Impact Assessment Methodology for Underutilized Inland Waterways

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ABSTRACT

Full year-round navigation on two federal inland waterway projects in the Southeast United States has not been consistently achieved since their construction. Many variables and circumstances have contributed to and sustained the condition. The U. S. Army Corps of Engineers (Corps) has performed many studies to investigate methods and operations that may maximize the percentage of time that full navigation is maintained. The states of Alabama, Georgia, and Florida have joined together in the Apalachicola-Chattahoochee-Flint (ACF) River (Basin) Compact. A similar compact exists for the Alabama-Coosa-Tallapoosa (ACT) river basin. The compacts direct the parties to the compact to "develop an allocation formula for equitably apportioning the surface waters of the ACF basin among the States while protecting the water quality, ecology, and biodiversity of the ACF and (ACT)." A programmatic environmental impact statement is being prepared by the Corps to evaluate the impacts that may result from an allocation formula proposed by the parties to the compact. This paper presents the methodology used to assess the economic impacts to commercial navigation on the ACT waterway, without knowledge of the final allocation formula. River flows over a 55-year period of record were used to calculate the percentage of time incremental navigational depths are available. Waterborne commerce forecasts for a future 50-year period, seasonally distributed, were moved on the waterway at full and less-than-full navigation depths when appropriate or shipped via railway when navigation was not possible. Shipping costs were calculated for a no-action alternative and three action alternatives: low flows, moderate flows, and high flows. The difference in shipping cost between the no-action and an action alternative yields a positive or negative impact to that alternative. Low- and moderate-flow impacts were nearly equal and insignificant. High-flow impacts were three times as large as the low and moderate, yet still insignificant. As expected in extreme drought cases, navigation was positively impacted when a high-flow alternative was followed. There may be more value for the decision-maker to examine the impacts during drought periods and rainy (wet) periods, and whether they are positive or negative.

INTRODUCTION

The Alabama River is an authorized navigation project located in southwest Alabama, stretching 289 miles from its confluence with the Mobile River to the city of Montgomery. There is an existing authorized 9-ft-by-200-ft navigation channel on the Alabama River, from its junction with the Mobile River to Montgomery, Alabama, including three locks and dams.

Initial hydraulic studies for the design of development of navigation on the Alabama River were based on historical flows, with no major storage reservoirs on the Coosa River, and with Alabama Power Company's (APCo's) Lake Martin on the Tallapoosa River operating to meet minimum flows near Montgomery. During the same period that the Corps was building projects on the Alabama River, APCo was building two large storage projects on the Coosa, and later modified the operating plan at Lake Martin. Therefore, the present low-flow regime for the Alabama River is different from the historical period prior to the mid-1960s.

Since the completion of the projects on the lower Alabama River, complicating factors have contributed to unreliability of a full 9-ft depth for navigation. Hydropower produced at Millers Ferry and Robert F. Henry is sold by the Southeastern Power Administration on a peaking basis rather than the run-of-the-river type of operation, as described in the basic hydrology design memoranda for these projects. Claiborne Lake does not have sufficient storage to provide needed releases during weekend shutdowns at upstream peaking hydropower plant operations.

HYDRAULIC CONDITIONS

The lower 72 miles of the Alabama River are free-flowing. It joins the Tombigbee River to form the Mobile River, which flows into the Gulf of Mexico. River stages at the mouth of the Alabama River are influenced by Gulf tides during low-flow conditions. The tidal range at Mobile averages about 1.5 ft, with spring tides only reaching a 2.5-ft range. The authorized navigation channel in the lower Alabama River is a 9-ft depth with 200-ft width, and is maintained primarily by dredging. The navigation channel depth is referenced to a water-surface profile defined by a flow that is exceeded or equaled 95 percent of the time. This flow has been determined to be 7,500 cubic feet per second (cfs). The dredging reference profile is determined by a HEC-2* backwater simulation, with the downstream boundary set to elevation 0.4 feet NGVD to represent a mean-tide condition.

During the period from 1981 to 1994, dredging in the Alabama River averaged 1.1 million yd^3 per year. Even with this level of effort, the 9-ft navigation depth was available only 74 percent of the time. This value ranged as low as 43 percent and as high as 100 percent from year to year. When the river flow drops to low values, and dredging activities are not complete, the navigation depth will not be available, even when flows exceed the 7,500-cfs value. Before dredging begins, the full 9-ft depth is available only with flows above 10,000 cfs. Dredging season begins in May, and can continue through

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* A steady-state backwater computer model developed by the Corps Hydrologic Engineering Center in Davis, California.

December if the spring floods have been high and significant shoaling has occurred. Also, late-fall rises in the river often cause additional shoaling, and require the dredge to re-dredge certain areas.

The initial design efforts of the navigation channel in the 1960s determined that the flow that was exceeded or equaled 95 percent of the time was 8,450 cfs. Further analysis during the 1980s, which included the 20 years of additional flow data, found that 7,500 cfs is the current 95 percent exceedance or equaled flow. Some river training works were constructed in the late '80s and early '90s to help reduce dredging requirements; however, the dredging reference profile was lowered to the 7,500 cfs at the same time. A lower dredging reference profile resulted in additional dredging, but the training works helped to offset some of the increase. Therefore, the actual average annual availability of the navigation depth was essentially unchanged.

OPERATIONS AND MAINTENANCE

The current project dimensions on the Alabama River have been provided through the dredging, training dikes, rock removal, flow regulation, cutoff, snagging, and 3 locks and dams, previously discussed. The navigation channel was constructed on the lower river, from the mouth to the Claiborne Lock and Dam, through dredging, construction of a cutoff at Fort Mims (Navigation Mile 7.0), construction (or rehabilitation) of training dikes at 13 sites, and rock removal at Limestone Creek (Navigation Mile 68.0). These training dikes were completed in 1973, while the initial channel dredging and cutoff were completed in 1968. The training works described in the 1987 Environmental Impact Statement (EIS) supplement, 12 fields from Claiborne Lock downriver to Navigation Mile 9.0, were constructed between 1989 and 1993. The EIS supplement also provided for additional within-banks and upland disposal areas. To date, none of the upland sites has been acquired. The district is currently pursuing acquisition of upland tracts at four sites.

NAVIGATION

The Alabama River is a terminus on the inland waterway system. It is accessed by the Black Warrior Tombigbee Waterway and the Gulf Intracoastal Waterway. Its major value as a water transportation resource is its ability to carry traffic to and from inland waterway points in Mississippi, Louisiana, and Texas. Barge navigation is provided by a series of three locks and dams. Claiborne Lock and Dam is the lowermost structure at Navigation Mile 117.5, above the Bankhead Tunnel in Mobile. It has a lift of 30 ft. Millers Ferry Lock and Dam is upstream of Claiborne at Navigation Mile 178 and has a lift of 45 ft. Robert F. Henry Lock and Dam is upstream of Millers Ferry at Navigation Mile 281.2. It has a lift of 45 ft. All three lock chambers have dimensions of 84 by 600 ft.

