-3 Months	3+ Months
-25 or more	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-20 to -25	0.000%	0.000%	0.000%	0.000%	0.002%	0.002%	0.002%	0.000%	0.000%	0.000%	0.000%	0.000%
-15 to -20	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-10 to -15	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.006%	0.000%	0.000%	0.000%	0.000%
-5 to -10	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-4 to -5	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-3 to -4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-2 to -3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
-1 to -2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
0	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
1 to 2	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
2 to 3	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
3 to 4	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
4 to 5	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
5 to 6	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
6 to 7	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.032%	0.028%	0.025%	0.000%	0.000%	0.000%
7 to 8	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.016%	0.014%	0.020%	0.051%	0.000%	0.000%
8 to 9	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.006%	0.000%	0.000%	0.000%	0.000%	0.000%
9 to 10	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
10 to 15	0.000%	0.000%	0.000%	0.000%	0.001%	0.002%	0.011%	0.010%	0.000%	0.000%	0.000%	0.000%
15 to 20	0.000%	0.000%	0.000%	0.001%	0.002%	0.002%	0.015%	0.013%	0.013%	0.022%	0.000%	0.000%
20 to 25	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
25 or more	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
					Joint breach probability = 0.30%							

* Head differentials are measured from White to Arkansas. Source: Generated from historical data by the Hydraulics and Hydrology Section, Corps of Engineers Little Rock District and expert panel convened for the study.

Based on the expert panel's judgment given historical frequencies and duration of head differentials on the Arkansas and White rivers, Table 2-10 displays the probabilities of a breach occurring in year 2 of the future without project. There was considerable variance in the responses provided for the baseline year 1 probability. Opinions ranged from a low of 0.005 percent to a high of 2.30 percent with a mean of 0.81 percent, a median of 0.30 percent, and standard deviation of 0.87 percent. In the NED analysis, the USACE relies on the mean across all experts that includes the exceptionally low value of expert number 5 (0.005 percent). Other than being much lower than the other experts, there is no apparent basis to disregard expert no. 5's low value even though it appears to be an outlier. It would be arbitrary to dismiss the value without some reasonable justification such as the expert had strong bias, which did not appear to be the case. If the lowest opinion value is eliminated, the mean and median for the baseline converge, but do not change drastically (the mean becomes 0.95 versus 0.87, and the median is 0.59 versus 0.31).

While it is true that a different panel of experts, assuming the USACE could assemble one with individuals with similar credentials and experience, it is unlikely that the responses would fall significantly outside the current ranges. However, it is possible that the responses might cluster around values in the current range resulting in less variation in the estimates. For example, three experts reported value ranging from 0.22 percent to 0.30 percent, and two reported values of 1.71 and 2.30 percent. If a different expert panel estimated values with less variation, but within a similar range (perhaps 0.10 to 0.50 or 1.00 to 3.00 percent), the baseline values would be higher or lower, but on average over the 50-year period analysis values tend to converge to around 7 to 8 percent regardless of the baseline.

Table 2-10
Expert Panel Results for Baseline and Mean Over Period of Analysis

	Baseline (year 1)	Mean over Period of Analysis
Expert 1	2.30%	8.50%
Expert 2	0.87%	7.79%
Expert 3	1.71%	8.34%
Expert 4	0.30%	7.89%
Expert 5	0.005%	3.61%
Expert 6	0.22%	7.75%
Expert 7	0.29%	7.83%
Standard Deviation	0.87%	1.69%
Mean	0.81%	7.39%
Median	0.30%	7.83%
Minimum	0.005%	3.61%
Maximum	2.30%	8.50%

2.3 Deterioration of Existing Structures

As noted above the expert's estimates are for the second year of the planning horizon, and the probability increases as existing containment structures deteriorate. Before providing their estimates of the probability of breach, the panel assumed that existing structures were in a fully repaired state; and thus, the initial probabilities apply to the first year of the future without project condition. As time progresses, however, structures deteriorate each year, and if cutoff probabilities were held constant over the entire period of analysis, they would be overly conservative for years 2 through 50 of the analysis.

To address the conservative nature of the calculations for all years other than the first and second years of the analysis, a growth function was estimated to determine the degree to which the structures deteriorate. The expert panel assessed each structure's structural integrity (i.e., Melinda and Jim Smith), and after inspecting the structures and comparing to design documents and photographs taken shortly after construction, the team estimated their structural integrity in terms of a percent confidence level. In 2006 the team was 80 percent confident that the Owens Lake structure was structurally sound versus 95 percent shortly after construction. In contrast, given its location and the hydrologic forces impacting it, the team had much less confidence in the Melinda Structure (65 percent after construction and only 20 percent at the time of the field visit). Based on the above changes in structural integrity, decay rates were calculated for both structures (1.1528 for Melinda and 1.045 for Owens Lake). At the time, the Jim Smith structure was relatively new (built in 2004); however, District engineers concluded that the rate of deterioration for Jim Smith and Melinda is very similar given their location and the hydrologic forces affecting each structure. Thus, the analysis assumes that the Jim Smith structure deteriorates at the same rate as the Melinda Structure.

Using estimated rates of deterioration, the probability of cutoff occurring in years 2 through 50 is:

$$P_1 = P_0(1+r)^t$$

where "P" is equal to the probability of a breach, "t" is time (year), and "r" is the rate of change for the probability of a breach.

As discussed above, assuming that the probability of a breach remains constant over a 50-year period is unrealistic. Likewise, assuming that the structures deteriorate indefinitely over the planning horizon is also unreasonable. Therefore, based on discussions with District leadership and engineers, it was assumed that SWL would not let the annual probability of failure exceed 30 percent. When the probability of failure approaches 30 percent, the District would rehabilitate structures to a degree where the rehabilitated structure had a one percent probability of failure.

In 2016, the analysis assumes the structures are fully repaired, and then each deteriorates accordingly. In years 2025 through 2075, the probability increases at rates described above until the probability approaches 30 percent. At this point, it is assumed that the Corps rehabilitates each structure to a level in which the probability of failure was 1.0 percent. Section 2.4 discusses the costs and timing of rehabilitating each structure in detail. Table 2-10 below show breach probabilities for years 1 through 50.

Table 2-10
Joint Breach Probability Estimates for Future Without Project Condition (Years 2016 through 2075)

Year	Arnold	Biedenharn	Eggburn	Haase	Webb	Mitchell	Raible
2016	2.30%	0.87%	1.71%	0.30%	0.005%	0.22%	0.29%
2017	3.05%	1.16%	2.28%	0.40%	0.006%	0.29%	0.39%
2018	3.52%	1.34%	2.63%	0.46%	0.007%	0.33%	0.45%
2019	4.06%	1.54%	3.03%	0.53%	0.009%	0.39%	0.52%
2020	4.68%	1.78%	3.49%	0.61%	0.010%	0.44%	0.60%
2021	5.39%	2.05%	4.02%	0.70%	0.011%	0.51%	0.69%
2022	6.22%	2.36%	4.64%	0.81%	0.013%	0.59%	0.80%
2023	7.17%	2.72%	5.34%	0.93%	0.015%	0.68%	0.92%
2024	8.26%	3.13%	6.16%	1.08%	0.017%	0.78%	1.06%
2025	9.52%	3.61%	7.10%	1.24%	0.02%	0.90%	1.22%
2026	10.98%	4.17%	8.19%	1.43%	0.02%	1.04%	1.41%
2027	12.66%	4.80%	9.44%	1.65%	0.03%	1.20%	1.62%
2028	14.59%	5.54%	10.88%	1.90%	0.03%	1.39%	1.87%
2029	16.82%	6.38%	12.54%	2.19%	0.04%	1.60%	2.16%
2030	19.39%	7.36%	14.46%	2.53%	0.04%	1.84%	2.49%
2031	22.35%	8.48%	16.66%	2.91%	0.05%	2.12%	2.86%
2032	25.76%	9.78%	19.21%	3.36%	0.05%	2.45%	3.30%
2033	29.70%	11.27%	22.14%	3.87%	0.06%	2.82%	3.81%
2034	1.00%	12.99%	25.53%	4.46%	0.07%	3.25%	4.39%
2035	1.15%	14.97%	29.43%	5.14%	0.08%	3.75%	5.06%
2036	1.33%	17.26%	1.71%	5.93%	0.10%	4.32%	5.83%
2037	1.53%	19.90%	1.00%	6.84%	0.11%	4.98%	6.72%
2038	1.77%	22.94%	1.33%	7.88%	0.13%	5.74%	7.75%
2039	2.04%	26.44%	1.53%	9.08%	0.15%	6.62%	8.93%
2040	2.35%	1.00%	1.77%	10.47%	0.17%	7.63%	10.30%
2041	2.71%	1.15%	2.04%	12.07%	0.19%	8.80%	11.87%
2042	3.12%	1.33%	2.35%	13.92%	0.22%	10.14%	13.68%
2043	3.59%	1.53%	2.71%	16.04%	0.26%	11.69%	15.78%
2044	4.14%	1.77%	3.12%	18.49%	0.30%	13.48%	18.18%
2045	4.78%	2.04%	3.59%	21.32%	0.34%	15.54%	20.96%
2046	5.51%	2.35%	4.14%	24.57%	0.40%	17.91%	24.17%
2047	6.35%	2.71%	4.78%	28.33%	0.46%	20.65%	27.86%
2048	7.32%	3.12%	5.51%	1.00%	0.53%	23.80%	1.00%
2049	8.44%	3.59%	6.35%	1.15%	0.61%	27.44%	1.15%
2050	9.72%	4.14%	7.32%	1.33%	0.70%	1.00%	1.33%
2051	11.21%	4.78%	8.44%	1.53%	0.81%	1.15%	1.53%
2052	12.92%	5.51%	9.72%	1.77%	0.93%	1.33%	1.77%
2053	14.90%	6.35%	11.21%	2.04%	1.07%	1.53%	2.04%
2054	17.17%	7.32%	12.92%	2.35%	1.23%	1.77%	2.35%
2055	19.79%	8.44%	14.90%	2.71%	1.42%	2.04%	2.71%
2056	22.82%	9.72%	17.17%	3.12%	1.64%	2.35%	3.12%
2057	26.30%	11.21%	19.79%	3.59%	1.89%	2.71%	3.59%
2058	1.00%	12.92%	22.82%	4.14%	2.18%	3.12%	4.14%
2059	1.15%	14.90%	26.30%	4.78%	2.51%	3.59%	4.78%
2060	1.33%	17.17%	1.00%	5.51%	2.90%	4.14%	5.51%
2061	1.53%	19.79%	1.15%	6.35%	3.34%	4.78%	6.35%
2062	1.77%	22.82%	1.33%	7.32%	3.85%	5.51%	7.32%
2063	2.04%	26.30%	1.53%	8.44%	4.44%	6.35%	8.44%
2064	2.35%	1.00%	1.77%	9.72%	5.11%	7.32%	9.72%
2065	2.71%	1.15%	2.04%	11.21%	5.90%	8.44%	11.21%

2066	3.12%	1.33%	2.35%	12.92%	6.80%	9.72%	12.92%
2067	3.59%	1.53%	2.71%	14.90%	7.84%	11.21%	14.90%
2068	4.14%	1.77%	3.12%	17.17%	9.03%	12.92%	17.17%
2069	4.78%	2.04%	3.59%	19.79%	10.41%	14.90%	19.79%
2070	5.51%	2.35%	4.14%	22.82%	12.00%	17.17%	22.82%
2071	6.35%	2.71%	4.78%	26.30%	13.84%	19.79%	26.30%
2072	7.32%	3.12%	5.51%	1.00%	15.95%	22.82%	1.00%
2073	8.44%	3.59%	6.35%	1.15%	18.39%	26.30%	1.15%
2074	9.72%	4.14%	7.32%	1.33%	21.20%	1.00%	1.33%
Annual average by expert	8.47%	7.79%	8.34%	7.89%	3.61%	7.75%	7.83%
Global average (2025-2075)	-	-	-	-	-	-	7.38%

2.4 Rehabilitation Costs for Existing Containment Structures

Existing containment structures, specifically the north and south structures in the Jim Smith corridor, and the Melinda structure, have been operational since 2003 and 1989, respectively. Both structures have taken the brunt of the damage in the project area, and the structures will need major rehabilitation during the period of analysis. Reconstruction is needed due to the fact that the structures have deteriorated from a repeated barrage of hydrologic events, and structural reliability decreases through time.[11]

As discussed in Section 2.2, which summarizes methods of estimating the annual probability of a breach, the PDT and expert panel evaluated structures in the project area to estimate structural integrity at the time of construction, and integrity at the time the 2009 Draft Ark-White Study was taking place. The District determined that it should not allow the integrity of the structures to fall below 70 percent for either the Jim Smith or Melinda Corridors. The PDT selected the 70 percent threshold in collaboration with District leadership and engineers. The figure is based on many factors, such as each structure's reliability and how this reliability changes with age. Based on estimated rates of degradation and this threshold, the PDT determined that existing structures would require rehabilitation twice over the period of analysis.

[11] The expert panel's estimates were included because they provided a basis for the structures integrities in 2004.Although the mission of the expert panel was to estimate the probability of a breach given varying hydrologic conditions, it was assumed that structure integrity and the panels breach estimates were perfectly correlated. Therefore the rate of change of each structure's integrity varies with each expert panel members breach estimates.

Based on estimated rates of degradation discussed in previous sections and this threshold, there is range of years in which existing structures would require rehabilitation based on each expert's estimate of the probability of a cut-off in the first year of the planning period (Table 2-11). The estimated year for the first rehabilitation spans from 2033 through 2049, and the second rehabilitation runs from 2057 through 2073. To account for timing uncertainty in timing, ranges in rehabilitation years served as maximum and minimum values for Monte Carlo simulation assuming a uniform probability density function. Table 2-12 shows results in a cumulative fashion (95^{th} to 5^{th} exceedance percentiles in increments of five). Table 2-13 shows the estimated total costs of rehabilitation for both structures is applied in each year and discounted to present value and annualized using the current FY2018 Corps discount rate of 2.750 percent.

Table 2-11
Estimated Year of Rehabilitation for Existing Containment Structures Based on Failure Probabilities of Expert Panel Members and Rate of Structure Deterioration

Expert Panel Member	1st rehabilitation	2nd rehabilitation
Leroy Arnold, PhD	2033	2057
Mitch Eggburn	2039	2063
David Biedenharn	2036	2059
Dr. Steve Haase, PhD	2047	2071
Nick Mitchell*	-	-
Glen Raible	2049	2073
Elmo Webb	2047	2071

*Dates based on Mr. Mitchell's probabilities fall outside the range of the planning horizon.
Source: U.S. Army Corps of Engineers, Little Rock District, Planning and Environmental Division.

Table 2-12
Probability Distribution Statistics and Stochastic
Ranges for Melinda and Jim Smith Containment Structures Rehabilitation Years
(assumes a uniform frequency distribution)

Statistic	**First Rehabilitation**	**Second Rehabilitation**
Minimum	2033	2057
Maximum	2049	2073
Mean	2041	2065
Standard Deviation	4.65	4.64
Variance	21.60	21.54
Skewness	0.000436566	-0.002487372
Kurtosis	1.80	1.81
Mode	2040	2060
Cumulative Distribution Percentiles		
5%	2034	2058
10%	2035	2058
15%	2035	2059
20%	2036	2060
25%	2037	2061
30%	2038	2062
35%	2039	2063
40%	2039	2063
45%	2040	2064
50%	2041	2065
55%	2042	2066
60%	2043	2067
65%	2043	2067
70%	2044	2068
75%	2045	2069
80%	2046	2070
85%	2047	2071
90%	2047	2071
95%	2048	2072

Source: Generated using @Risk statistical software by the U.S. Army Corps of Engineers, Little Rock District, Planning and Environmental Division.

Table 2-13
Cumulative Distribution for Rehabilitation Costs of Existing Containment Structures

Percentile (exceedance)	Total Discounted Present Value	Annualized Values
5%	$13,709,957	$520,267
10%	$13,455,625	$510,615
15%	$13,326,811[a]	$505,727
20%	$13,326,811[a]	$505,727
25%	$12,592,343	$477,855
30%	$12,240,431	$464,501
35%	$11,898,353	$451,520
40%	$11,677,628	$443,144
45%	$11,565,835	$438,901
50%	$11,242,610	$426,636
55%	$11,034,050	$418,721
60%	$10,623,007	$403,123
65%	$10,623,007	$403,123
70%	$10,326,130	$391,857
75%	$10,037,551	$380,906
80%	$9,757,036	$370,261
85%	$9,484,361	$359,913
90%	$9,484,361	$359,913
95%	$7,589,926	$288,023

a: Uncertainty in this case is based on the timing of rehabilitation, and since the year of implementation is a discrete variable, in some cases the simulation returned the same year for different percentiles.

Source: U.S. Army Corps of Engineers, Little Rock District, Planning and Environmental Division.

2.5 Repair Costs of Existing Control Structures

Over the past 26 years the Corps has repaired existing containment structures at fairly frequent intervals. Table 2-14 shows historical costs of repairing the Jim Smith and Melinda structures from 1991 through 2016. In FY 2018 dollars, on average the Corps has spent about $850,000 million per year over the period with annual costs ranging from about $600,000 to $10.5 million.

The Melinda structure has suffered regular damages since its inception. For example, high water events between January and May of 1990 resulted in repairs at a cost of $0.5 million (FY2018 $1.02 million). In the following year, a series of events between December and April damaged the Melinda Structure again at a cost of $1.1 million

(FY2018 $2.2 million). From 1991 to 1994 the southeast bank below the Melinda Structure slowly eroded, which necessitated that Corps build a revetment at a cost of nearly $0.32 million (FY2018 $0.59 million). The structures successfully weathered hydrologic events until Melinda suffered damaged again in 1997 when heavy spring rains and flooding resulted in the need for an additional $0.4 million (FY2018 $0.68 million). Two years later, engineers found a scour-hole at the base of the Melinda structure. Cost to repair the hole was about $1.4 million (FY2018 $2.35 million). The Geotube levee needed repairs in 2005 at a cost of $1.7 million (FY2018 $2.18 million). In March through July of 2011, a severe flood event flanked both the Melinda and Jim Smith structures causing severe erosion to occur. District engineers have stressed that future flood events similar to 2011 could easily bypass the existing containment structures and result in full blown breach. Repair costs due to the 2011 event cost, completed in 2014, totaled $10.2 million (FY2018 $10.5 million). Prior to 1989 and since the opening on the MKARNS, there were no projects or costs associated with stemming head-cutting in the study area.

