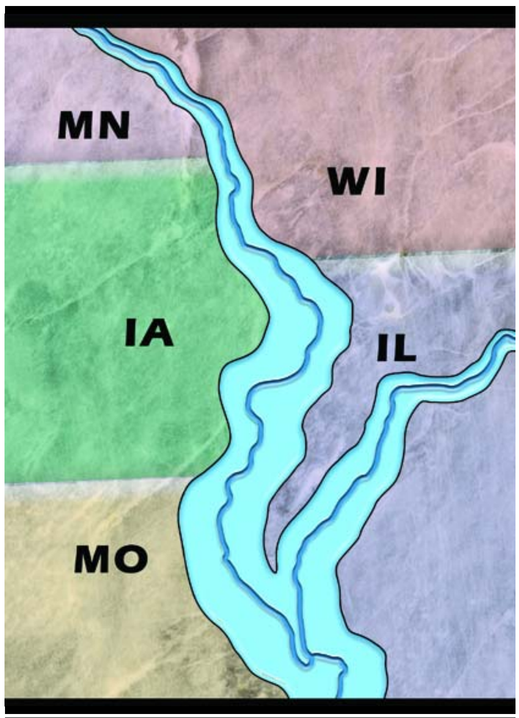
UPPER MISSISSIPPI RIVER COMPREHENSIVE PLAN



APPENDIX B

HYDROLOGY AND HYDRAULICS

Prepared by the
U.S. Army Corps of Engineers
Rock Island, St. Louis, and St. Paul Districts

JULY 2008

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ACKNOWLEDGEMENTS

This appendix is the result of the dedicated efforts of a number of employees in the Hydrologic and Hydraulics Branches of the St. Paul, Rock Island and St. Louis District offices, including Gregory Eggers, Stuart Dobberpuhl, Kevin Landwehr, John Burant, Dennis Stephens, and Donald Duncan, as well as Rich Astrack, Project Management, St. Louis District

Special recognition is given to Dr. Robert Barkau for the many hours he spent in developing a stochastic method of extending the observed period of flow record. This allowed a systemic analysis of the Mississippi and Illinois Rivers.

Also, the coordination and cooperation provided by Corps' study members, Bob Occhipinti, Eddie Brooks and Larry Banks from Mississippi Valley Division. It was with the strong support of these three members that we developed the stochastic model. Pat Foley from the St. Paul District and Marv Martens from the Rock Island District were very supportive in applying a new approach in systemic analysis.

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I. INTRODUCTION

A. Study Purpose. The Comprehensive Plan for the Upper Mississippi and Illinois Rivers Study develops a systemic, integrated strategy and implementation plan for flood damage reduction and related environmental restoration. The plan was developed in coordination with the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin; the Upper Mississippi River Basin Association; and non-governmental organizations such as the Upper Mississippi, Illinois, and Missouri Rivers Association, and the Mississippi River Basin Alliance. This Hydrology and Hydraulics (H & H) Appendix includes documentation of the existing conditions and the formulation and evaluation of alternatives for flood damage reduction.

B. Study Area. The geographic area of consideration for this study is the upper Mississippi and Illinois River basins. This area encompasses nearly 189,000 square miles. This study will focus primarily upon flood damage reduction for the .2% annual chance flood (500-year)) floodplains of the reach of the Upper Mississippi River between St. Paul, MN, and Thebes, IL, and the reach of the Illinois River that lies between its confluence with the Mississippi River and the confluence of the Kankakee and Des Plaines Rivers. The study area is the general floodplain, from bluff to bluff, adjacent to the Mississippi and Illinois Rivers for over 1,000 river miles.

C. Goals and Objectives. The overall goal of the Comprehensive Plan is to develop a systemic flood damage reduction plan for the Upper Mississippi and Illinois Rivers, sufficiently comprehensive to address flood damage reduction needs and supportive of evolving long-term Upper Mississippi River System (UMRS) economic and environmental sustainability goals.

D. Previous Studies. After the "Flood of '93", a systemic numerical modeling approach was incorporated for various studies in the UMRS. The following three reports were written after the 1993 flood and were instrumental in the development of this report.

Science for Floodplain Management into the 21st Century, Volumes 1-5, 1994-1996.

Floodplain Management Assessment, US Army Corps of Engineers, Main Report and Appendix A-E, June 1995.

Upper Mississippi River System Flow Frequency Report, US Army Corps of Engineers, Main Report and Appendices A-I, January 2004.

II. BASIN DESCRIPTION

A. Watershed Characteristics

1. Mississippi River. The Mississippi River rises in the lake and forest country of north-central Minnesota and flows north, east, and then south through this timbered landscape to Minneapolis-St. Paul. At this point, it leaves the northern woodlands and lakes, and meanders southward through the fertile prairies of the Midwest and many small towns and cities. Along the way, tributaries to the east and west join the Mississippi River and add to its flow. 1,370 miles from its headwaters, the Upper Mississippi River joins the Ohio River. The basin drains 189,000 square miles, including the Illinois River basin. The Mississippi River continues to flow another 964 miles to the Gulf of Mexico.

2. Illinois River. The Illinois River basin has a watershed of 28,900 square miles which includes the 673 square miles of the diverted Lake Michigan basin that also drains into the Illinois Waterway. The Illinois River extends from the mouth of the Chicago River, on Lake Michigan, following the Chicago Sanitary and Ship Canal, the lower Des Plaines River, and the Illinois River to the Mississippi at Grafton, IL. Upstream of Starved Rock Dam at river mile (RM) 230, the river is steep with a gradient of about 1.5 feet per mile. Downstream of Starved Rock, the gradient of the Illinois River is extremely flat at roughly 0.1 feet per mile. Numerous backwater areas and lakes parallel the main channel. Downstream of RM 202, extensive levee systems have been built to protect agricultural areas in the wide floodplain. Topography is generally characterized by high bluffs and rolling hills which descend to a wide, flat, floodplain adjacent to the river. Many small ungaged tributary streams as well as major rivers flow into the river along this reach.

B. Climatology. Nearly all surface water runoff in the Upper Mississippi River basin results from precipitation falling within its watershed boundaries. The average annual precipitation over the basin is 32 inches. Of this amount, an estimated 24 inches returns to the atmosphere by means of evaporation and/or transpiration. The remaining 8 inches contributes to surface water runoff and groundwater interaction. The annual runoff as a percentage of the annual precipitation varies greatly over the basin. The basin-wide ratio of average runoff to average precipitation is about 25 percent. The months of highest runoff are generally March through June, roughly paralleling the monthly precipitation pattern. The average monthly flows then generally taper off, reaching minimum values during the winter months. The March and April flows in the northern half of the basin are augmented by the melting snow, which accumulated during the winter months. Monthly flows in the southern portion of the basin are relatively high during the winter months as compared to the northern portion because annual precipitation is more evenly distributed and temperatures are more moderate.

C. Flood History

1. Mississippi River. Flooding in the Upper and Middle Mississippi River can be caused by spring snowmelt runoff, a combination of snowmelt and spring rainfall, or rainfall runoff events. Listed are flood events that were produced under different runoff scenarios.

a. Flood of 1965. The April 1965 flood is the flood of record for the 500-mile reach of the Mississippi River between Royalton, Minnesota, 100 miles upstream of Minneapolis, to just below Clinton, Iowa. The flood was caused by an early fall freeze that resulted in an unusually deep frost penetration prior to the snow cover and a February thaw with rain in southern Minnesota and northern Iowa under conditions of nearly impermeable surface ground conditions. A third contributing factor was the March snowfall (300 percent above normal) in east-central Minnesota, together with a late period of cold weather in March and early April that prevented the gradual runoff of the snow-pack.

b. Flood of 1973. Periods of snow and severe cold temperatures occurring during December 1972 and early January 1973 alternated with short periods of warmer weather accompanied by rainfall. Unseasonably warm weather during the second half of January and all of February caused considerable surface thawing and melting of snow cover. Flooding was generally caused by torrential rains falling on saturated soil and rivers with extremely high base stream flows. Flooding on the Mississippi River consisted of three distinct crests. In each case, the crests of the tributary stream rises coincided with the crest of the Mississippi River as it progressed downstream. This synchronization of tributary inflow sufficiently augmented the main-stem flows to cause the second crest to surpass all previous stages below Burlington, Iowa. The peak flow was 414,000 cubic feet per second (cfs) on April 25. In 1973, the crests at Hannibal, Missouri (28.59 feet) and Quincy, Illinois (28.90 feet) was four feet higher than 1965. The flood displaced 10,000 people and inundated 180,000 acres. The river was above flood stage at Hannibal for 106 days.

During the second week of March 1973, a very severe storm system developed over Kansas and moved northeastward over the upper Mississippi basin. The first major crest reached St. Louis on March 17, 1973, with a stage of 35.2 feet. A second crest developed in late March and peaked at St. Louis at 39.8 feet on April 5. By April 8, the stage was falling at St. Louis, and by April 10, the Mississippi River was falling at most gages within the St. Louis District boundary. A cloudburst across Missouri, Illinois, and Iowa on April 19 through April 21 caused a third crest. This third crest established record stages at every gage between Louisiana, MO to the north and Cape Girardeau, MO to the south. The third crest reached St. Louis on April 28 and registered a peak stage of 43.31 feet. The maximum measured discharge was 852,000 cfs. During this long duration flood, the Mississippi River at St. Louis was above flood stage a total 77 days and above a 40-foot stage (10 feet above flood stage) for 8 days.

c. Flood of 1993. The Flood of 1993 was unique in its areal extent as well as its duration. Excessive precipitation during April through July produced severe or record flooding in a nine-state area in the upper Mississippi River basin. Every gaging station along the main stem of the Mississippi River below Lock and Dam (L&D) No. 15 to Thebes, Illinois experienced a new flood of record. Above L&D 15, the 1993 flood was surpassed by only one other event (1965). Although typically floods occur in the spring, this flood occurred throughout the summer along the Mississippi River. Flooding and water levels above the flood stage continued from April through September in many regions along the Mississippi River. Record flow in excess of 500,000 cfs was estimated for the Hannibal, MO gage at a record stage of 31.8 feet. In Hannibal, MO, the Mississippi River remained above flood stage (16.0 feet) for more than six months.

The St. Louis gage crested on August 1 with a peak stage of 49.58 feet. The peak discharge of 1,070,000 cfs was the highest recorded discharge ever measured at St. Louis. The Mississippi River at St. Louis exceeded flood stage a total of 80 days, breaking by the record set during the 1973 flood. The 1993 flood also exceeded a 40-foot stage at St. Louis for 38 days. Standard hydrometeorological techniques applied to the 1993 precipitation amounts from periods from 2 months up to 12 months, estimated return period of the 1993 precipitation values exceeds 200 year (Kunkel et al., 1994).

d. Flood of 1995. From April 1995 through early June 1995, many areas of the central United States received more than twice their normal precipitation. An abnormally strong and persistent southwesterly flow of air at the jet stream level pushed a series of major storm systems across the country, resulting in repeated episodes of heavy rainfall. May 1995 was the wettest May on record in both Kansas City and St. Louis. This excessive rainfall, coupled with nearly saturated soil moisture conditions over much of the region, resulted in flooding along the lower and middle Missouri River, along the middle and lower Mississippi River, and along the lower Illinois River. The peak discharge was about 325,000 cfs at the Louisiana gage; 377,000 cfs at the Grafton gage; 800,000 cfs at the St. Louis gage; and 857,000 cfs at the Chester gage. The Mississippi River was at or above flood stage at Louisiana, Grafton, St. Louis, and Chester for 44 days, 52 days, 40 days, and 55 days, respectively. The crest stage at St. Louis gage was the third highest since records have been maintained. The peak stage for the 1995 flood at the Thebes gage was the highest stage recorded because of the influence of the backwater from the Ohio River.

2. Illinois River. Flooding in the Illinois River can be caused by severe rainfall and backwater events on the lower portion from the Mississippi River. Listed are flood events that occurred in the Illinois River.

a. Flood of 1943. The flood of May 1943 was produced by rainfall of more than twice the amount that normally occurs during the month. Rainfall over the Illinois River Basin during May totaled about 8.5 inches, as compared with the normal of 3.95 inches. The heaviest precipitation was recorded between May 7 and May 20. The peak flow of 83,100 cfs at Kingston Mines (RM 145.4) occurred on May 23. The peak flow of 123,000 cfs at Meredosia, IL occurred on May 26. The Illinois River was above flood stage at Meredosia for 70 consecutive days.

b. Flood of 1982. The December 1982 flood resulted from a prolonged spell of abnormally warm weather and moderate rainfall through late November. Saturated conditions and intense rainfall in early December produced a high percentage of runoff in many areas of Illinois. The record peak flow of 88,800 cfs at Kingston Mines occurred on December 7. The resulting peak flow of 112,000 cfs was the third highest recorded flow at Meredosia and occurred on December 12.

c. Flood of 1985. Rainfall on frozen ground in late February caused the Illinois River to rise above flood stage. Then, on March 3 and 4, about 2 inches of rain fell throughout the Illinois River basin on the already saturated soil. Record stages were recorded upstream of Peoria with near record stages at Beardstown and Meredosia. This spring flood produced the second largest peak flow at Meredosia of 122,000 cfs on March 10.

d. Flood of 1993. The flood of 1993 on the Mississippi River caused the Illinois River to swell to record-breaking stages at Hardin, Illinois, Pearl, Illinois and Florence Illinois gages. This flooding was due to backwater from the Mississippi River.

D. Levees. The construction of levees along the main stems of the Mississippi and Illinois Rivers has occurred since the late 1890s. However, the construction throughout the area was generally by private interests, local drainage and levee districts, or municipalities until after World War II. Prior to World War II, only a few levees were constructed with Federal funds. These levees protected primarily agricultural areas and were limited to moderate levels of protection (5% chance exceedance (20-year) or more frequent). Following World War II, Congress authorized numerous levee projects throughout the Mississippi and Illinois River system. Most of these projects were raises to existing levee systems, thereby giving a standard level of protection commensurate to the predominant land use of the interior.

The levees along Mississippi and Illinois Rivers that were used in our database are shown in tables B-1, B-2, B-3 and B-4. Levee failure due to geotechnical and structural deficiencies were not considered in these tables. The protection listed represents physical overtopping of the levee or area by floodwater. The levees are separated in four different reaches which will be explained later in this text. The levee construction and type of protection classification of the levees in this table are defined as follows:

- Federal levee - a levee project constructed by the U.S. Army Corps of Engineers (the Corps) to Corps specifications

- non-Federal levee - a levee project constructed by a public entity (non-Federal) or constructed under emergency authorization
- private levee - a levee project constructed by private entity (non-public).
- unprotected area - an urban area where there is no existing levee project
- wildlife area - federally-constructed wildlife area such as those that belong to the Environmental Management Program (EMP)

Furthermore, the levees were placed into two categories for classification—urban or agricultural. An *urban levee project* is one in which a majority of the project protects an urban area. This classification also includes agricultural areas where flood damages include significant urban and critical infrastructure impacts. An *agricultural (Ag) levee* project protects agricultural areas and does not contain any significant urban or critical infrastructure

Table B-1. Levees and Unprotected Areas - Mississippi River Reach 1

Name	State	River	Type of Construction	Urban or Ag	Acres	Start of Damages (Approximate Frequency)	Upstream RM	Downstream RM
Coon Rapids	MN	Mississippi	Unprotected	Urban		Unprotected		
Fridley	MN	Mississippi	Non-Federal	Urban		< 2% Flood		
Brooklyn Center	MN	Mississippi	Unprotected	Urban		Unprotected		
St. Paul - Power Plant	MN	Mississippi	Unprotected	Urban		Unprotected		
St. Paul – Downtown below Robert St. Bridge	MN	Mississippi	Unprotected	Urban		Unprotected		
St. Paul	MN	Mississippi	Federal	Urban	510	> .2% Flood	840.3	836.7
Area North of Newport	MN	Mississippi	Unprotected	Urban		Unprotected		
South St. Paul	MN	Mississippi	Federal	Urban	590	.2% Flood	834.3	832.2
Newport	MN	Mississippi	Non-Federal	Urban		< 2% Flood		
South St. Paul - Reach 2	MN	Mississippi	Non-Federal	Urban		1% Flood		
Inver Grove	MN	Mississippi	Non-Federal	Urban		< 2% Flood		
St. Paul Park	MN	Mississippi	Unprotected	Urban		Unprotected		
Nininger	MN	Mississippi	Unprotected	Urban		Unprotected		
Hastings	MN	Mississippi	Unprotected	Urban		Unprotected		
Prescott	WI	Mississippi	Unprotected	Urban		Unprotected		
Prairie Island	MN	Mississippi	Unprotected	Urban		Unprotected		
Trenton Island	WI	Mississippi	Unprotected	Urban		Unprotected		
Red Wing	MN	Mississippi	Unprotected	Urban		Unprotected		
Bay City	WI	Mississippi	Unprotected	Urban		Unprotected		
Old Frontenac	MN	Mississippi	Unprotected	Urban		Unprotected		
Lake City	MN	Mississippi	Non-Federal	Urban		< 2% Flood		
Deer Island	WI	Mississippi	Unprotected	Urban		Unprotected		
Maiden Rock-Stockholm-Pepin	WI	Mississippi	Unprotected	Urban		Unprotected		
Reads Landing	MN	Mississippi	Unprotected	Urban		Unprotected		
Wabasha	MN	Mississippi	Unprotected	Urban		Unprotected		
Alma	WI	Mississippi	Unprotected	Urban		Unprotected		
Buffalo City	WI	Mississippi	Unprotected	Urban		Unprotected		
Cochrane	WI	Mississippi	Non-Federal	Urban		2% Flood		
Fountain City	WI	Mississippi	Unprotected	Urban		Unprotected		
Winona	MN	Mississippi	Federal	Urban	6,000	.5-.2% Flood	731.6	723.1
Trempeauleau	WI	Mississippi	Unprotected	Urban		Unprotected		
Dakota	MN	Mississippi	Unprotected	Urban		Unprotected		

Table B-1. Levees and Unprotected Areas - Mississippi River Reach 1

Name	State	River	Type of Construction	Urban or Ag	Acres	Start of Damages (Approximate Frequency)	Upstream RM	Downstream RM
Dresbach	MN	Mississippi	Unprotected	Urban		Unprotected		
LaCrescent	MN	Mississippi	Unprotected	Urban		Unprotected		
LaCrosse	WI	Mississippi	Non-Federal	Urban		< 2% Flood		
Stoddard	WI	Mississippi	Unprotected	Urban		Unprotected		
Genoa	WI	Mississippi	Non-Federal	Urban		< 2% Flood		
Battle Island	WI	Mississippi	Unprotected	Urban		Unprotected		
Lansing	IA	Mississippi	Non-Federal	Urban		< 2% Flood		
Harper's Ferry	IA	Mississippi	Unprotected	Urban		Unprotected		
Ambrough	WI	Mississippi	Unprotected	Urban		Unprotected		
Prairie du Chien	WI	Mississippi	Unprotected	Urban		Unprotected		
Marquette	IA	Mississippi	Non-Federal	Urban		< 2% Flood		
McGregor	IA	Mississippi	Non-Federal	Urban		< 2% Flood		
Wyalusing	WI	Mississippi	Unprotected	Urban		Unprotected		
Clayton	IA	Mississippi	Non-Federal	Urban		< 2% Flood		
Bagley	WI	Mississippi	Unprotected	Urban		Unprotected		
Glen Haven	WI	Mississippi	Non-Federal	Urban		1% Flood		
Abel's Island	IA	Mississippi	Unprotected	Urban		Unprotected		
Guttenburg	MN	Mississippi	Federal	Urban	480	> .2% Flood	616.7	614.0
Cassville	WI	Mississippi	Unprotected	Urban		Unprotected		
Pool 11 Islands	IA	Mississippi	Wildlife Area	Other	10,342	< 2% Flood		
Dubuque	IA	Mississippi	Federal	Urban	1,100	> .2% Flood	582.6	578.6
East Dubuque	IL	Mississippi	Non-Federal	Urban	40	1% Flood		
Pool 12 Overwintering	IL	Mississippi	Wildlife Area	Other	628	< 2% Flood		
Bellevue	IA	Mississippi	Unprotected	Urban		Unprotected		
Pleasant Creek	IA	Mississippi	Wildlife Area	Other	2,530	< 2% Flood		
Green Island	IL	Mississippi	Non-Federal	Ag	4,490	< 2% Flood	548.1	546.4
Savanna	IL	Mississippi	Unprotected	Urban		Unprotected		
Sabula	IA	Mississippi	Federal	Urban	896	1 -.5% Flood	535.0	535.0
Minneapolis - Water Plant	MN	Mississippi	Unprotected	Urban		Unprotected		
Minneapolis - Right Bank	MN	Mississippi	Unprotected	Urban		Unprotected		
Minneapolis - Left Bank	MN	Mississippi	Unprotected	Urban		Unprotected		
Spring Lake	IA	Mississippi	Wildlife Area	Other	3,300	< 2% Flood		

Table B-2. Levees and Unprotected Areas - Mississippi River Reach 2

Name	State	River	Type of Construction	Urban or Ag	Acres	Start of Damages (Approximate Frequency)	Upstream RM	Downstream RM
Fulton	IL	Mississippi	Federal	Urban	6,800	> .2% Flood	522.5	517.0
Clinton	IA	Mississippi	Federal	Urban	1,940	> .2% Flood	520.6	513.9
Albany	IL	Mississippi	Unprotected	Urban		Unprotected		
Camanche	IA	Mississippi	Unprotected	Urban		Unprotected		
Meredosia	IL	Mississippi	Federal	Ag	10,310	.5% Flood	512.0	511.0
Princeton Refuge	IA	Mississippi	Wildlife Area	Other	1,129	< 2% Flood		
Cordova	IL	Mississippi	Unprotected	Urban		Unprotected		
Princeton	IA	Mississippi	Unprotected	Urban		Unprotected		
Port Byron	IL	Mississippi	Unprotected	Urban		Unprotected		
LeClaire	IA	Mississippi	Unprotected	Urban		Unprotected		
Rapids City	IL	Mississippi	Unprotected	Urban		Unprotected		
Pleasant Valley	IA	Mississippi	Unprotected	Urban		Unprotected		
Hampton	IL	Mississippi	Unprotected	Urban		Unprotected		
East Moline	IL	Mississippi	Federal	Urban	920	> .2% Flood	490.0	488.6
Bettendorf	IA	Mississippi	Federal	Urban	470	> .2% Flood	487.8	485.4
Moline	IL	Mississippi	Unprotected	Urban		Unprotected		
Davenport	IA	Mississippi	Unprotected	Urban		Unprotected		
Rock Island	IL	Mississippi	Federal	Urban	1,000	.2% Flood	482.3	480.1
Milan	IL	Mississippi	Federal	Urban	2,150	> .2% Flood	479.0	478.0
Linwood	IA	Mississippi	Unprotected	Urban		Unprotected		
Andalusia	IL	Mississippi	Non-Federal	Urban	150	< 2% Flood	473.4	473.4
Buffalo	IA	Mississippi	Unprotected	Urban		Unprotected		
Fairport	IA	Mississippi	Unprotected	Urban		Unprotected		
Andalusia	IL	Mississippi	Wildlife Area	Other	393	< 2% Flood		
Muscatine/Madd Creek	IA	Mississippi	Federal	Urban		1% Flood	456.0	456.0
Drury	IL	Mississippi	Federal	Ag	5,000	.5% Flood	458.9	451.5
Muscatine-Louisa County	IA	Mississippi	Non-Federal	Ag		> .2% Flood	455.0	442.0