The Alabama River is bounded on all fronts by navigable waterways: the Tennessee River on the north, the Apalachicola-Chattahoochee-Flint (ACF) River on the east, the Gulf Intracoastal Waterway on the south, and the Black Warrior-Tombigbee (BWT) River to the west. It competes with other waterways and other modes of transportation. Cost disadvantages that arise when barges must be light-loaded for low-water conditions, plus the lack of backhaul cargoes, have limited the opportunity for sustained growth and diversification of the Alabama's cargoes. The bulk of the traffic on the Alabama River is linked to resources originating along the river, which makes barge transportation essential and convenient for moving those resources.

Due to river bends and shoaling at the bends, typical tow size is a four-barge tow, except during very low water conditions, when tow sizes may be reduced to two barges. Coast Guard regulations restrict tow widths to one-half of the 200-foot channel width. These restrictions, though, would still allow most Gulf Intracoastal Waterway tows to navigate the Alabama River with full navigation, without breaking up tows.

FACILITIES

Facilities along the Alabama River are numerous and strategically located. The Alabama State Docks maintain three public terminals—Claiborne, Selma, and Montgomery—at river miles 74.4, 227.6, and 305.0, respectively, on the Alabama River. Tables 1 and 2 display the private and public terminals.

The U.S. Waterborne Commerce Statistics Center in New Orleans has identified about 300 docks on the Alabama River, from its junction with the Tombigbee River up to the head of navigation around Montgomery.

WATERBORNE COMMERCE

Historical Alabama River waterway traffic was aggregated into nine major commodity categories to facilitate an analysis of current and future potential. Major categories are

TABLE 1 Private Terminals: Alabama River

Canton Oil & Gas Co.	Carlton, Alabama	Mile 18.5
Alabama River Pulp	Claiborne, Alabama	Mile 67.5
MacMillan Bloedel United	Millers Ferry, Alabama	Mile 121.9

TABLE 2 Public Terminals: Alabama State Docks–Alabama River

Terminal	*Products Handled*	*Storage*	*Barges Handled*	*Operations*	*Connections*
Claiborne	Grain	Concrete Elevator 427,000 bu.	1 worked 2 held	As required	
Selma	General cargo Grain Dry bulk	Open, unpaved Elevator 302,000 bu.	1 worked 2 held	As required	
Montgomery	General cargo Grain Dry bulk	Open, unpaved Elevator 594,000 bu.	1 worked 2 held	As required	L&N Rail

farm products, metallic ores and products, coal, crude petroleum, nonmetallic minerals and products, forest products and pulp, industrial chemicals, agricultural chemicals and petroleum products. Alabama River traffic is almost entirely related to use of natural resources, and is dominated by just a few large cargo shippers. A more diverse traffic base would occur if the river served the heavy industry above the current head of navigation at Montgomery, but that can be realized only by constructing the authorized Coosa River navigation improvements. Traffic peaked in the mid-1980s at 4 million tons, then fell to the current level of less than 1 million tons. The decrease in commerce on the river since 1985 is probably attributable to competitive rates offered by other modes and low reliability of the river during the mid-80s drought. Though a relatively significant proportion of the time, full navigation is not available, the data reveal that there are few instances of sustained barge light-loading (drought years). Virtually all tows are fully loaded to 8.5 or 9 ft. Sand and gravel that move on flat-deck barges are loaded to 7 ft.

Figure 1 shows Alabama River waterborne commerce for all products from 1982 to 1996, as reported by the Waterborne Commerce Statistics Center, U.S. Army Corps of Engineers, New Orleans.

COMMODITY FORECASTS

Forecasts of waterway traffic on the Alabama-Coosa-Tallapoosa (ACT) and the ACF were developed through the year 2050. These forecasts include a continuation of present management practices (including seasonal use of navigation windows on the ACF), and

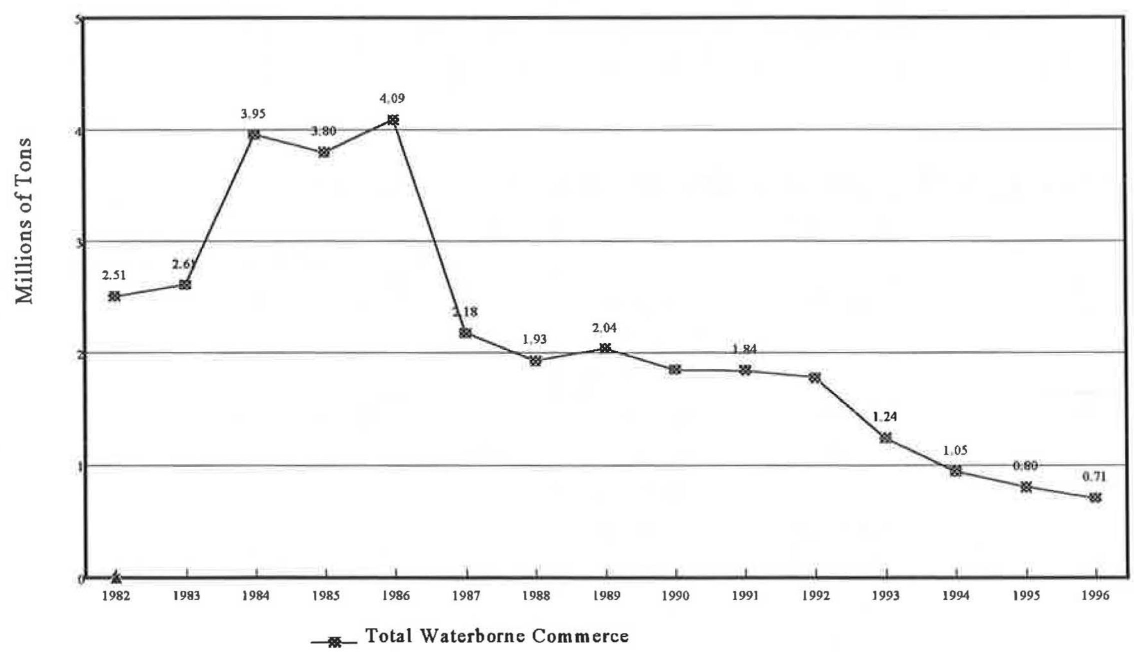

FIGURE 1 Alabama River waterborne commerce for all products: 1982–1996.

maintenance of a reliable channel. Each scenario includes high, medium, and low projections. The medium projection represents the central forecast, with the high and low representing a confidence interval based on historic percentage deviation from trend, by commodity.

Growth rates were developed independently for each commodity group, using multiple-regression analysis. Components of the regression varied by commodity, but in each case, a national index was used as one independent variable from published historic and forecast data of the WEFA Group (*1*). A second independent variable was derived from regional indexes developed by DRI/McGraw-Hill for the basinwide element of the ACT and ACF comprehensive study. Waterway traffic by commodity at the basin level or at the nation level was used as the dependent variable in the regression analysis. Historic waterway traffic on the Alabama was not used for the regression equations due to wide fluctuation in traffic volumes during exceptionally severe droughts of the 1980s. However, historic traffic from 1990 through 1994 on each waterway was used to develop a weighted base for projection purposes. Projected tonnages are presented in Figure 2 and Tables 3–5.