To estimate expected annual repairs included in the NED analysis, data from 1990 through 2016 were fitted with a frequency distributions and each distribution was tested for goodness of fit using five statistical tests: 1) Kolmogorov–Smirnov, 2) Anderson Darling, 3) Chi-square, 4) Akaike's Information Criterion, and 5) the Bayesian Information Criterion. Based on the five measures, the exponential distribution was the best fit. Assuming an exponential distribution, average annual repairs range from about $0. 27 million (95 percent exceedance) to $1.6 million (5 percent exceedance) with a 50th percentile of $0.38 million (Table 2-6). This range serves as the baseline for year 1 (2025) and recurs every year through year 50 (2075) of the planning horizon. Values are discounted to present value and annualized.

Table 2-14
Historical Repair Costs for Containment Structures in the Three Rivers Project Area

Year	Event	Construction costs (nominal dollars)	Inflation Adjusted Construction costs (2018 dollars)*
1971-1989	-	$0	$0
1990	Melinda structure repaired	$500,000	$1,029,887
1991	Melinda structure repaired	$1,100,000	$2,265,752
1992	-	$0	$0
1993	-	$0	$0
1994	Melinda revetment constructed	$320,000	$596,502
1995	-	$0	$0
1996	-	$0	$0
1997	-	$0	$0
1998	Melinda slope failure repair	$400,000	$695,971
1999	-	$0	$0
2000	Melinda scour hole repaired	$1,917,000	$3,163,600
2001	-	$0	$0
2002	-	$0	$0
2003	Geotubes installed (North end of Jim Smith)	$1,624,000	$2,498,509
2004	-	$0	$0
2005	-	$0	$0
2006	Geotubes levees repaired	$1,700,000	$2,194,408
2007	-	$0	$0
2008	-	$0	$0
2009	-	$0	$0
2010	-	$0	$0
2011	-	$0	$0
2012	-	$0	$0
2013	-	$0	$0
2014	Melinda and Jim Smith repairs	$10,200,000	$10,515,347
2915	-	$0	$0
2016	-	$0	$0
Total		$17,761,000	$22,959,976
Average Annual		$403,659	$521,818

* Updated using U.S. Army Corps of Engineers Civil Works Construction Cost Index System for levees and floodwalls. Source: U.S. Army Corps of Engineers, Little Rock District, Operations Division.

Table 2-15
Cumulative Probability Function for Repair Costs for Existing Containment Structures
(Exponential Frequency Distribution)

Distribution Statistics			
Minimum	$0		
Maximum	+Infinity		
Mean	$521,818		
Mode	$0		
Standard Deviation	$1,716,489		
Skewness	2.00		
Kurtosis	9.00		
Simulation Results			
Percentile (Exceedance)	**Average Annual Repair Costs**	**Present Value**	**Annualized Value**
5%	$26,766	$749,364	$27,757
10%	$54,979	$1,539,254	$57,015
15%	$84,805	$2,374,304	$87,946
20%	$116,440	$3,259,993	$120,753
25%	$150,117	$4,202,862	$155,678
30%	$186,119	$5,210,807	$193,013
35%	$224,790	$6,293,480	$233,116
40%	$266,557	$7,462,855	$276,431
45%	$311,962	$8,734,039	$323,517
50%	$361,696	$10,126,464	$375,094
55%	$416,675	$11,665,718	$432,109
60%	$478,136	$13,386,457	$495,847
65%	$547,815	$15,337,271	$568,107
70%	$628,253	$17,589,319	$651,525
75%	$723,392	$20,252,928	$750,187
80%	$839,832	$23,512,921	$870,940
85%	$989,949	$27,715,783	$1,026,618
90%	$1,201,528	$33,639,385	$1,246,034
95%	$1,563,224	$43,765,849	$1,621,127

Source: U.S. Army Corps of Engineers, Little Rock District, Construction and Engineering Division.

2.6 New Containment Structures

As head-cuts progress in the study area, SWL will need to install additional containment structures similar to those that exist today at some point in the future. SWL engineers provided estimates based on professional judgment regarding the types of new structures that would best control head-cut progression, and estimated the costs of these new structures. Engineers concluded that in the Corps would likely need to build three new structures (Figure 4).

Presently, a small pocket of erosion exists on the west side of the Melinda Channel. This verifies that flow is coming from the LaGrues Lake area. If nothing is done to change the flow conditions, this erosion pocket is projected to progress and cause a potential cutoff path. Because this area is passing significant flow, another structure is projected to be needed on this same flow path closer to LaGrues Lake. These two structures would work in conjunction with each other. The existing scour hole located approximately 2,000 feet southeast of Jim Smith Lake is projected to develop and potentially connect Jim Smith Lake to the Historic Cutoff Channel. According to District engineers, the best location for the new Jim Smith structure is about 1,000 feet south of the head-cut as resides today, structure number two is in the area west of the Melinda head-cut about 1,400 feet from the current head cutting location. The third structure would be roughly 4,500 feet south of LaGrues Lake.

While there is a consensus that the Corps will need to build new structures in the project area, the timing is uncertain. To assess when the new structures would be needed, the PDT examined past historical hydrological events, and head cut progression associated with each event. Over an 18-year period, there were a total of 18 events in each year ranging in frequency from 2 to 90 percent exceedance. Resultant erosion for each event range from about 15 to 458 feet with a mean of 156 feet and a standard deviation of 120 feet.

Large deviations from the mean indicate a good deal of variance in the data; and as was the case with estimating timing and costs of repairs and rehabilitation of existing structures, frequency distributions applied to historical head-cut progression data were tested using @Risk. Based on results of the goodness of fit metrics, the PDT selected a beta general distribution bounded at a lower end by a value of zero. Monte Carlo analysis generated the 95^{th} and 5^{th} percentiles for annual head cut progression. Under these assumptions, the expected annual rate of erosion ranges from 0 to 889 feet per year with a 95 percent exceedance value of 18 feet and 5 percent exceedance of 381 feet (Table 2-16 and Figure 5).

Lastly, based on the range of construction dates estimated costs including mitigation for each structures in each relevant year, and values are discounted to present value and annualized. It is also assumed that new structures would require repairs, and an annual average value based on the historical frequency distribution is applied ($568,380). The historical value is adjusted by a factor of 0.33 to distribute costs across three new structures. In some cases, the stochastic range of implementation dates for new structures fall outside of the planning period (2025 through 2075), and thus construction costs for dates in question are not included. However, annual repair costs are included if the implementation date occurs before 2025. SWL cost engineer estimated construction costs, and environmental planners provided estimated mitigation costs for each structure based on historical data.[12] Total capital expenditures are about $14 million, and mitigation costs amount to $3.0 million. Table 2-17 displays annualized values for construction and repairs for new structures.

[12] While it is true, that there is inherent uncertainty in engineering and mitigation cost estimates, it is assumed that uncertainty in the timing of construction and hence present value of costs outweighs the uncertainty of cost estimates.

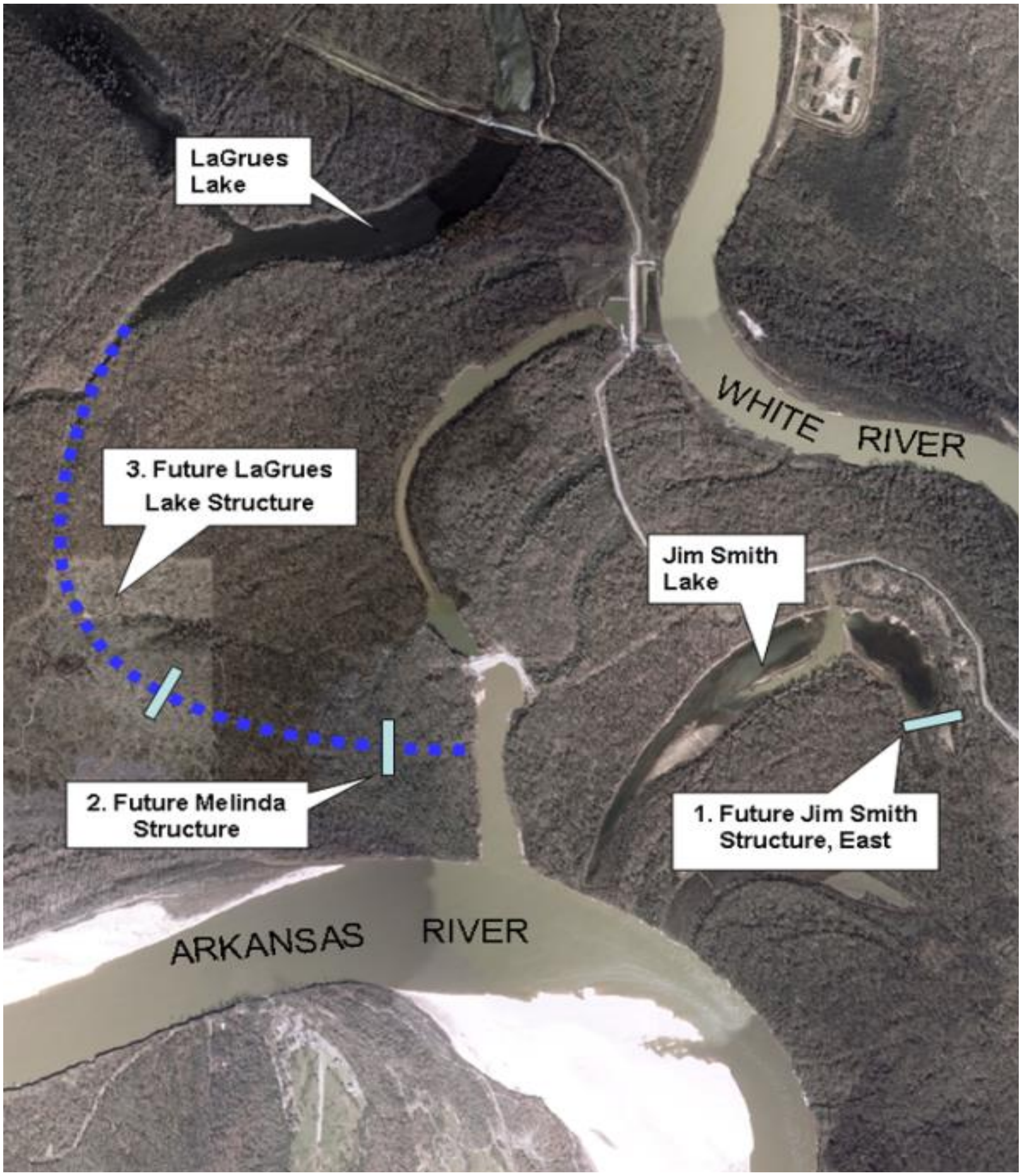

Figure 4
Expected Locations of Future Containment Structures[13]

[13] These are expected to consist of small scale structures similar to the existing Melinda and Jim containment structures.

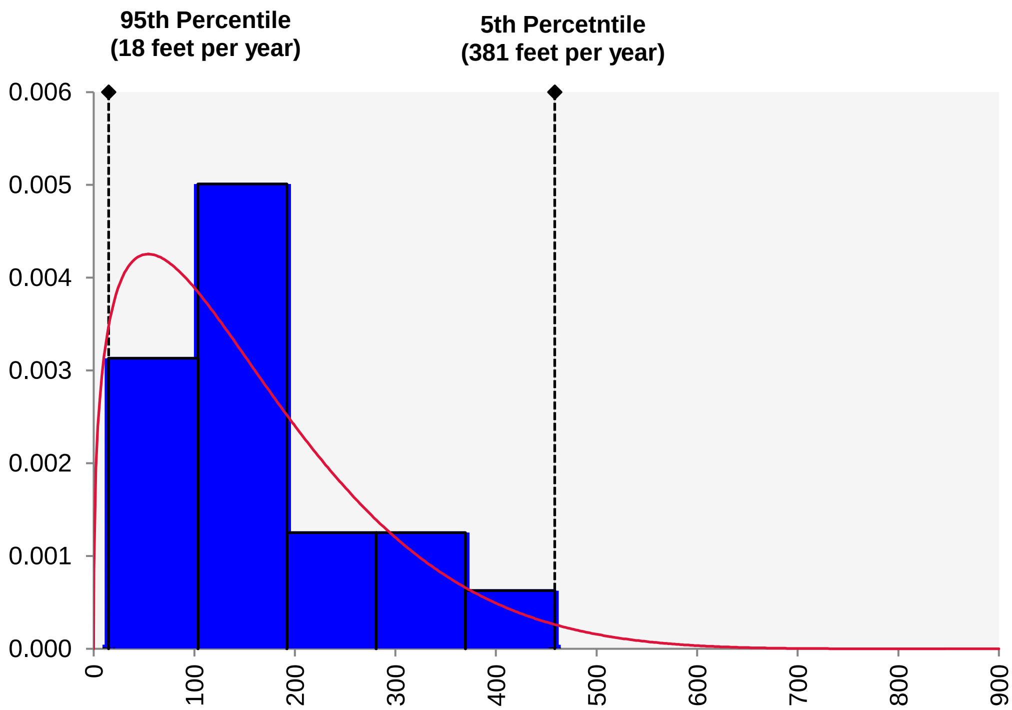

Figure 5
Frequency Distribution for Historical Headcut Progression in the Study Area (feet per year)

Table 2-16
Cumulative Probability Function for Construction of New Containment Structures
(Beta General Frequency Distribution)

Probability Distribution Statistics for Annual Head-cut Progression				
Minimum	0			
Maximum	887			
Mean	156			
Mode	54			
Median	131			
Standard Deviation	115			
Skewness	1			
Kurtosis	4			
Minimum	0			
Cumulative Distribution Percentiles for Head-cut Progression and Year of Implementation for New Structures				
		Year of Implementation*		
Exceedance	**Annual Head-cut Progression (feet per year)**	**Future Jim Smith Structure**	**Future Melinda Structure**	**Future LaGrues Lake Structure**
95%	18	2073	2095	2270
90%	31	2049	2062	2163
85%	43	2039	2049	2121
80%	54	2034	2042	2099
75%	66	2031	2037	2084
70%	78	2029	2034	2074
65%	90	2027	2031	2066
60%	101	2026	2030	2060
55%	113	2025	2028	2056
50%	130	2025	2027	2051
45%	145	2023	2026	2047
40%	162	2022	2025	2044
35%	179	2022	2024	2041
30%	199	2021	2023	2039
25%	221	2021	2022	2036
20%	246	2020	2022	2034
15%	278	2020	2021	2032
10%	319	2019	2020	2030
5%	381	2019	2020	2028

Source: Generated using @Risk statistical software by the U.S. Army Corps of Engineers, Little Rock District, Planning and Environmental Division.

Table 2-17
Cumulative Distribution for Construction and Repair Costs of New Containment Structures

Exceedance	Construction Costs		Annual Repair Costs	
	Total Discounted Present Value	Annualized Costs	Total Discounted Present Value	Annualized Costs
95%	$2,232,056	$84,700	$4,659	$200
90%	$5,350,187	$203,000	$248,452	$9,200
85%	$7,214,563	$273,700	$709,608	$26,200
80%	$8,404,661	$318,900	$1,268,481	$47,000
75%	$9,256,188	$351,300	$1,922,892	$71,200
70%	$11,331,311	$430,000	$2,817,369	$104,300
65%	$12,345,466	$468,500	$3,686,689	$136,600
60%	$13,233,788	$502,200	$4,782,753	$177,200
55%	$13,633,738	$517,400	$5,976,004	$221,300
50%	$14,079,381	$534,300	$7,314,557	$271,000
45%	$5,718,515	$435,300	$8,843,893	$327,600
40%	$3,456,696	$131,200	$10,418,947	$385,900
35%	$3,763,489	$142,800	$12,273,559	$454,600
30%	$3,983,001	$151,100	$14,440,131	$534,900
25%	$4,336,506	$164,600	$17,032,554	$630,800
20%	$4,461,180	$169,300	$19,981,900	$740,200
15%	$4,857,125	$184,300	$24,329,284	$901,200
10%	$5,140,425	$195,100	$30,200,685	$1,118,700
5%	$5,440,248	$206,400	$38,733,435	$1,434,700

Source: Generated using @Risk statistical software by the U.S. Army Corps of Engineers, Little Rock District, Planning and Environmental Division.

2.7 Costs of Damages and Contingency Plan in the Event of a Breach

Cost discussed thus far will likely occur regardless of whether there is a breach and subsequent cut-off; however, costs discussed in Sections 2.7 through 2.8 would accrue only if such an event happens. These include: 1) expenses of the District's contingency plan to repair a cut-off, 2) damages to Montgomery Point Lock and Dam, 3) dredging costs, and 4) costs to the shipping industry resulting from loss of navigation. The analysis treats impacts incurred due to a breach differently than those discussed previously. Breach impacts are monetized risks, which is the consequence of something happening weighted by the probability of the event occurring (i.e., risk = probability of a breach in a given year × consequence). This results in an annual monetized risk over the period of analysis.

2.7.1 Costs of Contingency Plan

If a cutoff forms, the District will go to the project area and close the cutoff to restore navigation. The District has a contingency plan in place; however, how soon the Corps could get to the area and start construction is subject to a high degree of uncertainty because a breach would most likely happen during a flood event, and the project area is in a remote part of the state with limited access roads.

Initially, the District would dispatch a survey boat and crew to investigate the size and conditions of the breach. Surveys would take between one and seven days, with a most likely estimate of four days. After surveys, the District would modify specifications of the plan as needed, award a contract and begin construction. The contingency plan is based on the assumed dimensions of a cutoff given that there is no historical data available. The cost estimate for the contingency plan is about $13.1 million (FY2018).

The Ark-White Study PDT set the estimated time frame to repair the breach at 220 days, which includes time for data collection, contract acquisition, construction, and limited access to the construction site given high flows and weather conditions. However, both the Ark-White PDT and Three Rivers PDT along with District leadership agreed that there is considerable uncertainty in the time frame; and as is the case with many other parameters in the NED analysis, a frequency distribution and simulation were used to generate a range of possible values with the midpoint serving as the point estimate (258 days). Table 2-18 displays the range of outage length expressed as a function of a uniform probability distributions.