Table B-2. Levees and Unprotected Areas - Mississippi River Reach 2

Name	State	River	Type of Construction	Urban or Ag	Acres	Start of Damages (Approximate Frequency)	Upstream RM	Downstream RM
Muscatine Island	IA	Mississippi	Federal	Urban	26,480	> .2% Flood	454.7	442.0
Big Timber	IA	Mississippi	Wildlife Area	Other	1,039	< 2% Flood		
Bay Island	IL	Mississippi	Federal	Ag	25,169	1 -.5% Flood	451.0	434.1
Lake Odessa	IA	Mississippi	Wildlife Area	Other	6,800	< 2% Flood		
New Boston	IL	Mississippi	Unprotected	Urban		Unprotected		
Iowa River-Flint CR Upper	IA	Mississippi	Federal	Ag	17,400	> .2% Flood	433.4	422.4
Keithsburg	IL	Mississippi	Non-Federal	Urban	226	2% Flood	427.4	427.7
Iowa River-Flint CR Middle	IA	Mississippi	Federal	Ag	22,500	1 -.5% Flood	422.1	410.6
Oquawka	IL	Mississippi	Non-Federal	Urban	70	< 2% Flood		
Henderson #3	IL	Mississippi	Non-Federal	Ag	2,250	< 2% Flood	414.4	412.0
Iowa River-Flint CR Lower	IA	Mississippi	Federal	Ag	2,910	.5-.2% Flood	410.2	406.0
Henderson #1	IL	Mississippi	Federal	Ag	7,300	1 -.5% Flood	411.4	403.2
Burlington Industrial	IA	Mississippi	Federal	Urban	223	> .2% Flood	407.0	406.0
Burlington	IA	Mississippi	Unprotected	Urban		Unprotected		
Gulfport	IL	Mississippi	Unprotected	Urban		Unprotected		
Henderson #2	IL	Mississippi	Federal	Ag	7,400	2 -1% Flood	403.2	401.5
Green Bay	IA	Mississippi	Federal	Ag	13,340	1 -.5% Flood	395.0	386.9
Dallas City	IL	Mississippi	Unprotected	Urban		Unprotected		
Pontoosuc	IL	Mississippi	Unprotected	Urban		Unprotected		
Niota	IL	Mississippi	Non-Federal	Urban	886	< 2% Flood		
Fort Madison	IA	Mississippi	Unprotected	Urban		Unprotected		

Table B-3. Levees and Unprotected Areas - Mississippi River Reach 3

Name	State	River	Type of Construction	Urban or Ag	Acres	Start of Damages (Approximate Frequency)	Upstream RM	Downstream RM
Keokuk	IA	Mississippi	Private	Urban		1 -.5% Flood		
Hamilton	IL	Mississippi	Unprotected	Urban		Unprotected		
Warsaw	IL	Mississippi	Unprotected	Urban		Unprotected		
Alexandria	MO	Mississippi	Unprotected	Urban		Unprotected	359.5	358.4
Des Moines/Mississippi	IA	Mississippi	Federal	Ag	10,990	.5% Flood		
Mississippi & Fox Upper	IA	Mississippi	Non-Federal	Ag	3,000	1% Flood	358.0	357.5
Mississippi & Fox Lower	IA	Mississippi	Non-Federal	Ag	4,700	2% Flood	357.4	355.0
Hunt-Lima	IL	Mississippi	Federal	Ag	21,290	1 -.5% Flood	358.4	344.9
Gregory	IA	Mississippi	Federal	Ag	8,000	.5% Flood	354.4	348.1
Canton	MO	Mississippi	Federal	Urban	500	.5% Flood	343.0	341.0
Indian Grave Upper	IL	Mississippi	Federal	Ag	12,680	.5% Flood	341.5	336.0
LaGrange	MO	Mississippi	Unprotected	Urban		Unprotected		
Union Township	IL	Mississippi	Federal	Ag	4,240	1 -.5% Flood	334.6	332.0
Indian Grave Lower	IL	Mississippi	Federal	Ag	6,960	1 -.5% Flood	335.7	330.0
Fabius	MO	Mississippi	Federal	Ag	14,260	1 -.5% Flood	331.5	324.0
Marion County	MO	Mississippi	Federal	Ag	4,000	1% Flood	323.4	321.4
South Quincy	IL	Mississippi	Federal	Urban	5,520	> .2% Flood	325.4	318.0
Reiff, Nick	MO	Mississippi	Non-Federal	Ag	1,200	< 2% Flood		
South River Industrial/ American Cyanamid	MO	Mississippi	Federal	Urban	1,626	> .2% Flood	319.0	319.0
South River	MO	Mississippi	Federal	Ag	10,300	2% Flood	318.6	312.7
Bay Island	MO	Mississippi	Wildlife Area	Other	450	< 2% Flood		
Hannibal	MO	Mississippi	Federal	Urban	37	.5-.2 % Flood	310.0	309.0
Sny Island Reach I	IL	Mississippi	Federal	Ag	44,200	1% Flood	314.6	300.6
Sny Island Reach II	IL	Mississippi	Federal	Ag	17,280	1% Flood	294.3	290.6
Ted Shanks State CA	MO	Mississippi	Wildlife Area	Other		< 2% Flood	293.0	286.2
Louisiana	MO	Mississippi	Unprotected	Urban		Unprotected		
Sny Island Reach III	IL	Mississippi	Federal	Ag	43,100	.5% Flood	288.9	275.6
Clarksville Refuge	MO	Mississippi	Wildlife Area	Other	346	< 2% Flood	270.5	267.6
Clarksville	MO	Mississippi	Unprotected	Urban		Unprotected		

Table B-3. Levees and Unprotected Areas - Mississippi River Reach 3

Name	State	River	Type of Construction	Urban or Ag	Acres	Start of Damages (Approximate Frequency)	Upstream RM	Downstream RM
Petus-Burns-Prewitt-Jeager	MO	Mississippi	Private	Ag	400	< 2% Flood	272.2	271.0
Clarksville Levees	MO	Mississippi	Private	Ag	2,340	< 2% Flood	270.5	267.6
Sny Island Reach IV	IL	Mississippi	Federal	Ag	9,800	.5% Flood	270.5	267.0
Kissinger Levee District	MO	Mississippi	Non-Federal	Ag	2,570	< 2% Flood	267.2	265.6
MRA (Rip-Rap Landing)	IL	Mississippi	Wildlife Area	Other	125	< 2% Flood		
Busch-Goose Pasture Farms	MO	Mississippi	Private	Ag	410	< 2% Flood	264.4	263.8
Annada	MO	Mississippi	Unprotected	Urban		Unprotected		
Annada D & LD	MO	Mississippi	Private	Ag	3,320	< 2% Flood	263.8	260.7
Cannon Wildlife Refuge	MO	Mississippi	Wildlife Area	Other	3,480	< 2% Flood	263.8	260.7
Elsberry	MO	Mississippi	Unprotected	Urban		Unprotected		
Elsberry Drainage District	MO	Mississippi	Non-Federal	Ag	23,500	< 2% Flood	260.2	251.7
Kings Lake Drainage District	MO	Mississippi	Non-Federal	Ag	3,300	< 2% Flood	251.5	246.6
Sandy Creek	MO	Mississippi	Non-Federal	Ag	944	< 2% Flood	246.0	245.4
Foley Drainage District	MO	Mississippi	Non-Federal	Ag	1,214	< 2% Flood	244.7	245.4
Foley	MO	Mississippi	Unprotected	Urban		Unprotected		
Batchtown Wildlife Area	IL	Mississippi	Wildlife Area	Other	2,540	< 2% Flood		
Cap Au Gris	MO	Mississippi	Non-Federal	Ag	4,150	< 2% Flood	243.2	239.1
Winfield	MO	Mississippi	Unprotected	Urban		Unprotected		
Winfield D & LD	MO	Mississippi	Non-Federal	Ag	2,826	< 2% Flood	239.1	238.7
Brevator	MO	Mississippi	Non-Federal	Ag	1,800	< 2% Flood	238.6	237.6
Schramm	MO	Mississippi	Private	Ag	280	< 2% Flood	237.5	237.0
Old Monroe	MO	Mississippi	Private	Ag	900	< 2% Flood	237.0	236.5
Heitman	MO	Mississippi	Private	Ag	300	< 2% Flood	236.4	236.4
Marstan-Portuchek	MO	Mississippi	Private	Ag	755	< 2% Flood	236.4	235.8
Old Monroe	MO	Mississippi	Unprotected	Urban		Unprotected		
Dardeene Creek	MO	Mississippi	New Levee	Ag	3,800	.5 -.2% Flood	233.1	230.3
St. Peters Drainage Association No. 1 (Urban)	MO	Mississippi	Federal	Urban	700	.5 -.2% Flood	230.0	230.0
St. Peters Drainage Association No. 1 (Ag)	MO	Mississippi	Non-Federal	Ag	300	< 2% Flood	230.0	229.5
Portage Des Sioux	MO	Mississippi	Unprotected	Urban		Unprotected		

Table B-3. Levees and Unprotected Areas - Mississippi River Reach 3

Name	State	River	Type of Construction	Urban or Ag	Acres	Start of Damages (Approximate Frequency)	Upstream RM	Downstream RM
Consolidated N. County	MO	Mississippi	Non-Federal	Ag	30,000	< 2% Flood	211.8	200.7
West Alton	MO	Mississippi	Unprotected	Urban		Unprotected		
Alton	IL	Mississippi	Unprotected	Urban		Unprotected		
Wood River	IL	Mississippi	Federal	Urban	13,700	> .2% Flood	200.5	195.6
Columbia Bottoms Levee	MO	Mississippi	Wildlife Area	Other		1% Flood	197.5	190.8
Chouteau Island	IL	Mississippi	Non-Federal	Ag	2,400	< 2% Flood	192.9	189.5
Chouteau, Nameoki and Venice	IL	Mississippi	Federal	Urban	4,800	> .2% Flood	194.6	185.2
Gabaret/Cabrolet Island	IL	Mississippi	Non-Federal	Ag	800	< 2% Flood	188.8	185.8
St. Louis Flood Protection Project	MO	Mississippi	Federal	Urban	3,160	> .2% Flood	186.8	176.6
Metro East Sanitary District	IL	Mississippi	Federal	Urban	74,000	> .2% Flood	174.4	167.0
Prairie Du Pont	IL	Mississippi	Federal	Urban	12,000	> .2% Flood	182.9	175.8
Columbia	IL	Mississippi	Federal	Ag	14,800	2% Flood	165.3	156.5
Arnold	MO	Mississippi	Unprotected	Urban		Unprotected		
Kimmswick	MO	Mississippi	Unprotected	Urban		Unprotected		
Herculaneum	MO	Mississippi	Unprotected	Urban		Unprotected		
Harrisonville	IL	Mississippi	Federal	Ag	27,800	2% Flood	155.5	130.2
Stringtown	IL	Mississippi	Federal	Ag	2,800	2% Flood	141.0	138.0
Fort Chartres and Ivy Landing	IL	Mississippi	Federal	Ag	15,900	2% Flood	138.0	130.0
Prairie Du Rocher & Modoc	IL	Mississippi	Federal	Ag	16,000	1% Flood	129.8	119.1
Ste. Genevieve Urban Levee	MO	Mississippi	Federal	Urban	505	> .2% Flood	124.8	122.7
Ste. Genevieve Levee District No. 2	MO	Mississippi	Private	Ag	7,000	< 2% Flood	122.1	116.9
Kaskaskia Island	MO	Mississippi	Federal	Ag	9,460	1 -.5% Flood	115.2	111.6
St. Mary's	MO	Mississippi	Unprotected	Urban		Unprotected		
Bois Brule	MO	Mississippi	Federal	Ag	26,060	2 -1% Flood	111.0	95.5
Degognia & Fountain Bluff	IL	Mississippi	Federal	Ag	36,200	1 -.5% Flood	99.0	84.5
Grand Tower	IL	Mississippi	Federal	Ag	14,800	2 -1% Flood	81.1	76.7
Preston	IL	Mississippi	Federal	Ag	16,200	.5% Flood	75.7	65.8
Miller Pond	IL	Mississippi	Federal	Ag	4,300	.5% Flood	75.7	65.8
Clear Creek	IL	Mississippi	Federal	Ag	18,000	.5% Flood	65.0	57.0
Cape Girardeau	MO	Mississippi	Federal	Urban	140	> .2% Flood	52.2	52.2

Table B-3. Levees and Unprotected Areas - Mississippi River Reach 3

Name	State	River	Type of Construction	Urban or Ag	Acres	Start of Damages (Approximate Frequency)	Upstream RM	Downstream RM
E. Cape Girardeau and Clear Creek	IL	Mississippi	Federal	Ag	9,400	.5 -.2% Flood	56.0	46.9
N. Alexander County	IL	Mississippi	Federal	Ag	3,600	.5% Flood	56.0	46.9
Little River	MO	Mississippi	New Levee	Ag	13,566			
Shawnee NF-Murphysboro District	IL	Mississippi	Wildlife Area	Other	14,329	< 2% Flood		
Laure-Pine Hills Ecological Area	IL	Mississippi	Wildlife Area	Other	1,200	< 2% Flood		
Ellis Bay & Teal Pond Habitat Areas	MO	Mississippi	Wildlife Area	Other	545	< 2% Flood		
Prairie Marsh Restoration Area	MO	Mississippi	Wildlife Area	Other	1,112	< 2% Flood		
Dresser Island CA	MO	Mississippi	Wildlife Area	Other	1,059	< 2% Flood		
Horseshoe Lake Mitigation Area	IL	Mississippi	Wildlife Area	Other	621	< 2% Flood		
MTNWR (Gilbert Lake Division)	IL	Mississippi	Wildlife Area	Other	736	< 2% Flood		
MTNWR (Calhoun Division)	IL	Mississippi	Wildlife Area	Other	435	< 2% Flood		
MRA (Calhoun Point)	IL	Mississippi	Wildlife Area	Other	2,057	< 2% Flood		
MTNWR (Batchtown Division)	IL	Mississippi	Wildlife Area	Other	2,403	< 2% Flood		
MTNWR (Delair Div.)	IL	Mississippi	Wildlife Area	Other	1,737	< 2% Flood		
Marais Temps Clair	MO	Mississippi	Wildlife Area	Other	918	< 2% Flood		
B.K. Leach CA	MO	Mississippi	Wildlife Area	Other	1,413	< 2% Flood		
Prairie Slough CA	MO	Mississippi	Wildlife Area	Other	120	< 2% Flood		
Olin Tract Natural Area	IL	Mississippi	Wildlife Area	Other	243	< 2% Flood		
Kidd Lake Marsh State	IL	Mississippi	Wildlife Area	Other	600	< 2% Flood		
Union County Conversation Area	IL	Mississippi	Wildlife Area	Other	6,096	< 2% Flood		

Table B-4. Levees and Unprotected Areas Illinois River Reach 4

Name	State	River	Type of Construction	Urban or Ag	Acres	Start of Damages (Approximate Frequency)	Upstream RM	Downstream RM
Ottawa	IL	Illinois	Unprotected	Urban		Unprotected		
Hennepin	IL	Illinois	Federal	Urban	2,600	< 2% Flood	207.0	202.8
Lacon	IL	Illinois	Unprotected	Urban		Unprotected		
Chillicothe	IL	Illinois	Unprotected	Urban		Unprotected		
Herman Levee	IL	Illinois	Non-Federal	Ag	380	< 2% Flood		
Rome	IL	Illinois	Unprotected	Urban		Unprotected		
Spring Bay	IL	Illinois	Unprotected	Urban		Unprotected		
Komatsu	IL	Illinois	Non-Federal	Urban	125	1% Flood	164.9	164.3
East Peoria Sanitary District	IL	Illinois	Federal	Urban		1% Flood	162.8	162.1
East Peoria	IL	Illinois	Federal	Urban	950	2% Flood	161.7	160.7
Peoria Sanitary District	IL	Illinois	Non-Federal	Urban	61	1% Flood	160.2	159.9
Creve Coeur	IL	Illinois	Unprotected	Urban		Unprotected		
Keystone	IL	Illinois	Non-Federal	Urban	375	< 2% Flood		
Pekin-LaMarsh	IL	Illinois	Federal	Ag	3,010	2% Flood	155.0	149.7
Banner Special	IL	Illinois	Federal	Urban	4,561	2% Flood	145.5	138.2
Banner Marsh	IL	Illinois	Wildlife Area	Other	5,524	< 2% Flood		
Spring Lake	IL	Illinois	Federal	Ag	13,120	.5% Flood	147.7	134.2
Rice Lake	IL	Illinois	Wildlife Area	Other	5,592	< 2% Flood		
East Liverpool	IL	Illinois	Federal	Ag	2,885	.2% Flood	131.7	128.4
Liverpool	IL	Illinois	Federal	Urban	2,885	< 2% Flood	127.9	126.4
Lake Chautauqua	IL	Illinois	Wildlife Area	Other	4,212	< 2% Flood		
Thompson	IL	Illinois	Federal	Urban	5,498	< 2% Flood	125.9	120.9
Lacey, Langellier, W. Matanzas, Kerton Valley	IL	Illinois	Federal	Ag	10,406	2% Flood	119.3	111.9
Big Lake	IL	Illinois	Federal	Ag	3,401	< 2% Flood	108.2	103.1
Kelly Lake	IL	Illinois	Federal	Ag	1,045	.5% Flood	102.6	100.7
Hager Slough	IL	Illinois	Non-Federal	Ag	3,698	2 -1% Flood	94.7	89.2
Lost Creek	IL	Illinois	Federal	Ag	2,740	.5 -.2% Flood	90.2	89.2
Sanitary Dist. of Beardstown	IL	Illinois	Federal	Urban	860	.5 -.2% Flood	88.8	88.4

Table B-4. Levees and Unprotected Areas Illinois River Reach 4

Name	State	River	Type of Construction	Urban or Ag	Acres	Start of Damages (Approximate Frequency)	Upstream RM	Downstream RM
Coal Creek	IL	Illinois	Federal	Ag	6,794	> .2% Flood	91.7	85.2
South Beardstown	IL	Illinois	Federal	Ag	10,516	> .2% Flood	87.9	80.4
Crane Creek	IL	Illinois	Federal	Ag	5,417	< 2% Flood	84.5	83.9
Little Creek	IL	Illinois	Federal	Ag	1,800	< 2% Flood	78.0	75.5
McGee Creek	IL	Illinois	Federal	Ag	10,800	1 -.5% Flood	75.0	67.8
Meredosia and Willow Creek	IL	Illinois	Federal	Ag	16,946	< 2% Flood	71.0	67.8
Coon Run	IL	Illinois	Federal	Ag	4,600	> .2% Flood	71.0	66.7
Smith Lake	IL	Illinois	Private	Ag	1,500	< 2% Flood	67.2	67.2
Oakes	IL	Illinois	Private	Ag	525	< 2% Flood	66.7	65.9
Valley City	IL	Illinois	Federal	Ag	4,900	1% Flood	66.6	63.5
Mauvaise Terre	IL	Illinois	Federal	Ag	4,900	2 -1% Flood	66.0	63.5
Robertson	IL	Illinois	Private	Ag	1,000	< 2% Flood	63.3	63.3
Scott County	IL	Illinois	Federal	Ag	10,500	< 2% Flood	61.3	57.2
Walnut Creek	IL	Illinois	Non-Federal	Ag	500	< 2% Flood	56.5	56.1
Big Swan	IL	Illinois	Federal	Ag	12,300	< 2% Flood	56.5	50.6
Hillview	IL	Illinois	Federal	Ag	12,900	< 2% Flood	49.7	43.5
Village of Pearl	IL	Illinois	Private	Urban	1,000	< 2% Flood	43.3	43.0
Hartwell	IL	Illinois	Federal	Ag	8,900	< 2% Flood	43.1	38.3
Keach	IL	Illinois	Federal	Ag	8,400	< 2% Flood	37.8	32.7
Schaefer-Farrow	IL	Illinois	Private	Ag	800	2% Flood	32.8	32.3
Bluffdale Farms	IL	Illinois	Non-Federal	Ag	1,000	< 2% Flood	32.3	32.3
Kampsville	IL	Illinois	Unprotected	Urban		Unprotected		
Eldred-Spankey	IL	Illinois	Federal	Ag	11,300	2% Flood	31.9	24.3
Michael	IL	Illinois	Unprotected	Urban		Unprotected		
Hardin	IL	Illinois	Unprotected	Urban		Unprotected		
Nutwood	IL	Illinois	Federal	Ag	11,300	< 2% Flood	23.2	15.5
MRA (Stump Lake WMA)	IL	Illinois	Wildlife Area	Other	3,580	< 2% Flood		
MRA (Fuller Lake WMA)	IL	Illinois	Wildlife Area	Other	1,088	< 2% Flood		
Meredosia Refuge	IL	Illinois	Wildlife Area	Other	300	< 2% Flood		

E. Flood Control Reservoirs

1. Federal Reservoirs. There are 76 flood control reservoirs in the upper Mississippi and Missouri river basins upstream of the mouth of the Ohio River. The Missouri River has 67 reservoirs—either Corps or U.S. Bureau of Reclamation (USBR) projects—on its main stem and tributaries. In addition to these flood control reservoirs, there are 25 locks and dams on the Mississippi River, and 8 locks and dams on the Illinois Waterway that maintain the 9-foot minimum depth of the navigation pools. The storage in the navigation pools is negligible during major flood events. Most of the reservoirs, which have the greatest potential to reduce flooding, are in the Missouri River basin. These structures range from the massive dams and reservoirs on the main stem Missouri River in Montana and the Dakotas to small headwater reservoirs on tributaries to both rivers. These reservoirs provided reduction to flood flows for every Mississippi River and Missouri River flood. During the last 20 years, flood stages have been reduced at St. Louis from2 to 7 feet, depending on the flood event. The reservoirs had a significant impact reducing stages during the 1993 flood. Without the reservoirs, most of the urban levees at St. Louis would have been overtopped.

a. Flood Control Reservoirs on the Missouri River. Numerous reservoirs and impoundments constructed by different interests for flood control, irrigation, power production, recreation, water supply, and fish and wildlife are located throughout the basin. The USBR and the Corps of Engineers have constructed the most significant of these structures. Although primarily constructed for irrigation and power production, the projects constructed by the USBR do provide some limited flood control in the upper basin. Six main stem dams constructed by the Corps are the most significant authorized flood control projects within the basin, providing a combined capacity in excess of 73.5 million acre-feet, of which more than 16 million acre-feet is for flood control. These six projects were completed in 1964 and provide flood protection by controlling runoff from the upper 279,000 square miles of the Missouri River basin.