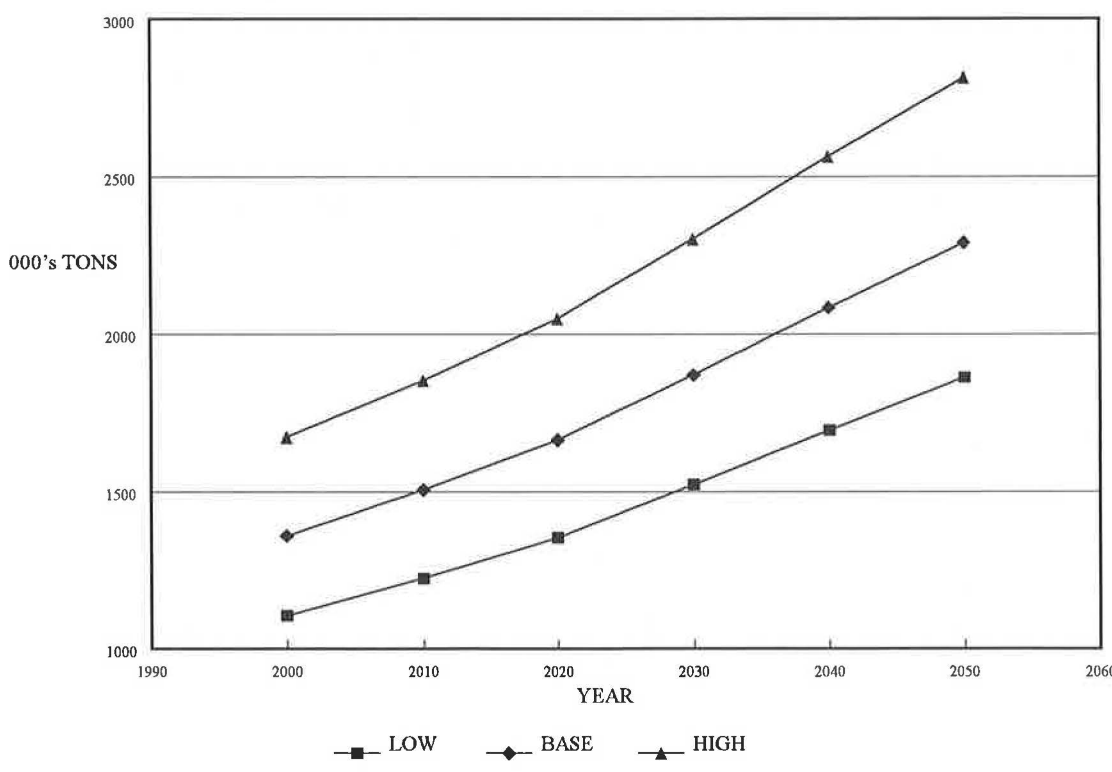

FIGURE 2 Projected Tonnage–Alabama River.

TABLE 3 Alabama River Projected Tonnage: Low Projection

Commodity	*1990–94 Weighted Average*	*2000*	*2010*	*2020*	*2050*	*Annual Rate 1995–2050*
Farm Products	333	310	359	424	689	1.33%
Crude Petroleum	53,800	44,026	43,955	45,063	48,560	-0.19%
Nonmetallics	541,667	451,560	491,184	508,939	566,147	0.08%
Forest Products	732,133	572,061	644,426	746,830	1,162,431	0.84%
Industrial Chemicals	3,067	2,713	3,458	4,265	7,997	1.76%
Petroleum Products	38,267	34,811	41,072	48,106	77,298	1.29%
TOTAL	1,369,267	1,105,481	1,224,454	1,353,627	1,863,122	

TABLE 4 Alabama River Projected Tonnage: Baseline Projection

Commodity	*1990-94 Weighted Average*	*2000*	*2010*	*2020*	*2050*	*Annual Rate 1995–2050*
Farm Products	333	364	421	498	809	1.63%
Crude Petroleum	53,800	53,471	53,385	54,731	58,978	0.17%
Nonmetallics	541,667	558,729	607,757	629,726	700,512	0.47%
Forest Products	732,133	704,461	793,576	919,680	1,431,470	1.23%
Industrial Chemicals	3,067	3,467	4,419	5,450	10,220	2.21%
Petroleum Products	38,267	39,669	46,804	54,820	88,086	2.28%
TOTAL	1,369,267	1,360,161	1,506,362	1,664,905	2,290,075	

TABLE 5 Alabama River Projected Tonnage: High Projection

Commodity	*1990–94 Weighted Average*	*2000*	*2010*	*2020*	*2050*	*Annual Rate 1995–2050*
Farm Products	333	428	495	585	951	1.92%
Crude Petroleum	53,800	64,943	64,838	66,473	71,631	0.52%
Nonmetallics	541,667	691,333	751,997	779,179	866,765	0.86%
Forest Products	732,133	867,505	977,245	1,132,536	1,762,776	1.61%
Industrial Chemicals	3,067	4,431	5,647	6,964	13,060	2.67%
Petroleum Products	38,267	45,206	53,337	62,471	100,380	1.77%
TOTAL	1,369,267	1,673,846	1,853,559	2,048,208	2,815,563	

ECONOMICS

The basic economic benefit of a navigation project is the reduction in the value of resources required to transport commodities. Favorable contributions to national economic development (NED) generated by navigation water resource projects or plans are determined by a benefit-cost evaluation.

METHODOLOGY

Transportation cost savings in this study are cost-reduction benefits (same origin-destination–same mode). For traffic that uses a waterway both with and without a project, the benefit is the reduction in the economic cost of using the waterway. This reduction represents an economic efficiency or NED gain because resources will be released for productive use elsewhere in the economy. Reductions or increases in costs of using the waterway may result from barges more fully loaded or less fully loaded, as dictated by channel availability.

When channel availability deteriorates to the state where navigation is not supported, then a shift-of-mode benefit may occur. Existing commodity movements retain original origins and destinations but shift transportation modes to rail or truck. This results in an additional cost to transport the once-waterborne commerce.

The rate at which existing traffic actually moves, either by rail or by truck, was determined and used to calculate current mode transportation costs. Transportation rates were calculated using the rail, barge, and truck computer cost modules developed as proprietary software by Reebie Associates.Estimated transportation costs of using the waterway under the current management practices, on an average annual basis, measure the status quo alternative to which all other possible alternative allocation formulas will be compared. Transportation costs are calculated and weighted seasonally based on the percentage of time depths associated with each alternative are available. Differential transportation costs between the status quo and an alternative allocation formula define the direct impacts. They are converted into average annual equivalents. These direct impacts, which are changes in business income, are submitted to the Economic Impact Forecasting System (EIFS), which applies regional economic multipliers to estimate the regional economic effects. Regional effects are compared with the rational threshold values for each basin or state, or both, as applicable for significance.