Table 2-18
Probability Distribution Statistics and Stochastic Ranges for Repair Duration of a Cutoff in Days
(assumes a uniform frequency distribution)

Statistic	**Value**
Minimum	150
Maximum	365
Mean	258
Standard Deviation	63
Skewness	0
Kurtosis	1.8
Exceedance Percentiles	**Number of Days**
95%	161
90%	172
85%	182
80%	193
75%	204
70%	215
65%	225
60%	236
55%	247
50%	258
45%	268
40%	279
35%	290
30%	301
25%	311
20%	322
15%	333
10%	344
5%	354

Source: Generated using @Risk statistical software by the U.S. Army Corps of Engineers, Little Rock District, Planning and Environmental Division.

2.7.2 Dredging Costs

Since the construction of Montgomery Point L&D, dredging has not been a problem in the study; however, if a cutoff occurs, sediment would transfer from the Arkansas to White River, typically during periods when the Mississippi River's stage was low. Also, low river stages would allow the White River to drain into the Arkansas River; thus causing shallow depths and frequent dredging to maintain the navigation depth.

According to the *Arkansas-White Cutoff, Letter Report Volume II of II*, March 1987, the suspended sediment measurements at Little Rock were used to develop the sediment-discharge curve and then used to estimate the sediment load at the project site. The amount of sediment deposition has been verified as reasonable in the *Arkansas-White River Evaluation Report*.[14] The estimated range of sediment deposition in the event of cut-off is 1.5 million to 2.7 million cubic yards. Based on an average cost per cubic yard of as reported by the District's Operations Division for years 2012 through 2015 ($13.02), and assuming a dredge material volume of 2.1 million cubic yards (median of 1.5 and 2.7), estimated dredging costs in the event of a breach is $27.3 million.

2.7.3 Montgomery Point Lock and Dam Damages

As discussed previously, Montgomery Point L&D is located slightly downstream of the project area. Montgomery Point's communication lines (fiber optic and electrical) are buried underground and run upstream of the project area, and a breach would destroy about 9,500 feet of buried fiber optic communication lines. Replacement costs would total about $387,000. As with the contingency plan, there is no historical data, and this estimate is based on engineering estimates. To incorporate uncertainty for costs of dredging, expenses for the contingency plan, and damages to Montgomery Point, the model applies a uniform probability distribution to the sum of each costs to yield cumulative distribution function as shown in Table 2-19. Maximum and minimum values for the simulation were plus and minus 25 percent of the mean.

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[14] FTN Associates, LTD. "Arkansas White River Evaluation Report." Prepared for the U.S. Army Corps Little Rock District, September 2001.

Table 2-19
Cumulative Probability Distribution for Dredging Costs, Damages to Montgomery Point, and Costs of Contingency Repairs

Distribution Statistics (uniform probability distribution)		
Minimum	$39,298,637	
Maximum	$52,029,167	
Mean	$45,663,697	
Mode	$41,526,137	
Standard Deviation	$23,854,329	
Skewness	0.000	
Kurtosis	1.800	
Simulation Results		
Percentile	**Total costs**	**Annualized costs**
5%	$37,214,814	$2,824,635
10%	$37,623,153	$2,855,629
15%	$38,032,000	$2,886,660
20%	$38,441,700	$2,944,852
25%	$38,849,888	$2,976,121
30%	$39,259,555	$3,007,509
35%	$39,668,405	$3,038,827
40%	$40,077,251	$3,070,147
45%	$40,486,224	$3,101,476
50%	$40,894,761	$3,132,768
55%	$41,304,209	$3,164,137
60%	$41,712,808	$3,195,439
65%	$42,121,859	$3,226,777
70%	$42,530,576	$3,258,081
75%	$42,939,586	$3,289,418
80%	$43,348,944	$3,320,775
85%	$43,757,438	$3,352,066
90%	$44,166,940	$3,383,442
95%	$44,575,354	$3,414,726

Source: U.S. Army Corps of Engineers, Little Rock District, Construction and Engineering Division.

2.8 Impact to Navigation in the Event of a Breach

As discussed previously, a key impetus for the Three Rivers Study is to avoid a situation where the Arkansas and White rivers join via a cutoff. If this happens, commercial navigation through the study area would become unreliable. High flows would create dangerous cross currents making navigation impossible, and low flows would make Montgomery Point unpassable to barge traffic due to draft constraints. Thus, a major component of NED benefits is the impact to navigation through the project area. Section 2.8 discusses the process used to estimate lost navigation NED benefits.

2.8.1 Traffic Projections

Projected commodity flows through the project area are a critical component of the future without project condition given that the NED benefits are based on transportation cost savings of shipping cargo by barge versus the least cost alternatives such as rail and truck. The Draft Ark-White Cutoff Study (2010) relied on projections developed for the 2005 Arkansas River Navigation Study; however, given that the projections for the navigation study are dated, projections for the Three Rivers study were updated using more current data regarding commodity flows on the MKARNs and related economic conditions. Updating projections is particularly important because the ARKNAV study used year 2003 as a baseline at a time when national and world economic growth was more robust relative to current conditions, and before the 2009 global recession.

As discussed previously, traffic on the MKARNs has trended up since the project's inauguration. There have been years where tonnage declined, and some commodities have trended up or down up over the 45 years the project has been operational; but all in all, activity has increased and the types and origin and destination of major commodities has been relatively stable. Looking into the future, one would expect the same general patterns to continue. Absent global or national catastrophe (be it economic or natural), the U.S. and world economies and populations will continue to grow as will interstate and international commerce. More people and economic activity translate into more demands on U.S. transportation infrastructure including inland waterways. Traffic projections developed for this study assume continued growth for most commodities on the rivers. For each major commodity group in the baseline, growth rates from secondary sources drive forecasts of future traffic. Sources and background for each are discussed below.

Projections run through 2075, and the base year for projections is 2016 and benefits begin to accrue based on projected tonnage in 2025. Table 2-20 and 2-21 show the baseline for inbound and outbound commodities. In some cases, the commodity aggregations differ slightly from those show in historical tables to better align with end uses and forecast drivers. The baseline is the annual average of the three most recent years of inbound and outbound MKARNS traffic approved and published by the Corps Waterborne Commerce Statistics Center.

Growth Rates for Inbound Commodities

Growth rates for inbound aluminum and aluminum ores are based on projected national level increases in the real value of shipments for energy intensive manufacturing prepared by the U.S. Energy Information Administration (EIA). Via the MKARNS, companies in Arkansas import aluminum ore (bauxite), which is used to produce alumina (a key feedstock for aluminum manufacturing and other non-metallurgic products such as abrasives, fire retardants, and refractories).

Although some fertilizer imports are for regional retail home and garden markets, most are for commercial crops; and as a result, national level projections for corn, soybean, wheat, and cotton production serve as short-term (i.e., through 2030) drivers for fertilizer imports on the river. The growth rate is an average for the four crops weighted by each crops share of fertilizer uptake as estimated by the USDA's Economic Research Service.[15] The long-term driver for fertilizer imports is projected U.S. population growth over the next five decades as estimated by the U.S. Census Bureau. Lastly, growth rates for shipments of animal feed ("Food and other farm products") are based on USDA national livestock production projections (i.e., the average for national level poultry and beef production), and as the case for crops, the long-term rate is expected growth in U.S. population.

As populations grow and communities need more houses, roads and buildings, demand for building materials including aggregates, cement and other similar goods will increase. Short-term (2016-2030) rates for inbound building materials are generated from construction employment projections for Oklahoma and Arkansas published by the Arkansas and Oklahoma Employment Security commissions, which in turn are based on national level estimates published by the U.S. Bureau of Labor Statistics. Since construction employment projections are short-term (i.e., through 2030) the long-term (2030-2070) rate is the expected growth in U.S. Real Gross Domestic Product (GDP) published by the National Bureau of Economic Research.

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[15] Fertilizer use by crop taken from: *Source: USDA Economic Research Service: Fertilizer Use and Price: Available at: http://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx

Inbound petroleum products (distillate fuel) are unique due to the fact that a substantial portion of current shipments power drilling rigs pumping from the Fayetteville Shale formation in northeast Arkansas. Thus, forecasts for petroleum products are reported in two sub groups -“petroleum products (shale gas drilling)” and “petroleum products (industrial and transportation).” The ratio of diesel fuel for gas drilling versus other uses was estimated based on historical data. Large-scale mining of the Fayetteville Shale began in 2005 and ramped up rabidly in subsequent years. At the same time, imports of diesel fuel increased from 99,000 tons in 2005 to 183,000 in 2006. In 2007, volumes rose to 302,000 tons and have more or less stayed in this range since. For study projections, the ratio of distillate for natural gas mining versus other uses is based on average volumes shipped from 2001 through 2005 compared to the mean of shipments from 2006 through 2014 (73 percent for shale gas and 23 percent for other uses). For fuel shipments used for purposes other than mining, the short and long-term growth rate applied is projected increases in real U.S. GDP, and for shale gas extraction the rate applied is from the EIA’s forecast for national gas shale production (1.2 percent).

The commodity group manufacturing ores and minerals contains a range of commodities used primarily in industrial applications such as sodium hydroxide, sodium chloride and manganese ore (used in steel production). For this group, the short and long-term driver is the EIA’s national level forecast for the value of real shipments for energy intensive manufacturing (2016 through 2040). The same EIA forecast is also the driver for inbound coal and coke traffic and iron and steel traffic, both of which are used by regional heavy industry including steel and cement producers.

Table 2-23 summarizes raw WCSC data for 2012 through 2014 by minor and major commodity groups. These data serve as the baseline for inbound traffic projections, which is an average value for each commodity over the three-year period.

Table 2-20
Projection Growth Rates for Inbound Commodities on the MKARNs

Commodity group	Primary market(s)	Short-term (2016-2030)	Long-term (2030-2070)	Description and sources
Aluminum	Domestic metals manufacturing	1.08%	1.60%	Short-term: Value of shipments in constant 2009 dollars for energy intensive manufacturing (2016-2040). U.S. Energy Information Administration, Annual Energy Outlook (2015). Long-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary.
Aluminum ores & concentrates	Domestic metals manufacturing	1.08%	1.60%	Same as above
Building materials and minerals	Domestic construction	1.75%	1.60%	Short-term: Average of short-term construction employment projections for Arkansas and Oklahoma (2012-2022). Employment Security Commissions of Arkansas and Oklahoma. Long-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary.
Petroleum products (industrial and transportation)	Domestic other (industrial and transportation fuel)	1.60%	1.60%	Short-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary. Long-term: Same as short-term
Petroleum products (shale gas drilling)	Domestic (Fayetteville Shale gas extraction)	1.20%	1.20%	Short-term: Projections for shale gas extraction 2015-2040. U.S. Energy Information Administration, Annual Energy Outlook (2015). Long-term: Same as short-term
Food and other farm goods (primarily animal feed)	Domestic livestock production	1.25%	0.42%	Short-term: Growth in U.S. livestock production (poultry and beef) Growth rates from: U.S. Department of Agriculture, Office of the Chief Economist and Interagency Agricultural Projections Council. "USDA Agricultural Projections to 2024 (OCE 2016-1)." February, 2016. Long-term: Projected U.S. population through 2060 from U.S. Census Bureau.
Manufacturing ores and chemicals	Domestic manufacturing	1.08%	1.60%	Short-term: Value of shipments in constant 2009 dollars for energy intensive manufacturing (2016-2040). U.S. Energy Information Administration, Annual Energy Outlook (2015).

				Long-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary.
Coal	Domestic metals manufacturing	1.08%	1.60%	Same as above
Coke	Domestic metals manufacturing	1.08%	1.60%	Same as above
Machinery and equipment	General domestic markets	1.60%	1.60%	Short-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary. Long-term: Same as short-term
Iron and steel	Domestic metals manufacturing	1.08%	1.60%	Short-term: Value of shipments in constant 2009 dollars for energy intensive manufacturing (2016-2040). U.S. Energy Information Administration, Annual Energy Outlook (2015). Long-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary.
Corn	Domestic livestock production	1.25%	0.42%	Short-term: Growth in U.S. livestock production (poultry and beef) Growth rates from: U.S. Department of Agriculture, Office of the Chief Economist and Interagency Agricultural Projections Council. “USDA Agricultural Projections to 2024 (OCE 2016-1).” February, 2016. Long-term: Projected U.S. population through 2060 from U.S. Census Bureau.
Rice	Domestic livestock production	1.25%	0.42%	Same as above
Soybeans	Domestic livestock production	1.25%	0.42%	Same as above
Wheat	Domestic livestock production	1.25%	0.42%	Same as above

Table 2-21
Baseline for Inbound Commodity Flows in Study Area (1000s of tons)

Commodity Group*	2012	2013	2014	Projection baseline (mean of 2012-2014)
Aluminum	71	49	51	57
Aluminum ores and concentrates	45	60	106	70
Chemical fertilizers	1,721	1,943	2,186	1,950
Building materials and minerals	345	365	309	339
Petroleum products (diesel fuel for shale gas extraction)	72	155	220	149
Petroleum products (industrial use and transportation fuel)	27	58	82	56
Food and other farm goods	290	255	222	256
Other manufacturing ores and chemicals	169	231	333	244
Coal	37	44	6	29
Coke	151	117	86	118
Machinery and equipment	12	3	2	6
Iron and steel	840	1,002	1,098	980
Corn	17	91	56	55
Rice	2	2	0	1
Soybeans	3	0	2	2
Wheat	0	9	11	7
Total inbound	3,899	4,598	5,071	4,523

*Totals may differ than those in Table 1-2 due to differences between LPMS and WCSC data.
Source: Generated using data from the USACE Waterborne Commerce Statistics Center.

Growth Rates for Outbound Commodities

Since they share the same markets and general end uses, several outbound commodities use the same growth rates and source including aluminum, aluminum ores, chemical fertilizers, manufacturing ores and chemicals, coke and iron and steel. For building materials and minerals, the short-term growth rate is national level construction employment projections (2014 through 2024) since destinations are broader geographically. For outbound coal shipments, which flow to deep draft ports for transfer to bulk carriers in route to thermoelectric generating stations along the Gulf Coast, the short and long-term rate is EIA’s forecast for national level coal consumption through 2040, which shows minimal increases in domestic consumption (about 0.2 percent per annum). As EIA notes; however, their projection does not take into account the USEPA’s proposed Clean Power Plan, which if implemented, would likely impact domestic coal consumption.

As noted previously, remaining outbound cargoes (grains and diesel fuel) flow to deep draft ports in Louisiana for export to world markets. Outbound growth rates for agricultural goods, the largest export from the system by tonnage, are USDA projections for crop exports. Despite declines in planted wheat acreage in recent years, USDA expects wheat exports to rise at a rate of 2.02 percent per year through 2025. While per capita domestic consumption of wheat in the U.S has declined sharply since 2000 due to changing consumer preferences, global consumption has risen and is expected to continue to grow in the near-term. Study projections rely on the USDA’s estimated rate for exports for the short-term (2016-2030), and over the long-term, study projections assume that wheat exports will grow at a rate equal to projected growth in world population (2031-2075).

USDA expects exports of other crops shipped out of the MKARNS to increase as well. Corn exports are projected to expand steadily, recovering part of the market share lost in recent years due to tight supplies related to ethanol fuel production. USDA also expects soybean exports to continue to grow, but at a slower rate than in the past, primarily due to rising competition from producers in South American, particularly Brazil. South American soybean harvests have set record highs nearly every year for almost a decade; and over the past 5 years, Brazilian exports surpassed U.S. exports. Whether this continues in the long run is uncertain as Brazil's transportation infrastructure must further develop before the country can more fully realize its potential in global agricultural markets. Also, Brazil’s exchange rate with the U.S. dollar, which affects domestic prices of soybeans, will heavily influence production in Brazil.

The USDA expects sorghum (97 percent of the major commodity group “food and other farm products”) to decline in the short-term due to reduced demand in China where price subsidies have led to record-high corn production and prompted imports of sorghum and barley as substitutes for expensive corn. However, China recently instituted policies to reduce domestic corn subsidies to curb corn production in erodible and drought-prone regions. Rice exports will likely continue to grow to meet increasing demands in Latin America. Note that USDA's rice export projections do not factor in the potential market for Arkansas rice in Cuba given that there is still considerable uncertainty in policy efforts aimed at opening Cuba markets for U.S. trade. For all crops exports, the long-term study growth rate is equal to projected growth in world population.

Table 2-23 summarizes raw WCSC data for 2012 through 2014 by minor and major commodity groups. These data serve as the baseline for inbound traffic projections, which is an average value for each commodity over the three-year period.

Table 2-22
Projection Growth Rates for Outbound Commodities on the MKARNs

Commodity group	Primary market(s)	Short-term (2016-2030)	Long-term (2030-2070)	Description and sources
Aluminum	Domestic metals manufacturing	1.08%	1.60%	Short-term: Value of shipments in constant 2009 dollars for energy intensive manufacturing (2016-2040). U.S. Energy Information Administration, Annual Energy Outlook (2015). Long-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary.
Aluminum ores & concentrates	Domestic metals manufacturing	1.08%	1.60%	Same as above

Table 2-22
Projection Growth Rates for Outbound Commodities on the MKARNs

Commodity group	Primary market(s)	Short-term (2016-2030)	Long-term (2030-2070)	Description and sources
Chemical fertilizers	Domestic crop production	0.91%	0.48%	Short-term: Growth in U.S. wheat, corn, soybean and cotton production weighted by fertilizer consumption share of each crop. Growth rates from: U.S. Department of Agriculture, Office of the Chief Economist and Interagency Agricultural Projections Council. "USDA Agricultural Projections to 2024 (OCE 2016-1)." February, 2016. Long-term: Projected growth in U.S. and world population (average of two rates) from U.S. Census Bureau, and United Nations.
Building materials and minerals	Domestic construction	1.22%	1.60%	Short-term: U.S. Construction employment projections from Bureau of Labor statistics (2014-2024). Long-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary.
Petroleum products	Foreign export	0.42%	0.42%	Short-term: U.S. Energy Information Administration, Annual Energy Outlook (2015), Total Energy Supply, Disposition, and Prices Summary. Petroleum Liquid Exports:(2016-2040) Long-term: Same as short-term.
Food and other farm goods	Foreign export	-7.44%	0.00%	Short-term: Growth in U.S. sorghum exports. Growth rates from: U.S. Department of Agriculture, Office of the Chief Economist and Interagency Agricultural Projections Council. "USDA Agricultural Projections to 2024 (OCE 2016-1)." February, 2016. Long-term: Held constant at 150 million bushels per year according to USDA projections.