In addition to the six main stem projects operated by the Corps, 65 tributary reservoirs operated by the USBR and the Corps provide over 15 million acre-feet of flood control storage. Tables B-5 and B-6 list the mainstem and tributary flood control projects operated by the Corps of Engineers and the USBR. The USBR operates many additional reservoirs for irrigation and power production, which provide incidental flood control benefits.

Additional storage can be found in many other reservoirs throughout the Missouri Basin. However, only a few have the large storage necessary to impact flow peaks downstream of Gavins Point Dam. Hebgen Lake, Gibson Reservoir, Fresno Reservoir, Angostura Reservoir, North Platte reservoirs and Truman Reservoir in aggregate are the only reservoirs with significant flood control storage downstream of Gavins Point Dam.

Table B-5. Corps of Engineers Reservoirs in Missouri River Basin

Project Name	River or Stream Location	Date of Closure	Total Storage Volume acre-feet	Flood Control Storage acre-feet
Fort Peck	Missouri River	June 24, 1937	18,688,000	3,692,000
Garrison	Missouri River	April 15, 1953	23,821,000	5,711,000
Oahe	Missouri River	August 3, 1958	23,137,000	4,303,000
Big Bend	Missouri River	July 24, 1963	1,859,000	177,000
Fort Randall	Missouri River	July 20, 1952	5,494,000	2,301,000
Gavins Point	Missouri River	July 31, 1955	492,000	152,000
Bowman-Haley	North Fork Grand River	August 1966	91,482	72,717
Cold Brook	Cold Brook	September 1952	7,200	6,680
Cottonwood Springs	Cottonwood Springs Creek	May 1969	8,385	7,730
Cedar Canyon	Deadmans Gulch	1959	136	123
Bull Hook Scott Coulee	Bull Hook Creek	1955	6,500	6,500
Pipestem	Pipestem Creek	July 1973	146,880	137,010
Papio Creek (10 dams)	Papillion Creek	1972-1984	42,237	31,323
Cherry Creek	Cherry Creek	October 1948	135,647	122,842
Chatfield	South Platte River	August 1973	235,098	206,945
Bear Creek	Bear Creek	July 1977	30,684	28,757
Kelly Road	Westerly Creek	1953	360	360
Westerly Creek	Westerly Creek	1991	4,150	4,150
Salt Creek (10 dams)	Salt Creek	1963-1973	189,933	139,462
Harlan County	Republican	1951	825,782	496,718
Milford	Republican	1964	1,145,485	756,669
Tuttle Creek	Big Blue	1959	2,257,185	1,922,085
Wilson	Saline	1963	772,732	530,204
Kanopolis	Smoky Hill	1946	418,752	369,278

Table B-5. Corps of Engineers Reservoirs in Missouri River Basin

Project Name	River or Stream Location	Date of Closure	Total Storage Volume acre-feet	Flood Control Storage acre-feet
Perry	Delaware	1966	725,509	515,961
Clinton	Wakarusa	1965	397,538	268,367
Smithville	Little Platte	1976	243,443	101,777
Longview	Little Blue	1983	46,944	24,810
Blue Springs	Little Blue	1986	26,557	15,715
Long Branch	Little Chariton	1976	64,516	30,327
Rathbun	Chariton	1967	545,621	345,791
Melvern	Osage	1970	360,258	208,207
Pomona	Osage	1962	243,102	176,460
Hillsdale	Osage	1980	159,840	83,570
Stockton	Osage	1968	1,650,943	776,066
Pomme De Terre	Osage	1960	644,177	406,821
Harry S Truman	Osage	1977	5,209,353	4,005,949
Total COE Project Storage			**90,127,429**	**28,135,374**

Table B-6. Bureau of Reclamation Projects Operated for Flood Control

Project Name	River or Stream Location	Date of Closure	Total Storage Volume acre-feet	Flood Control Storage acre-feet
Clark Canyon	Beaverhead River	June 1964	257,150	79,090
Canyon Ferry	Missouri River	December 1951	2,051,520	99,460
Tiber	Marias River	1952	1,555,960	400,900
Boysen	Wind River	October 1951	952,400	150,400
Yellowtail	Bighorn River	November 3,	1,328,360	258,330
Heart Butte	Heart River	October 4, 1949	223,600	147,900
Shadehill	Grand River	July 1, 1950	357,400	218,300
Keyhole	Belle Fourche River	February 12, 1952	334,200	140,500
Pactola	Rapid Creek	August 1956	99,029	43,057
Jamestown	James River	February 1954	221,000	185,400
Glendo	North Platte River	October 17, 1957	789,400	271,900
Enders	Frenchman Creek	1950	74,520	30,040
Hugh Butler	Red Willow Creek	1961	86,630	48,854
Bonny	S. Fork Republican	1950	170,160	128,820
Swanson	Republican	1953	246,291	134,077
Harry Strunk	Republican	1949	88,420	52,715
Keith Sebelius	Prairie Dog Creek	1964	134,740	98,805
Lovewell	White Rock Creek	1957	92,150	50,450
Kirwin	N. Fork Soloman	1955	314,550	215,115
Webster	S. Fork Soloman	1956	260,740	183,370
Waconda	Soloman	1967	963,775	722,315
Cedar Bluff	Smoky Hill	1950	418,752	191,860
Total USBR Project Storage			**11,020,747**	**3,851,658**

b. Irrigation Development for the Missouri River. Irrigation first appeared in the Missouri Basin about 1650 by the Taos Indians along Ladder Creek in northern Scott County, Kansas. "Modern" irrigation appeared in the basin in the 1860s, and water use for irrigation and other uses grew rapidly through the remainder of the 19th century and into the early 20th century as agricultural uses of water grew, especially in the more arid western plains. Estimates of irrigation and other use depletions by the USBR range as high as 9,000,000 acre-feet by 1920 upstream of Rulo, Nebraska. Irrigation development leveled off for the next 30 years but has since been steadily increasing. According to USBR estimates, irrigation and other depletions have reached 13.5 million acre-feet by the mid-1990s above Rulo, Nebraska. Approximately 60 percent of the depletions in the Omaha District occur upstream of Sioux City, Iowa.

c. Flood Control Reservoirs on the Mississippi River. The Corps constructed five timber dams on the Mississippi River Headwaters between 1881 and 1892, creating reservoirs primarily to augment river flow for navigation. These are the first reservoirs built in the Mississippi Basin by the Corps. The six Mississippi River Headwaters lakes—Sandy, Winnibigoshish, Leech, Gull, Pokegama and Pine—are located in north central Minnesota between Duluth and Moorhead. Today, the lakes support flood control, Indian Treaty Trust resources, sport and commercial fisheries, wild rice production, fish and wildlife habitat, agricultural uses as far downstream as the Minneapolis/St. Paul Metropolitan area. Since the construction of the locks and dams below St. Paul in the late 1930s, the release of water from the Headwaters lakes for navigation purposes has been virtually eliminated.

In addition to the headwater dams, there are eight flood control reservoirs located on downstream tributaries of the Mississippi River above the Ohio River. The Eau Galle Dam and the Lac Qui Parle Lakes are on the tributaries of the Mississippi River and are operated and maintained by the St. Paul District. The Rock Island District operates and maintains three flood control reservoirs in Iowa—Coralville Lake located on the Iowa River, and Lake Red Rock and Saylorville Lake on the Des Moines River. The St. Louis District operates and maintains three multi-purpose reservoirs in Illinois—Lake Shelbyville and Carlyle Lake on the Kaskaskia River and Rend Lake on the Big Muddy River. In addition, the St. Louis District operates Mark Twain Lake on the Salt River, and Wappapello Lake on the St. Francis River, in Missouri. The St. Francis River will not be addressed in this report because it enters the Mississippi River downstream of the Ohio River. The reservoirs in the Mississippi River Basin above the Ohio River excluding those in Missouri River Basin are shown in table B-7.

Table B-7. Corps of Engineers Reservoirs in Mississippi River Basin

Project Name	River or Stream Location	Date of Closure	Total Storage Volume acre-feet	Flood Control Storage acre-feet
Sandy Lake	Mississippi River	1895	131,980	117,680
Winnibigoshish	Mississippi River	1884	1,578,685	1,151,250
Gull	Mississippi River	1911	70,830	70,830
Pokegama	Mississippi River	1884	259,350	201,520
Pine	Mississippi River	1886	295,940	191,850
Eau Galle Dam	Eau Galle River\Chippewa River	Mar 24, 1969	43,550	42,000
Lac Qui Parle	Minnesota River	Sep 7, 1950	122,800	81,800
Lake Red Rock	Des Moines River	July 1968	1,625,000	1,436,000
Saylorville Lake	Des Moines River	July 1975	641,000	567,000
Coralville Lake	Iowa River	July 1958	739,000	697,000
Mark Twain Lake	Salt River	Sep 1, 1983	1,341,000	884,000
Lake Shelbyville	Kaskaskia River	Aug 1, 1970	654,000	474,000
Carlyle Lake	Kaskaskia River	Apr 1, 1967	9,329,000	699,900
Rend Lake	Big Muddy River	Oct 24, 1970	269,000	109,000
Total CE Project Storage			**14,598,000**	**4,866,900**

2. Reservoir Analysis Constraints. The study of reservoir effects using a systemic approach is very complex. It can be the subject of considerable differences of opinion. Unless evaluations are done using a detailed, systematic process, with several calibrations during the process, the results cannot be defended based on scientific procedures. The use of different hydrologic models to evaluate various combinations of these runoff relationships occurs throughout the basin, but none evaluate all of the processes over the entire watershed, which is necessary when evaluating flood volume and peak reduction for flood control reservoirs at the basin scale. A comprehensive look at flood control reservoirs would require a much more intensive look at their operations and the localized benefits supplied versus the benefits to mainstem flooding. This analysis was beyond the scope of this study when considering the time and monetary constraints.

The analysis of alternatives presented in subsequent paragraphs does not consider additional flood control reservoirs or changes in operation to existing flood control reservoirs. The stochastic analysis performed to develop discharge boundary conditions for the Mississippi River mainstem modeling uses the observed reservoir influences for the period of record without adjustments. The 1,000-year synthetic record used for the alternatives analysis is developed by randomly selecting a flood peak from the revised flood probability distributions and flood volume (template) from the observed record. The synthetic flood ordinates are a ratio of the random flood peak and the observed flood ordinates. The randomly selected flood peaks are paired with a range of similar observed peaks to preserve flood volume relationships as related to storage within the system.

F. Sediment

Sedimentation will be covered in Appendix A, *Environmental Planning and Analysis*, Chapter V, *Environmental Alternatives Formulation and Evaluation*.

III. HYDRAULIC MODELING METHODOLOGY

A. Modeling Overview. The original philosophy of the Comprehensive Plan hydraulic analyses incorporated both the hydraulic models developed for the Upper Mississippi River Flow Frequency Study (FFS) and the FFS method of calculating stage frequency at each location along the river system. While the analyses of this study do incorporate the same hydraulic models developed for FFS, the FFS method of computing stage frequency was not used. In the method developed for FFS, each involved Corps district independently computed stage frequency within their own district boundaries using a multi-step process of developing rating curves from the hydraulic model, distributing frequency flows along river reaches and then combining the rating curves and frequency flows to compute stage frequency. The results were then coordinated with the adjacent Corps districts to assure proper stage frequency at the district boundaries. While this method worked sufficiently well for computing the stage frequency of the existing floodplain condition, it was very time consuming and manually intensive. Also, dividing hydraulic models at jurisdictional boundaries does not provide for the best way to simulate hydraulic processes systemically.

The hydraulic analyses of alternatives formulated in this study utilize the existing numerical hydraulic (UNET) models developed for the FFS along with a stochastically-generated 1000 years of tributary inflows representing the climatic conditions of the observed period. The hydraulic models were revised to begin and end at more hydraulically significant break points than the jurisdictional district boundaries. Each model simulation, using the full 1,000 years of tributary inflow record produces a series of 1,000 annual peak stages at each model cross section location. These computed peak stages are used to form a non-analytical stage frequency curve at each location. Comparing the computed stage frequency from each alternative simulation with that of an existing condition simulation provides the stage impacts for each alternative. These stage impacts are then applied to the published frequency water surface elevations of the Flow Frequency Study to produce a final frequency water surface elevation to be used in computing economic flood damages and construction costs for each alternative.

The hydraulic analysis method developed for this Comprehensive Study, which is mostly an automated process, allows for more study alternatives to be simulated with less manual intervention and fewer opportunities to introduce user error than the FFS method. The only cost of this method is a significant increase in computer computation time.

B. Expanding the Period of Flow Record. Dr. Robert Barkau developed a process for this study to generate an extended, synthetic flow record. This extended flow record and its application in hydraulic models help streamline the analysis of multiple study alternatives and more effectively compute the impacts of each alternative systemically to the full river system. The process stochastically sampled the FFS flow frequency curve at the primary river flow gages along with the magnitude, duration and volume of flood events in the observed record to produce a period of record for 1,000 years. This generated record will reproduce the frequency, volume and duration curves of the observed record at flow gages on the Mississippi and Illinois Rivers representing the climatic conditions of the observed period. This generated period of record is represented as a time series of flows arbitrarily placed in the years 2101 to 3100. The generated hydrology for the 1,000 years of record is linked to the UNET model to compute stage frequency profiles along the river. A detailed description of the methodology of extending the period of record is found in Supplement 1 to this appendix. A brief discussion for each reach is discussed below. The reach designation is depicted on Plate B-1.

The basin was separated into four distinct routing reaches:

Reach 1 - Mississippi River from St. Paul, MN to L&D 13 (Clinton, IA)
Reach 2 - Mississippi River from L&D 13 (Clinton, IA) to L&D 19 (Keokuk, IA)
Reach 3 - Mississippi River from L&D 19 (Keokuk, IA) to Thebes, IL (above the backwater area of the Ohio River)
Reach 4 – Illinois River from Lockport, IL to the mouth at Grafton, IL (confluence with the Mississippi River)

The boundary conditions were selected based upon physical and meteorological reasons. District boundaries were not a factor in these reaches. The reach boundaries at Clinton and Keokuk were selected for the reliable observed flow records of the U.S. Geological Survey (USGS) gages at those locations.

1. Reach 1 - Mississippi River from St. Paul, MN to Lock and Dam 13 (Clinton, IA). The flooding characteristics of the Mississippi Basin in this reach are predominately caused from snowmelt events. Tabulation of historic events indicates snowmelt floods predominate above Davenport, Iowa and rainfall floods predominate downstream of Davenport, IA (Reach 2). Statistical analyses were done for the primary gages on the Mississippi River at the Anoka, St. Paul, Winona, McGregor and Clinton sites. The statistics at the primary and secondary tributary gages were used to generate the 1000 years period of record. The hydraulic reach was from Anoka, MN at RM 864.5 to Dubuque, IA at RM 579.9.

2. Reach 2 - Mississippi River from Lock and Dam 13 (Clinton, IA) to Lock and Dam 19 (Keokuk, IA). The flooding characteristics of the Mississippi Basin in this reach can be caused by snowmelt, rainfall or the combination of the two events. The rainfall flood can occur at any time of the year, and snowmelt floods occur in the spring of the year. A rainfall flood may coincide with a snowmelt flood. The height and volume of the snowmelt hydrograph builds as one moves downstream, but the basic shape of the hydrograph is maintained. In contrast, for large rivers, the rainfall event has multiple crests, corresponding to bursts of rainfall. A statistical relationship was created from historical events to determine these types of events. The primary gages on the Mississippi River that statistics were used in this reach to simulate the period of record were at the Keokuk, the Clinton, and the McGregor sites. The hydraulic model extends between McGregor, IA at RM 633.5 to Grafton, IL at RM 218.0.

3. Reach 3 - Mississippi River from Lock and Dam 19 (Keokuk, IA) to Thebes, IL (above the backwater from the Ohio River). The primary flooding characteristics of the Mississippi Basin in this reach is attributed to rainfall events. Tabulating the annual events in this reach indicate that snowmelt events are not a major source of flooding. Statistical analyses on the primary gages on the Mississippi River were the Keokuk, the L&D 24, the St. Louis, the Chester, and the Thebes sites. The period of record was generated from the statistics of the basin. The hydraulic model extends from Keokuk, IA at RM 364.2 to Thebes, IL at RM 43.7 for the Mississippi River. The hydraulic model for the Illinois River extends from Meredosia, IL at RM 70.8 to Grafton, IL at the mouth of the Illinois River (RM 0.0).

4. Reach 4 – Illinois River from Lockport, IL to the mouth at Grafton, IL (confluence with the Mississippi River). The primary flooding characteristics of the Illinois Basin is attributed to rainfall events. Statistics were collected at the Lockport, the Marseilles, the Kingston Mines, and the Valley City gages to generate the period of record. These statistics were applied to the Illinois Basin. The hydraulic model was from Lockport Dam Tailwater, IL at RM 290.9 to Grafton, IL at the mouth of the Illinois River (RM 0.0). An Illinois River flood was coincident with the Mississippi River flood when the date of the maximum flow at Valley City occurred within the starting and ending dates of a maximum flow event at Thebes. In other words, a coincident event is one where the maximum flow from the Illinois contributed to the Mississippi River flood hydrograph. The generated period of record at Grafton was the observed tailwater stage for the Illinois River. All statistics were based on these generated stages.

C. Numerical Hydraulic Modeling. The numerical hydraulic models used in this study are based on the UNET modeling system developed by Dr. Robert L Barkau. UNET is a one-dimensional, unsteady open-channel flow numerical model that can simulate flow in single channels or complex networks of interconnected channels. UNET has the capability to simulate storage areas, used to represent the leveed areas along the Mississippi and Illinois River. These storage areas act as lake-like regions that can either divert water from, or provide water to, a river channel. UNET also has the capability to simulate the hydraulic effect of navigation dams, which are numerous along the Upper Mississippi and Illinois Rivers.

D. Model Development

1. Model Geometry. The geometry of the model was the same developed from the FFS, consisting of the Mississippi River, Illinois River, and tributary cross sections, navigation dams, and levee systems. The cross sections were regrouped from the original district models into four new models representing the four separate routing reaches used in this study. The levees are defined in the model as storage cells in a separate file, commonly referred to as the "Include" file. The Include file, contains the properties for each levee, such as top of levee crown elevation, elevation-volume relationship, upstream and downstream locations where overtopping will occur, and linear routing coefficients.

2. River Geometry. The main-stem geometry consists primarily of a series of geospatial cross sections extending bluff to bluff across the river valley. The cross sections were extracted from a digital surface of the river valley created from a combination of floodplain digital terrain models and digital hydrographic surveys. The floodplain digital terrain models were developed from aerial photography and photogrammetry from the years 1995 to 1998. Mississippi River floodplain ("bluff-to-bluff") digital terrain model data was designed and compiled so that spot elevations on well-defined features would be within 0.67 feet (vertical) of the true position (as determined by a higher order method of measurement) 67 percent of the time. The 0.67 feet (vertical) is as per ASPRS Class I Standards as stated in the USACE EM 1110-1-1000, dated 31 March 1993. The digital terrain models consist of mass points and break-lines that define the hydraulically significant features of the floodplain, such as roads, railroads and levees.

The hydrographic surveys were assembled from navigation channel maintenance surveys, dam periodic inspection surveys, and environment management project surveys. All digital hydrographic surveys date from 1997 or later. The horizontal accuracy of the hydrographic survey data is the accuracy usually attributed to the US Coast Guard's Differential GPS (DGPS). The published accuracy of this system is +/- 9 feet (horizontal). The vertical accuracy is published as being +/- 0.5 ft as per ASPRS Class III Standards as stated in the USACE EM1110-1-1000, dated 31 March 1993. For areas where no digital hydrographic surveys were available, such as in some side channels and chutes, depths were estimated from the most current printed surveys available. Bridge decks were not added to the model, as it is assumed that that bridge decks are sufficiently high as to not significantly alter the computed Mississippi River water surface.

3. Tributary Geometry. Cross section geometry is included in the UNET model for all tributaries that have USGS gaging stations. These gaging stations supply the inflow data needed to run the UNET model. Each tributary is modeled from its confluence with the Mississippi River upstream to the USGS gaging station location, located between 4 and 50 river miles upstream of the confluence with the Mississippi River. Tributary cross section data were taken either from preexisting HEC2 hydraulic models or developed from a combination of channel soundings taken at the USGS gage during flow measurements and USGS 7.5 minute series quadrangle topographic maps. The assembled cross section data for each tributary is suitable for flow routing only. Accurate stage computation on the tributaries is not possible with the coarse data employed in the development of the tributary cross sections.

4. Boundary Conditions. Boundary conditions are required at every location where water passes into or out of the model. The inflow and stage data (input data), which drive the computations of the UNET program, are accessed via the boundary condition file. The primary boundaries for the model occur at the upstream and downstream end of each study reach, which for this study occur at USGS gages used to generate statistics in the FFS. However, where a distinct physical boundary does not exist between two reaches, the models overlap. This overlap places the model boundaries a sufficient distance away from the study reach to prevent the predefined boundary conditions from impacting the computed solutions of the model. Upstream boundary conditions for tributaries were also located at a USGS gage with generated flow statistics from the known period of record.

5. Levees Storage Areas. The hydraulic model represents the areas protected by levees as storage areas with connections to the river channel. These storage areas are defined separately from the model cross sections. Each storage area is defined by an elevation versus volume relationship, a location and elevation for each connection to the river, and by inflow and outflow parameters associated with levee overtopping flows. The elevation versus volume relationship is calculated from the same digital survey of the floodplain used to generate model cross sections. Connections between the river and the storage area are located where the levee is likely to overtop first. Typically, there are two connection locations, one each near the upstream and downstream ends of the mainstem levee. The elevation of each connection is determined from the most recently verified survey available. For many levees, the 1998 Digital Terrain Models from aerial photography represent this survey, though other recent ground surveys have been provided by levee associations for this task.

All levees along the Mississippi and Illinois Rivers were considered for this analysis. However, a few levees were not defined as storage areas in the model, either because the area protected was small and the levee was sufficiently high to hold out the .2% annual chance flood (500-year) event or because the levee crown was too low to assume that the storage area approach would accurately define the flow into and through the levee area for the full range of flows. Many environmental management levees are not modeled as storage areas, but rather as part of the full cross section with ineffective flow limits to the crown of each levee.

6. Levee Exceedence. When the computed river stage exceeds the elevation of a levee at one or more levee connections the levee storage area begins to fill. If the levee is overtopped at only one connection location, the storage area only acts to store the water from the river. A levee storage area may convey flow if the levee is overtopped at two connections and the storage volume is sufficiently full that flow enters the storage area through one connection and simultaneously leaves the storage area through another. The computation of conveyance into and out of a storage area is a dynamic process that uses linear routing to simulate the flow through a levee breach, considering available storage area volume.