STORAGE UTILIZATION FOR NAVIGATION

In the ACT, basin storage is fairly closely controlled by rule or guide curves. The adherence to these guide curves means that between October 1 and December 15, 530,000 acre-ft will be drawn from storage and added to the flow of the Alabama River. This flow is equivalent to adding about 3 ft of depth to the river, in the 8- to 9-ft range. Such a release from storage may quite often considerably augment the depth of the river during this normally dry period. However, when the fall is wet, the summer is drier, and the flow augmentation may not be useful for navigation.

ALTERNATIVES CONSIDERED

The navigation water demand element of the comprehensive study (*2*) determined the amount of water required to support the navigation projects on the ACT and ACF basins, as authorized by Congress. The study considered the historic and current relationship between the availability of a navigation channel and river flow to predict future use up to the year 2050.

The no-action alternative is the baseline condition against which an action (possible water-allocation formula) is compared. The no-action alternative provides the baseline flows for estimating the impacts of a particular action alternative. This baseline represents the conditions in the ACT basin at the time the comprehensive study elements were prepared. The no-action alternative has as a basis that existing project operations will continue unchanged into the future. Additionally, it also assumes that water-supply demand will continue to increase through the year 2050. These demands were derived from the comprehensive study elements.

HEC-5

Three action-alternative flow conditions—high, moderate, and low—were selected to evaluate the potential impacts associated with different flows. These particular flow conditions were formulated to encompass the endpoints and an expected midpoint bracket that could include reasonable allocation formula. HEC-5, simulation of flood control and conservation systems, was used to simulate the operation of reservoirs in both the ACF and ACT basins. Year 1995, 2020, and 2050 results were obtained for the baseline, the no-action alternative, and each action alternative: high, moderate, and low flows.

All action alternatives and the no-action alternative were evaluated through hydrologic modeling of flow conditions over a 55-year period of record. The flows at Claiborne Lock and Dam were used to develop a relationship between flow and channel depth for three conditions. The three conditions were pre-dredging flow, transition flow, and post-dredging flow. Table 6 shows the relationships that were used to estimate the percentage of time-depth availability statistics.

TABLE 6 Dredging Period and Flow Estimates: Alabama River–Claiborne Lock and Dam

Flow Condition	9-ft Channel	8.5-ft Channel	8.0-ft Channel	7.5-ft Channel	Dredging Start	Period Finish
Pre-Dredge	11,600	11,050	10,500	9,950	1 Nov	1 May
Transition Flow	10,550	10,175	9,800	9,425	1 May	1 Sep
Post-Dredge Flow	9,500	9,300	9,100	8,900	1 Sep	1 Nov

Source: Mobile District Corps of Engineers, Engineering Division.

BASELINE NO-ACTION CONDITION

The HEC-5 model run output was post-processed to convert flows on the ACT navigation system to equivalent percentage of time-depth availability statistics. That is, for a given project operation scheme—high, moderate, or low flow—a set of percentage of time-depth availability statistics was compiled for navigation depths of 9 ft (full navigation), 8.5 ft, 8.0 ft and 7.5 ft. Additionally, these statistics are provided for each month to pick up on the seasonal trends that occur during the wet and dry periods of the year.

These statistics are assumed to represent the proportion of the year that a corresponding channel depth is available. An assumption is made that the towing companies and their tow operators have information with regard to depth availability, and they will load barges restricted only by depth availability and under keel clearance. When channel depth availability is below 7.5 ft, no navigation is assumed, and during this time, the commerce mode shifts to the next least-costly alternative mode of transportation—rail, in this evaluation.

There is a sampling of HEC-5 flow output in Table 7, from the run of the 1995 existing operation at Claiborne Lock and Dam, the no-action alternative. All flow data are in cubic feet per second (cfs).

An algorithm was written that calculates, by month, the percentage of time that flows equal or exceed the targets displayed in Table 6. For example, if flows in the month of October 1940 equaled or exceeded 9,500 cfs on 20 of the 31 days, then a 9-ft or greater channel depth was available 64.5 percent of the time in that month. Similarly, depth availability is calculated for 8.5-, 8.0-, 7.5- and less-than-7.5-ft depth availability.

Table 8 shows the results of the baseline percentage of time-depth availability for all alternatives at the three points in time: 1995, 2020, and 2050.

TABLE 7 ACT 1995 Existing Operation: No Action Alternative

Sample HEC-5 Flow Output (cfs)

	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
1 Oct	12,176	11,507	10,990	15,610	12,701	7,562	8,614	24,044	10,039	13,147	8,329	13,742
2 Oct	18,927	11,428	11,241	16,220	7,215	13,307	11,228	22,679	6,921	8,203	8,957	17,861
3 Oct	19,070	11,229	11,360	13,064	7,277	12,678	11,558	21,110	9,872	6,925	14,590	16,887
4 Oct	18,068	11,111	6,499	13,933	11,606	12,160	11,483	19,693	6,987	13,080	13,785	16,354
5 Oct	17,568	6,538	6,506	18,153	11,639	11,841	11,352	11,666	7,119	13,123	14,588	15,244
6 Oct	16,956	6,480	10,756	18,118	11,496	11,889	6,238	10,904	6,727	14,320	13,703	14,156
7 Oct	9,922	10,107	11,015	17,539	11,287	7,448	6,519	17,758	7,767	13,834	14,520	8,755
8 Oct	9,703	10,914	10,855	17,350	10,848	7,162	12,208	15,682	10,747	13,075	10,142	9,440
9 Oct	16,631	10,976	10,804	16,438	7,184	11,235	12,934	15,740	6,857	7,440	11,016	13,875
10 Oct	15,242	11,116	10,672	10,940	6,997	12,575	13,367	14,411	9,599	7,278	14,433	13,385
11 Oct	14,429	11,165	6,593	10,916	9,246	9,720	12,877	14,677	6,954	13,975	14,098	13,176
12 Oct	14,096	6,551	6,593	15,490	10,603	11,707	12,778	9,728	7,030	14,311	13,510	13,002
13 Oct	13,911	6,484	9,647	14,866	10,595	11,610	7,423	10,246	7,139	14,052	13,787	12,845
14 Oct	7,814	10,128	10,115	14,204	10,662	6,792	8,121	14,141	10,198	13,461	13,673	8,199
15 Oct	8,097	10,775	10,064	13,954	10,940	6,870	8,903	14,124	9,831	13,033	12,685	8,787
16 Oct	14,000	10,669	10,047	13,498	6,721	6,943	12,222	13,313	7,052	7,428	14,325	14,181
17 Oct	13,755	10,385	6,572	7,859	6,885	11,733	12,016	12,909	10,730	7,332	18,204	13,333
18 Oct	13,379	10,249	7,162	8,162	10,608	11,699	11,367	13,972	7,085	11,846	19,137	13,805
19 Oct	12,722	6,329	6,578	13,049	11,060	12,020	11,270	8,349	7,172	13,480	17,473	12,658
20-Oct	12,378	6,365	6,528	12,433	11,045	6,985	6,796	8,255	7,692	12,835	14,859	17,100
21 Oct	7,220	9,328	6,487	12,684	10,974	6,921	6,745	13,843	7,326	12,668	14,215	12,826
22 Oct	6,930	10,228	9,719	11,863	10,801	6,742	12,258	14,034	8,414	12,659	11,305	16,602
23 Oct	12,585	10,310	6,264	12,959	7,092	11,407	16,279	13,274	10,860	7,120	11,480	19,530
24 Oct	12,579	10,513	8,279	7,983	7,373	11,539	16,093	13,959	10,816	7,210	14,305	19,513
25 Oct	12,115	10,442	5,998	10,238	8,546	11,577	15,680	13,122	7,354	12,161	14,678	17,953
26 Oct	12,431	6,658	6,204	15,477	10,917	11,038	15,954	7,743	7,874	13,582	14,526	17,025