Table 2-22
Projection Growth Rates for Outbound Commodities on the MKARNs

Commodity group	Primary market(s)	Short-term (2016-2030)	Long-term (2030-2070)	Description and sources
Manufacturing ores and chemicals	Domestic manufacturing (aggregates, cements, construction materials)	1.08%	1.60%	Short-term: Value of shipments in constant 2009 dollars for energy intensive manufacturing (2016-2040). U.S. Energy Information Administration, Annual Energy Outlook (2015). Long-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary.
Coal	Domestic electricity production	0.27%	0.27%	Short-term: U.S. Energy Information Administration, Annual Energy Outlook (2015), Total Energy Supply, Disposition, and Prices Summary. U.S. Coal Consumption (2016-2040). Long-term: Same as short-term
Coke	Domestic production of calcined petroleum coke for use in metals manufacturing	1.08%	1.60%	Short-term: Value of shipments in constant 2009 dollars for energy intensive manufacturing (2016-2040). U.S. Energy Information Administration, Annual Energy Outlook (2015). Long-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary.
Machinery and equipment	Various domestic consumers	1.60%	1.60%	Short-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary. Long-term: Same as short-term

Table 2-22
Projection Growth Rates for Outbound Commodities on the MKARNs

Commodity group	Primary market(s)	Short-term (2016-2030)	Long-term (2030-2070)	Description and sources
Iron and steel	Domestic metals manufacturing	1.08%	1.60%	Short-term: Value of shipments in constant 2009 dollars for energy intensive manufacturing (2016-2040). U.S. Energy Information Administration, Annual Energy Outlook (2015). Long-term: Projected growth in U.S. real GDP through 2060: National Bureau of Economic Research, Report 2015 Number 1: Research Summary.
Corn	Foreign export	2.15%	0.53%	Short-term: Growth in U.S. corn exports. Growth rates from: U.S. Department of Agriculture, Office of the Chief Economist and Interagency Agricultural Projections Council. “USDA Agricultural Projections to 2024 (OCE 2016-1).” February, 2016. Long-term: Growth in world population from the United Nations Population Division, Department of Economic and Social Affairs.
Rice	Foreign export	2.16%	0.53%	Short-term: Growth in U.S. rice exports (USDA same source above) Long-term: Same as above
Soybeans	Foreign export	1.06%	0.53%	Short-term: Growth in U.S. soybean exports (USDA same source above) Long-term: Same as above
Wheat	Foreign export	2.32%	0.53%	Short-term: Growth in U.S. wheat exports (USDA same source above) Long-term: Same as above.

Table 2-23
Baseline for Outbound Commodity Flows in Study Area (1000s of tons)

Commodity Group*	2012	2013	2014	Projections baseline (mean of 2012-2014)
Aluminum	0	0	0	0
Aluminum ores and concentrates	0	0	2	1
Chemical fertilizers	563	399	434	465
Building materials and minerals	649	459	570	559
Petroleum products	587	671	74	444
Food and other farm goods	52	78	109	80
Other manufacturing ores and chemicals	58	64	63	62
Coal	353	343	62	253
Coke	186	94	126	135
Machinery and equipment	29	54	11	31
Iron and steel	596	560	465	540
Corn	245	251	89	195
Rice	181	173	90	148
Soybeans	935	853	1,372	1,053
Wheat	1,043	1,529	1,217	1,263
Total inbound	5,477	5,528	4,684	5,230

* Totals may differ than those in Table 1-4 due to differences between LPMS and WCSC data.
Source: Generated using data from the USACE Waterborne Commerce Statistics Center.

Projected Commodity Flows

From 2016 through 2075, tonnage through the study area is expected to grow from about 9.5 million per year tons to 17.5 million (an increase of 84 percent) at rate of 1.03 percent per year (Table 2-26). In contrast, the projected rate is lower than the historical rate from 1971 through 2014 (3.97 percent per year). The reason is that traffic increased rapidly in the initial years after the MKARNs opened as shippers adjusted their logistics to take advantage of the cheaper mode of transport. For example, from 1971 through 1980, tonnage shipped on the system grew from 1.8 to 6.7 million tons (270 percent increase), but as the system matured, demand leveled off and annual increases tapered off and reflected overall macroeconomic conditions. In other words, the market achieved some level of equilibrium.

Table 2-26
Historical and Projected Commodity Flows through the Three Rivers Study Area

Year	Tons (1000s)
1971	1,817
1975	2,739
1980	6,715
1985	5,814
1990	6,327
1995	7,981
2000	9,127
2005	8,722
2010	8,764
2014	9,367
Baseline (2016)	9,804
2020	10,210
2025	10,880
2030	11,611
2035	12,148
2040	12,713
2045	13,314
2050	13,953
2055	14,634
2060	15,359
2065	16,132
2070	16,956
2075	17,836
Projected growth rate (baseline-2075)	1.03%
Historical annual growth rates	
1971-2014	3.89%
1980-2014	0.98%
1990-2014	1.65%
2000-2014	0.19%
2010-2014	1.68%

Source: Historical data from U.S. Army Corps of Engineers Lock Performance and Monitoring System and Waterborne Commerce Statistics Center. Projections developed by U.S. Army Corps of Engineers, Little Rock District, Planning and Environmental Division.

Incorporation of Uncertainty into Commodity Projections

An assumption for projections is that current origin destination patterns remain the same over the forecast horizon; however, over the long-term commodity flow patterns will likely change but it is extremely difficult to project these changes with any degree of accuracy 60 years into the future. On the other hand, the pattern for major inbound and outbound commodities shipped on the MKARNs has remained relatively constant through time. For example, grain from the Midwest has flowed down to Gulf Coast ports for export, and inbound fertilizers have come from producers in Texas and Louisiana and sold to farmers in the Midwest. Regardless, there will likely be some changes in origins and destinations, and the U.S. and world economies will wax and wane resulting in positive and negative variations on year to year basis. But in the absence of global upheaval or substantial and protracted economic decline, future demand for shipping on the MKARNs will increase.

Despite probable increases in MKARNS traffic, analyzing uncertainty is an important part of the plan formulation process. For study projections, the PDT examined historic variation in traffic through the study area. As shown in Figure 8, annual ups and downs in tonnage since the system was built vary with the greatest annual changes occurring shortly after the waterway opened (about 1971 through 1978) as the number of terminals increased and producers modified production processes to take advantage of the new waterway. Since then, annual changes have followed a more stable pattern varying on average roughly plus or minus 8 percent per year with an overall positive trend. To model uncertainty in projections, probability distribution were fitted to data for annual percent variation in traffic since 1980 (Figure 6). Inter-annual variability prior to 1980 was not included, since these large positive values were due to the system ramping up. As shown in Table 2-27 and Figure 7, goodness of fit statistical tests including the Chi-square, Anderson-Darling, Bayesian (BIC), Akaike (AIC), and Kolmogorov-Smirnov are in consensus that a Gaussian distribution is best suited based on the historical data. Variation captured in the Gaussian distribution was applied to aggregate commodity growth rates to develop a stochastic range of projections. Table 2-28 and Figure 8 displays the stochastic range of study projections.

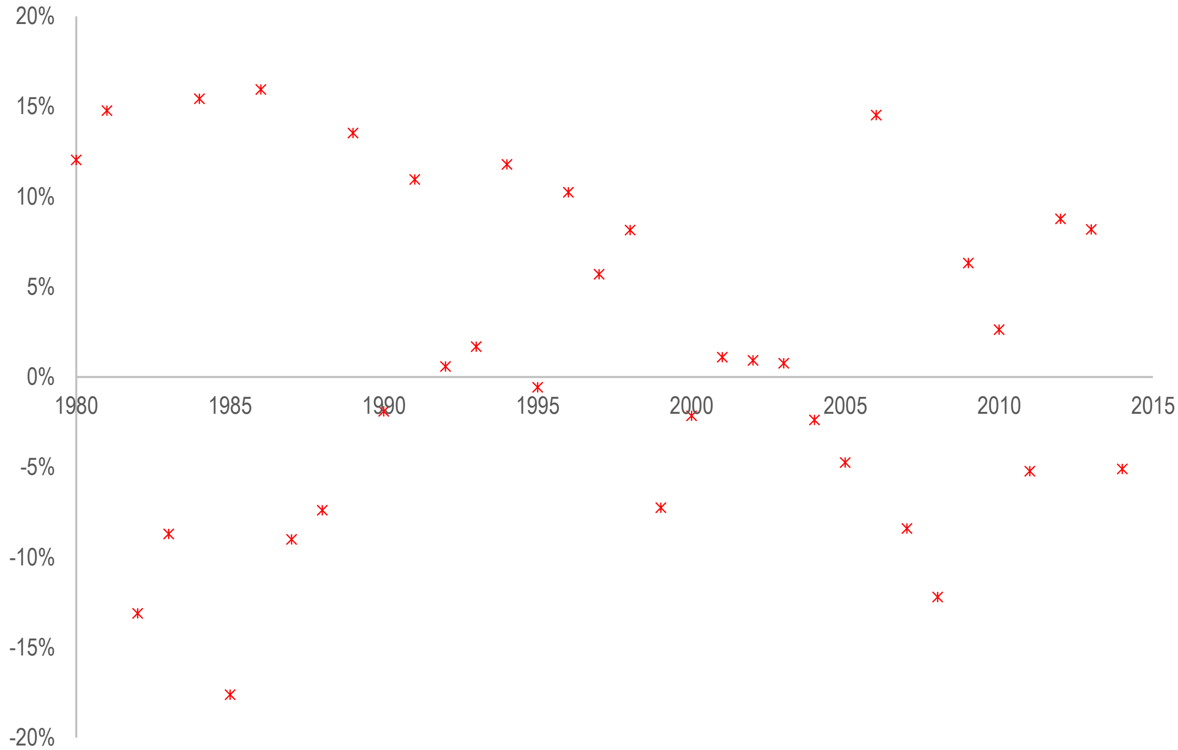

Figure 6: Percent Annual Variation in Commodity Flows through Study Area (1980-2014)

Table 2-27
Probability Distributions for Annual Variation in Commodity Traffic on the MKARNS (1980-2014)

Goodness of fit test	**Distribution ranking based on goodness of fit statistic**		
	ExtValue	**Logistic**	**Normal**
Akaike (AIC)	4	3	1
Bayesian (BIC)	4	3	1
Chi-Square	1	2 (tie)	2 (tie)
Kolmogorov-Smirnov	2	3	1
Anderson-Darling	3	2	1
	Data ranges (fitted)		
Percentile	**ExtValue**	**Logistic**	**Normal**
95%	-12.4%	-14.3%	-13.4%
90%	-10.1%	-10.3%	-10.1%
85%	-8.4%	-7.7%	-7.9%
80%	-7.0%	-5.8%	-6.1%
75%	-5.7%	-4.3%	-4.5%
70%	-4.5%	-2.9%	-3.2%
65%	-3.3%	-1.7%	-1.9%
60%	-2.1%	-0.5%	-0.7%
55%	-0.9%	0.6%	0.5%
50%	0.3%	1.7%	1.7%
45%	1.6%	2.8%	2.8%
40%	2.9%	3.9%	4.0%
35%	4.4%	5.1%	5.2%
30%	6.0%	6.3%	6.5%
25%	7.9%	7.7%	7.9%
20%	10.1%	9.3%	9.4%
15%	12.8%	11.1%	11.2%
10%	16.5%	13.7%	13.4%
5%	22.7%	17.7%	16.8%

Source: Generated by U.S. Army Corps of Engineers, Little Rock District, Planning and Environmental Division using movement data from the Lock Performance and Monitoring System and Waterborne Commerce Statistics Center.

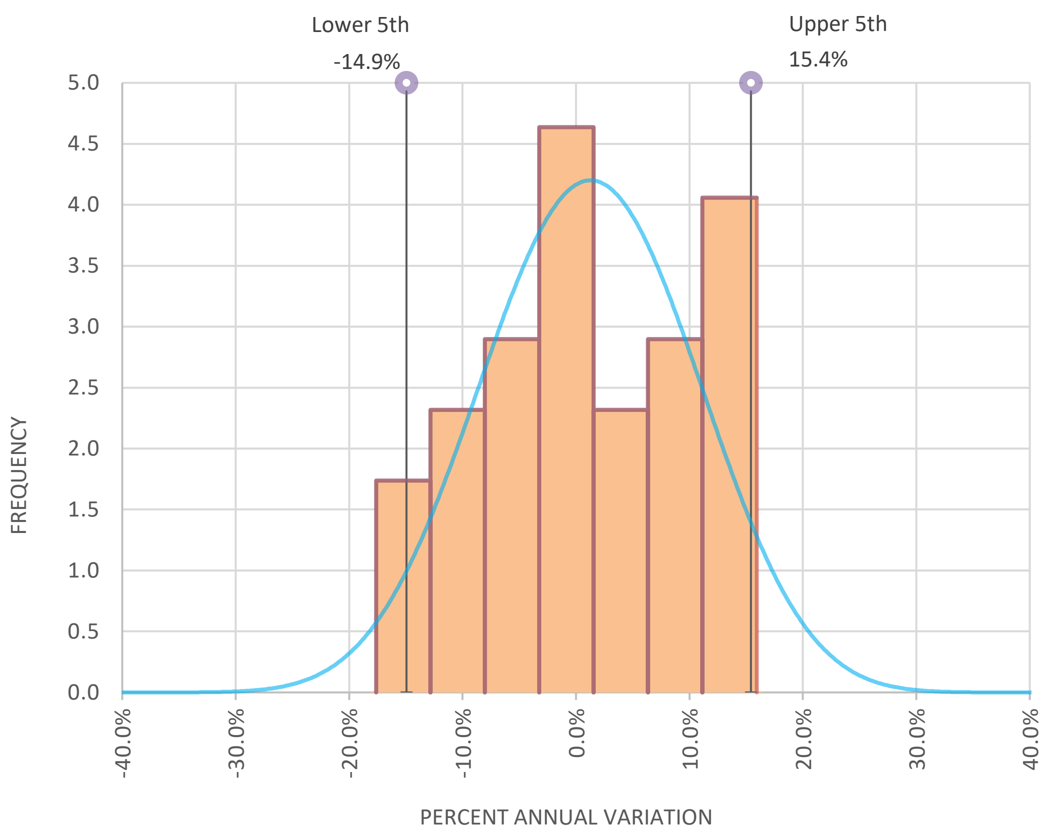

Figure 7: Distribution Fitted to Historical Variations in Annual Commodity Flows in the Three Year Rivers Study Area (based on data from 1980-2014)

Table 2-28
Historical and Stochastic Projections for Commodity Flows through the Three Rivers Project Area

Year	5% exceedance	25% exceedance	50% exceedance	75% exceedance	95% exceedance
1971	-	-	1,817	-	-
1975	-	-	2,739	-	-
1980	-	-	6,715	-	-
1985	-	-	5,814	-	-
1990	-	-	6,327	-	-
1995	-	-	7,981	-	-
2000	-	-	9,127	-	-
2005	-	-	8,722	-	-
2010	-	-	8,764	-	-
2014	-	-	9,376	-	-
Baseline (2016)	9,810	9,810	9,810	9,810	9,810
2020	11,900	10,950	10,220	9,650	8,720
2025	12,620	11,570	10,880	10,120	9,110
2030	13,390	12,220	11,620	10,630	9,510
2035	14,210	12,900	12,150	11,150	9,940
2040	15,070	13,620	12,720	11,700	10,390
2045	15,990	14,390	13,320	12,280	10,850
2050	16,960	15,190	13,960	12,890	11,340
2055	17,990	16,050	14,640	13,530	11,840
2060	19,080	16,950	15,360	14,200	12,380
2065	20,240	17,900	16,140	14,900	12,930
2070	21,470	18,900	16,960	15,640	13,510
2075	22,780	19,960	17,840	16,410	14,110
Projected growth rates (baseline-2075)	1.44%	1.22%	1.03%	0.89%	0.63%
Historical annual growth rates					
1971-2014	-	-	3.97%	-	-
1980-2014	-	-	1.88%	-	-
1990-2014	-	-	1.79%	-	-
2000-2014	-	-	0.42%	-	-
2010-2014	-	-	2.51%	-	-

Source: Historical data from U.S. Army Corps of Engineers Lock Performance and Monitoring System and Waterborne Commerce Statistics Center. Projections developed by U.S. Army Corps of Engineers, Little Rock District, Planning and Environmental Division.