The levees have the ability within the UNET model to recover to initial conditions after a simulated levee overtopping. After a levee is overtopped, once the river stage had receded to a predefined level that is below the levee toe, the levee is repaired within the model to protect against the next high water event. Any residual water within the storage area after the levee has recovered is pumped back to the river.

E. Model Calibration. The UNET models were initially calibrated during the FFS and recalibrated in this study using a multi-step process designed to adjust the model to reproduce observed stage and flow records for the entire period of observed record with emphasis on reproducing high water events. Due to the new model reaches formed for this study, some minor recalibration was necessary to reproduce FFS frequency stages at mainstem USGS gages. The UNET model was calibrated to within one-half foot of observed rating curves.

1. Manning Roughness Values. The calibration of the UNET model is a multi-step process, beginning with the selection and adjustment of channel and overbank roughness values. Manning's n-value is the roughness parameter used to establish the initial conveyance properties for each cross section. The placement and verification of n-values is completed in the early development of the hydraulic model using HEC-RAS software. Channel n-values were derived from experience gained in previous hydraulic modeling efforts of the Mississippi and Illinois Rivers and range between 0.02 and 0.045

2. Application of Automatic Calibration Conveyance Adjustment. Automatic Calibration Conveyance Adjustment provides a method to adjust the conveyance in a model reach using rating curves. At each stage gage location, the model-computed flow record is combined with the observed stage record for a given period of time. The result is a scatter of data through which a single rating curve can be estimated, also known in the model as a KR curve. These KR curves provide a good estimate of the stage versus flow relationship at each gage location, when no measured relationship may be available. The UNET model geometry processor applies a series of steady-flow backwater computations to reaches between gage locations in which the KR curves serve as the downstream boundary of each reach. From each backwater computation the computed stage is compared with the KR curve of the next upstream gage. Any conveyance adjustments necessary to make the computed stage match the upstream KR curve are applied uniformly to the geometric property tables of each cross section in that reach. The KR curves are computed and applied at each of the mainstem stage gage location. These curves match closely with the measured rating curves at the USGS gages.

3. Calibration Fine-Tuning for Flow/Stage Effects. Manning's n-values alone cannot fully describe the changes in conveyance caused by changes in discharge, water temperature, and other factors. The UNET program has three tools for fine-tuning the stage calibration of the model. These tools are applied within the boundary condition file and consist of different methods to adjust the discharge-stage-conveyance relationship at a cross section or series of cross sections within the model. The individual adjustments (factors) are applied as ratios of conveyance within the property tables of each cross section. A factor less than 1.0 reduces the cross section conveyance and increases the computed stage. Likewise, a factor greater than 1.0 increases the cross section conveyance and decreases the computed stage.

The Conveyance Change Factors adjust the conveyance at all cross-sections in a specified calibration reach for all stages and flows. A unique factor is available for the channel and another for the overbank. These factors simulate a systematic change in roughness that is apparent for all stages over the entire length of the simulation.

The Discharge-Conveyance Change Factors adjust conveyance based on a series of discharge ranges at all cross-sections in a specified calibration reach. These factors provide a conveyance change for changes in roughness specific to certain flow ranges. The factors are manually defined and applied to a table of equal intervals flow ranges that represent the full range of observed flows.

The Seasonal Conveyance Change Factors change the overall conveyance multiplier with time, allowing the simulation of seasonal shifts in roughness. The seasonal adjustment, given by a time series of factors, is applied to all the cross-sections in a calibration reach at all stages. The factors simulate the variability of stage due to changes in viscosity caused by changes in water temperature.

F. Modeling Output

After simulating the 1,000 years of record for a specified study alternative, the UNET program extracts yearly maximum stages and flows for each cross section location from its output files. A statistical analysis is then performed on these stages and flows. Stage–probability and flow–probability curves are generated at each cross section using a 5th degree polynomial fit. The 5th degree polynomial fit gave the best general fit to the FFS frequency curves and data points through the majority of the frequency range, including at the infrequent events which are the focus of this study. The 5th degree fit did occasionally result in the curve turning upward at the very frequent events, 98-99.9 percent exceedance probability. A comparison of the 5th degree polynomial fit to the 1000 period of record is shown in Plates B-2 through B-5 for each of the four study reaches. Stages and flows corresponding to commonly used frequencies ranging from the 50 percent chance (2-year) to 0.2% chance (500-year)) flood events were tabulated in Microsoft Excel. In some instances, the exact reproduction of the relationship between the adopted FFS frequency curve and the 5th degree polynomial fit curve was not achieved because of frequency discharge differences. Because of this phenomenon, differences between an alternative and existing polynomial fit frequency curves were always applied to the known FFS frequency curves.

IV. GENERAL ALTERNATIVE ANALYSIS

The possible structural measures that may be applied for various alternative analyses are dependent upon the modeling tool used. The limitations of the existing hydraulic model used in this study were considered while developing the systemic alternative analyses. Measures for floodplain reductions were divided into different categories. The flood control measures that can be modeled with the current hydraulic modeling tool, UNET, and that can give measurable results for flood damage reduction are levee set-backs, levee raises, levees with controlled failure, levee removal and diversion channels. Flood control measures that can be modeled with UNET but will not be expected to give measurable results for flood damage reduction are low profile berms to protect environmentally sensitive areas, modifying/reducing localized constrictions such as at bridges and levees, re-alignment of levees and vegetation management. Measures that will need additional H & H modeling tools other than UNET and that can result in flood damage reduction are wetlands restoration, improvement of interior drainage, new flood control reservoirs, dry detention reservoirs, and small watershed ponds and detentions. Measures that cannot be modeled in the H & H arena for flood damage reduction are modification of existing rule curves for flood control reservoirs, land use/construction regulation, acquisition/buy-outs, increased channel capacity using underwater weirs, flood proofing of structures, relocation of structures, and improved flood-warning/preparedness for communities.

For levee raises in the alternatives of this study, freeboard is added to the levee height to provide additional protection above the design water surface level. The Corps no longer uses the concept of freeboard when designing or analyzing the adequacy of levee heights. The current practice uses the concepts of risk and uncertainty to determine the necessary height of a levee crown above the design water surface. However, the application of risk and uncertainty is beyond the scope of this study, where over 100 levees are simulated for each alternative. Instead a standard freeboard is applied to each raised levee in the alternative simulations. To insure that levees first overtop at the downstream end of the levee district, which minimizes internal damages, an additional foot of freeboard is added to the upstream end of the levee. For levee raises to protect to the .5% (200-year) or .2% (500-year) annual chance flood level of protection 4 feet of freeboard is added to the upstream end of the levee and 3 feet is added to the downstream end. For levee raises to protect to the 2% (50-year) or 1% (100-year) annual chance flood level 3 feet of freeboard is added to the upstream end of the levee and 2 feet is added to the downstream end. The lesser freeboard for alternatives incorporating 2% (50-year) or 1% (100-year) annual chance flood level protection is intended to dissuade development behind these levees. With the lesser freeboard these leveed areas would not have sufficient flood protection to be considered outside of the regulatory floodplain.

It was under a general understanding in this study that all impacts due to implementation of plans/alternatives would be mitigated. The mitigation measures require compensating for impacts were not quantified for in this study. But all recommended plans would require a closer investigation of mitigation measures (types and monetary) in the follow up studies.

When the alternatives and the hydraulic results are studied, it is evident that levee districts below the Missouri River did not fare well in the final analysis. The Missouri River is a significant contributor to major floods on the Mississippi River below its confluence. For example, during the 1993 flood the Missouri River contributed 60 to 70% of the flow at the St. Louis gage. The instantaneous peaks for the Hermann Gage at RM 97.7 on the Missouri River, for the Grafton Gage on the Mississippi River at RM 218.6, and for the St. Louis Gage on the Mississippi River at RM 179.6 were 750,000 cfs on July 31, 1993; 598,000 cfs on August 1, 1993; and 1,080,000 cfs on August 1, 1993 respectively. This phenomenon has been observed in floods on the Mississippi River below St. Louis. Confining floods to a higher degree of protection (1% to .5% annual chance flood) below the Missouri River is a major undertaking considering the magnitude of floods which are extremely high compared to the rest of the upstream watershed. Altering the levees below the Missouri River on the Mississippi River has a significant impact to the existing equilibrium state that exists at this time. The goals of staying within the alternative modeling criteria and decreasing flood damage reduction below the Missouri River on the Mississippi River were extremely hard. For purposes of hydraulics, a 1 foot raise above the 1% annual chance flood (100-year) at St. Louis is 39,000 cfs, and at Grafton is 28,000 cfs not considering backwater from the Missouri River. One of the alternatives in this analysis—Plan B—increased the discharges at the Grafton and the St. Louis gages approximately 20,000cfs. Plan B accounted for only 50 percent allowable modeling criteria increase at the St. Louis Gage of a 1-foot raise.

A. Modeling Criteria

Three design criteria were applied in this study for evaluation of alternatives during hydraulic simulation. The first criterion is the allowable increase of the 1% annual chance flood (100-year) flood. The second criterion is the impact to an existing levee system referred as Mississippi River and Tributary Levee system (MR&T). The third criterion is the economic damage per acre protected for levee districts. These three criteria will help determine which levees are modified and how levees are modified within each study alternative.

Floodplain development is managed by local, state, and Federal laws and statutes. Floodways for state or local communities in the Federal Insurance Program are developed using a maximum allowable induced rise in the floodplain of 1.0 foot for the 1% annual chance flood (100-year). This minimum criterion that is set by FEMA can be modified by state and local ordinances to develop even more stringent guidelines. For example, the State of Illinois has imposed a maximum allowable stage increase of 0.1 foot with allowable compensation to all landowners impacted by the exceedance of the allowable stage increase. While the Comprehensive Plan is not computing a new Mississippi River

Floodway and does not necessarily meet all of the FEMA requirements necessary to allow for a full 1 foot of computed surcharge, the criterion not to exceed the 1.0 foot for the 1% flood will still be used for the plans in this study.

The second criterion relates to the stage impact caused by study alternative at the downstream limits of the study at Thebes, Illinois. This study reach ends at the start of the MR&T levee system. The MR&T levee systems protect thousands of square miles of floodplain up to the Project Design Flood level. Slight increases in discharges and stages to the MR&T levee system may require costly levee raises. The preferred criterion should have minimal increase to stages along the lower levee system.

The third criterion uses the ratio of total average annual damages prevented versus the acres protected by a given levee district when determining which levee districts to improve, if not all levees can be raised to the alternative level of protection. The districts are ordered by the ratio of average annual damages to acres protected. If an alternative plan could only afford to improve the level of protection of one levee district, the levee district with the higher ratio would be selected for improvement.

B. Systemic Plans

1. Alternative A – Confined Condition - .2% Annual Chance Flood (500-yr) Urban and Agricultural Protection

a. Background. Alternative A is the highest systemic protection alternative simulated. Without regard for any of the three general modeling criteria, this alternative gives a .2% annual chance flood (500-year) level of protection to all urban and agricultural levee districts as well as any unprotected communities. The levees crests are set to the .2% annual chance flood (500-yr) water surface level with four feet of additional freeboard at the upstream overtopping point and 3 feet at the downstream overtopping point.

- Urban Levees - .2% annual chance flood (500-yr) protection
- Agricultural Levees –.2% annual chance flood (500-yr) protection
- Unprotected Urban Areas – .2% annual chance flood (500-yr) protection (ring w/no development)
- Unprotected Agricultural Areas – no protection
- Mitigation for all impacts due to plan implementation

b. Method. The levees were raised as high as needed to insure no overtopping. The hydraulic model could only utilize the floodplain not protected by levees.

c. Results. The 1% annual chance flood (100-year) water surface differences computed in this alternative are shown in table B-8 for the main river gages. The profile increases were dramatic for Reaches 3 and 4. The maximum increase for Reach 3 on the Mississippi River is 2.7 feet for the 1% annual chance flood (100-year) frequency between RMs 86 and 101, 4.6 feet for the 200-year frequency from RMs 91 through 93 and 7.9 feet for the.2% annual chance flood (500-year) frequency from RMs 89 through 93. The maximum increase on the Illinois River in Reach 4 for the same 1% (100-year), .5% (200-year) and .2% (500-year) annual chance flood frequencies 1.33 feet from RMs 48 through 49, 1.97 from RMs 49 through 54, and 3.11 feet from RMs 43 through 56, respectively. The stage increases below the Meredosia Gage on the Illinois River is partial due to the backwater effects from the Mississippi River.

Comparison plots of the Existing Condition and Alternative A stage frequency curves for select gages in Reaches 3 and 4 are shown on plates B-6 and B-7. The comparisons for Reaches 1 and 2 were not shown because this alternative had no measurable increase in water surface elevations. The water surface increases for this alternative by reach and frequency, as compared with the existing condition, are shown in table B-8. The percent difference between the 1% annual chance flood (100-year) existing frequency discharge and the computed 1% annual chance flood (100-year) discharge for this alternative is shown in table B-9.

Table B-8. Stage Increases - Alternative A

1% Flood

Reach	Maximum	Average	Minimum
3	2.73	1.47	0.10
4	1.33	0.49	0.00

.5% Flood (200-Year)

Reach	Maximum	Average	Minimum
3	4.55	2.33	0.28
4	1.97	0.71	0.00

.2% Flood (500-year)

Reach	Maximum	Average	Minimum
3	7.90	3.87	0.65
4	3.11	1.08	0.00

Table B-9. 1% Annual Chance Flood (100-Year) Frequency Flow Increases - Alternative A

Reach 3 - Mississippi River - Keokuk, IA to Thebes, IL

Gage Site	State	RM	Drainage Area (sq. mi.)	Alt. A (% increase)
Keokuk	IA	364.2	119,000	0
Hannibal	M0	309	137,200	2
Grafton	IL	218	171,300	11
St. Louis	MO	179.6	697,000	2
Chester	IL	109.9	708,600	7
Thebes	IL	43.7	713,200	12

Reach 4 - Illinois River

Gage Site	State	RM	Drainage Area (sq. mi.)	Alt. A (% increase)
Marseilles	IL	246.5	8,259	0
Kingston Mines	IL	145.4	15,818	0
Valley City	IL	61.3	26,600	4

2. Alternative B – .2% Annual Chance Flood (500-yr Urban) and Agricultural Protection

a. Background. Alternative B provides 500-yr level of protection for existing urban and agricultural levees/floodwalls while minimizing the impacts on the Lower Mississippi River. The results from Alternative A showed that raising all levees would not meet the general modeling criteria. The results from Alternative A revealed excessive stage increases in the vicinity of Louisiana, MO on the Mississippi River and along the Mississippi River downstream of the Missouri River confluence. The focus of this alternative is on keeping the stage increases below one foot at the 100-yr frequency and on minimizing the stage and flow impacts at the MR&T levee system, while still providing .2% annual chance flood (500-year) protection to all urban areas and highest value agricultural areas. The .2% annual chance flood (500-year) level of protection applies to urban and agriculture levees, and currently unprotected communities. This alternative does not add protection for currently unprotected agriculture areas. The hydraulic impacts of this alternative on the Lower Mississippi River will be minimized through creation of additional storage areas and/or the exclusion of some agricultural districts from the plan.

- Urban Levees -.2% annual chance flood (500-yr) protection
- Agricultural Levees – .2% annual chance flood (500-yr) protection
- Unprotected Urban Areas – .2% annual chance flood (500-yr) protection (ring w/no development)
- Unprotected Agricultural Areas – no protection
- Mitigation for all impacts due to plan implementation

b. Method. The levees crests were set to the .2% annual chance flood (500-yr) level with and additional 4 feet of freeboard at the upstream overtopping location and 3 feet at the downstream overtopping location. This alternative required many hydraulic model iterations, applying new levee storage areas, setting back and/or degrading existing agricultural levees as necessary. The creation of additional storage area consisted of identifying an unprotected agricultural area large enough to provide additional flood volume capacity during major flood events when a designed levee was placed around them. These areas were located just north of St. Louis, MO and Thebes, IL

c. Results. The 1% annual chance flood (100-year) water surface differences computed in this alternative are shown in table B-11 for the main river gages. The maximum increase for Reach 3 on the Mississippi River is 1.0 feet for the 1% annual chance flood (100-year) between RMs 253 through 263, 1.6 feet for the .5% annual chance flood (200-yr) at RM 261, and 2.7 feet for the .2% annual chance flood (500-year) from RMs 309 through 311. The maximum increase on the Illinois River in Reach 4 is .99 feet from RMs 43 through 51, 1.52 from RMs 54 through 56, and 2.46 feet from RMs 55 through 57, for the 1% (100-year), .5% (200-year) and .2% (500-year) annual chance floods respectively. The color index used to describe the levee modification for the alternatives is shown in table B-10. The modification that was applied to each levee in Reaches 1-3 is shown in table B-11. The necessary levee modifications were determined using a single computed levee elevation at the midpoint of the levee. This elevation was computed by averaging the overtopping elevations at the upstream and downstream ends of the levee and did not consider any fluctuations in the existing levee crown. Comparison plots of the Existing Condition and Alternative B stage frequency curves for select gages in Reaches 3 and 4 are shown on plates B-8 and B-9. The comparisons for Reaches 1 and 2 were not shown because this plan had no measurable increase in water surface elevations.

Table B-10. Color Index for Levee Modification Tables

Economics

Blue	The existing levee has .2% flood protection both before and after the plan is implemented. There may be less freeboard than before the plan.
Yellow	The levee will be raised to have .2% flood protection.
Orange	The levee is already at or above the plan level but will not be given .2% flood protection. There may be induced damages from larger floods.
Green	The levee is raised to the plan level, which is less than the .2% flood level. There may still be induced damages from larger floods.
Red	The levee will not be raised. There may be induced damages.
Brown	The area may or may not have protection at this time.

Construction

Blue	This levee will not be raised. The section may still require strengthening.
Yellow	This levee will be raised to a .2% flood level of protection, including freeboard.
Orange	This levee will not be raised. The section may still require strengthening.
Green	This levee will be raised to the alternative level of protection, including freeboard.
Red	This levee will not be raised. The section may require strengthening or may be left alone.
Brown	A new levee will be constructed. The area may or may not have protection at this time.

Table B-11. Levee Modifications - Alternative B Mississippi River Reaches 1-3

Levee Name	Mid Point RM	Acreage	Levee Modification [1]
Dubuque	580.60	1100	Existing Levee is Adequate (.2 % + Freeboard)
Sabula	535.00	896	Raise levee to .2% + freeboard (4'us, 3'ds)
Fulton	519.80	6800	Existing Levee is Adequate (.2 % + Freeboard)
Clinton	517.30	1940	Existing Levee is Adequate (.2 % + Freeboard)
Meredosia	511.50		Raise levee to .2% + freeboard (4'us, 3'ds)
East Moline	489.30	920	Existing Levee is Adequate (.2 % + Freeboard)
Bettendorf	486.60	470	Existing Levee is Adequate (.2 % + Freeboard)
Rock Island	481.20	650	Raise levee to .2% + freeboard (4'us, 3'ds)
Milan	478.50	2150	Raise levee to .2% + freeboard (4'us, 3'ds)
Andalusia	473.40	81	Raise levee to .2% + freeboard (4'us, 3'ds)
Muscatine/Mad Creek	456.00		Raise levee to .2% + freeboard (4'us, 3'ds)
Drury	455.20	4170	Raise levee to .2% + freeboard (4'us, 3'ds)
Muscatine Island	448.40	26480	Existing Levee is Adequate (.2% + Freeboard)
Bay Island	442.60	25169	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Upper	427.90	17400	Raise levee to .2% + freeboard (4'us, 3'ds)
Keithsburg	427.60	226	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Middle	416.40	22500	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Lower	408.10	2910	Raise levee to .2% + freeboard (4'us, 3'ds)
Henderson #1	407.30	6160	Raise levee to .2% + freeboard (4'us, 3'ds)
Henderson #2	402.40	6970	Raise levee to .2% + freeboard (4'us, 3'ds)
Green Bay	391.00	13340	Raise levee to .2% + freeboard (4'us, 3'ds)
Des Moines/Mississippi	358.95	10990	Raise levee to .2% + freeboard (4'us, 3'ds)
Mississippi & Fox Upper	357.75	2370	Raise levee to .2% + freeboard (4'us, 3'ds)
Mississippi & Fox Lower	356.20	4230	Raise levee to .2% + freeboard (4'us, 3'ds)
Hunt-Lima	351.65	21290	Raise levee to .2% + freeboard (4'us, 3'ds)
Gregory	351.25	8000	Raise levee to .2% + freeboard (4'us, 3'ds)
Canton	342.00	337	Raise levee to .2% + freeboard (4'us, 3'ds)
Indian Grave Upper	338.75	12680	Raise levee to .2% + freeboard (4'us, 3'ds)
Union Township	333.30	4240	Raise levee to .2% + freeboard (4'us, 3'ds)
Indian Grave Lower	332.85	6960	Raise levee to .2% + freeboard (4'us, 3'ds)
Fabius	327.75	14260	Raise levee to .2% + freeboard (4'us, 3'ds)
Marion County	322.40	4000	Raise levee to .2% + freeboard (4'us, 3'ds)
South Quincy	321.70	5520	Raise levee to .2% + freeboard (4'us, 3'ds)
South River Industrial	319.00	1626	Existing Levee is Adequate (.2% + Freeboard)
South River	315.65	10300	Raise levee to .2% + freeboard (4'us, 3'ds)
Hannibal	309.50	37	Raise levee to .2% + freeboard (4'us, 3'ds)
Sny Island Reach I	307.60	44200	Raise levee to .2% + freeboard (4'us, 3'ds)
Sny Island Reach II	292.45	17280	Raise levee to .2% + freeboard (4'us, 3'ds)
Riverland	289.59		Conservation Levee - No Raise
Sny Island Reach III	282.25	43100	Raise levee to .2% + freeboard (4'us, 3'ds)