TABLE 8 ACT Depth Percentage Availability—
No-Action Alternative: 1995, 2020, and 2050 (Period of Record Averaged)

1995 No Action						2020 No Action						2050 No Action				
9 ft or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less		9 ft or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less		9 ft or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less
68.79%	69.73%	70.69%	71.58%	28.42%	Oct	62.42%	63.38%	64.33%	65.30%	34.70%	Oct	64.79%	65.79%	66.71%	67.71%	32.29%
73.86%	76.36%	78.64%	80.00%	20.00%	Nov	70.49%	73.65%	76.32%	77.98%	22.02%	Nov	70.76%	73.61%	76.17%	78.09%	21.91%
89.92%	91.35%	92.49%	93.75%	6.25%	Dec	89.10%	90.94%	92.03%	93.33%	6.67%	Dec	88.50%	90.42%	91.68%	92.76%	7.24%
95.63%	96.55%	97.02%	97.43%	2.57%	Jan	95.59%	96.28%	96.76%	97.17%	2.83%	Jan	95.22%	96.07%	96.71%	97.20%	2.80%
99.65%	99.79%	99.92%	99.97%	0.03%	Feb	99.66%	99.78%	99.93%	99.97%	0.03%	Feb	99.60%	99.76%	99.91%	99.96%	0.04%
99.36%	99.65%	99.76%	99.79%	0.21%	Mar	99.26%	99.64%	99.75%	99.79%	0.21%	Mar	99.26%	99.62%	99.76%	99.79%	0.21%
96.20%	96.88%	97.61%	98.19%	1.81%	Apr	95.71%	96.32%	97.22%	97.88%	2.12%	Apr	95.83%	96.59%	97.46%	98.04%	1.96%
92.52%	93.64%	94.44%	95.16%	4.84%	May	91.15%	92.16%	92.92%	93.91%	6.09%	May	91.58%	92.60%	93.48%	94.33%	5.67%
83.30%	85.13%	86.33%	87.42%	12.58%	Jun	78.00%	80.26%	81.97%	83.84%	16.16%	Jun	78.55%	80.72%	82.46%	84.31%	15.69%
77.24%	79.14%	80.68%	82.28%	17.72%	Jul	70.95%	74.00%	75.92%	77.54%	22.46%	Jul	72.14%	75.00%	77.21%	78.67%	21.33%
66.41%	69.13%	71.25%	73.18%	26.82%	Aug	59.84%	62.75%	65.11%	67.05%	32.95%	Aug	62.54%	65.52%	67.56%	69.63%	30.37%
62.22%	63.61%	64.82%	65.93%	34.07%	Sep	56.24%	57.80%	58.87%	59.82%	40.18%	Sep	58.21%	59.72%	60.66%	61.74%	38.26%

TABLE 8 *(continued)* ACT Depth Percentage Availability—
High-Flow Alternative: 1995, 2020, and 2050 (Period of Record Averaged)

1995 High Flow						2020 High Flow						2050 High Flow				
9 ft Or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less		9 ft or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less		9 ft or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less
40.82%	44.05%	46.87%	50.61%	32.29%	Oct	40.04%	43.02%	46.08%	49.50%	32.29%	Oct	38.48%	40.40%	43.63%	46.45%	32.29%
38.37%	41.27%	43.79%	48.51%	21.91%	Nov	37.94%	40.84%	43.33%	47.66%	21.91%	Nov	37.27%	40.04%	42.63%	46.15%	21.91%
81.58%	84.36%	86.50%	88.96%	7.24%	Dec	81.02%	83.97%	86.23%	88.64%	7.24%	Dec	79.99%	83.01%	85.56%	87.70%	7.24%
95.38%	96.02%	96.91%	97.27%	2.80%	Jan	95.13%	95.94%	96.78%	97.24%	2.80%	Jan	94.76%	95.73%	96.49%	97.13%	2.80%
99.89%	99.91%	99.92%	99.93%	0.04%	Feb	99.89%	99.91%	99.92%	99.93%	0.04%	Feb	99.89%	99.91%	99.92%	99.93%	0.04%
99.62%	99.73%	99.97%	100.00%	0.21%	Mar	99.62%	99.72%	99.96%	100.00%	0.21%	Mar	99.61%	99.71%	99.90%	100.00%	0.21%
98.31%	98.54%	98.77%	99.10%	1.96%	Apr	98.27%	98.52%	98.73%	99.09%	1.96%	Apr	98.20%	98.46%	98.67%	99.03%	1.96%
93.57%	94.98%	96.41%	97.40%	5.67%	May	93.23%	94.75%	96.22%	97.20%	5.67%	May	92.45%	93.74%	95.17%	96.57%	5.67%
80.66%	83.67%	86.01%	88.94%	15.69%	Jun	79.60%	82.73%	85.35%	88.06%	15.69%	Jun	77.14%	80.19%	83.21%	85.69%	15.69%
68.28%	71.42%	75.03%	79.27%	21.33%	Jul	67.20%	70.54%	73.72%	78.05%	21.33%	Jul	64.46%	67.81%	71.04%	74.45%	21.33%
52.88%	57.32%	62.59%	67.63%	30.37%	Aug	51.89%	56.22%	61.29%	66.72%	30.37%	Aug	49.65%	53.36%	57.88%	63.44%	30.37%
45.26%	49.19%	52.94%	57.03%	38.26%	Sep	43.83%	47.55%	51.76%	55.90%	38.26%	Sep	39.84%	43.36%	47.15%	51.17%	38.26%

TABLE 8 *(continued)* ACT Depth Percentage Availability—
Moderate-Flow Alternative: 1995, 2020, and 2050 (Period of Record Averaged)