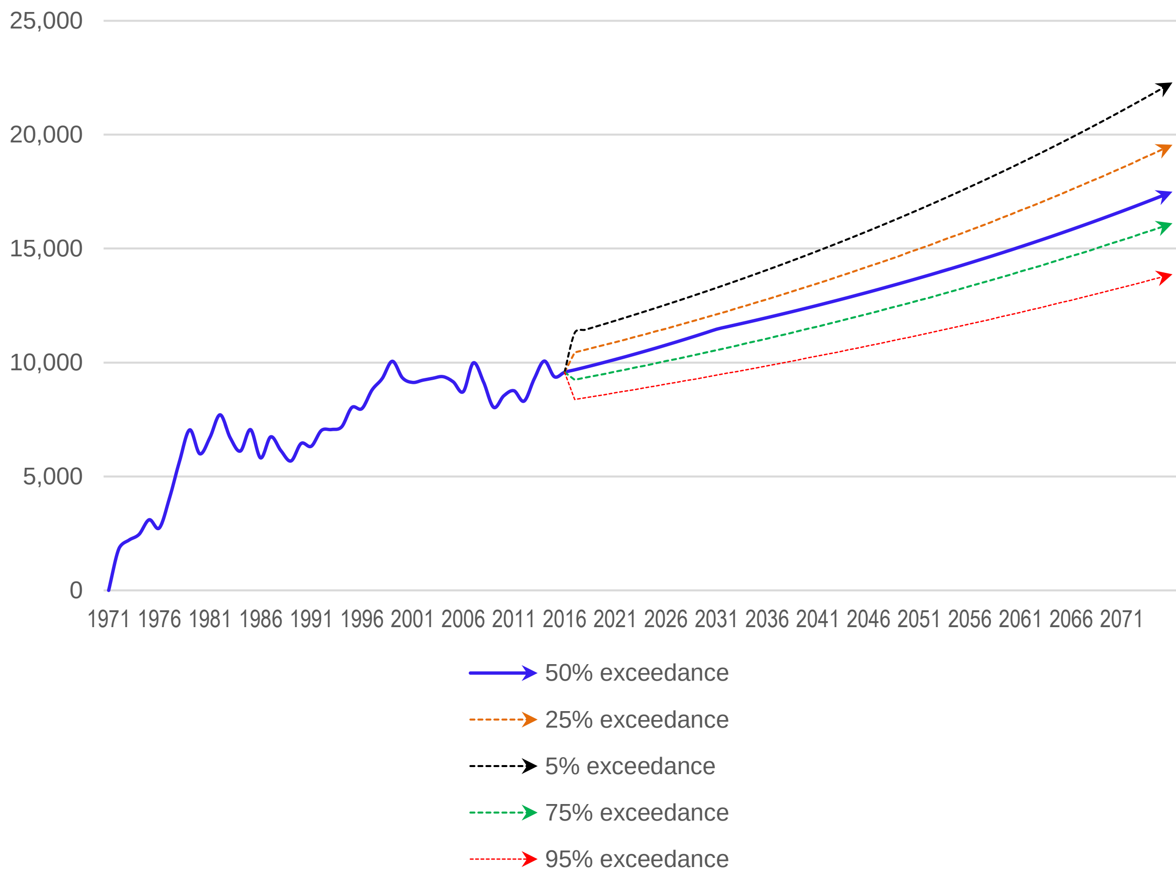

Figure 8. Historical and Projected Commodity Flows through Study Area (1971-2075, thousands of tons)

2.8.2 Hydrologic Conditions during Cut-off Closure

Hydrologic modeling based on 21 years of daily flow and surface water elevation data on the White and Arkansas rivers allowed SWL hydrologists to estimate the expected number of non-navigable days if a cut-off formed. On average, 125 of the 258 days during repair and closure of a cut-off would be non-navigable with a standard deviation of 41 days based on a Gaussian frequency distribution. The number of non-navigation days per year were calculated to occur when either water surface elevation in the entrance channel (upstream of Montgomery Point) was less than 105.5 feet or flows through the cutoff exceed 50 percent of upstream White River flows.

Given the hydrologic dynamics of the river system, it is unlikely that the number of non-navigable days would be consecutive. There would be groups of consecutive days separated by navigable periods during the 258 day repair period, but again based on the sample of historic hydrologic data there is uncertainty as to the duration of navigable versus unnavigable periods during the repair. Based on historical stream gauge data, the mean number of consecutive days where conditions would allow navigation is 6 with a standard deviation of 8. The maximum is 47 days and the minimum is 1 day (Table 2-29). These statistics indicate considerable variability in the data; and although tows could get through Montgomery Point some of the time when the cut-off was under repair, it would be very difficult for high volume regular shippers of commodities to plan and schedule shipments. Compounding the problem would a backlog of pending shipments created during period when conditions closed navigation.

Table 2-29
Descriptive Statistics for Duration of Consecutive Days where Conditions Would Be Non-navigable versus Navigable in the Event of a Cut-Off

Non-navigable*	**Number of Days**
Mean	6
Median	3
Standard Deviation	8
Maximum	47
Minimum	1
Navigable	**Number of Days**
Mean	8
Median	3
Standard Deviation	11
Maximum	67
Minimum	1

* Non-navigation days per year were calculated to occur when either water surface elevation in the entrance channel (upstream of Montgomery Point) was less than 105.5 feet or flows through the cutoff exceed 50 percent of upstream White River flows. Source: U.S. Army Corps of Engineers, Little Rock District Hydraulics and Hydrology Section. Based on historical stream gauge data near the Montgomery Point Lock and Dam.

As with hydrologic conditions during the breach, the timing of such a breach in terms of weather patterns is also uncertain. Obviously, it would most likely occur during a heavy rain event, which are typical during spring and winter months in Arkansas and Oklahoma. Rainfall during the summer often consists of isolated pockets of deep convection; although remnants of tropical systems from the Gulf of Mexico can produce extended basin wide rainfall events and flooding. Thus, making an accurate prediction of when containment structures could fail in any given year is difficult. In addition, while there are upticks in the spring and late autumn, barge traffic through the project area occurs year round, and in the aggregate traffic patterns are not highly cyclical seasonal (Table 2-30 and Figure 9). Commodity flows generally rise in the spring in response to fertilizers shipments for spring grain cultivation, and correspondingly rise in late fall as outbound grain flows to ports in Louisiana for export.

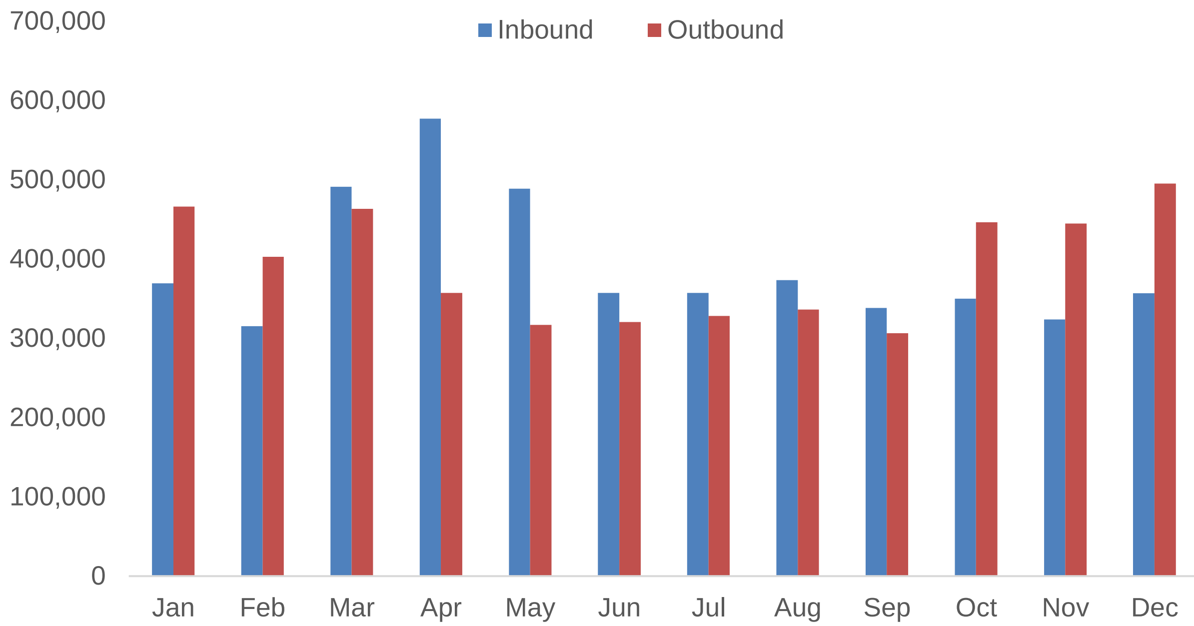

Figure 9. Distribution of Tonnage by Direction and Month through Study Area (2014)

Source: Generated by the U.S. Army Corps of Engineers, Little Rock District using data from the Waterborne Commerce Statistics Center

Table 2-30
Commodity Flows through the Project Area by Month and Volume (1000s of tons, 2014)

Inbound								
Month	Aluminum Products	Grain (Animal Feed)	Building materials and minerals	Chemicals	Coal and Coke	Fertilizers	Petroleum Products	Iron and Steel
Jan	3	15	14	43	16	177	8	107
Feb	18	17	6	23	8	166	4	81
Mar	5	15	33	29	2	265	22	117
Apr	17	40	62	37	11	278	25	100
May	25	47	28	41	2	215	50	90
Jun	26	45	27	19	2	130	40	60
Jul	13	30	28	28	17	113	39	93
Aug	17	16	21	34	2	164	26	99
Sep	21	9	33	8	6	170	28	52
Oct	2	8	25	39	14	160	11	90
Nov	6	22	16	14	14	109	21	109
Dec	4	28	18	19	0	161	28	99
Outbound								
Month	Building materials and minerals	Grain	Coal and Coke	Fertilizers	Petroleum Products	Iron and steel		
Jan	20	304	0	74	19	42		
Feb	24	245	31	42	27	29		
Mar	38	263	35	43	35	44		
Apr	40	192	2	34	34	48		
May	32	164	14	34	23	43		
Jun	31	153	27	11	43	47		
Jul	17	202	16	24	20	41		
Aug	45	180	17	23	30	36		
Sep	48	176	12	8	13	37		
Oct	23	334	13	32	8	28		
Nov	23	324	13	35	12	34		
Dec	16	338	9	74	22	35		

Source: Generated by the U.S. Army Corps of Engineers, Little Rock District using data from the Waterborne Commerce Statistics Center

2.8.3 Shipper Response to Navigation Conditions during Repair

Examples of Historical Closures on U.S. Inlands Waterways and the MKARNS

As discussed earlier, a breach and subsequent cut-off would create hazardous or impassable conditions including cross currents during high water, and draft constraints during dry periods. Thus, there is little doubt that navigation would decline at a minimum or perhaps cease all together while the Corps closed the cut-off.

Conceptually, a breach and closure would be very similar to an unplanned lock outage with the exception that it would be longer in duration than many lock failures. Obviously, when the conditions were unnavigable during the closure, barges could not leave or enter the MKARNs; and a possible scenario is that shippers would opt to transport cargo via alternative modes such as rail or truck until the Corps closed the cut-off rather than risk long delays in getting cargo downstream or upstream. Another possibility is that some shippers may opt to continue to use the river during periods when it is navigable during the repair assuming the navigable periods were long enough to get cargo on the river and get it out or in of the system, but as discussed previously the duration and timing of non-navigable versus navigable periods is highly uncertain. Overall, navigation would decline or cease, but this depends on hydrologic conditions and shipper responses, and there does not appear to be a historical precedent for a closure similar to the one possible in the study area.

Although there is no historical precedent, the Corps has cataloged and analyzed the effect of lock and dam closures through surveys of the inland shipping industry. For example, between 8 September and 31 October 2003, the main lock chamber at the Greenup Locks and Dam on the Ohio River closed to navigation.[16] Originally, the closure was scheduled for 18 days; however, during the inspection, engineers discovered cracking in the lock gates, and the closure extended for emergency repairs. The closure that was originally planned to last 18 days stretched to over 52 days. After the closure, the Corps surveyed shippers and carriers to find out what measures were taken to mitigate the effects of the main chamber closure at Greenup and to estimate the associated costs.

Shippers reported a wide variety of reactions to the outage, ranging from no changes in procedures to shifting production to different facilities. Most respondents reported that the closure was well-handled, that they had sufficient notification, and that they were

[16] U.S. Army Corps of Engineers, Planning Center of Expertise for Inland Navigation, "Shipper Carrier and Response to September through October Greenup Main Lock Closure." IWR Report 05-NETS-R-02. February, 2005.

able to adjust, but several indicated that the unscheduled portion of the closure was particularly problematic and expensive for them. Several respondents indicated that their experience with Greenup caused them to do such things as increase stockpiles, plan alternative transportation and to prepare for a worst-case scenario in other closure situations. Shippers and carriers provided estimates of additional costs incurred as a result of the closure. Aside from delay costs, costs to industry totaled $28.7 million, and delay costs for carriers totaled about $13.2 million. Of the industry costs, $8.6 million were due to modal shifts, $13.1 million consisted of lost sales revenues, $1.9 million were for stockpiling, and the remainder for various costs including shifts in production location and altered production processes. Total reported costs for the closure were $41.9 million.[17]

Two more examples include a closure at the McAlpine Lock and Dam in Kentucky on the Ohio River, and Lock 27 on the Mississippi River. McAlpine closed for emergency repairs from 3 August 2004 through 16 August 2004 (about 2 weeks).[18] Survey results indicated that the emergency closures caused serious disruption to towing companies and their customers. Carriers experienced delays and equipment idling at a cost of $2.7 million, while shippers incurred costs of $3.7 million in additional costs and $0.7 in lost sales revenues. Total reported costs were $6.3 million. Lock 27 closed from 26 July 2004 through 10 August 2004 for gate repairs. Shippers and carriers reported additional financial costs totaling about $0.23 million, and reported costs of modal shifts were about $3.9 million.

On the MKARNS there are scheduled lock outages and for short periods (usually a week) for maintenance and or repair; and, shippers and carriers are notified well in advance and impacts are minimal. The navigation industry is also accustomed to fairly regular shutdowns of the system due to high water events that occur in some years (but not all), particularly during late winter to late spring. Weather related closures usually last for a few weeks, and the typical response is wait for navigation to resume when flows decrease to acceptable levels; although some opt for alternative land based routes during these periods.

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[17] The $41.9 million in total costs to industry was compiled from partial information. Many companies, including some major users of the Greenup facility, declined to participate in the survey. Other companies participated in the survey and indicated that they had had added costs during the closure period, but were unable to isolate and provide those costs. For these reasons, total costs cited are understated.

[18] U.S. Army Corps of Engineers, Planning Center of Expertise for Inland Navigation, “McApline Lock Closure August 2004: Shipper and Carrier Response.” IWR Report 05-NETS-R-08. September, 2005.

Although most high flow closures are relatively short, in 2015 the MKARNS experienced its worst (longest) weather related shutdown. In late spring of 2015, the system shut down for about 7 weeks after record setting rains hit the region (50-year event in many locations) largely due to the remnants of an early tropical storm in the Gulf of Mexico. May 2015 was the second-wettest May in recorded history with areas in both states having received almost 15 inches of rain. According to Bob Portiss, Director at the Tulsa Port of Catoosa, it was "…*a hell of a mess*," and "*the longest period of time in the history of the port that we haven't been able to ship cargo on the waterway*."[19] Since the Port of Catoossa is a multimodal facility, many shippers opted to move cargo by rail and truck; however, because shipping via waterway is the least expensive option for companies, some shippers chose to wait out the rain and strong water flows. Other than delays and higher shipping costs, the hardest hit sector were barge owners and operators who were idled for almost two months.

Survey of MKARNS Shipping Industry

Since there are limited historical precedents for a long term disruption in navigation in the study area, the Corps conducted industry surveys and interviews via a contract with Gulf Engineers and Consultants, LLC (GEC) who have extensive knowledge of the MKARNs and maritime industry contracts. GEC conducted fieldwork in the summer and fall of 2016. The Corps received approval from the Federal Office of Management Budget to conduct interviews in July of 2016. Interviews focused on how unplanned navigation disruptions might affect the industry, and was conducted in person via interviews with key port personnel, terminal operators and shippers.

Prior to discussing key survey findings, it is important to stress that confidentiality was and is very important with respect to data and information gathered during the study. GEC conducted meetings and communications under strict conditions of confidentiality as documented by written communications from the Corps consisting of a Navigation Notice and a letter to the President of the Arkansas Oklahoma Port Operators Association (see Addendum B of this Appendix). Results discussed in this appendix summarizes findings of the interviews and data and information provided by individual respondents are not presented. Notwithstanding assurances of confidentiality,

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19 "Recent rains' impact 'horrific' on waterway shipping for navigation system." Tulsa Port of Catoosa, Tulsa World, July 5th 2015. See also, Murray, D. "High water continues to stall MKARNS shipping." Waterways Journal. June, 22 2015.

respondents were often reluctant to discuss proprietary business matters in any degree of detail.

In addition, in contrast to port and terminal operators, it many cases it was difficult to identify "shippers" to interview. Shippers with regard to individuals and entities that choose and purchase transportation modes were difficult to identify without input from port and terminal operators. The relatively lower volumes of barge movements on a tributary waterway to the Mississippi River System such as the MKARNS compared to larger volumes on the main stem Mississippi River usually resulted in multipurpose users of particular ports and terminals. Except for a few very large shippers with private access to particular docks such as at Tulsa Port of Catoosa most MKARNS shippers use docks and terminals of third party providers. While third party port and terminal operators could attest to the cargoes they transport, they often had limited information regarding origins, destinations and freight rates other than port handling costs. This lack of shipper identity with respect to mode choice characterized by the use of third party docks and terminals was particularly prevalent in the many small shippers who receive freight via MKARNS, but have little input into mode choice. Consequently, attempts to contact shippers who make mode choice decisions that are or could be affected by unplanned disruptions to navigation for extended periods of time, possibly months, because of flooding often involved multiple layers of persons and organizations.

Given the obstacles in identifying MKARNS shippers, GEC or the USACE were unable to extract a random sample from a population of shippers. Without a random sampling frame, we are restricted to a less satisfactory form of sample that cannot be randomly selected because not all individuals within that population will have the same probability of being selected for the sample. Thus, the sample of shippers is a non-probability sample, which is not suitable for statistical inference (e.g., confidence intervals and margins of error), and the validity of the findings from statistical standpoint is unknown and cannot be established, but the data are the best available information. Without an extended study schedule and resources, the USACE believes that the results are suitable for planning purposes. Even with an extended schedule and additional resources, it would be very difficult to identify the universe of shippers and participation would still be voluntary.[20]

[20] Section 5 contains sensitivity analysis showing how NED benefits vary with different cargo diversion rates.

Despite challenges and caveats noted above, GEC identified 49 firms that ship on the MKARNS. Of these they were able to establish contact with 38 firms. Three of the contacted firms provided limited if any information, and two were not currently shipping on the MKARNS. Thus, in total representatives of 33 companies agreed to provide information to GEC representatives (Table 2-31). The 33 firms that provided information move almost 40 percent of tonnage through the study area each year.

Table 2-31
Number of Firms Interviewed for the Shipper Survey and Typical Annual Volume Shipped

Commodity	Number of Firms	Annual Tonnage Shipped (1000s)
Fertilizers	8	2,225,0000
Iron and Steel	14	250,000
Grains	1	620,000
Coal and Coke	2	125,000
Petroleum Products	2	Not specified
Minerals (clays and bauxite)	3	180,000
Molasses	1	80,000
Animal Feed	1	150,000
Asphalt	1	3,000
Total	**33**	**3,658,000**

Several large shippers handle a significant amount of the total cargo moving on the MKARNS, and represent a conglomerate of enterprises with alternative sources of supply and markets. As a result, they can respond to unplanned disruptions to navigation via a network of alternate logistics facilities and modes of transportation. In fact, these shippers have already responded to unplanned navigation disruptions affecting the MKARNS such as the disruption in 2005 when Hurricane Katrina shutdown shipping on the Lower Mississippi, and flooding in late 2014 and early 2015 effectively closed the MKARNS for nearly two months.