Table B-11. Levee Modifications - Alternative B Mississippi River Reaches 1-3

Levee Name	Mid Point RM	Acreage	Levee Modification [1]
Petus-Burns-Prewitt-Jeager Private Levee	271.60	400	Raise levee to .2% + freeboard (4'us, 3'ds)
Clarksville Levees	269.04	2340	Remains at existing conditions (Less than .2% protection)
Sny Island Reach IV	268.75	8300	Raise levee to .2% + freeboard (4'us, 3'ds)
Kissinger Levee District	266.41	2570	Remains at existing conditions (Less than .2% protection)
Busch-Goose Pasture Farms	264.10	410	Raise levee to .2% + freeboard (4'us, 3'ds)
Cannon Wildlife Refuge Levee	262.24	3480	Conservation Levee - No Raise
Annada	262.22	3320	Remains at existing conditions (Less than .2% protection)
Elsberry Drainage District	255.94	18200	Raise levee to .2% + freeboard (4'us, 3'ds)
Elsberry Drainage District – A	255.94	5300	5300ac as storage between MRM 260 17 & 255 26
Kings Lake Drainage District	249.04	3300	Remains at existing conditions (Less than .2% protection)
Sandy Creek Drainage District	245.70	944	Raise levee to .2% + freeboard (4'us, 3'ds)
Foley Drainage District	245.03	1214	Raise levee to .2% + freeboard (4'us, 3'ds)
Cap Au Gris D&LD	241.16	3491	Raise levee to .2% + freeboard (4'us, 3'ds)
Winfield D&LD	238.88	2826	Raise levee to .2% + freeboard (4'us, 3'ds)
Brevator D&LD	238.08	1800	Raise levee to .2% + freeboard (4'us, 3'ds)
Schramm Private Levee	237.25	280	Raise levee to .2% + freeboard (4'us, 3'ds)
Old Monroe Private Levee	236.75	900	Raise levee to .2% + freeboard (4'us, 3'ds)
Heitman Private Levee	236.39	300	Raise levee to .2% + freeboard (4'us, 3'ds)
Marstan-Portuchek Private Levee	236.09	755	Raise levee to .2% + freeboard (4'us, 3'ds)
NEW LEVEE	231.40	3800	New levee
St. Peters Drainage Assoc No.1/Urban	230.02	700	Raise levee to .2% + freeboard (4'us, 3'ds)
St. Peters Drainage Association No. 1	229.76	300	Raise levee to .2% + freeboard (4'us, 3'ds)
Consolidated North County Levee District	206.25	30000	Remains at existing conditions (Less than .2% protection)
Wood River	198.05	13700	Existing Levee is Adequate (.2% + Freeboard)
Columbia Bottoms Levee	194.15		Remains at existing conditions (Less than .2% protection)
Chouteau Island D&LD	191.19	2400	Remains at existing conditions (Less than .2% protection)
Chouteau, Nameoki & Venice D&LD	189.89	4800	Existing Levee is Adequate (.2% + Freeboard)
Gabaret/Cabrolet Island D&LD	187.32	800	Remains at existing conditions (Less than .2% protection)
St. Louis Flood Protection Project	181.69	3160	Raise levee to .2% + freeboard (4'us, 3'ds)
Metro East Sanitary Dist.	179.35	61645	Existing Levee is Adequate (.2% + Freeboard)
Prairie du Pont	170.71	12000	Existing Levee is Adequate (.2% + Freeboard)
Columbia	160.89	10300	Remains at existing conditions (Less than .2% protection)
Harrisonville	142.89	22500	Remains at existing conditions (Less than .2% protection)
Stringtown	139.50	2800	Remains at existing conditions (Less than .2% protection)
Fort Chartres & Ivy Landing	134.00	15900	Remains at existing conditions (Less than .2% protection)
Prairie Du Rocher & Modoc	124.45	16000	Remains at existing conditions (Less than .2% protection)
Ste. Genevieve Urban Levee	123.75	505	Raise levee to .2% + freeboard (4'us, 3'ds)
Ste. Genevieve Levee District No. 2	119.51	7000	Remains at existing conditions (Less than .2% protection)
Kaskaskia Island	113.40	9460	Remains at existing conditions (Less than .2% protection)
Bois Brule	103.22	26060	Remains at existing conditions (Less than .2% protection)

Table B-11. Levee Modifications - Alternative B Mississippi River Reaches 1-3

Levee Name	Mid Point RM	Acreage	Levee Modification [1]
Degognia & Fountain Bluff	91.75	36200	Remains at existing conditions (Less than .2% protection)
Grand Tower	78.90	14800	Remains at existing conditions (Less than .2% protection)
Miller Pond	70.75	4300	Remains at existing conditions (Less than .2% protection)
Preston	70.73	16200	Remains at existing conditions (Less than .2% protection)
Clear Creek	61.02	18000	Remains at existing conditions (Less than .2% protection)
Cape Girardeau	52.15	140	Existing Levee is Adequate (.2% + Freeboard)
E. Cape Girardeau & Clear Creek	51.47	9400	Remains at existing conditions (Less than .2% protection)
N. Alexander Co.	51.45	3600	Remains at existing conditions (Less than .2% protection)
NEW LEVEE	49.28	13566	New levee

\1 The necessary modifications were based on the computed average levee elevation at the midpoint of the levee and did not consider any fluctuations in existing levee crown.

3. Alternative C – .2% Annual Chance Flood (500-yr) Urban/ .5% Annual Chance Flood (200-yr) Agricultural Protection

a. Background. This alternative increases protection of existing levees/floodwalls to the .2% annual chance flood (500-yr) level for urban areas and the .5% annual chance flood (200-yr) level for agricultural areas. Unprotected urban areas are given protected to the .2% annual chance flood (500-yr) level. And the hydraulic impacts of this alternative on the Lower Mississippi River are minimized through creation of two additional storage areas and the non-improvement of select agricultural levees.

- Urban Levees - .2% annual chance flood (500-yr) protection
- Agricultural Levees – .5% annual chance flood (200-yr) protection
- Unprotected Urban Areas – .2% annual chance flood (500-yr) protection (ring w/no development)
- Unprotected Agricultural Areas – no protection
- Mitigation for all impacts due to plan implementation

b. Method. All urban areas were given .2% annual chance flood (500-year) frequency level of protection. The agricultural levees crests were set to the .5% annual chance flood (200-yr) level. All levees were given an additional four feet of freeboard at the upstream overtopping location and 3 feet at the downstream overtopping location. Conservation levees and the island levees near St. Louis were left at the existing elevations. Several model iterations were necessary to meet the modeling criteria. During these iterations, all major agricultural levee districts downstream of St. Louis, with the exception of Bois Brule, were set to the existing conditions in an effort to satisfy the criterion of minimal impact below Thebes. Bois Brule was raised because of its high economic damage to acre ratio. In addition, two new levee districts built for flood storage were added to the system. These levees are in the same location as those introduced in Alternative B.

c. Results. The 1% annual chance flood (100-year) water surface differences computed in this alternative are shown in table B-12 for the main river gages. The maximum increase for Reach 3 on the Mississippi River is 1.0 feet for the 1% annual chance flood (100-yr) between RMs 260 through

262, 1.4 feet for the .5% annual chance flood (200-yr) at RM 265, and 2.2 feet for the .2% annual chance flood (500-yr)from RMs 154 through 165. The maximum increase on the Illinois River in Reach 4 is .99 feet from RMs 43 through 51, 1.52 from RMs 54 through 56, and 2.46 feet from RMs 55 through 57, for the 1% (100-year), .5% (200-year) and .2% (500-year) annual chance floods respectively. The modification applied to each levee in Reaches 1-3 is shown in table B-13. A comparison between the Existing Condition frequency curve and Alternative C frequency curve is not shown because the comparison would be similar to the Alternative B comparison.

Table B-12. 1% Annual Chance Flood (100-Year) Frequency Stage Increases - Alternatives A, B & C

Reach 1 - Mississippi River from St. Paul, MN to Clinton, IA

Gage Site	State	RM	Drainage Area (sq. mi.)	Alt. A (ft.)	Alt. B (ft.)	Alt. C (ft.)
St. Paul	MN	839.3	36,800	0.0	0.0	0.0
Prescott	MN	811.4	44,800	0.0	0.0	0.0
Winona	MN	725.7	59,200	0.0	0.0	0.0
McGregor	IA	633.4	67,500	0.0	0.0	0.0
Dubuque	IA	579.9	81,600	0.0	0.0	0.0

Reach 2 - Mississippi River from Clinton, IA to Keokuk, IA

Gage Site	State	RM	Drainage Area (sq. mi.)	Alt. A (ft.)	Alt. B (ft.)	Alt. C (ft.)
Clinton	IA	511.8	85,600	0.0	0.0	0.0
Rock Island	IL	482.9	88,500	0.0	0.0	0.0
Muscatine	IA	453.0	99,500	0.0	0.0	0.0

Reach 3 - Mississippi River from Keokuk, IA to Thebes, IL

Gage Site	State	RM	Drainage Area (sq. mi.)	Alt. A (ft.)	Alt. B (ft.)	Alt. C (ft.)
Keokuk	IA	364.2	119,000	0.1	0.1	0.1
Hannibal	M0	309	137,200	0.9	0.6	0.4
Grafton	IL	218	171,300	1.2	0.7	0.8
St. Louis	MO	179.6	697,000	1.4	0.5	0.7
Chester	IL	109.9	708,600	2.7	0.4	0.6
Thebes	IL	43.7	713,200	2.1	0.2	0.2

Reach 4 - Illinois River

Gage Site	State	RM	Drainage Area (sq. mi.)	Alt. A (ft.)	Alt. B (ft.)	Alt. C (ft.)
Marseilles	IL	246.5	8,259	0.0	0.0	0.0
Kingston Mines	IL	145.4	15,818	.31	.27	.27
Valley City	IL	61.3	26,600	1.22	.91	.91

Table B-13. Levee Modifications - Alternative C Mississippi River Reaches 1 - 3

Levee Name	Midpoint RM	Acreage	Levee Modification [1]
Dubuque	580.60	1100	Existing Levee is Adequate (.2% + Freeboard)
Sabula	535.00	896	Raise levee to .2% + freeboard (4'us, 3'ds)
Fulton	519.80	6800	Existing Levee is Adequate (.2% + Freeboard)
Clinton	517.30	1940	Existing Levee is Adequate (.2% + Freeboard)
Meredosia	511.50		Raise levee to .5% + freeboard (4'us, 3'ds)
East Moline	489.30	920	Existing Levee is Adequate (.2% + Freeboard)
Bettendorf	486.60	470	Existing Levee is Adequate (.2% + Freeboard)
Rock Island	481.20	650	Raise levee to .2% + freeboard (4'us, 3'ds)
Milan	478.50	2150	Existing Levee is Adequate (.2% + Freeboard)
Andalusia	473.40	81	Raise levee to .2% + freeboard (4'us, 3'ds)
Muscatine/Mad Creek	456.00		Raise levee to .2% + freeboard (4'us, 3'ds)
Drury	455.20	4170	Raise levee to .5% + freeboard (4'us, 3'ds)
Muscatine Island	448.40	26480	Existing Levee is Adequate (.2% + Freeboard)
Bay Island	442.60	25169	Raise levee to .5% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Upper	427.90	17400	Existing Levee is at or above plan design level
Keithsburg	427.60	226	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Middle	416.40	22500	Raise levee to .5% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Lower	408.10	2910	Raise levee to .5% + freeboard (4'us, 3'ds)
Henderson #1	407.30	6160	Raise levee to .5% + freeboard (4'us, 3'ds)
Henderson #2	402.40	6970	Raise levee to .5% + freeboard (4'us, 3'ds)
Green Bay	391.00	13340	Raise levee to .5% + freeboard (4'us, 3'ds)
Des Moines/Mississippi	358.95	10990	Raise levee to .5% + freeboard (4'us, 3'ds)
Mississippi & Fox Upper	357.75	2370	Raise levee to .5% + freeboard (4'us, 3'ds)
Mississippi & Fox Lower	356.20	4230	Raise levee to .5% + freeboard (4'us, 3'ds)
Hunt-Lima	351.65	21290	Raise levee to .5% + freeboard (4'us, 3'ds)
Gregory	351.25	8000	Raise levee to .5% + freeboard (4'us, 3'ds)
Canton	342.00	337	Raise levee to .2% + freeboard (4'us, 3'ds)
Indian Grave Upper	338.75	12680	Raise levee to .5% + freeboard (4'us, 3'ds)
Union Township	333.30	4240	Raise levee to .5% + freeboard (4'us, 3'ds)
Indian Grave Lower	332.85	6960	Raise levee to .5% + freeboard (4'us, 3'ds)
Fabius	327.75	14260	Raise levee to .5% + freeboard (4'us, 3'ds)
Marion County	322.40	4000	Raise levee to .5% + freeboard (4'us, 3'ds)
South Quincy	321.70	5520	Raise levee to .2% + freeboard (4'us, 3'ds)
South River Industrial	319.00	1626	Existing Levee is Adequate (.2% + Freeboard)
South River	315.65	10300	Raise levee to .5% + freeboard (4'us, 3'ds)
Hannibal	309.50	37	Raise levee to .2% + freeboard (4'us, 3'ds)
Sny Island Reach I	307.60	44200	Raise levee to .5% + freeboard (4'us, 3'ds)
Sny Island Reach II	292.45	17280	Raise levee to .5% + freeboard (4'us, 3'ds)
Riverland	289.59		Remains at existing conditions.
Sny Island Reach III	282.25	43100	Raise levee to .5% + freeboard (4'us, 3'ds)
Petus-Burns-Prewitt-Jeager Private Levee	271.60	400	Raise levee to .5% + freeboard (4'us, 3'ds)
Clarksville Levees	269.04	2340	Raise levee to .5% + freeboard (4'us, 3'ds)
Sny Island Reach IV	268.75	8300	Raise levee to .5% + freeboard (4'us, 3'ds)
Kissinger Levee District	266.41	2570	Raise levee to .5% + freeboard (4'us, 3'ds)

Levee Name	Midpoint RM	Acreage	Levee Modification [1]
Busch-Goose Pasture Farms	264.10	410	Raise levee to .5% + freeboard (4'us, 3'ds)
Cannon Wildlife Refuge Levee	262.24	3480	Remains at existing conditions.
Annada	262.22	3320	Remains at existing conditions.
Elsberry Drainage District	255.94	18200	Raise levee to .5% + freeboard (4'us, 3'ds)
Kings Lake Drainage District	249.04	3300	Raise levee to .5% + freeboard (4'us, 3'ds)
Sandy Creek Drainage District	245.70	944	Raise levee to .5% + freeboard (4'us, 3'ds)
Foley Drainage District	245.03	1214	Raise levee to .5% + freeboard (4'us, 3'ds)
Cap Au Gris D&LD	241.16	3491	Raise levee to .5% + freeboard (4'us, 3'ds)
Winfield D&LD	238.88	2826	Raise levee to .5% + freeboard (4'us, 3'ds)
Brevator D&LD	238.08	1800	Raise levee to .5% + freeboard (4'us, 3'ds)
Schramm Private Levee	237.25	280	Raise levee to .5% + freeboard (4'us, 3'ds)
Old Monroe Private Levee	236.75	900	Raise levee to .5% + freeboard (4'us, 3'ds)
Heitman Private Levee	236.39	300	Raise levee to .5% + freeboard (4'us, 3'ds)
Marstan-Portuchek Private Levee	236.09	755	Raise levee to .5% + freeboard (4'us, 3'ds)
NEW LEVEE	231.40	3800	New levee
St. Peters Drainage Association No. 1/Urban	230.02	700	Raise levee to .2% + freeboard (4'us, 3'ds)
St. Peters Drainage Association No. 1	229.76	300	Raise levee to .5% + freeboard (4'us, 3'ds)
Consolidated North County Levee District	206.25	30000	Remains at existing conditions
Wood River	198.05	13700	Existing Levee is Adequate (.2% + Freeboard)
Columbia Bottoms Levee	194.15		Remains at existing conditions
Chouteau Island D&LD	191.19	2400	Remains at existing conditions
Chouteau, Nameoki and Venice D&LD	189.89	4800	Existing Levee is Adequate (.2% + Freeboard)
Gabaret/Cabrolet Island D&LD	187.32	800	Remains at existing conditions
St. Louis Flood Protection Project	181.69	3160	Raise levee to .2% + freeboard (4'us, 3'ds)
Metro East Sanitary District	179.35	61645	Existing Levee is Adequate (.2% + Freeboard)
Prairie du Pont	170.71	12000	Raise levee to .2% + freeboard (4'us, 3'ds)
Columbia	160.89	10300	Remains at existing conditions
Harrisonville	142.89	22500	Remains at existing conditions
Stringtown	139.50	2800	Remains at existing conditions
Fort Chartres & Ivy Landing	134.00	15900	Remains at existing conditions
Prairie Du Rocher & Modoc	124.45	16000	Remains at existing conditions
Ste. Genevieve Urban Levee	123.75	505	Raise levee to .2% + freeboard (4'us, 3'ds)
Ste. Genevieve Levee District No. 2	119.51	7000	Remains at existing conditions
Kaskaskia Island	113.40	9460	Remains at existing conditions
Bois Brule	103.22	26060	Raise levee to .5% + freeboard (4'us, 3'ds)
Degognia & Fountain Bluff	91.75	36200	Remains at existing conditions
Grand Tower	78.90	14800	Remains at existing conditions
Miller Pond	70.75	4300	Remains at existing conditions
Preston	70.73	16200	Remains at existing conditions
Clear Creek	61.02	18000	Remains at existing conditions
Cape Girardeau	52.15	140	Existing Levee is Adequate (.2% + Freeboard)
E. Cape Girardeau & Clear Creek	51.47	9400	Remains at existing conditions
N. Alexander Co.	51.45	3600	Remains at existing conditions
NEW LEVEE	49.28	13566	New levee

[1] The necessary modifications were based on the computed average levee elevation at the midpoint of the levee and did not consider any fluctuations in existing levee crown.

4. Alternative D – .2% Annual Chance Flood (500-yr) Urban/ 1% Annual Chance Flood (100 yr) Agricultural Protection

a. Background. This alternative increases protection for existing levees/floodwalls to the .2% annual chance flood (500-yr) level for urban areas and approximately the 1% annual chance flood (100-yr) level for agricultural areas. The protection afforded to the agricultural levees would not provide sufficient protection for FEMA certification. Unprotected urban areas would be protected to the .2% annual chance flood (500-yr) level. The hydraulic impacts of this alternative on the Lower Mississippi River will be minimized through creation of additional storage areas and the non-improvement of select agricultural levees.

- Urban Levees -.2% annual chance flood (500-yr) protection
- Agricultural Levees – 1% annual chance flood about (100-yr) protection
- Unprotected Urban Areas – .2% annual chance flood (500-yr) protection (ring w/no development
- Unprotected Agricultural Areas – no protection
- Mitigation for all impacts due to plan implementation

b. Method. All urban levees were set to the .2% annual chance flood (500-year) level of protection with an additional 4 feet of freeboard at the upstream overtopping location and 3 feet at the downstream overtopping location. Agricultural levees not already above the required level were increased to an elevation of the 1% annual chance flood (100-year) water surface elevation with an additional 3 feet of freeboard at the upstream overtopping location and 2 feet at the downstream overtopping location. Small island levees near St. Louis and conservation levees were left at the existing elevation. This initial run satisfied the 1-foot criterion, but the impacts at Thebes for the .2% annual chance flood (500-year) flood were too great. Four additional trials were run before the impacts were reduced to acceptable levels.

c. Results. This alternative met the modeling criteria without degrading or setting back any existing levee district. Two new levee districts were introduced in the system to be used for flood peak storage. These districts are both located within Reach 3, Mississippi River from Keokuk to Thebes. One district is located just south of Cape Girardeau. The second is located upstream from St. Louis near the St. Peters federal levee.

The 1% annual chance flood (100-year) water surface differences computed in this alternative are shown in table B-19 for the main river gages. The maximum increase for Reach 3 on the Mississippi River is 0.8 feet for the 1% annual chance flood (100-year) between RMs 145 through 173, 1.2 feet for the .5% annual chance flood (200-year) at RM 165, and 1.7 feet for the .2% annual chance flood (500-year) from RMs 165 through 167. The maximum increase on the Illinois River in Reach 4 is .75 feet from RM 71, 1.02 from RMs 98 through 104, and 1.69 feet from RMs 101 through 112, for the 1% annual chance flood (100-year), .5% annual chance flood (200-year) and .2% annual chance flood (500-year) respectively. The modification applied to each levee in Reaches 1-3 is shown in table B-14.