1995 Moderate Flow						2020 Moderate Flow						2050 Moderate Flow				
9 ft or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less		9 ft or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less		9 ft or more	8.5 ft Or more	8 ft or more	7.5 ft or more	7.5 ft or less
75.16%	77.79%	79.43%	81.17%	32.29%	Oct	73.02%	75.26%	77.83%	79.50%	32.29%	Oct	70.13%	72.82%	75.01%	77.51%	32.29%
78.37%	82.61%	87.36%	90.89%	21.91%	Nov	76.92%	81.40%	86.01%	89.90%	21.91%	Nov	74.92%	79.57%	83.92%	88.33%	21.91%
89.99%	91.02%	92.97%	95.70%	7.24%	Dec	89.59%	90.77%	92.50%	95.19%	7.24%	Dec	88.83%	90.50%	91.80%	94.47%	7.24%
94.15%	94.62%	95.40%	95.88%	2.80%	Jan	94.09%	94.44%	95.25%	95.80%	2.80%	Jan	94.01%	94.31%	94.88%	95.63%	2.80%
99.71%	99.95%	99.96%	99.98%	0.04%	Feb	99.69%	99.95%	99.96%	99.98%	0.04%	Feb	99.66%	99.91%	99.96%	99.97%	0.04%
99.39%	99.49%	99.51%	99.60%	0.21%	Mar	99.38%	99.47%	99.51%	99.59%	0.21%	Mar	99.36%	99.43%	99.50%	99.58%	0.21%
94.51%	95.11%	95.94%	96.81%	1.96%	Apr	94.42%	94.96%	95.83%	96.55%	1.96%	Apr	94.25%	94.78%	95.68%	96.27%	1.96%
90.09%	91.14%	92.14%	93.39%	5.67%	May	89.49%	90.64%	91.62%	92.91%	5.67%	May	88.82%	89.79%	90.94%	92.03%	5.67%
74.51%	77.92%	80.03%	82.55%	15.69%	Jun	71.20%	74.96%	78.45%	80.44%	15.69%	Jun	67.81%	70.59%	74.46%	77.89%	15.69%
62.60%	65.18%	67.94%	70.30%	21.33%	Jul	60.57%	63.02%	65.83%	68.39%	21.33%	Jul	58.17%	60.31%	62.64%	65.57%	21.33%
45.67%	48.61%	51.39%	54.06%	30.37%	Aug	43.79%	46.93%	49.58%	52.42%	30.37%	Aug	41.18%	44.43%	47.49%	50.20%	30.37%
44.57%	46.18%	48.42%	50.74%	38.26%	Sep	43.37%	44.47%	46.37%	48.55%	38.26%	Sep	41.90%	43.10%	44.11%	45.64%	38.26%

TABLE 8 *(continued)* ACT Depth Percentage Availability—
Low-Flow Alternative: 1995, 2020, and 2050 (Period of Record Averaged)

1995 Low Flow						2020 Low Flow						2050 Low Flow				
9 ft or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less		9 ft or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less		9 ft or more	8.5 ft or more	8 ft or more	7.5 ft or more	7.5 ft or less
70.13%	72.82%	75.01%	77.51%	32.29%	Oct	62.42%	63.38%	64.33%	65.30%	34.70%	Oct	64.79%	65.79%	66.71%	67.71%	32.29%
74.92%	79.57%	83.92%	88.33%	21.91%	Nov	70.49%	73.65%	76.32%	77.98%	22.02%	Nov	70.76%	73.61%	76.17%	78.09%	21.91%
88.83%	90.50%	91.80%	94.47%	7.24%	Dec	89.10%	90.94%	92.03%	93.33%	6.67%	Dec	88.50%	90.42%	91.68%	92.76%	7.24%
94.01%	94.31%	94.88%	95.63%	2.80%	Jan	95.59%	96.28%	96.76%	97.17%	2.83%	Jan	95.22%	96.07%	96.71%	97.20%	2.80%
99.66%	99.91%	99.96%	99.97%	0.04%	Feb	99.66%	99.78%	99.93%	99.97%	0.03%	Feb	99.60%	99.76%	99.91%	99.96%	0.04%
99.36%	99.43%	99.50%	99.58%	0.21%	Mar	99.26%	99.64%	99.75%	99.79%	0.21%	Mar	99.26%	99.62%	99.76%	99.79%	0.21%
94.25%	94.78%	95.68%	96.27%	1.96%	Apr	95.71%	96.32%	97.22%	97.88%	2.12%	Apr	95.83%	96.59%	97.46%	98.04%	1.96%
88.82%	89.79%	90.94%	92.03%	5.67%	May	91.15%	92.16%	92.92%	93.91%	6.09%	May	91.58%	92.60%	93.48%	94.33%	5.67%
67.81%	70.59%	74.46%	77.89%	15.69%	Jun	78.00%	80.26%	81.97%	83.84%	16.16%	Jun	78.55%	80.72%	82.46%	84.31%	15.69%
58.17%	60.31%	62.64%	65.57%	21.33%	Jul	70.95%	74.00%	75.92%	77.54%	22.46%	Jul	72.14%	75.00%	77.21%	78.67%	21.33%
41.18%	44.43%	47.49%	50.20%	30.37%	Aug	59.84%	62.75%	65.11%	67.05%	32.95%	Aug	62.54%	65.52%	67.56%	69.63%	30.37%
41.90%	43.10%	44.11%	45.64%	38.26%	Sep	56.24%	57.80%	58.87%	59.82%	40.18%	Sep	58.21%	59.72%	60.66%	61.74%	38.26%

TABLE 9 Seasonal Distribution of Commodities (ACT)

	Farm Products	Metals & Ores	Coal[a]	Crude Petroleum[a]	Nonmetallic	Forest Products	Industrial Chemicals	Agricultural Chemicals	Petroleum Products[a]
January	25.0%		8.3%	8.3%	6.8%	7.4%	40.0%	8.3%	8.3%
February	50.0%		8.3%	8.3%	8.9%	7.7%		25.0%	8.3%
March	25.0%		8.3%	8.3%	7.6%	9.5%		25.0%	8.3%
April			8.3%	8.3%	7.0%	8.3%		25.0%	8.3%
May		63.7%	8.3%	8.3%	9.5%	3.6%		16.7%	8.3%
June			8.3%	8.3%	10.8%	9.6%			8.3%
July		36.3%	8.3%	8.3%	7.2%	10.8%	26.7%		8.3%
August			8.3%	8.3%	7.0%	6.6%	6.6%		8.3%
September			8.3%	8.3%	7.3%	10.5%	26.6%		8.3%
October			8.3%	8.3%	4.9%	3.0%			8.3%
November			8.3%	8.3%	15.8%	15.8%			8.3%
December			8.3%	8.3%	7.0%	7.9%			8.3%

[a] Since these commodities are not shipped regularly on the waterway, the assumption is made that they will be shipped proportionally throughout the year.

TABLE 10 ACT Commodity Forecasts (Tons)

	Farm Products	Metals & Ores	Nonmetallic	Forest Products	Industrial Chemicals	Agricultural Chemicals	Petroleum Products	Commodity Total
1995	333		541,667	732,133	3,067		38,267	1,369,267
2020	498		629,726	919,680	5,450		54,820	1,664,905
2050	809		700,512	1,431,470	10,220		88,086	2,290,075

Source: ACT and ACF River Basin Comprehensive Study, Navigation Water Demand Element, Preliminary Draft Report, November 1997.