Smaller shippers in terms of both volume and frequency generally have not had to respond to unplanned disruptions of MKARNS navigation unless they are involved in other river ports and terminals of the Mississippi River System. Effects of unplanned disruptions are regarded as minimal when shipment volumes are small and relatively infrequent such as several barges a year resulting in sufficient inventories for an extended duration of time over several months. Conversely, shippers with seasonal fluctuations of demand such as fertilizers view unplanned disruptions to MKARNS navigation as "devastating" or "catastrophic" if the disruptive event occurred during peak shipping season. Otherwise, many can usually tolerate unplanned disruptions up to about one month duration, possibly longer depending on inventory and level of demand particularly in off peak periods such as fertilizers. Overall except for peak demand periods most shippers can absorb unplanned disruptions to MKARNS navigation for several weeks extending out to about one month. Tolerance to longer periods of disruption may be possible for off peak demands or smaller shippers relative to barge lot sizes (1,500 tons) that results in more than one month of inventory.

For past long periods of disruption or potential periods greater than 30 days or an event similar to the closure in the event of cut-off in the study area, the most common shipping alternatives reported by interviewees were rail or truck or purchase from another supplier at a higher cost, which implies that the commodity purchased would be shipped by either rail or truck, or a combination of rail, truck and alternative port such as ports in St. Louis or Memphis. One interviewee representing a large importer of cargo from the MKARNS recalled the devastation at New Orleans after Hurricane Katrina and impacts on imports via the Lower Mississippi River and MKARNS. The interviewee noted that if there was an unplanned disruption to MKARNS navigation, they would take action almost immediately (depending on the time of the year and the expected duration). Hurricane Katrina shutdown the Port of New Orleans (and the entire river navigation system for their imported product) and at the time they did not know for how long. They began making supply arrangements the next day after the hurricane, shifting to rail and domestic suppliers. The volume of throughput at the MKARNS Port of Catoosa was not affected; it only shifted from barge (imports) to rail (domestic).

One respondent stated that they carry sufficient inventories to continue operations for three to more months and then cease operations for longer periods until navigation resumed, and several iron and steel importers stated that they would have to purchase from domestic suppliers at a higher cost. Reported cost increases due to alternatives to shipping on the MKARNS ranged from $20 per ton to $110 per ton with a mean of $38 per ton and a median of $28 per ton. In addition to higher transportation costs, a major concern of MKARNS shippers was the effect of unplanned disrupted navigation on possible lost customers and future sales. These losses could not be readily quantified other than the temporary absorption of the higher freight and or procurement costs to maintain competitive services to existing customers during the duration of unplanned disruption to MKARNS navigation.

Figure 10 summarizes interviewee responses when asked how they would handle a long-term unplanned closure of the MKARNS. Again, the definition of long-term varied by respondent, and generally ranged from 30 to 60 days.

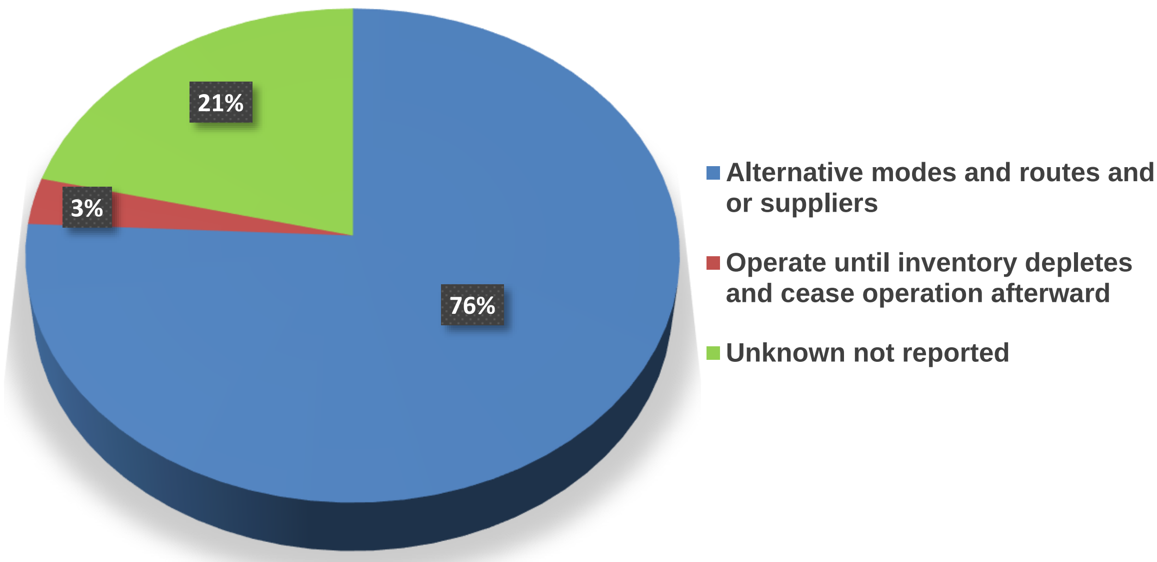

Figure 10: Reported Responses to a Long-term Unplanned Closure of MKARNS

3.6.2 Transportation Costs Savings of Waterway Shipping

A key metric in estimating the NED benefits for navigation is the cost differential between water routes and the least cost alternative of rail. As discussed previously, if navigation through the study area is disrupted for extended period, many shippers will likely move cargo via a combination of rail and truck, which is more expensive.

To estimate cost savings, the District sponsored a rate study under contract with Texas A&M University Transportation Institute (TTI) Center for Ports and Waterways and GEC

(Gulf Engineers & Consultants, LLC).[21] Researchers at TTI developed a full range of transportation routings, line-haul rates, and supplemental costs for a sample of 171 movements provided by the District (originating, terminating, or through). All 171 movements were contained in and selected from 2013 Waterborne Commerce Statistics Center's (WCSC) commodity movement data. Freight rates for each sampled movement were developed based on the actual water-inclusive routing and for a competing (least-cost) alternative. Rates and fees are stated in FY2017 dollars per net ton. Results were documented on a movement-by-movement basis by unique origin, destination and commodity (ODC) combination via a separate rate sheet for each observation.[22]

Section 3.6.2 describes rate study parameters, data sources, methods employed, findings and results, research, limitations encountered, supporting assumptions, and conclusions.

Waterborne Movement Sample

The District provided a raw dataset consisting of 8,383 waterborne movements from which sample records were extracted. The sample of 4,299 loaded movements was selected by USACE that mirrored the population as accurately as possible such that the distribution of tonnage by commodity group in the sample mirrored the distribution of tonnage by commodity group in the WCSC population of movements. The sample of 4,299 movements corresponds to 74 percent of loaded movements and tonnage that entered and exited (i.e., that flowed through the study area and would be affected by a navigation closure) the MKARNS in 2014 (Table 2-32).

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[21] Kruse, C.J., Warner, E.W., Olson, L.E., and Lee, D. "Transportation Rates Research: McClellan-Kerr Arkansas River Navigation System (MKARNS)." Prepared for the U.S. Army Corps of Engineers Little Rock District under contract with Engineering Consulting Services-Gulf Engineers & Consultants Joint Venture, January, 2017.

[22] References to "movement" herein refer to the 171 records with unique ODC combinations, not individual physical movements. Each record typically summarizes multiple shipments.

Table 2-32
Distribution of Movements and Tonnage by Commodity Group through the Three Rivers Study Area by Population and Sample

	Universe	Sample	Percent
Trips	5,860	4,299	74%
Tons	9,844,435	7,240,825	74%
Origin Destination Pairs	635	171	27%
Commodities in Origin and Destination Pair Sample as Percent of Total Commodities			
Aluminum	49,430	40,647	82%
Fertilizers	2,342,223	1,612,917	69%
Ores, Minerals and Building Materials	759,382	405,109	53%
Other Food and Ag	284,520	183,980	65%
Coal and Coke	855,035	726,864	85%
Chemicals	129,255	88,304	68%
Iron and Steel	1,523,529	1,296,668	85%
Fuel and Oils	931,623	765,928	82%
Corn	331,891	217,930	66%
Rice	174,490	115,282	66%
Soybean	853,015	539,097	63%
Wheat	1,529,225	1,219,375	80%
Other	80,817	28,724	36%
Total	**9,844,435**	**7,240,825**	**74%**

Source: Sample drawn from U.S. Army Corps of Engineers Waterborne Commerce Statistics Center 2013 dataset.

Existing Waterway Routing

An overall waterway movement includes the movement to and from individual ports or docks to and from the ultimate origin destination and line-haul component over the waterway. Over the course of performing inland waterway movement economic evaluations during previous projects, efforts were undertaken to examine individual ports and docks and conduct telephone discussions with terminals and facilities. During these investigations, TTI researchers discovered that off-river origins and destinations were either nonexistent, unidentifiable, vast in number, or unknown. In many instances, privately owned and operated docks serve as holding docks for adjoining or nearby industrial facilities; midstream holding docks between sibling facilities of the same corporation; import export docks; or distribution points to a very large number of off-river origins and destinations such as grain elevators. Thus, TTI concluded that no land movement per se beyond a facility port or dock could be isolated and identified. Loading and unloading of barges is typically performed via pump, conveyor belt, or crane with clamshell directly from a port or dock. Therefore, water origin and destinations were assumed to be the ultimate origin and destination.

The analysis relied heavily on the Barge Costing Model (BCM) originally developed by the Tennessee Valley Authority (TVA) over 25 years ago and has been updated and used continuously, extensively, and successfully by the Corps. The BCM provides shipper cost information on line-haul movements of commodities between points on the Inland Waterway System. Additionally, the model calculates transfer costs to and from barge (i.e., a barge operator's cost of time to load or unload a barge for a particular routing). The model uses information obtained from various sources including:

- the Corps Lock Performance Monitoring System (LPMS) and WCSC databases,
- *Inland River Record* (barge and towboat characteristics),[23]
- *Shallow Draft Vessel Costs* (fixed and variable cost data),[24]
- Shippers and receivers, and
- Barge and towing industry sources.

The BCM underwent an extensive review in 2013 by the University of Oregon, referred to as the Wilson Review that identified issues with the model.[25] TTI acquired the version of the BCM used for this analysis from North Dakota State University (NDSU) that incorporates improvements based on the Wilson Review. In addition, NDSU incorporated several enhancements to the BCM, including integrated input and output of Microsoft Excel spreadsheets. The NDSU model version used data updated in 2011. The Corps contracted with Oakridge National Research Laboratory (ORNL) to update the BCM databases using 2014 data. TTI acquired updated databases in October 2016 and incorporated the data into the BCM used in this study, which in turn was used to estimate rates per ton for the 171 sample movements.

In addition to calculating line-haul water rates with the BCM, two major barge operators provided water line-haul rates in 2014 dollars for 155 of the 171 movements (91

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[23] The Waterways Journal. *Inland River Record*. January 2017.

[24] U.S. Army Corps of Engineers, Economic Guidance Memo #05-06: Shallow Draft Vessels Operating Costs FY 2004.

[25] Wilson, W. K., and Gleasman, W. "Final Report on Review of the Barge Costing Model." University of Oregon. May 2013.

percent). Operator rates were compared to rates produced by the BCM and were very close for dry commodity movements, but significantly different for liquid commodities. TTI researchers contacted barge operators who stated that rates for liquid cargo in 2014 were much higher than normal, especially rates for liquid cargoes use for oil and gas extraction, due to extremely high demand and utilization rates for barges. Following a discussion with the Corps, the decision was made to treat 2014 actual rates as an anomaly and use BCM estimates rates for the 29 liquid movements.

For dry commodity movements, barge operator rates were used where reported. Water line-haul distances and times, load and unload times, and any supplemental are BCM estimates. For dry commodity movements without a reported barge operator rate, the BCM-calculated rate was used. Final water line-haul rates for the entire sample resulted in 129 barge operator rates and 42 BCM estimated rates, 73 percent and 27 percent respectively.

Load and unload rates generated by the BCM were consistent with previous work conducted on the Arkansas River.[26] Of particular note, in the previous work, TTI researchers discovered that separate and distinct handling charges do not exists for liquid bulk goods. In contrast to dry bulk, liquid bulk terminals have a completely different cost structure for cargo transfers involving marine vessels including barges. Generally, cargo handling costs are included in rental charges for liquid storage tanks paid by the shipper, with a maximum number of tank turnovers per rental period. In other words, a certain number of cargo transfers are built into the rates. The logistics calculation performed by shippers is not as simple as adding several dollars per ton to the barge freight rate to account for cargo handling costs.

TTI adjusted fuel prices in the BCM by using the Energy Information Administration's (EIA) Refiner Petroleum Product Prices by Sales Type for 2014 prices. Lastly, water line-haul rates were indexed 2017 dollars using Bureau of Labor Statistics Producer Price Index for inland water freight transportation. Since cost escalation in the rail and barge industry is similar, the PPI was used throughout the analysis.

Least Cost Routing

A close examination of each origin and destination via online photography and satellite images, FindTheData.com, and the Corps *Ports and Waterways Facilities* showed that most docks are attached to facilities with on-site access to and from a rail mainline (rail connector or spur). Given the bulk, low unit value of waterway commodities, TTI

[26] Texas Transportation Institute, "*Transportation Rates Research: Gulf Intracoastal Waterway–East (GIWW-E), Arkansas River, Red River*." January 2013.

assumed that the least-cost line-haul alternative would likely be rail in the absence of barge transportation. In cases where the origin or destination facility did not have on-site rail access to a rail mainline, TTI identified the nearest railhead with trans-loading facilities. A short truck haul requirement, 15 miles on average, was estimated between each such facility and the nearest railhead. The requisite truck charges were added to rail line-haul charges as applicable to obtain the cost of all-overland routings.

The Surface Transportation Board's (STB) Carload Waybill Samples (CWS) 2014 (confidential files) were obtained through the Corps Planning Center of Expertise for Inland Navigation for purposes of this work. Initially, an attempt was made to use the CWS 2014 to acquire rail mileage and rate (revenue per net ton). Each waybill was analyzed for movements of similar origin-destination-commodity (ODC) triples at two geographic levels, the county Federal Information Processing Standard (FIPS) level and the Business Economic Area (BEA) level. The analysis was performed at both the 5-digit and 2-digit Standard Transportation Commodity Code (STCC) system used by railroads, depending on how well the codes in the CWS shipments matched commodities being analyzed. A BEA region typically includes one or more counties. Differences between the WCSC commodity classification system and the STCC system only occasionally permits matching the 5-digit WCSC code to the 2-digit STCC code. For example, the closest match to Benzene, Pure (WCSC code 51122) at the 5-digit STCC level was STCC 28141 *Crude Products from Coal Tar, Natural Gas*. An equivalent ODC triple combination could only be found at the 2-digit STCC level (28 *Chemicals and Allied Products*). Waybills did not exist for many ODC triples. The absence of waybills for ODC triples identical or similar to waterborne movements is not surprising since waterborne transportation competes effectively with rail, especially for movements included in the sample.

Although many ODC triples were not captured in CWS 2014, there were instances where the rail mileage in the captured ODC triples could be used for other movements. These movements had the same origin and destinations as a captured ODC triple but did not match a commodity. In movements not captured by CWS 2014 the program PCRail by ALK Technologies, Inc. was used to calculate rail distances per railroad along routes between movement origins and destinations. The "practical mileage" was the distance used. The program breaks down the rail mileage by railroad utilized to perform the trip.

Determining rail rates for movements not captured by matching the ODC in CWS 2014 involved using a table developed by the Corps that formulates rail rates for all CWS 2014 rail movements. The Corps Waybill Statistics allows for capturing the rail rate based on railroad, commodity, distance, and number of carloads. The primary railroad based on distance was captured from PCRail, while the number of carloads was estimated by dividing the total waterway commodity tons by the number of shipments per movement. The tons-per-shipment calculation was then divided by 105 tons per railcar to estimate the number of railcars required to move the shipment. To capture the associated rail rate in the Waybill Statistics table, the STCC 5-digit commodity code most closely associated with the major commodity was selected for each movement. Finally, the cost per mile value captured was then converted to cost per ton using the table's tons per carload value and PCRail's total length of haul.

Rail costs were then adjusted to 2016 dollars using the PPI. Of the 171 movements, 48 (28 percent) acquired costs from matching the ODC in the STB Waybill Sample, with the remaining 123 (72 percent) movements using costs from the Waybill Statistics table. Previous rate analysis projects completed by TTI have assumed a reported system average speed of 26.2 mph for Union Pacific Railroad (UP); however, for this study average speed was reduced to 21 mph to reflect in route terminal dwell times. At the time of this project, UP's system average speed was 26.7 mph, and the system average speed was 24.9 mph for all Class I railroads Based on these numbers, the 21 mph was again chosen to reflect in route terminal dwell times and was used to calculate the mainline rail trip time in days. Two days were added to origin legs and one day to destination legs with on-site or nearby rail line access to account for the rail load/unload time, travel time, and dwell/switch time required for local rail service between mainline railheads and individual facilities or trans-load terminals.

Short truck hauls between facilities without on-site rail access and the nearest railhead with trans-loading capability were estimated to be 15 miles on average at an average speed of 40 mph. Truck trip times, either for line-haul or short haul to the nearest railhead, were reported in days to allow comparison with rail and water trip times. Short haul truck miles, time, and rates were added to line-haul rail miles, time, and rates, as applicable, to obtain all-overland routing figures. Truck rates per net ton-mile were obtained through communication with national motor carriers and compared to online truck rate websites. Websites produced similar rates as the quoted motor carrier rates, so the motor carrier rate was deemed appropriate for this study. For short delivery distances requested, rates included a day rate of $300, which was then converted to a rate per ton-mile. A truckload net cargo weight of 22.5 tons (45,000 pounds), densities of representative commodities, and trip distances and durations were taken into consideration to calculate a truck cost in dollars per ton-mile for all commodities on a nationwide basis. For long-haul truck movements, two scenarios presented themselves in discussions with the motor carrier companies. The first involved long-haul shipments under 150 roadway miles, which were quoted at a flat rate of $900. Only one record met this criterion. The other scenario was for longer shipment distances where a rate per mile of $3.60 per mile was quoted. Long-haul trucking rates were then compared to the calculated rail rates to determine the least-cost all-overland option. Truck was found to be the least-cost all-overland mode in 15 of the 171 movements.