Table B-14. Levee Modifications - Alternative D Mississippi River Reaches 1-3

Levee Name	Mid point RM	Acreage	Levee Modification [1]
Dubuque	580.60	1100	Existing Levee is Adequate (.2% + Freeboard)
Sabula	535.00	896	Raise levee to .2% + freeboard (4'us, 3'ds)
Fulton	519.80	6800	Existing Levee is Adequate (.2% + Freeboard)
Clinton	517.30	1940	Existing Levee is Adequate (.2% + Freeboard)
Meredosia	511.50		Raise levee to 1% FFF + freeboard (3'us, 2'ds)
East Moline	489.30	920	Existing Levee is Adequate (.2% + Freeboard)
Bettendorf	486.60	470	Existing Levee is Adequate (.2% + Freeboard)
Rock Island	481.20	650	Raise levee to .2% + freeboard (4'us, 3'ds)
Milan	478.50	2150	Existing Levee is Adequate (.2% + Freeboard)
Andalusia	473.40	81	Raise levee to .2% + freeboard (4'us, 3'ds)
Muscatine/Mad Creek	456.00		Raise levee to .2% + freeboard (4'us, 3'ds)
Drury	455.20	4170	Existing Levee is at or above plan design level
Muscatine Island	448.40	26480	Existing Levee is Adequate (.2% + Freeboard)
Bay Island	442.60	25169	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Iowa R.-Flint Cr Upper	427.90	17400	Existing Levee is at or above plan design level
Keithsburg	427.60	226	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Middle	416.40	22500	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Iowa R.-Flint Cr Lower	408.10	2910	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Henderson #1	407.30	6160	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Henderson #2	402.40	6970	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Green Bay	391.00	13340	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Des Moines/Mississippi	358.95	10990	Existing Levee is at or above plan design level
Mississippi & Fox Upper	357.75	2370	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Mississippi & Fox Lower	356.20	4230	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Hunt-Lima	351.65	21290	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Gregory	351.25	8000	Existing Levee is at or above plan design level
Canton	342.00	337	Raise levee to .2% + freeboard (4'us, 3'ds)
Indian Grave Upper	338.75	12680	Existing Levee is at or above plan design level
Union Township	333.30	4240	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Indian Grave Lower	332.85	6960	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Fabius	327.75	14260	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Marion County	322.40	4000	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
South Quincy	321.70	5520	Raise levee to .2% + freeboard (4'us, 3'ds)
South River Industrial	319.00	1626	Existing Levee is Adequate (.2% + Freeboard)
South River	315.65	10300	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Hannibal	309.50	37	Raise levee to .2% + freeboard (4'us, 3'ds)
Sny Island Reach I	307.60	44200	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Sny Island Reach II	292.45	17280	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Riverland	289.59		Remains at existing conditions.
Sny Island Reach III	282.25	43100	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Petus-Burns-Prewitt-Jeager Private Levee	271.60	400	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Clarksville Levees	269.04	2340	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Sny Island Reach IV	268.75	8300	Existing Levee is at or above plan design level
Kissinger Levee District	266.41	2570	Raise levee to 1% FFF + freeboard (3'us, 2'ds)

Levee Name	**Mid point RM**	**Acreage**	**Levee Modification** [1]
Busch-Goose Pasture Farms	264.10	410	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Cannon Wildlife Refuge Levee	262.24	3480	Remains at existing conditions
Annada	262.22	3320	Remains at existing conditions
Elsberry Drainage District	255.94	18200	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Kings Lake Drainage District	249.04	3300	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Sandy Creek Drainage District	245.70	944	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Foley Drainage District	245.03	1214	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Cap Au Gris D&LD	241.16	3491	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Winfield D&LD	238.88	2826	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Brevator D&LD	238.08	1800	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Schramm Private Levee	237.25	280	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Old Monroe Private Levee	236.75	900	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Heitman Private Levee	236.39	300	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Marstan-Portuchek Private Levee	236.09	755	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
NEW LEVEE	231.40	3800	New levee
St. Peters Drainage Association No. 1/Urban	230.02	700	Raise levee to .2% + freeboard (4'us, 3'ds)
St. Peters Drainage Association No. 1	229.76	300	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Consolidated North County Levee District	206.25	30000	Remains at existing conditions
Wood River	198.05	13700	Existing Levee is Adequate (.2% + Freeboard)
Columbia Bottoms Levee	194.15		Remains at existing conditions
Chouteau Island D&LD	191.19	2400	Remains at existing conditions
Chouteau, Nameoki and Venice D&LD	189.89	4800	Existing Levee is Adequate (.2% + Freeboard)
Gabaret/Cabrolet Island D&LD	187.32	800	Remains at existing conditions
St. Louis Flood Protection Project	181.69	3160	Raise levee to .2% + freeboard (4'us, 3'ds)
Metro East Sanitary District	179.35	61645	Existing Levee is Adequate (.2% + Freeboard)
Prairie du Pont	170.71	12000	Existing Levee is Adequate (.2% + Freeboard)
Columbia	160.89	10300	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Harrisonville	142.89	22500	Existing Levee is at or above plan design level
Stringtown	139.50	2800	Existing Levee is at or above plan design level
Fort Chartres & Ivy Landing	134.00	15900	Existing Levee is at or above plan design level
Prairie Du Rocher & Modoc	124.45	16000	Existing Levee is at or above plan design level
Ste. Genevieve Urban Levee	123.75	505	Raise levee to .2% + freeboard (4'us, 3'ds)
Ste. Genevieve Levee District No. 2	119.51	7000	Remains at existing conditions
Kaskaskia Island	113.40	9460	Existing Levee is at or above plan design level
Bois Brule	103.22	26060	Raise levee to 1% FFF + freeboard (3'us, 2'ds)
Degognia & Fountain Bluff	91.75	36200	Existing Levee is at or above plan design level
Grand Tower	78.90	14800	Existing Levee is at or above plan design level
Miller Pond	70.75	4300	Existing Levee is at or above plan design level
Preston	70.73	16200	Existing Levee is at or above plan design level
Clear Creek	61.02	18000	Existing Levee is at or above plan design level
Cape Girardeau	52.15	140	Existing Levee is Adequate (.2% + Freeboard)
E. Cape Girardeau & Clear Creek	51.47	9400	Existing Levee is at or above plan design level
N. Alexander Co.	51.45	3600	Existing Levee is at or above plan design level
NEW LEVEE	**49.28**	**13566**	**New levee**

[1] The necessary modifications were based on the computed average levee elevation at the midpoint of the levee and did not consider any fluctuations in existing levee crown.

5. Alternative E – .2% Annual Chance Flood (500-yr) Urban/ 2% Annual Chance Flood (50-yr) Agricultural Protection

a. Background. This alternative provides protection for existing levees/floodwalls to the .2% annual chance flood (500-yr) level for urban areas and approximately the 2% annual chance flood (50-yr) level for agricultural areas. Unprotected urban areas would be protected to the.2% annual chance flood (500-yr) level. The hydraulic impacts of this alternative on the Lower Mississippi River will be minimized through creation of additional storage areas and the non-improvement of select agricultural levees.

- Urban Levees - .2% annual chance flood (500-yr) protection
- Agricultural Levees – 2% annual chance flood (50-yr) protection
- Unprotected Urban Areas – .2% annual chance flood (500-yr) protection (ring w/no development)
- Unprotected Agricultural Areas – no protection
- Mitigation for all impacts due to plan implementation

b. Method. All urban levees were set to the .2% annual chance flood (500-yr) level of protection, including 4 feet of freeboard at the upstream overtopping location and 3 feet at the downstream overtopping location. Any agricultural levee not at the 2% annual chance flood (50-yr) level of protection was raised with an additional 3 feet of freeboard at the upstream overtopping location and 2 feet at the downstream overtopping location. Conservation levees were left at the existing elevation.

c. Results. The 1% annual chance flood (100-year) water surface differences that this plans caused are shown in table B-19 at the main gages. The maximum increase for Reach 3 on the Mississippi River is 0.5 feet for the 1% annual chance flood (100-year) between RMs 257 through 262, 0.6 feet for the .5 annual chance flood (200-yr) from RMs 260 through 261, and 0.7 feet for the .2% annual chance flood (500-year) from RMs 260 through 261. The maximum increase on the Illinois River in Reach 4 is .45 feet from river mile 71, 0.69 from RMs 101 through 106, and 1.16 feet at RM 103, for the 1% annual chance flood (100-year), .5% annual chance flood (200-year) and .2% annual chance flood (500-year) respectively. The modification that was applied to each levee in Reaches 2 and 3 is shown in table B-15.

Table B-15. Levee Modifications - Alternative E Mississippi River Reaches 1-3

Levee Name	Mid point RM	Acreage	Levee Modification [1]
Dubuque	580.60	1100	Existing Levee is Adequate (.2% + Freeboard)
Sabula	535.00	896	Raise levee to .2% + freeboard (4'us, 3'ds)
Fulton	519.80	6800	Existing Levee is Adequate (.2% + Freeboard)
Clinton	517.30	1940	Existing Levee is Adequate (.2% + Freeboard)
Meredosia	511.50		Existing Levee is at or above plan design level
East Moline	489.30	920	Existing Levee is Adequate (.2% + Freeboard)
Bettendorf	486.60	470	Existing Levee is Adequate (.2% + Freeboard)
Rock Island	481.20	650	Raise levee to .2% + freeboard (4'us, 3'ds)
Milan	478.50	2150	Existing Levee is Adequate (.2% + Freeboard)
Andalusia	473.40	81	Raise levee to .2% + freeboard (4'us, 3'ds)
Muscatine/Mad Creek	456.00		Raise levee to .2% + freeboard (4'us, 3'ds)
Drury	455.20	4170	Existing Levee is at or above plan design level
Muscatine Island	448.40	26480	Existing Levee is Adequate (.2% + Freeboard)
Bay Island	442.60	25169	Existing Levee is at or above plan design level
Iowa R.-Flint Cr Upper	427.90	17400	Existing Levee is at or above plan design level
Keithsburg	427.60	226	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Middle	416.40	22500	Existing Levee is at or above plan design level
Iowa R.-Flint Cr Lower	408.10	2910	Raise levee to 2% + freeboard (3'us, 2'ds)
Henderson #1	407.30	6160	Existing Levee is at or above plan design level
Henderson #2	402.40	6970	Raise levee to 2% + freeboard (3'us, 2'ds)
Green Bay	391.00	13340	Existing Levee is at or above plan design level
Des Moines/Mississippi	358.95	10990	Existing Levee is at or above plan design level
Mississippi & Fox Upper	357.75	2370	Existing Levee is at or above plan design level
Mississippi & Fox Lower	356.20	4230	Raise levee to 2% + freeboard (3'us, 2'ds)
Hunt-Lima	351.65	21290	Existing Levee is at or above plan design level
Gregory	351.25	8000	Existing Levee is at or above plan design level
Canton	342.00	337	Raise levee to .2% + freeboard (4'us, 3'ds)
Indian Grave Upper	338.75	12680	Existing Levee is at or above plan design level
Union Township	333.30	4240	Existing Levee is at or above plan design level
Indian Grave Lower	332.85	6960	Existing Levee is at or above plan design level
Fabius	327.75	14260	Existing Levee is at or above plan design level
Marion County	322.40	4000	Existing Levee is at or above plan design level
South Quincy	321.70	5520	Raise levee to .2% + freeboard (4'us, 3'ds)
South River Industrial	319.00	1626	Existing Levee is Adequate (.2% + Freeboard)
South River	315.65	10300	Raise levee to 2% + freeboard (3'us, 2'ds)
Hannibal	309.50	37	Raise levee to .2% + freeboard (4'us, 3'ds)
Sny Island Reach I	307.60	44200	Existing Levee is at or above plan design level
Sny Island Reach II	292.45	17280	Existing Levee is at or above plan design level
Riverland	289.59		Remains at existing conditions
Sny Island Reach III	282.25	43100	Existing Levee is at or above plan design level
Petus-Burns-Prewitt-Jeager Private Levee	271.60	400	Raise levee to 2% + freeboard (3'us, 2'ds)
Clarksville Levees	269.04	2340	Raise levee to 2% + freeboard (3'us, 2'ds)
Sny Island Reach IV	268.75	8300	Existing Levee is at or above plan design level
Kissinger Levee District	266.41	2570	Raise levee to 2% + freeboard (3'us, 2'ds)

Levee Name	Mid point RM	Acreage	Levee Modification [1]
Busch-Goose Pasture Farms	264.10	410	Raise levee to 2% + freeboard (3'us, 2'ds)
Cannon Wildlife Refuge Levee	262.24	3480	Remains at existing conditions
Annada	262.22	3320	Raise levee to 2% + freeboard (3'us, 2'ds)
Elsberry Drainage District	255.94	18200	Raise levee to 2% + freeboard (3'us, 2'ds)
Kings Lake Drainage District	249.04	3300	Raise levee to 2% + freeboard (3'us, 2'ds)
Sandy Creek Drainage District	245.70	944	Raise levee to 2% + freeboard (3'us, 2'ds)
Foley Drainage District	245.03	1214	Raise levee to 2% + freeboard (3'us, 2'ds)
Cap Au Gris D&LD	241.16	3491	Raise levee to 2% + freeboard (3'us, 2'ds)
Winfield D&LD	238.88	2826	Raise levee to 2% + freeboard (3'us, 2'ds)
Brevator D&LD	238.08	1800	Raise levee to 2% + freeboard (3'us, 2'ds)
Schramm Private Levee	237.25	280	Raise levee to 2% + freeboard (3'us, 2'ds)
Old Monroe Private Levee	236.75	900	Raise levee to 2% + freeboard (3'us, 2'ds)
Heitman Private Levee	236.39	300	Raise levee to 2% + freeboard (3'us, 2'ds)
Marstan-Portuchek Private Levee	236.09	755	Raise levee to 2% + freeboard (3'us, 2'ds)
St. Peters Drainage Association No. 1/Urban	230.02	700	Raise levee to .2% + freeboard (4'us, 3'ds)
St. Peters Drainage Association No. 1	229.76	300	Raise levee to 2% + freeboard (3'us, 2'ds)
Consolidated North County Levee District	206.25	30000	Remains at existing conditions
Wood River	198.05	13700	Existing Levee is Adequate (.2% + Freeboard)
Columbia Bottoms Levee	194.15		Remains at existing conditions
Chouteau Island D&LD	191.19	2400	Raise levee to 2% + freeboard (3'us, 2'ds)
Chouteau, Nameoki and Venice D&LD	189.89	4800	Existing Levee is Adequate (.2% + Freeboard)
Gabaret/Cabrolet Island D&LD	187.32	800	Raise levee to 2% + freeboard (3'us, 2'ds)
St. Louis Flood Protection Project	181.69	3160	Existing Levee is Adequate (.2% + Freeboard)
Metro East Sanitary Dist.	179.35	61645	Existing Levee is Adequate (.2% + Freeboard)
Prairie du Pont	170.71	12000	Existing Levee is Adequate (.2% + Freeboard)
Columbia	160.89	10300	Raise levee to 2% + freeboard (3'us, 2'ds)
Harrisonville	142.89	22500	Existing Levee is at or above plan design level
Stringtown	139.50	2800	Existing Levee is at or above plan design level
Fort Chartres & Ivy Landing	134.00	15900	Existing Levee is at or above plan design level
Prairie Du Rocher & Modoc	124.45	16000	Existing Levee is at or above plan design level
Ste. Genevieve Urban Levee	123.75	505	Raise levee to .2% + freeboard (4'us, 3'ds)
Ste. Genevieve Levee District No. 2	119.51	7000	Remains at existing conditions
Kaskaskia Island	113.40	9460	Existing Levee is at or above plan design level
Bois Brule	103.22	26060	Raise levee to 2% + freeboard (3'us, 2'ds)
Degognia & Fountain Bluff	91.75	36200	Existing Levee is at or above plan design level
Grand Tower	78.90	14800	Existing Levee is at or above plan design level
Miller Pond	70.75	4300	Existing Levee is at or above plan design level
Preston	70.73	16200	Existing Levee is at or above plan design level
Clear Creek	61.02	18000	Existing Levee is at or above plan design level
Cape Girardeau	52.15	140	Existing Levee is Adequate (.2% + Freeboard)
E. Cape Girardeau & Clear Creek	51.47	9400	Existing Levee is at or above plan design level
N. Alexander Co.	51.45	3600	Existing Levee is at or above plan design level

[1] The necessary modifications were based on the computed average levee elevation at the midpoint of the levee and did not consider any fluctuations in existing levee crown.

6. Alternative F – .2% Annual Chance Flood (500-year) Urban and Highway Approach Protection

a. Background. This alternative provides .2% annual chance flood (500-year) level of protection for urban areas with existing levees/floodwalls. It also provides ring levees around smaller urban centers within predominantly agricultural levee districts and raises highway approaches to major river bridge crossings to an elevation above the .2% annual chance flood (500-year) flood event. The hydraulic impacts of this alternative on the Lower Mississippi River will be minimized through creation of additional storage areas and/or the non-improvement of some of the agricultural levees.

- Urban Levees - .2% annual chance flood (500-yr) protection
- Agricultural Levees – No increase in protection
- Urban Areas within Agricultural Levees – protect communities (ring w/no development)
- Bridge Approaches within Agricultural Levees – protected only if needed for emergency access.
- Unprotected Urban Areas – .2% annual chance flood (500-yr) protection (ring w/no development)
- Unprotected Agricultural Areas – no protection
- Mitigation for all impacts due to plan implementation

b. Method. No hydraulic analysis was performed for this alternative due to the foreseeable lack of economic benefits.

c. Results. The effects of placing small ring levees within existing agricultural levees would likely have minimal impacts on the flood profiles. Since each bridge situation is unique, the impacts from raising bridge approaches could vary widely.

7. Alternative G – .2% Annual Chance Flood (500-yr) Urban and Agricultural Protection without Minimization of Impact to MR&T Levee System

a. Background. Alternative G provides .2% annual chance flood (500-year) level of protection for both urban and agricultural levees, but does not hold to the criterion to minimize the impacts to levee systems downstream of Thebes. This alternative focuses primarily on the criterion of the maximum water surface impacts at the 1% chance event. Additional agricultural levees south of St. Louis could be raised, as compared with Alternative B, while still satisfying the one-foot rise in the 1% chance flood criterion.

- Urban Levees -.2% annual chance flood (500-yr) protection
- Agricultural Levees – .2% annual chance flood (500-yr) protection within criterion
- Unprotected Urban Areas –.2% annual chance flood (500-yr) protection (ring w/no development)
- Unprotected Agricultural Areas – no protection

b. Method. For this alternative, all urban levees were raised to the .2% annual chance flood (500-year) level of protection if not already at that level. Agricultural districts were raised when possible to keep water surface impacts at the 1% annual percent chance event (100-yr) below one foot. Unprotected communities were given protection with a ring levee around the communities. Additional protection was not given to unprotected agricultural areas.

This alternative was evaluated after the completion of alternative B, so any modifications done upstream of St. Louis in alternative B could be used for this alternative. A trial from Alternative B was used as a starting point as it nearly satisfied all the criteria for this alternative. Modifications were made to the levee districts downstream of St. Louis in an attempt to maximize the area protected while minimizing the negative impacts to other districts. Levee setbacks, levee degradations, and bridge modifications were all tested in developing this alternative. A total of ten trials were simulated for this alternative.

c. Results. This alternative is identical to Alternative B for all districts upstream of St. Louis. South of St. Louis, many changes were made. First, the Jefferson Barracks Bridge was modified to create a larger flow area in the overbank on the Illinois side. Removing a portion of the embankment and raising it as a roadway on piers achieved the desired increase. The Columbia Levee District was left at its existing elevations. The levee protecting a 10,000-acre segment at the northern end of the Harrisonville District was degraded to the 10% annual chance flood (10-year) elevation. The remainder of the Harrisonville District was raised to the .2% annual chance flood (500-year) level of protection. Additionally, Kaskaskia Island, Bois Brule, and Prairie Du Rocher districts were all raised to the .2% annual chance flood (500-year) level of protection.

The 1% annual chance flood (100-year) water surface differences computed in this alternative are shown in table B-19 for the main river gages The maximum increase for Reach 3 on the Mississippi River is 1.0 feet for the 1% annual chance flood (100-year) between RMs 137 through 149, 2.1 feet for the .5% annual chance flood (200-year) from RMs 143 through 146, and 4.1 feet for the .2% chance flood (500-year) from RMs 140-148. The maximum increase on the Illinois River in Reach 4 is .99 feet from RMs 43 through 51, 1.52 from RMs 54 through 56, and 2.46 feet from RMs 55 through 57, for the 1% (100-year), .5% (200-year)and .2% (500-year) annual chance floods respectively. The 1% annual chance flood (100-year) water surface differences that this plans caused are show in table B-16 at the main gages. The modification that was applied to each levee in reaches 1through 3 is shown in table B-16.

Table B-16. Levee Modifications - Alternative G Mississippi River Reaches 1-3

Levee Name	Midpoint RM	Acreage	Levee Modification[1]
Dubuque	580.60	1100	Existing Levee is Adequate (.2% + Freeboard)
Sabula	535.00	896	Raise levee to .2% + freeboard (4'us, 3'ds)
Fulton	519.80	6800	Existing Levee is Adequate (.2% + Freeboard)
Clinton	517.30	1940	Existing Levee is Adequate (.2% + Freeboard)
Meredosia	511.50		Raise levee to .2% + freeboard (4'us, 3'ds)
East Moline	489.30	920	Existing Levee is Adequate (.2% + Freeboard)
Bettendorf	486.60	470	Existing Levee is Adequate (.2% + Freeboard)
Rock Island	481.20	650	Raise levee to .2% + freeboard (4'us, 3'ds)
Milan	478.50	2150	Existing Levee is Adequate (.2% + Freeboard)
Andalusia	473.40	81	Raise levee to .2% + freeboard (4'us, 3'ds)
Muscatine/Mad Creek	456.00		Raise levee to .2% + freeboard (4'us, 3'ds)
Drury	455.20	4170	Raise levee to .2% + freeboard (4'us, 3'ds)
Muscatine Island	448.40	26480	Existing Levee is Adequate (.2% + Freeboard)
Bay Island	442.60	25169	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Upper	427.90	17400	Raise levee to .2% + freeboard (4'us, 3'ds)
Keithsburg	427.60	226	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Middle	416.40	22500	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Lower	408.10	2910	Raise levee to .2% + freeboard (4'us, 3'ds)
Henderson #1	407.30	6160	Raise levee to .2% + freeboard (4'us, 3'ds)
Henderson #2	402.40	6970	Raise levee to .2% + freeboard (4'us, 3'ds)
Green Bay	391.00	13340	Raise levee to .2% + freeboard (4'us, 3'ds)
Des Moines/Mississippi	358.95	10990	Raise levee to .2% + freeboard (4'us, 3'ds)
Mississippi & Fox Upper	357.75	2370	Raise levee to .2% + freeboard (4'us, 3'ds)
Mississippi & Fox Lower	356.20	4230	Raise levee to .2% + freeboard (4'us, 3'ds)
Hunt-Lima	351.65	21290	Raise levee to .2% + freeboard (4'us, 3'ds)
Gregory	351.25	8000	Raise levee to .2% + freeboard (4'us, 3'ds)
Canton	342.00	337	Raise levee to .2% + freeboard (4'us, 3'ds)
Indian Grave Upper	338.75	12680	Raise levee to .2% + freeboard (4'us, 3'ds)
Union Township	333.30	4240	Raise levee to .2% + freeboard (4'us, 3'ds)
Indian Grave Lower	332.85	6960	Raise levee to .2% + freeboard (4'us, 3'ds)
Fabius	327.75	14260	Raise levee to .2% + freeboard (4'us, 3'ds)
Marion County	322.40	4000	Raise levee to .2% + freeboard (4'us, 3'ds)
South Quincy	321.70	5520	Raise levee to .2% + freeboard (4'us, 3'ds)
South River Industrial	319.00	1626	Existing Levee is Adequate (.2% + Freeboard)
South River	315.65	10300	Raise levee to .2% + freeboard (4'us, 3'ds)
Hannibal	309.50	37	Raise levee to .2% + freeboard (4'us, 3'ds)
Sny Island Reach I	307.60	44200	Raise levee to .2% + freeboard (4'us, 3'ds)
Sny Island Reach II	292.45	17280	Raise levee to .2% + freeboard (4'us, 3'ds)
Riverland	289.59		Conservation Levee - No Raise
Sny Island Reach III	282.25	43100	Raise levee to .2% + freeboard (4'us, 3'ds)
Petus-Burns-Prewitt-Jeager Private Levee	271.60	400	Raise levee to .2% + freeboard (4'us, 3'ds)
Clarksville Levees	269.04	2340	Remains at existing conditions (Less than .2% protection)
Sny Island Reach IV	268.75	8300	Raise levee to .2% + freeboard (4'us, 3'ds)
Kissinger Levee District	266.41	2570	Remains at existing conditions (Less than .2% protection)