COMMODITIES

The annual commodity forecasts were seasonally apportioned based on past patterns, as extracted from the lock performance monitoring system records. Table 9 presents seasonal distribution percentages by month. Table 10 shows the commodity forecasts from the navigation element of the comprehensive study for the years 1995, 2020, and 2050. Tables 11–13 show the yearly commodity forecasts, apportioned by month.

TABLE 11 1995 ACT Seasonal Distribution of Commodities (Tons)

	Farm Products	Metals & Ores	Coal[1]	Crude Petroleum[1]	Nonmetallic	Forest Products	Industrial Chemicals	Agricultural Chemicals	Petroleum Products[1]
January	83			4,465	36,833	54,178	1,227		3,188
February	167			4,465	48,208	56,374			3,176
March	83			4,465	41,167	68,821			3,176
April				4,465	37,917	60,767			3,176
May				4,465	51,458	26,357			3,176
June				4,465	58,500	69,553			3,176
July				4,465	39,000	78,338	819		3,176
August				4,465	37,917	47,589	202		3,176
September				4,465	39,542	76,142	816		3,176
October				4,465	26,542	21,964			3,176
November				4,465	85,583	114,945			3,176
December				4,465	37,917	57,106			3,176
Total	333			53,800	541,667	732,133	3,067		38,267

[1] Since these commodities are not shipped regularly on the waterway, the assumption is made that they will be shipped proportionally throughout the year.

TABLE 12 2020 ACT Seasonal Distribution of Commodities (Tons)

	Farm Products	Metals & Ores	Coal[1]	Crude Petroleum[1]	Nonmetallic	Forest Products	Industrial Chemicals	Agricultural Chemicals	Petroleum Products[1]
January	125			4,543	42,821	68,056	2,180		4,567
February	249			4,543	56,046	70,815			4,550
March	125			4,543	47,859	86,450			4,550
April				4,543	44,081	76,333			4,550
May				4,543	59,824	33,108			4,550
June				4,543	68,010	87,370			4,550
July				4,543	45,340	98,406	1,455		4,550
August				4,543	44,081	59,779	360		4,550
September				4,543	45,970	95,647	1,450		4,550
October				4,543	30,857	27,590			4,550
November				4,543	99,497	144,390			4,550
December				4,543	44,081	71,735			4,550
Total	498			54,731	629,726	919,680	5,450		54,820

[1] Since these commodities are not shipped regularly on the waterway, the assumption is made that they will be shipped proportionally throughout the year.

TABLE 13 2050 ACT Seasonal Distribution of Commodities (Tons)

	Farm Products	Metals & Ores	Coal[a]	Crude Petroleum[a]	Nonmetallic	Forest Products	Industrial Chemicals	Agricultural Chemicals	Petroleum Products[a]
January	202			4,895	47,635	105,929	4,088		7,338
February	405			4,895	62,346	110,223			7,311
March	202			4,895	53,239	134,558			7,311
April				4,895	49,036	118,812			7,311
May				4,895	66,549	51,533			7,311
June				4,895	75,655	135,990			7,311
July				4,895	50,437	153,167	2,729		7,311
August				4,895	49,036	93,046	675		7,311
September				4,895	51,137	148,873	2,719		7,311
October				4,895	34,325	42,944			7,311
November				4,895	110,681	224,741			7,311
December				4,895	49,036	111,655			7,311
Total	809			58,978	700,512	1,431,470	10,220		88,086

[a] Since these commodities are not shipped regularly on the waterway, the assumption is made that they will be shipped proportionally throughout the year.

TRANSPORTATION COSTS

When barges are light-loaded less to depths below full navigation, there is a corresponding increase in the shipping cost per ton. Table 14 presents the matrix of shipping cost per barge-ton for the ACT navigation system, from the comprehensive study navigation element.

Action Alternatives

Three action alternatives that would encompass any probable allocation formula were formulated for specific flow-demand conditions: 1) high flows-low demands, 2) moderate flows-moderate demands, and 3) low flows-high demands. Each of these action alternatives was evaluated using the above-described methodology to determine the yearly transportation cost of the same commodities, holding all variables constant except for HEC-5 output flows associated with each action alternative.

Direct Impacts

The transportation costs represent the aggregate cost of shipping 1995, 2020, and 2050 commodities, utilizing the navigation project when depths are available, and rail transportation otherwise. These transportation costs were accumulated and averaged for the period of record. Table 15 presents the average yearly transportation costs for the no- action and the three action alternatives.

TABLE 14 ACT Average Transportation Cost by Mode at Alternative Channel Depths

ACT COMMODITY	Average Annual Tons 1970-93	Weighted Barge Cost per Ton at 7.5'	Weighted Barge Cost per Ton at 8.0'	Weighted Barge Cost per Ton at 8.5'	Weighted Barge Cost per Ton at 9.0'	Weighted Rail Cost per Ton
Farm Products	31,122	$2.06	$1.74	$1.63	$1.41	$2.93
Metals & Ores	860	$6.30	$5.62	$5.40	$4.95	$13.11
Coal	537	$2.30	$1.99	$1.89	$1.68	$3.50
Crude Petroleum	23,326	$5.44	$4.56	$4.27	$3.68	$9.19
Nonmetallic	1,459,948	$2.18	$1.89	$1.79	$1.60	$3.01
Forest Products	585,459	$1.94	$1.94	$1.94	$1.94	$4.95
Industrial Chem.	4,777	$9.37	$8.29	$7.93	$7.20	$14.33
Agricultural Chem.	13,002	$4.52	$4.01	$3.83	$3.49	$5.13
Petroleum Prod.	27,657	$6.14	$5.15	$4.82	$4.15	$7.15
TOTAL	2,146,688					

Source: ACT and ACF River Basin Comprehensive Study, Navigation Water Demand Element, Preliminary Draft Report, November 1997, Table B-9-1.

TABLE 15 ACT Average Yearly Transportation Costs (1998 Dollars)

	No Action	High Flow	Moderate Flow	Low Flow
1995	$3,122,147	$3,372,495	$3,217,097	$3,208,373
2020	$3,924,926	$4,149,124	$3,978,701	$3,972,237
2050	$3,924,926	$5,928,046	$5,670,928	$5,664,975

Total transportation shipping costs were calculated for the period of record for each year in the no-action alternative. This was accomplished by calculating shipping costs for each month. The monthly percentage of time-depth availability represented that percentage of commerce shipped at the corresponding depth's shipping cost. All commerce not shipped on the waterway, due to there being less than 7.5 feet of depth available, was assumed to ship at the rail rate.

Total transportation shipping cost was converted into an annual average value. The no-action alternative annual transportation costs for 1995, 2020 and 2050 were $3,122,147, $3,924,926, and $3,924,926, respectively.

Summary Table 16 shows the direct annual impacts of each action alternative, along with the average annual direct impacts in 1998 dollars.