As applicable, calculations include requisite handling (loading unloading and transfer) costs. Loading and unloading costs at facilities to and from rail or truck, as well as transfer costs at trans-load terminals in terms of dollars per net ton, were determined by the type of transfer equipment. Each commodity group was assigned assumed equipment for the transfer.

It must be noted that the logistics involved in a modal shift from barge to rail or truck may be challenging in reality, considering the significant capacity advantage of barges. The economic analysis for the Three Rivers Study assumes that adequate rail and road capacity exists as a simplifying assumption.

Results

Barge operators consider groupings of commodities based on similarity of barge types required to move the commodities. The TTI research team, in collaboration with barge operating companies, developed eight groups of commodities with similar shipping characteristics (Table 2-33). These groups were used in calculating transportation rates for similar commodities. Table 2-34 shows the number of trips and tons per project commodity group for the sample of MKARNS movements.

Rates in dollars per net ton-mile obtained for existing water routings, the least-cost routing, and the ratio of least-cost route miles to existing water route miles obtained for each movement were averaged by commodity group for the sample. Table 2-35 displays transportation rates per net ton-mile by commodity. As shown, barge shipments are the least-cost transportation alternative for every commodity group when averaging across an entire commodity group. On an individual movement basis, 18 movements indicate that barge was not the least-cost alternative.

Table 2-33
Project Commodity Groups Based on Similar Shipping Characteristics

Project Group Number	Commodities
Group 1 Grains & Fertilizers	Soybeans, Wheat, Corn, Rice, Sorghum; Fertilizer (pellet); Oil Cake & Oils, Solid Residues; Sodium Nitrate
Group 2 Coke, Petro., etc.	Coke, Petro, Bitumen, Petro Coke, Pitch and Pitch Coke
Group 3 Fuel Oils	Fuel Oils, Gasoline; Sodium Hydroxide
Group 4 Molasses	Molasses
Group 5 Iron, Gravel, etc.	Iron & Steel, Ferrous Waste; Portland; Slag; Aggregate, Minerals
Group 6 Aluminum Products and Minerals	Aluminum, Aluminum ores; Clays, Vermiculites, etc.,
Group 7 Anhydrous Ammonia	Anhydrous Ammonia (primarily fertilizer)
Group 8 Chemical Fertilizers, Nitrogenous	Nitrogenous Chemical Fertilizers

Source: Texas Transportation Institute Center for Ports and Waterways

Table 2-34
Sample Project Commodity Group Totals

Commodity Group		Trips	Percent	Tons	Percent	Average Trip Length (miles)
1	Grains & Fertilizers	2,332	54%	3,670,786	51%	791
2	Coke, Petro., etc.	463	11%	740,324	10%	862
3	Fuel Oils	259	6%	827,071	11%	958
4	Molasses	34	1%	48,300	1%	860
5	Iron, Gravel, etc.	1,046	24%	1,606,457	22%	888
6	Aluminum Products and Minerals	95	2%	151,392	2%	633
7	Anhydrous Ammonia	19	0%	47,500	1%	931
8	Chemical Fertilizers, Nitrogenous	51	1%	148,995	2%	988
Total		**4,299**	**100%**	**7,240,825**	**100%**	**844**

Source: Texas Transportation Institute Center for Ports and Waterways analysis of data from the U.S. Army Corps of Engineers Waterborne Commerce Statistics Center

Table 2-35
Transportation Rates per Net Ton-Mile by Project Commodity Group

Commodity Group	Existing Water Routing	Least Cost Routing	Average Ratio of Land to Water Miles
Grains & Fertilizers	$0.02	$0.11	0.86
Coke, Petro., etc.	$0.02	$0.11	0.86
Fuel Oils	$0.03	$0.08	0.81
Molasses	$0.02	$0.06	0.86
Iron, Gravel, etc.	$0.02	$0.09	0.75
Aluminum Products and Minerals	$0.02	$0.10	1.01
Anhydrous Ammonia	$0.06	$0.15	0.67
Chemical Fertilizers, Nitrogenous	$0.03	$0.05	0.87

Source: Texas Transportation Institute Center for Ports and Waterways analysis of data from the U.S. Army Corps of Engineers Waterborne Commerce Statistics Center

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To calculate costs to ship by water and least-cost routing, transportation rates per net ton-mile are multiplied by the length-of-haul and tons per sample movement. Table 2-36 shows transportation for each commodity group for both the water and least-cost routing. For sample movements, which account for 74 percent of tonnage on the MKARNS, annual cost savings are $378million. Notably, the alternative was not the least-cost for Chemical Fertilizers, Nitrogenous. This is due to a limited sample size where land miles were low enough when compared to water miles, and the difference in ton-mile rates was more than offset by the shipment distance.

Table 2-36
Transportation Costs and Savings for the Sample Movements

Commodity Group	Existing Water Routing	Least Cost Overland Routing	Annual Cost Savings
Grains & Fertilizers	$46,658,728	$269,274,852	$222,616,124
Coke, Petro., etc.	$10,363,618	$63,251,253	$52,887,635
Fuel Oils	$19,863,228	$49,266,328	$29,403,100
Molasses	$933,722	$2,177,225	$1,243,503
Iron, Gravel, etc.	$22,463,306	$85,393,805	$62,930,498
Aluminum Products and Minerals	$1,700,498	$8,275,178	$6,574,681
Anhydrous Ammonia	$2,128,126	$3,657,207	$1,529,081
Chemical Fertilizers, Nitrogenous	$4,190,162	$5,472,301	$1,282,139
Total	**$108,301,388**	**$486,768,149**	**$378,466,761**

Source: Texas Transportation Institute Center for Ports and Waterways analysis of data from the U.S. Army Corps of Engineers Waterborne Commerce Statistics Center

To estimate cost savings for the entire population of traffic through the study area, the research team distributed the sample of commodities into the project commodity groups used in the rate analysis. Most sample commodities closely matched the commodity groups used to estimate cost savings and allowed direct placement into an associated project commodity group. Remaining sample commodities required distribution across multiple project commodity groups. Cost savings for the population was then estimated based on movement sample by commodity provided by the Corps (Table 2-37). Using percentages in Table 2-37, costs for water and least-cost routings were calculated for the full population. As shown, the estimated savings total more than $514 million (Table 2-38).

Table 2-37
Distribution of Tonnage by Project Commodity Group in Population and Sample

Commodity Group	Universe	Sample	Percent
Grains & Fertilizers	5,242,954	3,670,786	70%
Coke, Petro., etc.	880,266	740,324	84%
Fuel Oils	1,021,925	827,071	81%
Molasses	74,695	48,300	65%
Iron, Gravel, etc.	2,047,066	1,606,457	78%
Aluminum Products and Minerals	260,120	151,392	58%
Anhydrous Ammonia	68,899	47,500	69%
Chemical Fertilizers, Nitrogenous	248,510	148,995	60%
Total	**9,844,435**	**7,240,825**	**74%**

Source: Texas Transportation Institute Center for Ports and Waterways analysis of data from the U.S. Army Corps of Engineers Waterborne Commerce Statistics Center

Table 2-38
Estimated Transportation Costs and Savings for Commodity Shipments through the Three Rivers Study Area

Commodity Group	Waterway	Least Cost Alternative	Cost Savings
Grains & Fertilizers	$66,642,288	$384,603,117	$317,960,829
Coke, Petro., etc.	$12,322,632	$75,207,509	$62,884,877
Fuel Oils	$24,542,909	$60,873,237	$36,330,329
Molasses	$1,443,975	$3,367,018	$1,923,043
Iron, Gravel, etc.	$28,624,400	$108,815,079	$80,190,679
Aluminum Products and Minerals	$2,921,771	$14,218,296	$11,296,525
Anhydrous Ammonia	$3,086,878	$5,304,834	$2,217,955
Chemical Fertilizers, Nitrogenous	$6,988,813	$9,127,306	$2,138,493
Total	**$146,573,666**	**$661,516,396**	**$514,942,730**
Average per ton	**$14.89**	**$67.20**	**$52.31**

Source: Texas Transportation Institute Center for Ports and Waterways analysis of data from the U.S. Army Corps of Engineers Waterborne Commerce Statistics Center

2.8.4 Forgone Navigation NED Benefits

Forgone NED benefits Based on projected cargo traffic, potential shipper response to a navigation closures at Three Rivers, and estimated costs savings of waterway shipping versus the least cost alternative, which in this case is an all overland route. Several simplifying assumptions incorporated into NED navigation benefit estimates including:[27]

1) Seventy-five percent commercial barge traffic in terms of tonnage through the study area routes to the least cost alternative mode and route as discussed in the previous section. Twenty-percent of traffic sails through the area during navigable periods over the course of repairs. The majority of the 25 percent of shipments would come from firms that are able to hold inventories, and ship relatively small volumes are infrequent intervals (e.g., one tow per quarter).

2) There are no assumptions regarding seasonality or timing of when a cut-off forms, and thus any assumptions regarding the distribution of commodities affected. Average daily tonnage is multiplied by the average cost savings per ton ($52.31) multiplied by the length of repair (258 days).

3) Truck and rail capacity is adequate to transport cargo diverted from the river during repair period. Similarly, possible impacts associated with increased road congestion and atmospheric emissions are not estimated or included.

4) Rather than apply hypothetical frequency distributions to the uncertainty associated with the proportion of cargo diverted from the MKARNS and estimated rate savings, the analysis assumes that the uncertainty incorporated in traffic projections and days of navigation closure adequately capture the variability inherent in the NED navigation benefits estimation.

5) Although, they are important, the analysis does not estimate potential impacts to regional economies that would likely follow a reduction in waterway transportation (e.g., loss income and wages for carriers and resultant multiplier impacts) given that these measures are not included in NED benefit cost ratios under Corps planning policies and procedures.

[27] Ideally, some of these restrictive assumptions would be relaxed; however, given time and budget constraints of any study, parsimony in terms of study depth and complexity is necessary.

As shown in Table 2-39, annualized NED losses associated navigation restrictions in the study area range from $317 million (95 percent exceedance) to $477 million (5 percent exceedance) with a midpoint of $385 million (50 percent exceedance).

Table 2-39
Forgone National Economic Development Navigation Benefits due to Formation of Cut-off in the Three Rivers Study Area

Percentile (expressed as % exceedance)	Forgone NED Benefits
95%	$316,878,832
90%	$333,111,839
85%	$344,247,150
80%	$353,222,527
75%	$360,977,037
70%	$368,037,384
65%	$374,642,605
60%	$380,921,310
55%	$386,347,500
50%	$384,983,954
45%	$399,315,900
40%	$405,588,125
35%	$412,124,639
30%	$419,094,871
25%	$426,674,147
20%	$435,156,131
15%	$445,185,751
10%	$457,957,129
5%	$477,257,959

Source: U.S. Army Corps of Engineers Little Rock District

2.8.5 Summary of Without Project Costs

As discussed previously, under the without project conditions, some costs are realized regardless of whether or not a cutoff forms and some costs are realized only if a cutoff forms (no cut-off costs). New structures, repairs, and reconstruction costs will realize whether or not a cutoff forms under the assumption that the Corps will continue to construct new structures and conduct repairs to keep the navigation channel as reliable as possible. Remaining costs; lost navigation, expenses of implementing the repair contingency plan, increased dredging costs, and costs to repair Montgomery Point Lock and Dam's communication and electrical lines realize only if a cutoff occurs (cut-off costs). As summarized in Table 2-40, total annualized costs that will or could emanate under the without project condition range from $27.5 million (95 percent exceedance) to $43.5 million (5 percent exceedance) with a midpoint of $34.2 million (50 percent exceedance). Reductions in any of these costs via a project alternative are NED benefits.

Table 2-40
Summary of Annualized Benefits*

Percentile (expressed as % exceedance)	No Cut-Off		With Cut-Off		Total
	Rehabs and repairs	New Structures	Navigation	Contingency plan and dredging	
95%	$552,700	$87,800	$24,051,365	$2,824,635	$27,516,500
90%	$572,600	$213,800	$25,283,471	$2,855,629	$28,925,500
85%	$598,700	$298,700	$26,128,640	$2,886,660	$29,912,700
80%	$618,000	$362,400	$27,058,848	$2,944,852	$30,984,100
75%	$639,600	$417,100	$27,652,879	$2,976,121	$31,685,700
70%	$663,900	$529,700	$28,193,791	$3,007,509	$32,394,900
65%	$691,400	$598,700	$28,699,773	$3,038,827	$33,028,700
60%	$726,700	$671,500	$29,180,753	$3,070,147	$33,649,100
55%	$769,500	$730,100	$29,596,424	$3,101,476	$34,197,500
50%	$809,200	$796,100	$29,491,932	$3,132,768	$34,230,000
45%	$858,600	$681,700	$30,589,863	$3,164,137	$35,294,300
40%	$906,900	$516,900	$31,070,361	$3,195,439	$35,689,600
35%	$979,200	$596,700	$31,571,123	$3,226,777	$36,373,800
30%	$1,051,800	$685,000	$32,105,019	$3,258,081	$37,099,900
25%	$1,139,600	$793,600	$32,685,682	$3,289,418	$37,908,300
20%	$1,250,000	$907,500	$33,335,425	$3,320,775	$38,813,700
15%	$1,395,500	$1,082,700	$34,103,734	$3,352,066	$39,934,000
10%	$1,614,900	$1,310,300	$35,082,158	$3,383,442	$41,390,800
5%	$1,916,800	$1,636,900	$36,560,674	$3,414,726	$43,529,100

*Breach impacts are monetized risks, which is the consequence of something happening weighted by the probability of the event occurring (i.e., risk = probability of a breach in a given year × consequence). Annual values are then discounted and annualized over the period of analysis. Source: U.S. Army Corps of Engineers Little Rock District.

3. WITH PROJECT CONDITION

The Future without Project Condition analyzes the impacts of implementing the final array of alternatives in relation to the No Action or without Project Condition. As designed, both alternatives in the final array (Alternative 1 and Alternative 2) would negate all non-cut-off costs, and the benefit of eliminating these costs is constant for both alternatives. In contrast, alternatives only reduce potential cut-off costs to extent that they mitigate the risk of a cut-off forming.

Alternatives will reduce the probability of certain head and duration intervals - P(H&D), which in turn lowers the potential for a breach given head and duration combinations P(B|H&D). For example, if water is held back by a new soil cement containment structure designed specifically to mitigate head differentials, the likelihood of experiencing a head differential of 20 feet and lasting for any duration is reduced significantly since higher water surface elevations are needed to generate the head differential, compared to without project conditions. This significantly reduces the annual likelihood that there would be navigation losses, and other impacts associated with a breach and a subsequent uncontrolled cut-off between the Arkansas and White rivers.

The methodology used to evaluate risks of alternatives for this study is identical to the methodology used to estimate the probability of cut-off forming in the without project condition, and relies on analysis from the Ark-White Study.

3.1 Risk Analysis for Final Array of Alternatives

The 2009 Ark White Study contained a final array of six alternatives:

- Alternative 2A consisted of gated control structure that would operate to restore natural hydrology in historic cut-off.
- Alternative 2B was identical to Alt 2 with the exception that a passive weir would restore natural hydrology in historic cut-off.
- Alternative 6 (155) would have raised Owens lake structure and soil cement dike to an elevation of 155 feet.
- Alternative 6 (160) would have raised Owens lake structure and soil cement dike to an elevation of 160 feet.
- Alternative 6 (153) would have raised Owens lake structure and soil cement dike to an elevation of 153 feet.

- Alternative 6 (157) would have raised Owens lake structure and soil cement dike to an elevation of 157 feet.

Thus, there were two groups of alternatives: 1) Alternative 2 would allow overland flows through the historic cut-off thereby reducing head differentials and restore the natural hydrology that existed in the study area prior to the construction of the MKARNS; and 2) Alternative 6 which involved finding an optimal elevation (in terms of cost and risk) for the existing soil cement structure. Table 3-1 displays the estimated average annual probabilities of failure due to head differentials over a 50-year period. Again, the values were estimated using the same methodology and expert panel from the Ark-White Study. As shown, each alterative significantly lowers the risk of failure when compared the average value for the without project conditions (7.38 percent).

Table 3-1
Average Annual Probability of Failure due to Head Differentials, Final Array of Alternatives from 2009 Ark White Cut-Off Study

Alternative	**Average Annual Risk of Failure**
Alt 2A (Gated Structure) - Restores natural hydrology in historic cut-off	0.31%
Alt 2A (Passive Weir) - Restores natural hydrology in historic cut-off	0.32%
Alt 6A - Raise Owens Lake structure and soil cement dike to 155 feet	0.32%
Alt 6B - Raise Owens Lake structure and soil cement dike to 160 feet	0.53%
Alt 6 (153) - Raise Owens Lake structure and soil cement dike to 153 feet	1.14%
Alternative 6 (157) - Raise Owens Lake structure and soil cement dike to 157 feet	0.08%
Average	**0.45%**

Source: U.S. Army Corps of Engineers Little Rock District, “Arkansas-White River Cutoff Study General Re-evaluation Report (Draft). 2009.

Alternative 1 of the Three Rivers Study is very similar to a combination of Alternative 2a (Passive Weir) and Alternative 6 (Raise Owens Lake structure and soil cement dike to elevation 157 feet). As discussed in detail in main report and engineering appendix of this report, Alternative 1 consists of a newly constructed containment structure at an elevation of 157 feet above sea level. The new structure would begin on natural high ground just south and west of the existing Melinda Structure located on the south side of Owens Lake. It would continue east and cross the Melinda Headcut south of the existing Melinda Structure. From there, it would traverse northeast and connect to the existing containment structure north of J. Smith Lake and terminate at the Historic Cutoff Containment Structure. Alternative 1 would also open at the Historic Cutoff with a width between 500 feet and 1,000 feet at elevation 145 feet above sea level. The new opening would further reduce, maximum head differentials across the isthmus allowing the Corps to control the location of future overtopping events. Given that Alternative 1 is very similar to Alternative 6 (157 foot levee) from the Ark-White analysis with exception of location and the likelihood that addition of a passive weir for Alternative 1 would have a synergistic effect in reducing the risk, the PDT opted to assume that that Alterative 1 for the Three Rivers Study, has the same risk of failure as Alternative 2A from the Ark-White study (0.08 percent). As stated previously, District engineers and hydrologists optimized levee elevation to minimize risk of failure, and an elevation of 157 was the lowest.[28]

Alternative 2 would use existing footprints of oxbow lakes and the Historic Cutoff in the isthmus. Multiple step down structures would be put in place in Owens Lake, La Grues Lake, the Historic Cutoff, and possibly J. Smith Lake that would facilitate the exchange of water. Elevations considered for the structure are 115 feet, 125 feet and 135 feet above sea level. The Ark White study did not analyze an alternative similar to Alternative 2 of the Three Rivers study; however, the PDT opted not to reconvene an expert panel to estimate the failure risk of Alternative 2 under the following rationales: 1) financial costs of Alternative 2 are substantially higher that Alternative 1 – annualized $5.7 million versus $8.3 million; and 2) it is very unlikely that the risk would be lower than Alternative 1, and even if it were, it would not come close to affecting selecting the NED plan given the large cost differential between the two projects.