Levee Name	Midpoint RM	Acreage	Levee Modification[1]
Busch-Goose Pasture Farms	264.10	410	Raise levee to .2% + freeboard (4'us, 3'ds)
Cannon Wildlife Refuge Levee	262.24	3480	Conservation Levee - No Raise
Annada	262.22	3320	Remains at existing conditions (Less than .2% protection)
Elsberry Drainage District	255.94	18200	Raise levee to .2% + freeboard (4'us, 3'ds)
Elsberry Drainage District – A	255.94	5300	5300ac as storage between MRM 260 17 & 255 26
Kings Lake Drainage District	249.04	3300	Remains at existing conditions (Less than .2% protection)
Sandy Creek Drainage District	245.70	944	Raise levee to .2% + freeboard (4'us, 3'ds)
Foley Drainage District	245.03	1214	Raise levee to .2% + freeboard (4'us, 3'ds)
Cap Au Gris D&LD	241.16	3491	Raise levee to .2% + freeboard (4'us, 3'ds)
Winfield D&LD	238.88	2826	Raise levee to .2% + freeboard (4'us, 3'ds)
Brevator D&LD	238.08	1800	Raise levee to .2% + freeboard (4'us, 3'ds)
Schramm Private Levee	237.25	280	Raise levee to .2% + freeboard (4'us, 3'ds)
Old Monroe Private Levee	236.75	900	Raise levee to .2% + freeboard (4'us, 3'ds)
Heitman Private Levee	236.39	300	Raise levee to .2% + freeboard (4'us, 3'ds)
Marstan-Portuchek Private Levee	236.09	755	Raise levee to .2% + freeboard (4'us, 3'ds)
St. Peters Drainage Assoc. No. 1/Urban	230.02	700	Raise levee to .2% + freeboard (4'us, 3'ds)
St. Peters Drainage Association No. 1	229.76	300	Raise levee to .2% + freeboard (4'us, 3'ds)
Consolidated N. County Levee District	206.25	30000	Remains at existing conditions (Less than .2% protection)
Wood River	198.05	13700	Raise levee to .2% + freeboard (4'us, 3'ds)
Columbia Bottoms Levee	194.15		Remains at existing conditions (Less than .2% protection)
Chouteau Island D&LD	191.19	2400	Remains at existing conditions (Less than .2% protection)
Chouteau, Nameoki and Venice D&LD	189.89	4800	Existing Levee is Adequate (.2% + Freeboard)
Gabaret/Cabrolet Island D&LD	187.32	800	Remains at existing conditions (Less than .2% protection)
St. Louis Flood Protection Project	181.69	3160	Raise levee to .2% + freeboard (4'us, 3'ds)
Metro East Sanitary Dist.	179.35	61645	Raise levee to .2% + freeboard (4'us, 3'ds)
Prairie du Pont	170.71	12000	Raise levee to .2% + freeboard (4'us, 3'ds)
Columbia	160.89	10300	Remains at existing conditions (Less than .2% protection)
Harrisonville	142.89	12500	Raise levee to .2% + freeboard (4'us, 3'ds)
Harrisonville – A	142.89	10000	10,000 acres as storage between RM 155 54 & 144 85
Stringtown	139.50	2800	Raise levee to .2% + freeboard (4'us, 3'ds)
Fort Chartres & Ivy Landing	134.00	15900	Raise levee to .2% + freeboard (4'us, 3'ds)
Prairie Du Rocher & Modoc	124.45	16000	Raise levee to .2% + freeboard (4'us, 3'ds)
Ste. Genevieve Urban Levee	123.75	505	Raise levee to .2% + freeboard (4'us, 3'ds)
Ste. Genevieve Levee District No. 2	119.51	7000	Remains at existing conditions (Less than .2% protection)
Kaskaskia Island	113.40	9460	Raise levee to .2% + freeboard (4'us, 3'ds)
Bois Brule	103.22	26060	Raise levee to .2% + freeboard (4'us, 3'ds)
Degognia & Fountain Bluff	91.75	36200	Remains at existing conditions (Less than .2% protection)
Grand Tower	78.90	14800	Remains at existing conditions (Less than .2% protection)
Miller Pond	70.75	4300	Remains at existing conditions (Less than .2% protection)
Preston	70.73	16200	Remains at existing conditions (Less than .2% protection)
Clear Creek	61.02	18000	Remains at existing conditions (Less than .2% protection)
Cape Girardeau	52.15	140	Raise levee to .2% + freeboard (4'us, 3'ds)
E. Cape Girardeau & Clear Creek	51.47	9400	Remains at existing conditions (Less than .2% protection)
N. Alexander Co.	51.45	3600	Remains at existing conditions (Less than .2% protection)

[1] The necessary modifications were based on the computed average levee elevation at the midpoint of the levee and did not consider any fluctuations in existing levee crown.

8. Alternative H – .2% Annual Chance Flood (500-yr) Urban and Agricultural Protection with Selective Buyouts

a. Background. This alternative is similar to Alternative A, providing .2% annual chance flood (500-year) protection for all urban areas with existing levees/floodwalls and for unprotected communities. Two-tenths percent annual chance flood (500-year) protection will also be provided for agricultural levee areas except for those levees where the cost of the levee improvement exceeds the value of the land to be protected. These areas would be purchased in fee title and actively managed for ecosystem benefit. The levees are assumed to remain in place at their current height, and the water levels within the interior of the drainage district would be actively managed for wildlife purposes. The hydraulic impacts of this alternative on the Lower Mississippi River will be minimized through creation of additional storage areas and/or the non-improvement of some agricultural levee districts.

- Urban Levees - .2% annual chance flood (500-yr) protection
- Agricultural Levees - improvements based on cost vs. value of land protected.
- Unprotected Urban Areas – .2% annual chance flood (500-yr) protection (ring w/no development)
- Unprotected Agricultural Areas – no protection
- Mitigation for all impacts due to plan implementation

b. Method. No hydraulic analysis was performed for this alternative.

c. Results. No hydraulic results are available for this alternative.

9. Alternative I – Relocation of Urban Resources Outside of the 1% Annual Chance Flood (100-year) Floodplain

a. Background. This alternative relocates all flood-impacted urban properties out of the 1% annual chance flood (100-year) floodplain through voluntary incentive programs or through condemnation.

- Urban Levees - buyout all structures below 1% annual chance flood (100-yr) flood level
- Agricultural Levees – No increase in protection
- Urban Areas within Agricultural Levees– buyout communities
- Bridge Approaches - no protection for approaches.
- Unprotected Urban Areas – buyout communities
- Unprotected Agricultural Areas – no protection

b. Method. No hydraulic analysis was performed for this alternative.

c. Results. No hydraulic results are available for this alternative.

10. Alternative J – Floodplain Management with Agricultural Levees Removed

a. Background. This alternative removes all agricultural levees along the Mississippi and Illinois Rivers. Urban levees remain intact. Agricultural levee removal would likely result in an uncertain mix of floodplain development. To capture the impacts of different floodplain development on the model simulations, a bound of floodplain developments was created for this alternative. The lower bound, which would provide the lowest impedance to flow, would be a managed agricultural regime. At the upper bound would be a floodplain condition reverting back to natural ecological succession. With the agricultural levees removed, the resulting floodplain condition would likely be within these bounds.

- Urban Levees – .2% annual chance flood (500-year) protection
- Agricultural Levees – Removed/no protection
- Unprotected Urban Areas –.2% annual chance flood (500-yr) protection (ring w/no development)
- Unprotected Agricultural Areas – no protection
- Mitigation for all impacts due to plan implementation

b. Method. Removing all agricultural levees provides significant additional flow in the hydraulic model as the cross sections can be upward of several miles wide. Physical factors such as channel meandering, vegetation, topography; structures such as roads and railroads; and other components will restrict effective flow width to a value much less than the cross section width. However, the UNET model uses the entire cross section width, and therefore overstates the available flow area. Modifying the UNET model to accurately reflect the actual conveyance changes at each cross section was not possible for this assessment. Therefore effective flow width, and other factors which reduce cross section conveyance, were accounted for in the UNET model by adjusting roughness values.

Roughness values were selected to provide a reasonable lower and upper bound for computed results. Various forms of land use with the overbank area will have considerably different roughness values. Generally accepted Manning's "n" values are 0.04 for agricultural land use and 0.16 for natural wooded floodplain. These values were doubled to approximate a 50 percent reduction in the overbank effective flow area. The roughness values of 0.08 was used to model agricultural activity and vegetation growth in the overbanks, and a roughness value of 0.32 was used to model natural vegetation growth in the overbanks. These values were used uniformly throughout the Mississippi and Illinois Rivers when agricultural levees were removed. These roughness values were the same values used in the Flood Plain Management Assessment Report (FPMA) when analyzing the 1993 Flood. A special routine, developed in UNET for the FPMA study, allows assessment of this condition without physically modifying each model cross section.

c. Results. Simulations were conducted for the two bounds of floodplain development. The simulations are named agricultural growth and natural growth in the tables of results. The changes in 1% annual chance flood (100-year) water surface elevations for selected river gages are shown in tables B-17 and B-18. The values represent the changes in water surface profile and discharges for the 1% annual chance flood (100-year) event as compared with the existing condition. The results are similar to those presented in the FPMA report for the 1993 flood. Using the 2004 Upper Mississippi River Flow Frequency Study results the 1993 flood is approximately a 350-year flood at St. Louis. Results for the Thebes gage are not shown in the tables. The existing condition rating curve at Thebes is used as the downstream boundary condition for Reach 3. This alternative creates such a departure from the existing condition that computes stages near Thebes are not reliable.

Table B-17. 1% Annual Chance Flood (100-Year) Frequency Stage Changes - Alternative J

Reach 1 - Mississippi River from St. Paul, MN to Clinton, IA

Gage Site	State	RM	Drainage Area (sq. mi.)	Agricultural Growth (ft.)	Natural Growth (ft.)
St. Paul	MN	839.3	36,800	0.0	0.0
Prescott	MN	811.4	44,800	0.0	0.0
Winona	MN	725.7	59,200	0.0	0.0
McGregor	IA	633.4	67,500	0.0	0.0
Dubuque	IA	579.9	81,600	0.0	0.0

Reach 2 - Mississippi River from Clinton, IA to Keokuk, IA

Gage Site	State	RM	Drainage Area (sq. mi.)	Agricultural Growth (ft.)	Natural Growth (ft.)
Clinton	IA	511.8	85,600	-0.1	-0.1
Rock Island	IL	482.9	88,500	-1.4	-1.0
Muscatine	IA	453	99,500	-5.7	-3.3

Reach 3 - Mississippi River from Keokuk, IA to Thebes, IL

Gage Site	State	RM	Drainage Area (sq. mi.)	Agricultural Growth (ft.)	Natural Growth (ft.)
Keokuk	IA	364.2	119,000	-3.9	-3.0
Hannibal	MO	309	137,200	-7.7	-4.4
Grafton	IL	218	171,300	-1.9	-1.9
St. Louis	MO	179.6	697,000	-2.9	-2.3
Chester	IL	109.9	708,600	-7.3	-3.7

Reach 4 - Illinois River

Gage Site	State	RM	Drainage Area (sq. mi.)	Agricultural Growth (ft.)	Natural Growth (ft.)
Marseilles	IL	246.5	8,259	0.0	0.0
Kingston Mines	IL	145.4	15,818	-5.2	-4.2
Valley City	IL	61.3	26,600	-4.9	-3.0

Table B-18. 1% Annual Chance Flood (100-Year) Frequency Flow Changes - Alternative J

Reach 1 - Mississippi River from St. Paul, MN to Clinton, IA

Gage Site	State	RM	Drainage Area (sq. mi.)	Agricultural Growth (% increase)	Natural Growth (% increase)
St. Paul	MN	839.3	36,800	0	0
Prescott	MN	811.4	44,800	0	0
Winona	MN	725.7	59,200	0	0
McGregor	IA	633.4	67,500	0	0
Dubuque	IA	579.9	81,600	0	0

Reach 2 - Mississippi River from Clinton, IA to Keokuk, IA

Gage Site	State	RM	Drainage Area (sq. mi.)	Agricultural Growth (% increase)	Natural Growth (% increase)
Clinton	IA	511.8	85,600	0	0
Rock Island	IL	482.9	88,500	0	0
Muscatine	IA	453	99,500	0	0

Reach 3 - Mississippi River from Keokuk, IA to Thebes, IL

Gage Site	State	RM	Drainage Area (sq. mi.)	Agricultural Growth (% increase)	Natural Growth (% increase)
Keokuk	IA	364.2	119,000	-4	-5
Hannibal	MO	309	137,200	-3	-7
Grafton	IL	218	171,300	6	1
St. Louis	MO	179.6	697,000	-1	-5
Chester	IL	109.9	708,600	5	-1

Reach 4 - Illinois River

Gage Site	State	RM	Drainage Area (sq. mi.)	Agricultural Growth (% increase)	Natural Growth (% increase)
Marseilles	IL	246.5	8,259	0	0
Kingston Mines	IL	145.4	15,818	19	11
Valley City	IL	61.3	26,600	12	-4

11. Alternative K – Protection of Critical Infrastructure

a. Background. This alternative provides .2% annual chance flood (500-yr) protection to regional critical infrastructure using structural (levees, road-raising) and/or non-structural methods (flood proofing, relocation, etc.). Identifying infrastructure to be protected will be consistent with the Presidential Commission on Critical Infrastructure's definition of critical infrastructure ("Infrastructures deemed to be so vital that the incapacity or destruction of critical components within them would have a debilitating regional or national impact"), and will include infrastructure identified in executive order 13010 (1996), namely: electrical power systems; gas and oil; transportation; emergency services; telecommunications; water supply systems; banking and finance; and continuity of government.

- Urban Levees -.2% annual chance flood (500-yr) protection
- Agricultural Levees –.2% annual chance flood (500-yr) protection (structural or non-structural) if containing regional critical infrastructure, with no raise otherwise
- Unprotected Urban Areas – .2% annual chance flood (500-yr) protection (ring w/no development)
- Unprotected Agricultural Areas – no protection
- Mitigation for all impacts due to plan implementation

b. Method. No hydraulic analysis was performed for this alternative.

c. Results. No hydraulic results are available for this alternative.

12. Alternative L - Protection of Critical Bridge Structures

a. Background. In this alternative all critical bridge approaches and floodplain highways are raised to the .2% annual chance flood (500-yr) protection level. The alternative would also keep the induced water surface increase to no more than 1 foot for the 1% annual chance flood (100-year) event. Mitigation for all induce water surface increases would be required.

- Bridge approaches raised/protected to .2% annual chance flood (500-yr) level
- Mitigation for all impacts due to plan implementation

b. Method. No hydraulic analysis was performed for this alternative.

c. Results. No hydraulic results are available for this alternative.

d. Protection of Quincy Bridge Approach

1. Background. Hydraulic analysis was performed for a subset of Alternative L by looking at only one bridge in the system; it may be likely that benefits exceed the cost of protecting the bridge approach for U.S. Highway 24, through the Fabius Drainage and Levee District (D&LD), near Quincy, IL. Benefits would be mainly in transportation savings and flood damage reduction. Initial analysis indicates that it is more cost effective to raise the Fabius D&LD levee and approaches than to raise the road alone across the levee district.

2. Method. The Fabius D&LD levee was raised to a .2% annual chance flood (500-year) level of protection. The protection of the roadway in this district on the Missouri side will insure that travel to the Quincy Bridge is possible during a major flood event. The levee district is located between RMs 324.0 and 331.5 on the Mississippi River.

3. Results. Raising the Fabius D&LD levee impacts only Reach 3 of this study. The maximum increase for Reach 3 on the Mississippi River is 0.1 ft. for the 1% annual chance flood (100-year) frequency between RMs 309 and 311, 0.1 ft. for the .5% annual flood (200-year) frequency from RMs 300 and 342, and for the .2% annual chance flood (500-year) frequency an increase of 0.1 ft. from river miles 294 to 303, 0.2 ft. from RMs 303 to 318 and 0.1 ft. from RMs 319 to 360.

13. Alternative M – .2% Annual Chance Flood (500-yr) Urban and Agricultural Protection without Minimization of Impact to MR&T Levee System

a. Background. Alternative M provides .2% annual chance flood (500-year) level of protection for both urban and agricultural levees, but does not hold to the criterion to minimize the impacts to levee systems downstream of Thebes. This alternative focuses primarily on the criterion of the maximum water surface impacts at the 1% chance event. Additional agricultural levees south of St. Louis could be raised, as compared with Alternative B, while still satisfying the one-foot rise in the 1% chance flood criterion. Additionally, this Alternative attempts to address public comments discouraging Alternative G. These comments focused on the storage portion of the Harrisonville district. Members of that levee district stated that they would prefer their entire levee be left at existing elevation.

- Urban Levees -.2% annual chance flood (500-yr) protection
- Agricultural Levees – .2% annual chance flood (500-yr) protection within criterion
- Unprotected Urban Areas –.2% annual chance flood (500-yr) protection (ring w/no development)
- Unprotected Agricultural Areas – no protection

b. Method. For this alternative, all urban levees were raised to the .2% annual chance flood (500-year) level of protection if not already at that level. Agricultural districts were raised when possible to keep water surface impacts at the 1% annual percent chance event (100-yr) below one foot. Unprotected communities were given protection with a ring levee around the communities. Additional protection was not given to unprotected agricultural areas.

This alternative was evaluated after the completion of alternative B, so any modifications done upstream of St. Louis in alternative B could be used for this alternative. Alternative G was used as a starting point. Modifications were made to the levee districts downstream of St. Louis in an attempt to maximize the area protected while minimizing the negative impacts to other districts. Levee setbacks, levee degradations, and bridge modifications were all tested in developing this alternative. A total of ten trials were simulated for this alternative.

c. Results. This alternative is identical to Alternative B for all districts upstream of St. Louis.

South of St. Louis, many changes were made. First, the Jefferson Barracks Bridge was modified to create a larger flow area in the overbank on the Illinois side. Removing a portion of the embankment and raising it as a roadway on piers achieved the desired increase. The Columbia Levee District was left at its existing elevations, as were Harrisonville, Fort Chartres and Stringtown. Kaskaskia Island, Bois Brule, and Prairie Du Rocher districts were all raised to the .2% annual chance flood (500-year) level of protection.

The maximum increase for Reach 3 on the Mississippi River is 1.0 feet for the 1% annual chance flood (100-year) at RMs 168.8, 1.4 feet for the .5% annual chance flood (200-year) from RMs 159 through 169, and 2.3 feet for the .2% chance flood (500-year) from RMs 164-167. The maximum increase on the Illinois River in Reach 4 is .99 feet from RMs 43 through 51, 1.52 from RMs 54 through 56, and 2.46 feet from RMs 55 through 57, for the 1% (100-year), .5% (200-year)and .2% (500-year) annual chance floods respectively. The 1% annual chance flood (100-year) water surface differences that this plans caused at the main gage are shown in table B-19s. The modification that was applied to each levee in Reaches 1-3 is shown in table B-20.

Table B-19. 1% Annual Chance Flood (100-Year) Frequency Stage Increases - Alternatives D, E, G & M

Reach 1 Mississippi River from St. Paul, MN to Clinton, IA

Gage Site	State	RM	Drainage Area (sq. mi.)	Alt. D (ft.)	Alt. E (ft.)	Alt. G (ft.)	Alt. M (ft)
St. Paul	MN	839.3	36,800	0.0	0.0	0.0	0.0
Prescott	MN	811.4	44,800	0.0	0.0	0.0	0.0
Winona	MN	725.7	59,200	0.0	0.0	0.0	0.0
McGregor	IA	633.4	67,500	0.0	0.0	0.0	0.0
Dubuque	IA	579.9	81,600	0.0	0.0	0.0	0.0

Reach 2 - Mississippi River from Clinton, IA to Keokuk, IA

Gage Site	State	RM	Drainage Area (sq. mi.)	Alt. D (ft.)	Alt. E (ft.)	Alt. G (ft.)	Alt M (ft)
Clinton	IA	511.8	85,600	0.0	0.0	0.0	0.0
Rock Island	IL	482.9	88,500	0.0	0.0	0.0	0.0
Muscatine	IA	453.0	99,500	0.0	0.0	0.0	0.0

Reach 3 - Mississippi River from Keokuk, IA to Thebes, IL

Gage Site	State	RM	Drainage Area (sq. mi.)	Alt. D (ft.)	Alt. E (ft.)	Alt. G (ft.)	Alt M (ft)
Keokuk	IA	364.2	119,000	0.0	0.0	0.1	0.1
Hannibal	MO	309	137,200	0.1	0.0	0.4	0..4
Grafton	IL	218	171,300	0.7	0.4	0.8	0.8
St. Louis	MO	179.6	697,000	0.7	0.4	0.7	0.7
Chester	IL	109.9	708,600	0.7	0.3	0.6	0.7
Thebes	IL	43.7	713,200	0.2	0.1	0.3	0.3

Reach 4 - Illinois River

Gage Site	State	RM	Drainage Area (sq. mi.)	Alt. D (ft.)	Alt. E (ft.)	Alt. G (ft.)	Alt M (ft)
Marseilles	IL	246.5	8,259	0.0	0.0	0.0	0.0
Kingston Mines	IL	145.4	15,818	0.4	0.3	0.3	0.3
Valley City	IL	61.3	26,600	0.4	0.4	0.9	0.9

Table B-20. Levee Modifications - Alternative M Mississippi River Reaches 1-3

Levee Name	Midpoint RM	Acreage	Levee Modification[1]
Dubuque	580.60	1100	Existing Levee is Adequate (.2% + Freeboard)
Sabula	535.00	896	Raise levee to .2% + freeboard (4'us, 3'ds)
Fulton	519.80	6800	Existing Levee is Adequate (.2% + Freeboard)
Clinton	517.30	1940	Existing Levee is Adequate (.2% + Freeboard)
Meredosia	511.50		Raise levee to .2% + freeboard (4'us, 3'ds)
East Moline	489.30	920	Existing Levee is Adequate (.2% + Freeboard)
Bettendorf	486.60	470	Existing Levee is Adequate (.2% + Freeboard)
Rock Island	481.20	650	Raise levee to .2% + freeboard (4'us, 3'ds)
Milan	478.50	2150	Existing Levee is Adequate (.2% + Freeboard)
Andalusia	473.40	81	Raise levee to .2% + freeboard (4'us, 3'ds)
Muscatine/Mad Creek	456.00		Raise levee to .2% + freeboard (4'us, 3'ds)
Drury	455.20	4170	Raise levee to .2% + freeboard (4'us, 3'ds)
Muscatine Island	448.40	26480	Existing Levee is Adequate (.2% + Freeboard)
Bay Island	442.60	25169	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Upper	427.90	17400	Raise levee to .2% + freeboard (4'us, 3'ds)
Keithsburg	427.60	226	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Middle	416.40	22500	Raise levee to .2% + freeboard (4'us, 3'ds)
Iowa R.-Flint Cr Lower	408.10	2910	Raise levee to .2% + freeboard (4'us, 3'ds)
Henderson #1	407.30	6160	Raise levee to .2% + freeboard (4'us, 3'ds)
Henderson #2	402.40	6970	Raise levee to .2% + freeboard (4'us, 3'ds)
Green Bay	391.00	13340	Raise levee to .2% + freeboard (4'us, 3'ds)
Des Moines/Mississippi	358.95	10990	Raise levee to .2% + freeboard (4'us, 3'ds)
Mississippi & Fox Upper	357.75	2370	Raise levee to .2% + freeboard (4'us, 3'ds)
Mississippi & Fox Lower	356.20	4230	Raise levee to .2% + freeboard (4'us, 3'ds)
Hunt-Lima	351.65	21290	Raise levee to .2% + freeboard (4'us, 3'ds)
Gregory	351.25	8000	Raise levee to .2% + freeboard (4'us, 3'ds)
Canton	342.00	337	Raise levee to .2% + freeboard (4'us, 3'ds)
Indian Grave Upper	338.75	12680	Raise levee to .2% + freeboard (4'us, 3'ds)
Union Township	333.30	4240	Raise levee to .2% + freeboard (4'us, 3'ds)
Indian Grave Lower	332.85	6960	Raise levee to .2% + freeboard (4'us, 3'ds)
Fabius	327.75	14260	Raise levee to .2% + freeboard (4'us, 3'ds)
Marion County	322.40	4000	Raise levee to .2% + freeboard (4'us, 3'ds)
South Quincy	321.70	5520	Raise levee to .2% + freeboard (4'us, 3'ds)
South River Industrial	319.00	1626	Existing Levee is Adequate (.2% + Freeboard)
South River	315.65	10300	Raise levee to .2% + freeboard (4'us, 3'ds)
Hannibal	309.50	37	Raise levee to .2% + freeboard (4'us, 3'ds)
Sny Island Reach I	307.60	44200	Raise levee to .2% + freeboard (4'us, 3'ds)
Sny Island Reach II	292.45	17280	Raise levee to .2% + freeboard (4'us, 3'ds)
Riverland	289.59		Conservation Levee - No Raise
Sny Island Reach III	282.25	43100	Raise levee to .2% + freeboard (4'us, 3'ds)
Petus-Burns-Prewitt-Jeager Private Levee	271.60	400	Raise levee to .2% + freeboard (4'us, 3'ds)
Clarksville Levees	269.04	2340	Remains at existing conditions (Less than .2% protection)
Sny Island Reach IV	268.75	8300	Raise levee to .2% + freeboard (4'us, 3'ds)
Kissinger Levee District	266.41	2570	Remains at existing conditions (Less than .2% protection)