TABLE 16 ACT Direct Impacts-Navigation

	Low Flow	Moderate Flow	High Flow
1995	($86,226)	($94,950)	($250,348)
2020	($47,311)	($53,775)	($224,198)
2050	($194,505)	($200,458)	($457,576)
AVERAGE ANNUAL	($73,413)	($80,728)	($251,615)

EXTREME CONDITION

To estimate the impacts for an extreme event, the data were examined for the worst case throughout the period of record. The reasoning for this action is to associate impacts of an extreme event, such as a drought year, and impacts of the period of record as a whole. Analysis of the data revealed that the year 1986 exhibited the highest shipping costs of all the years studied and analyzed. That is, in the drought year of 1986, the largest amount of commerce was diverted to the alternative mode of transportation.

Tables 17–20 show the depth available at the various channel depths for the various alternative conditions during the 1986 drought. These statistics were obtained by finding the flow in each month of the extreme year. Subsequently, the shipping costs (Table 21) were calculated to ascertain the impacts. The results are displayed in Table 22.

TABLE 17 ACT–Extreme Condition: 1986 Drought–Time-Depth Available; 1995 No-Action Alternative

	9 ft or more	8.5 to 9.0 ft	8.0 to 8.5 ft	7.5 to 8 ft	Less than 7.5 ft
October	76.8%	1.3%	1.3%	1.4%	19.2%
November	81.2%	0.5%	0.5%	0.5%	17.3%
December	90.3%	2.8%	1.3%	1.2%	4.4%
January	81.2%	0.6%	0.6%	0.6%	17.0%
February	95.8%	1.1%	0.7%	0.7%	1.7%
March	67.7%	14.4%	5.0%	1.5%	11.4%
April	13.3%	4.6%	14.5%	12.7%	54.9%
May	39.9%	6.0%	4.3%	1.2%	48.6%
June	1.7%	1.4%	1.8%	2.0%	93.1%
July	0.0%	0.0%	0.0%	0.0%	100.0%
August	0.0%	0.0%	0.0%	0.0%	100.0%
September	0.0%	0.0%	0.0%	0.0%	100.0%

TABLE 18 ACT–Extreme Condition: 1986 Drought–Time-Depth Available; 1995 High-Flow Condition

	9 ft or more	8.5 to 9.0 ft	8.0 to 8.5 ft	7.5 to 8 ft	Less than 7.5 ft
October	45.4%	0.7%	1.2%	6.6%	46.1%
November	31.8%	1.3%	1.3%	7.9%	57.7%
December	75.1%	5.9%	6.5%	8.1%	4.4%
January	68.0%	6.6%	20.2%	5.2%	0.0%
February	99.1%	0.8%	0.1%	0.0%	0.0%
March	79.7%	5.5%	13.0%	1.8%	0.0%
April	27.6%	8.0%	4.3%	11.7%	48.4%
May	47.1%	1.9%	1.7%	1.3%	48.0%
June	14.1%	2.5%	7.2%	19.1%	57.1%
July	0.0%	0.0%	0.0%	0.0%	100.0%
August	0.0%	0.0%	0.0%	0.0%	100.0%
September	2.2%	9.2%	8.7%	6.7%	73.2%

TABLE 19 ACT–Extreme Condition: 1986 Drought–Time-Depth Available; 1995 Moderate-Flow Condition

	9 ft or more	8.5 to 9.0 ft	8.0 to 8.5 ft	7.5 to 8 ft	Less than 7.5 ft
October	98.4%	1.6%	0.0%	0.0%	0.0%
November	99.9%	0.1%	0.0%	0.0%	0.0%
December	92.5%	3.4%	2.7%	1.4%	0.0%
January	23.3%	10.8%	17.1%	15.3%	33.5%
February	96.1%	1.1%	0.9%	0.8%	1.1%
March	71.7%	0.8%	1.3%	4.5%	21.7%
April	1.2%	0.9%	0.9%	9.5%	87.5%
May	30.9%	3.0%	3.9%	3.5%	58.7%
June	3.4%	1.1%	1.1%	1.2%	93.2%
July	0.0%	0.0%	0.0%	0.0%	100.0%
August	0.0%	0.0%	0.0%	0.0%	100.0%
September	0.0%	0.0%	0.0%	0.0%	100.0%

TABLE 20 ACT–Extreme Condition: 1986 Drought–Time-Depth Available; 1995 Low-Flow Condition

	9 ft or more	8.5 to 9.0 ft	8.0 to 8.5 ft	7.5 to 8 ft	Less than 7.5 ft
October	98.3%	1.3%	0.4%	0.0%	0.0%
November	99.2%	0.8%	0.0%	0.0%	0.0%
December	92.8%	3.1%	3.1%	1.0%	0.0%
January	23.3%	4.6%	13.1%	14.9%	44.1%
February	93.2%	2.5%	1.4%	0.9%	2.0%
March	70.3%	0.9%	1.0%	0.9%	26.9%
April	0.0%	0.7%	0.9%	1.0%	97.4%
May	15.9%	1.3%	9.0%	2.8%	71.0%
June	1.9%	0.6%	0.6%	0.8%	96.1%
July	0.0%	0.0%	0.0%	0.0%	100.0%
August	0.0%	0.0%	0.0%	0.0%	100.0%
September	5.6%	1.6%	0.7%	0.7%	91.4%

TABLE 21 ACT Extreme Case: 1986 Drought—Commerce Shipping Costs

	No Action	High	Moderate	Low
1995	$4,319,070	$4,281,680	$4,377,647	$4,449,175
2020	$5,327,977	$5,287,603	$5,376,629	$5,531,793
2050	$7,497,246	$7,635,633	$7,657,546	$7,849,749

TABLE 22 ACT Extreme Case: 1986 Drought—Direct Impacts on Navigation

	High	Moderate	Low
1995	$37,391	($58,577)	($130,105)
2020	$40,374	($48,652)	($203,816)
2050	($138,388)	($160,301)	($352,504)
Average Annual	$26,071	($60,753)	($185,776)

CONCLUSIONS

Each alternative measure, evaluated over the period of record, presented negative yet small impacts to navigation on the ACT river system. Low- and moderate-flow impacts were nearly equal and insignificant. High-flow impacts were three times as large as the low and moderate, yet still insignificant. As expected in extreme drought cases, navigation was positively impacted when a high-flow alternative was followed. There may be more value for the decision-maker to examine the impacts during drought periods and rainy (wet) periods, and whether they are positive or negative.

LIMITATIONS

The methodology presented here was suitable for the purpose served, presenting the regional impacts to navigation for the stakeholders' benefit. Current federal guidance requires the use of risk and uncertainty analysis to state the risks associated with federal actions. A more informative analysis for the decision-maker would result if a risk and uncertainty analysis were done using risk variables for tonnages, rates, and percentage of depth available.

REFERENCES

1. WEFA Group, *U.S. Long-Term Economic Outlook*, Vol. 1: *Trend/Moderate Growth Scenario*, and *U.S. Long-Term Historical Data*. First quarter, 1996.
2. *ACT and ACF River Basin Comprehensive Study, Navigation Water Demand Element*, Preliminary Draft Report, November 1997.