3.2 NED Comparison of Final Array of Alternatives and NED Plan

The National Economic Development (NED) Plan is the alternative which provides the greatest net benefits to the nation. Tables 3-2 and 3-3 compare costs and benefits of each alternative. Alternative 1 (Containment Structure at Elevation 157 feet with a Relief

[28] Alternative 1 differs from the 2009 plan in that this alternative would have a smaller footprint for the structure that would minimize disturbance to natural hydrology in the bottomland hardwood forest without impacting efficacy of reducing head differentials and thus the risk of failure and subsequent cutoff formation.

Channel through Historic Cutoff at Elevation 145 feet) has the greatest net benefits of the two alternatives and is the NED plan.

Table 3-2
Cost Benefit Comparison for Alternative 1

Parameters			
Period of Analysis (Years)	50		
Construction Period (Years)	3.0		
Interest Rate (FY2018)	2.75%		
Capital Outlays			
Total Construction Costs	$178,694,360		
Total Mitigation Costs	$684,000		
Total Real Estate Costs	$916,640		
Interest During Construction	$7,356,087		
Total Investment	$187,651,087		
Annualized Costs			
Interest	$5,160,400		
Amortization	$1,790,400		
OMRR&R*	$724,454		
Total Annual Costs	$7,675,254		
Annualized Benefits		**95 percent exceedance**	**5 percent exceedance**
Navigation NED Benefits	$29,121,832	$23,409,560	$37,034,981
OMRR&R	$4,689,186	$3,769,398	$5,963,358
Total Cost Savings	$33,811,018	$27,178,958	$42,998,340
Benefit to Cost Ratio	4.4	3.5	5.6
Net Annualized Benefits	$26,135,764	$19,503,703	$35,323,085

*Operations, Maintenance, Repair, Replacement, and Rehabilitation. Source: U.S. Army Corps of Engineers Little Rock District

Table 3-3
Cost Benefit Comparison for Alternative 2

Parameters			
Period of Analysis (Years)	50		
Construction Period (Years)	3.0		
Interest Rate (FY2018)	2.75%		
Capital Outlays			
Total Construction Costs	$245,000,000		
Total Mitigation Costs	$684,000		
Total Real Estate Costs	$916,640		
Interest During Construction	$10,085,608		
Total Investment	$256,686,248		
Annualized Costs			
Interest	$7,058,900		
Amortization	$2,449,000		
OMRR&R*	$993,268		
Total Annual Costs	$10,501,168		
Annualized Benefits		**95 percent exceedance**	**5 percent exceedance**
Navigation NED Benefits	$29,121,832	$23,409,560	$37,034,981
OMRR&R	$4,689,186	$3,769,398	$5,963,358
Total Cost Savings	$33,811,018	$27,178,958	$42,998,340
Benefit to Cost Ratio	3.2	2.6	4.1
Net Annualized Benefits	$23,309,850	$16,677,790	$32,497,172

*Operations, Maintenance, Repair, Replacement, and Rehabilitation. Source: U.S. Army Corps of Engineers Little Rock District

4.0 Sensitivity Analysis for the NED Plan

Benefit to cost ratios (BCRs) and the most of the key underlying variables driving benefits have been described in stochastic terms throughout this appendix. However, sensitivity analysis as required by Corps planning policy and guidance involves varying key variables to assess how each affects the magnitude of NED benefits and thus the BCR for the NED plan. Key variables include:

- Growth rate for traffic on the MKARNS;
- Federal interest rate used to discount future benefits and costs;
- Length of repair period required to close a cut-off and restore navigation;
- Percentage of cargo diverted to the least cost alternative routing; and,
- Transportation cost savings per tons of waterborne shipping versus the least cost alternative route.

Table 4.1 shows variation in BCRs for each variable holding all other variables constant at the base rate. For example, the base value for the federal discount is the current USACE rate of 2.75 percent (FY2018), and the base BCR for Alternative 1 is 4.4. Table cells to left and right show how the BCR changes in response to a higher or lower interest rate, while other variables are held constant at the base rate.

Table 4-1
Sensitivity Analysis for Key Benefit Parameters for NED Plan*

NED Analysis Parameter						**Base Value**					
Percentage of cargo diverted	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1.0
Benefit cost ratio	3.1	3.4	3.6	3.9	4.1	4.4	4.6	4.9	5.1	5.4	5.6
Commodity growth rate	-0.50%	-0.20%	0.10%	0.40%	0.70%	1.00%	1.30%	1.60%	1.90%	2.20%	2.50%
Benefit cost ratio	2.6	2.9	3.3	3.7	4.0	4.4	4.7	5.1	5.4	5.8	6.2
Length of repair period (days)	160	180	200	220	240	260	285	305	325	345	365
Benefit cost ratio	2.9	3.2	3.5	3.8	4.1	4.4	4.8	5.1	5.3	5.6	5.9
Transportation cost savings (per ton)	$20	$26	$33	$39	$46	$52	$60	$67	$75	$82	$90
Benefit cost ratio	2.1	2.5	3.0	3.4	3.9	4.4	4.9	5.4	6.1	6.5	7.1
Federal discount rate	7.00%	6.15%	5.30%	4.45%	3.60%	2.75%	2.40%	2.05%	1.70%	1.35%	1.00%
Benefit cost ratio	2.4	2.7	3.0	3.3	3.8	4.4	4.7	5.0	5.3	5.7	6.2

*Table cells to left and right of the base value column show how the BCR changes in response to a higher or lower variable, while other variables are held constant at the base rate.

Addendum A
Biographical Sketches of Expert Panel Members

Dr. Leroy Arnold: Dr. Arnold is a civil engineer and geotechnical specialist with over 30 of experience with the Corps. He is the principle advisor and geotechnical engineer for all major geotechnical and civil engineering discipline aspects of the Engineering and Construction Division's Dam Safety evaluation and monitoring efforts. He also manages emergency response plans preparation, construction quality assurance for features of water resource projects consisting primarily of concrete gravity, earth and rock-fill dams, locks, channels and harbor facilities.

Dr. David Biedenharn Ph.D.: Dr. Biedenharn is a professional engineer with 30 years of experience in hydraulics, river engineering and fluvial geomorphology with the Corps Vicksburg District, Lower Mississippi Valley Division office, and the U.S. Army Engineer Research Development Center at the Waterways Experiment Station (WES). He is presently a research hydraulic engineer with the Rivers and Structures Division, River Sedimentation Engineering Branch at WES. He has authored over 50 technical papers and reports on hydraulic engineering, fluvial geomorphology, channel restoration, and sedimentation.

Mr. Mitch Eggburn: Mr. Eggburn has over 22 years of service with the Corps including 11 years in River Engineering and Hydraulic Design and seven years in Construction. He has worked on the analysis and design of several Melinda structure repairs and administered contracts on two Melinda structure repairs and on the Jim Smith Lake Headcut Control Structure. During his seven years of construction he was posted at Montgomery Point Lock and Dam, where he observed flow patterns through the Arkansas-White River corridor during high water events as they happened.

Dr. Steve Haase Ph.D.: Dr. Haase works for the Nature Conservancy, has a Ph.D. in Geology and Geochemistry, and more 30 years professional experience in basic and applied hydro-geologic research. Before joining the Nature Conservancy he conducted and managed a wide range of environmental cleanup and restoration projects, and water resource investigations for various public and private organizations. Since joining the Conservancy in 2002, Dr. Haase has served as the Project Manager for the Nature Conservancy's Lower White River Basin Project and currently serves as a regional hydrologist and river scientist providing technical support to TNC projects throughout the Southeastern and South-central USA. His specific project responsibilities include hydrologic analysis and interpretation of discharge and stage data to determine natural flow regime characteristics for river systems and to determine the nature and extent of flow alteration associated with anthropogenic changes; development of ecologically sustainable flow prescriptions for application in water allocation and water resource management decisions; watershed geomorphologic assessments and channel stability analysis of riverine systems to support development of watershed-scale river restoration plans based on natural channel design principles; interpretation of chemical data for surface water and groundwater systems; and development and implementation of Site Conservation Plans for priority conservation areas.

Mr. Nick Mitchell: Mr. Mitchell has over 24 years of experience with the Little Rock District. He's held various positions in Construction and Operations Divisions. He's worked extensively on bank stabilization, dredging and channel improvement projects. During his career with the Corps he served as Chief of the Contracts Support Branch in the Pine Bluff Project Office from 1995 to 1999. He returned to the District Office in 1999 and began working in the Navigation and Maintenance Section where he coordinates dredging and bank stabilization needs for the district on the MKARNS. Nick is also the chairman for the lock and dam operator training program.

Mr. Glen Raible: Mr. Raible is a registered professional engineer and has over 24 years of service with the Corps including 16 years as a hydraulic engineer, 5 years Arkansas River System Engineer, and 2 years as the Little Rock Districts technical expert hydraulic engineer. Glen has experience applying hydraulic and hydrologic principles and methodologies to HEC-1, HMS and HEC-2, RAS numerical models. He has designed many projects and structures, including the Table Rock Auxiliary Spillway, flood control channels, drainage structures, weirs, drop structures, and erosion and bank failure protection structures. He's planned and performed detail phases of the Little Rock Districts water quality program, worked with WES (ERDC) in physical modeling of a selective withdrawal structure for Table Rock Lake, and worked with A/E's on physical fixed and movable bed models for the North Little Rock Hydropower Plant at the Murray Lock and Dam.

Mr. Elmo Webb: Mr. Webb has over 17 years of experience with the Corps, most of which has been in geotechnical services. One of Mr. Webb's first projects was the Arkansas White River Cutoff project. While on the project delivery team, he was responsible for coordinating the subsurface investigation, sampling, testing, soil-cement mix design, and geotechnical design of the structures. Mr. Webb also has extensive knowledge of the area's subsurface conditions and history of the project.

Addendum B
MKARNS Shipper Interviews Notification Letters and Interview Guide

DEPARTMENT OF THE ARMY
LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
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CESWL-PE

21 June 2016

President, Arkansas Oklahoma Port Operators Association, Fred Taylor, 5350 Cimarron Road, Catoosa, OK 74015

SUBJECT: Three Rivers Feasibility Study, Economic Rate Study, Shipper Survey Cover Letter

The Little Rock District Corps of Engineers and the Arkansas Waterways Commission are conducting the Three Rivers Feasibility Study, which is assessing long-term solutions to erosion near the Montgomery Point Lock and Dam (river mile 0.5) at the confluence of the Arkansas, White and Mississippi rivers. If left unchecked, this erosion could result in a diversion of water flow from the White River to the Arkansas River via a breach in existing containment structures. If this happens, the Corps would have to repair the breach, and during the repairs, navigation and thus access to the Mississippi River through Montgomery Point would be limited.

As part of the study, we will be conducting a survey of shippers along the McClellan-Kerr Arkansas River Navigation System (MKARNS) to gauge the potential economic effects of a disruption in navigation through the area near the Montgomery Point due to a breach as described above. The survey will ask you to estimate how such an event might affect your business. The survey contains three parts:

- Part 1 asks for basic information about your business (e.g., primary commodities, location);
- Part 2 asks about how a disruption in river transportation from the MKARNS to and from the Mississippi River would affect your business; and,
- Part 3, asks for information on currents rates for commodities shipped. Information on rates is needed to estimate potentially higher costs of alternate routings (i.e., via rail or truck) if access to the Mississippi River via the MKARNS was restricted.

The survey is scheduled to start in the next few weeks and will be conducted in person by representatives of the Corps. This letter is to notify all interested parties of the survey. We ask that you share this information with any interested stakeholders.

SUBJECT: Three Rivers Feasibility Study, Economic Rate Study, Shipper Survey Cover Letter

Please note that the survey is voluntary, and any information specific to your firm will be held strictly **confidential,** and under federal law (5 U.S.C. Sec. 552 b.4) **any proprietary data provided is exempt from Freedom of Information Act (FOIA) requests**. Information provided will not be reported for individual survey respondents in the feasibility study report, and the Corps will not release survey data for individual firms to the public.

If you have questions about the survey please contact Mr. Norvell, Economist, via email, stuart.d.norvell@usace.army.mil or by phone at (501) 324-7343. For general comments or concerns, please contact Ms. Dana Coburn, Project Manager, via email, dana.o.coburn@usace.army.mil or by phone at (501) 324-5601.

Randy Hathaway, PhD, PE
Deputy for Program Management

NAVIGATION NOTICE Number SWL 16-39

McClellan-Kerr Arkansas River Navigation System

June 22, 2016

U.S. Army Corps of Engineers
Little Rock District

In Reply Refer to: CESWL-OP
P. O. Box 867
Little Rock, AR. 72203-0867
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THREE RIVERS FEASIBILITY STUDY – ECONOMIC SURVEY MCCLELLAN-KERR ARKANSAS RIVER NAVIGATION SYSTEM

The Little Rock District Corps of Engineers and the Arkansas Waterways Commission are conducting the Three Rivers Feasibility Study, which is assessing long-term solutions to erosion near the Montgomery Point Lock and Dam (river mile 0.5) at the confluence of the Arkansas, White and Mississippi rivers.

As part of the study, we will be conducting a survey of shippers along the McClellan-Kerr Arkansas River Navigation System (MKARNS) to gauge the economic effects of a potential disruption in navigation through the area near the Montgomery Point due to a breach in river containment structures separating the Arkansas and White rivers near Montgomery Point Lock and Dam. Representatives of the Corps will be visiting terminals and businesses in the next several weeks to conduct this survey. This navigation notice is to notify all interested parties of the survey. We ask that you share this navigation notice with any interested stakeholders.

Please note that the survey is voluntary, and any specific information will be held strictly confidential, and under federal law (5 U.S.C. Sec. 552 b.4) any proprietary data provided is exempt from Freedom of Information Act (FOIA) requests. Information provided will not be reported for individual survey respondents in the feasibility study report, and the Corps will not release survey data for individual firms to the public.

Questions or requests for additional information concerning this notice should be directed to James McKinnie in the Little Rock District Office, at (501) 324-5739 or (501)324-5096, or you may email CESWL-OP-OM@usace.army.mil.

//signed//
Kevin J. McDaniels
Chief, Operations Division

Part 1: Shipper Information

Date survey completed	
Terminal Operator (firm)	
Parent Firm/Terminal Owner	
Terminal Location	
Zip Code	
River Mile	
State (select one)	□ OK □ AR
Type of Terminal (select one)	□ Private □ Public
Primary Commodities Shipped	

Part 2: Shipper Response to Navigation Closure near Montgomery Point Lock and Dam

1. How long could you sustain normal operations if navigation through the area near Montgomery Point Lock and Dam (access to and from Mississippi River) ceased unexpectedly for an unknown duration?
2. What would you do if river transportation through the area near Montgomery Point L&D became unreliable or navigation ceased altogether? Wait □ Reschedule □ Reroute □ Other (please explain below) If other, please explain:

3. What is the likely alternative routing for traffic shipped to and from the MKARNS if river transportation through the area Montgomery Point L&D became unreliable or ceased altogether?

4a) If access to Mississippi River was closed for 15 days or less would you (select one):

□ Wait □ Reschedule □ Reroute □ Other (please explain below)

If other, please explain:

4b) For question 4a, if re-routed, rescheduled or "other" what would be the business effects and costs?

Business effects:

Costs:

5a) If access to Mississippi River was closed for 15 to 30 days would you (select one)?

□ Wait □ Reschedule □ Reroute □ Other (please explain below)

If other, please explain:

5b) For question 5a, if re-routed, rescheduled or "other" what would be the business effects and costs?

Business effects:

Costs:

6a) If access to Mississippi River was closed for 30 to 60 days would you (select one)?

□ Wait □ Reschedule □ Reroute □ Other (please explain below)

If other, please explain:

6b) For question 6a, if re-routed, rescheduled or “other” what would be the business effects and costs? Business effects: Costs:
7a) If access to Mississippi River was closed for 90 to 180 days would you (select one)? □ Wait □ Reschedule □ Reroute □ Other (please explain below) If other, please explain:
7b) For question 7a, if re-routed, rescheduled or “other” what would be the business effects and costs? Business effects: Costs:
8a) What would you do if river transportation from the MKARNS to and from the Mississippi River become unreliable for about 220 days (assume that over the period river conditions were unnavigable for tows and barges for 110 days; these would not be 110 consecutive days but would occur intermittently in periods ranging from days to weeks)? 7a) If access to Mississippi River was closed for 90 to 180 days would you (select one)? □ Wait □ Reschedule □ Reroute □ Other (please explain below) If other, please explain:
8b) For question 8a, if re-routed, rescheduled or “other” what would be the business effects and costs? Business effects: Costs:

Notes or additional comments:

Part 3: Rate Information (This information will be used to estimate costs of rerouting cargo. Rate information reported for individual firms is strictly confidential and not subject to public release under the Freedom of Information Act)

9) What are your charges for the primary commodities you handle and ship (if you have a published rate schedule, you may attach this in lieu of completing question 9).

Primary Commodity(s)	Mode	Typical Number of Miles Shipped	Typical Handling Charge per Ton	Typical Charge per Ton for Line Haul
1)	Truck			
	Rail			
	Barge			
2)	Truck			
	Rail			
	Barge			
3)	Truck			
	Rail			
	Barge			
4)	Truck			
	Rail			
	Barge			
5)	Truck			
	Rail			
	Barge			
6)	Truck			
	Rail			
	Barge			

10) Are there any other charges for the primary commodities you handle (if so please specify)?

11) Note or additional comments