Levee Name	Midpoint RM	Acreage	Levee Modification[1]
Busch-Goose Pasture Farms	264.10	410	Raise levee to .2% + freeboard (4'us, 3'ds)
Cannon Wildlife Refuge Levee	262.24	3480	Conservation Levee - No Raise
Annada	262.22	3320	Remains at existing conditions (Less than .2% protection)
Elsberry Drainage District	255.94	18200	Raise levee to .2% + freeboard (4'us, 3'ds)
Elsberry Drainage District – A	255.94	5300	5300ac as storage between MRM 260 17 & 255 26
Kings Lake Drainage District	249.04	3300	Remains at existing conditions (Less than .2% protection)
Sandy Creek Drainage District	245.70	944	Raise levee to .2% + freeboard (4'us, 3'ds)
Foley Drainage District	245.03	1214	Raise levee to .2% + freeboard (4'us, 3'ds)
Cap Au Gris D&LD	241.16	3491	Raise levee to .2% + freeboard (4'us, 3'ds)
Winfield D&LD	238.88	2826	Raise levee to .2% + freeboard (4'us, 3'ds)
Brevator D&LD	238.08	1800	Raise levee to .2% + freeboard (4'us, 3'ds)
Schramm Private Levee	237.25	280	Raise levee to .2% + freeboard (4'us, 3'ds)
Old Monroe Private Levee	236.75	900	Raise levee to .2% + freeboard (4'us, 3'ds)
Heitman Private Levee	236.39	300	Raise levee to .2% + freeboard (4'us, 3'ds)
Marstan-Portuchek Private Levee	236.09	755	Raise levee to .2% + freeboard (4'us, 3'ds)
St. Peters Drainage Assoc. No. 1/Urban	230.02	700	Raise levee to .2% + freeboard (4'us, 3'ds)
St. Peters Drainage Association No. 1	229.76	300	Raise levee to .2% + freeboard (4'us, 3'ds)
Consolidated N. County Levee District	206.25	30000	Remains at existing conditions (Less than .2% protection)
Wood River	198.05	13700	Raise levee to .2% + freeboard (4'us, 3'ds)
Columbia Bottoms Levee	194.15		Remains at existing conditions (Less than .2% protection)
Chouteau Island D&LD	191.19	2400	Remains at existing conditions (Less than .2% protection)
Chouteau, Nameoki and Venice D&LD	189.89	4800	Existing Levee is Adequate (.2% + Freeboard)
Gabaret/Cabrolet Island D&LD	187.32	800	Remains at existing conditions (Less than .2% protection)
St. Louis Flood Protection Project	181.69	3160	Raise levee to .2% + freeboard (4'us, 3'ds)
Metro East Sanitary Dist.	179.35	61645	Raise levee to .2% + freeboard (4'us, 3'ds)
Prairie du Pont	170.71	12000	Raise levee to .2% + freeboard (4'us, 3'ds)
Columbia	160.89	10300	Remains at existing conditions (Less than .2% protection)
Harrisonville	142.89	22500	Remains at existing conditions (Less than .2% protection)
Stringtown	139.50	2800	Remains at existing conditions (Less than .2% protection)
Fort Chartres & Ivy Landing	134.00	15900	Remains at existing conditions (Less than .2% protection)
Prairie Du Rocher & Modoc	124.45	16000	Raise levee to .2% + freeboard (4'us, 3'ds)
Ste. Genevieve Urban Levee	123.75	505	Raise levee to .2% + freeboard (4'us, 3'ds)
Ste. Genevieve Levee District No. 2	119.51	7000	Remains at existing conditions (Less than .2% protection)
Kaskaskia Island	113.40	9460	Raise levee to .2% + freeboard (4'us, 3'ds)
Bois Brule	103.22	26060	Raise levee to .2% + freeboard (4'us, 3'ds)
Degognia & Fountain Bluff	91.75	36200	Remains at existing conditions (Less than .2% protection)
Grand Tower	78.90	14800	Remains at existing conditions (Less than .2% protection)
Miller Pond	70.75	4300	Remains at existing conditions (Less than .2% protection)
Preston	70.73	16200	Remains at existing conditions (Less than .2% protection)
Clear Creek	61.02	18000	Remains at existing conditions (Less than .2% protection)
Cape Girardeau	52.15	140	Raise levee to .2% + freeboard (4'us, 3'ds)
E. Cape Girardeau & Clear Creek	51.47	9400	Remains at existing conditions (Less than .2% protection)
N. Alexander Co.	51.45	3600	Remains at existing conditions (Less than .2% protection)

[1] The necessary modifications were based on the computed average levee elevation at the midpoint of the levee and did not consider any fluctuations in existing levee crown.

V. MEASURE EVALUATION: SNY ISLAND LEVEE SETBACK

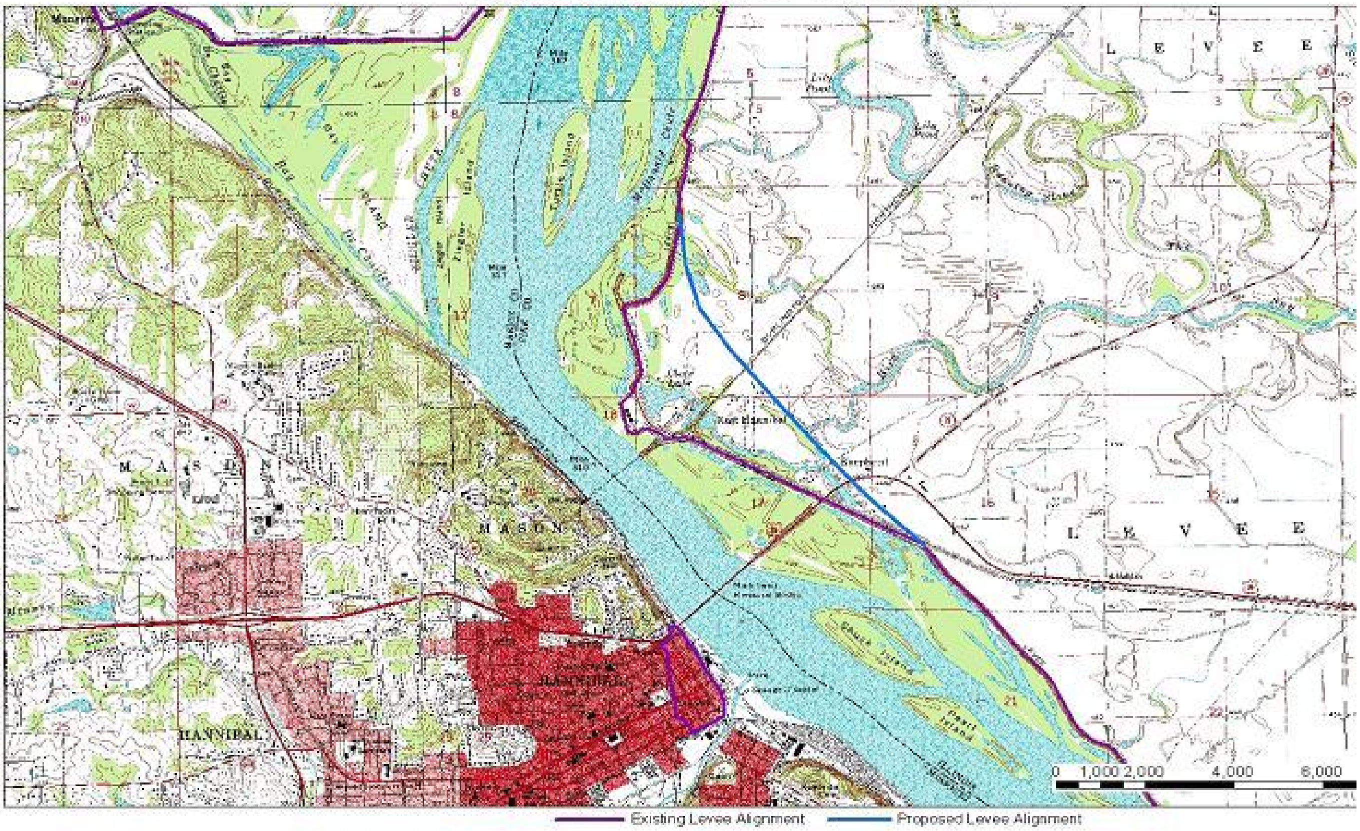
A. Background. One proposed method to reduce flood stages through modification of existing levees is the setback, or realignment, of levees that excessively or inconsistently encroach on the floodplain. One noted area occurs near Hannibal, Missouri where the Sny Island Levee, along with railroad and highway bridge approaches act to reduce the active left bank floodplain for a 2-mile stretch. This localized reduction in floodplain width has been considered a constriction that results in increased flood stages upstream. This analysis computes the flood stage reduction, which could be expected by realigning the Sny Island Levee in this reach.

B. Method. Starting with the existing-condition model, the Sny Island Levee was realigned on the left bank between RMs 311.3 and 308.6 (approx. 10,000 feet) to create a more uniform, unobstructed width between levees. The maximum setback is approximately 3,000 ft. from the existing alignment. The new levee alignment was selected to match with more uniform floodplain width upstream and downstream of the encroached reach. Along with the levee setback, the existing bridge approaches for both highway and railroad are degraded in the model to the elevation of the surrounding floodplain. This assumes that the roads and railroad tracks will be realigned and bridges extended so as not to block the conveyance between the setback levee and the main river channel. The proposed levee alignment is shown in the figure on the following page. The reestablished floodplain, after the setback of the levee, is assumed to be a managed grass area, as opposed to a wooded area, which would likely result if left unmanaged. The grass allows for a lower roughness value and improved conveyance through the floodplain.

Two hydraulic model simulations were conducted. The first simulation portrays the realignment on existing conditions, where all modeled levees overtop at existing elevations. The second simulation portrays the realignment on confined conditions, where all modeled levees are raised to an elevation that will not be overtopped for any flood event.

C. Results. To present the computed impacts of this proposed realignment, the results of the simulations with the realigned levee are compared to the simulation results using the existing levee alignment. The first simulation represents existing conditions (unconfined), allowing levees to overtop at existing elevations. The second simulation represents confined conditions, where levees do not overtop for any flood magnitude. The resulting stage impacts for the unconfined and confined conditions are nearly equal, with the maximum water surface reduction due to realignment being 0.4 ft and 0.5 ft at RM 311.4, respectively. The unconfined levee alignment resulted in stages reduction downstream to RM 310.0 before the 1% annual chance flood (100-year) profile is the same as existing profile and upstream to RM 317.5 before matching the existing profile. The confined levee alignment resulted in stage reduction downstream similar to the unconfined levee alignment and upstream to RM 318.0 before matching the existing profile.

Sny Levee Setback near Hannibal, MO



VI. EMERGENCY ACTION SCENARIOS

A. Background. Emergency Action Scenarios (EAS) were developed to better understand the hydraulic and economic impacts of flood fighting on the Upper Mississippi River System. A series of four EAS was conducted to represent successively higher levels of systemic flood fighting. The primary hydraulic impacts of concern are potential increases in the computed frequency stages (i.e., 100-yr and 500-yr flood levels) resulting from temporary increases in levee heights during a flood. The primary economic concern is the reduction in flood damages resulting from the flood fighting. The potential for induced damages were not evaluated as part of the EAS.

The EAS represent systemic flood fighting efforts (simulated as increases to levee crest elevations) conducted during a flood event. Each successive scenario offers a higher level of emergency protection to the modeled levee districts. Based on knowledge of previous emergency operations, the maximum raise of a levee that can be achieved system-wide, on a safe and consistent basis, is 3 feet. Some communities do have the capability to increase their level of protection by more than 3 feet if given sufficient forewarning of impending high water. However, because of the system-wide nature of the study, all analyses were limited to a raise of 3 feet. The 3-foot rise represents all emergency actions, including sandbagging, flash boarding, pushing material on top of a levee and all other temporary measures used to raise an existing level of protection.

B. Method. Levees were divided into three categories for the EAS: urban, industrial, agricultural and conservation. The urban and industrial levees received emergency response in each of the EAS, while the agricultural levees receive increasing levels of protection in each of the successive scenarios. The conservation levees are not raised in any of the EAS. These levees are commonly used for wildlife refuges or other conservation purposes and, by design, are typically not raised during flood events. For the purposes of the EAS, Federal, non-Federal, and private levees were treated equally. Areas currently unprotected were not included in the scenarios. Finally, all levee raises were uniform within each of the three levee categories.

The four EAS established by the Comprehensive Plan are:

EAS1 - Raise only the urban and industrial levees by two (2) feet. Agricultural levees and conservation levees are left at existing elevations.

EAS2 – Raise urban and industrial levees by two (2) feet. Raise agricultural levees by one (1) foot. Conservation levees left at existing elevations.

EAS3 - Raise urban, industrial and agricultural levees by two (2) feet. Conservation levees left at existing elevations.

EAS4 - Raise urban, industrial and agricultural levees by three (3) feet. Conservation levees left at existing elevations.

C. Results. The results of each EAS for the four river reaches identified by for this study are summarized in table B-20.

The maximum computed stage increases for the 1% annual chance flood (100-yr) and 0.2% annual chance flood (500-yr) events are shown in table B-20 below. The information in the table shows that:

- there is no induced rise in frequency stage in Reaches 1 and 2 for any of the scenarios. This implies that induced damages are not a concern when determining emergency response priorities within these reaches.

- there is no induced rise in frequency stage anywhere along the length of the Mississippi River or Illinois River (Reaches 1-4) caused by increasing the level of protection of only urban and industrial areas.

- induced damages could be a concern for systemic agricultural levee raises in Reaches 3 and 4.

Table B-21. Stage Increases Emergency Action Scenarios

Maximum Induced Stage Frequency Increase at 1% Chance Event

River Reach	EAS1 Max. Rise (ft)	EAS2 Max. Rise (ft)	EAS3 Max. Rise (ft)	EAS4 Max. Rise (ft)
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.4	0.7	1.1
4	0.0	0.3	0.6	0.8

Maximum Induced Stage Frequency Increase at 0.2% Chance Event

River Reach	EAS1 Max. Rise (ft)	EAS2 Max. Rise (ft)	EAS3 Max. Rise (ft)	EAS4 Max. Rise (ft)
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.1
3	0.0	1.1	1.9	2.9
4	0.1	0.6	1.3	1.8

VII. STANDARD PROJECT FLOOD – SCOPE OF WORK

A. Introduction. The development of the Standard Project Flood (SPS) for the Mississippi and Illinois River was requested by the Comprehensive Study Collaboration Team. The SPS development was beyond the scope of the Comprehensive Study but a scope of work was developed for this study in an event that additional funding/authorization could be achieved.

B. Proposal for Work. The following work items shall be performed for the successful completion of the Standard Project Flood for the Upper Mississippi and Illinois Rivers Comprehensive Study. St. Paul (MVP), Rock Island (MVR) and St. Louis (MVS) Districts will perform the work.

C. Definitions

Standard Project Flood (SPF) is the flood resulting from the worst combination of hydrologic and meteorological events reasonable characteristic of the geological region involved, excluding extremely rare combinations.

Standard Project Storm (SPS) is the precipitation/storm that causes the SPF

Probable Maximum Flood (PMF) is the flood resulting from the most severe combinations of meteorological and hydrologic conditions reasonably possible in the region

Probable Maximum Storm (PMS) is the precipitation/storm that causes the PMF. The storm causing the PMS is usually about double the SPS.

D. Development of SPF for the St. Paul District for the Upper Mississippi River

1. Literature search, research, review information on SPF and PMF, and obtain previous reports. MVP shall research, review and obtain all available reports on the preparation of the SPF, and PMF. This would include the information on the precipitation/storm available for the SPS and PMS.

2. Coordination with MVS and MVR. MVP shall coordinate with the MVS and MVR during their preparation of the SPF.

3. SPF Preparation. Information from previous reports on the SPF for MVP shall be used. For Example, Design Memorandum and Environmental Assessment, "St. Paul Flood Control Project", Mississippi River at St. Paul, Minnesota, March 1990 will be used. A minimum of three stations will be selected to define the SPF for the UMR in MVP.

4. SPF Graph. MVP will develop a graph showing the SPF discharge and drainage area at the selected sites in the Upper Mississippi River.

5. SPF Flood Profile. The discharge flood profile for the SPF will be developed using the information from the Flood Flow Frequency Study.

6. Stage Profile Development. MVP will develop the SPF stage profile for the Mississippi River by using the information from the Flood Flow Frequency Study.

7. Schedule. The work required under this contract in Paragraph A shall be completed within nine months from the date adequate funding is available as per the cost estimate.

E. Development of SPF for the Rock Island District for the Illinois River

1. Literature search, research, review information on SPF and PMF, and obtain previous reports. Rock Island District shall research, review and obtain all available reports on the preparation of the SPF and PMF. This would include the information on the precipitation/storm available for the SPS and PMS.

2. Coordination with MVS and MVP. MVR shall coordinate with the St. Louis and the MVPs during their preparation of the SPF. MVR will be responsible for the entire Illinois River Basin to simplify the analysis.

3. SPF Preparation. A minimum of three stations shall be selected to determine the SPF on the Illinois River. The centering of the PMS will be determined using the HMR-51, HMR-52 and HEC-HMS. The SPS will be determined by proportioning the PMS by a value selected from 0.4 to 0.6.

4. SPF Graph. MVR will develop a graph showing the SPF discharge and drainage area at the selected sites along the Illinois River.

5. SPF Flood Profile. The discharge flood profile for the SPF will be developed using the information from the Flood Flow Frequency Study.

6. Stage Profile Development. MVR will develop the SPF stage profile for the Illinois River by using the information from the Flood Flow Frequency Study. Two separate stage profiles will be developed. The first stage profile will consider a normal depth starting at the junction of the Mississippi and Illinois Rivers and the second stage profile will consider a backwater condition of the SPF from the Mississippi River. The resulting SPF flood profile will be the higher of the two profiles

7. Schedule. The work required under this contract in Paragraphs B shall be completed in 9 months from the date adequate funding is available as per the cost estimate.

F. Development of SPF for the Rock Island District for the Mississippi River

1. Literature search, research, review information on SPF and PMF, and obtain previous reports. MVR shall research, review and obtain all available reports on the preparation of the SPF and PMF. This would include the information on the precipitation/storm available for the SPS and PMS.

2. Coordination with MVS and MVP. MVR shall coordinate with the St. Louis and the MVPs during their preparation of the SPF.

3. SPF Preparation. Rock Island District will review historical rainfall events. The HEC-HMS model will be used to study the worst combination of rainfall events by repositioning the historic rainfall events and or using the HMR-51 to adjust the precipitation values to equate to a PMF/SPF event. Two or more stations shall be selected to determine the SPF on the Mississippi River. This method of SPF computation is discussed in EM 110-2-1411, page 3, paragraph e.

4. SPF Graph. Rock Island District will develop a graph showing the SPF discharge and drainage area at the selected sites along the Mississippi River from L&D 10 to the St. Louis Gage.

5. SPF Flood Profile. The discharge flood profile for the SPF will be developed using the information from the Flood Flow Frequency Study.

6. Stage Profile Development. MVR will develop the SPF stage profile for the Mississippi River by using the information from the Flood Flow Frequency Study.

7. Schedule. The work required under this contract in Paragraphs C shall be completed in nine months from the date adequate funding is available as per the cost estimate.

G. Development of SPF for the St. Louis District for the Mississippi River

1. Literature search, research, review information on SPF and PMF, and obtain previous reports. MVS shall research, review and obtain all available reports on the preparation of the SPF and PMF. This would include the information on the precipitation/storm available for the SPS and PMS.

2. Coordination with MVR and MVP. MVS shall coordinate with the Rock Island and the St. Paul Districts during their preparation of the SPF.

3. SPF Preparation. St. Louis District will review historical rainfall events. The HEC-HMS model will be used to study the worst combination of rainfall events by repositioning the historic rainfall events and or using the HMR-51 to adjust the precipitation values to equate to a PMF/SPF event. Two or more stations shall be selected to determine the SPF on the Mississippi River. This method of SPF computation is discussed in EM 110-2-1411, page 3, paragraph e.

4. SPF Graph. MVS will develop a graph showing the SPF discharge and drainage area at the selected sites along the Mississippi River.

5. SPF Flood Profile. The discharge flood profile for the SPF will be developed using the information from the Flood Flow Frequency Study.

6. Stage Profile Development. MVS will develop the SPF stage profile for the Mississippi River by using the information from the Flood Flow Frequency Study upstream of the Thebes gage.

7. Schedule. The work required under this contract in Paragraph D shall be completed within nine months from the date adequate funding is available as per the cost estimate.

H. Current Conditions. This analysis will only consider current basin conditions and not future

I. Communication. Telephone conversations and face-to-face team meetings between members of the St. Paul, Rock Island and St. Louis Districts will be used the fullest to insure successful completion of this work order.

J. Report. One report will be written to capsulate the results of all three districts.

K. Independent Technical Review. An independent review will be done on the analysis.

L. Cost Estimate. The cost estimate for this SPS study is $375,000.

VIII. LESSONS LEARNED

The following observations were made during the H & H modeling and may be of value to future modeling efforts.

1. When the Columbia Levee District was raised for any of the .2% annual chance flood (500-yr) protection alternatives, the stage increase computed near the Jefferson Barracks gage (upstream of the levee district) was greater than 1 foot. The loss of storage during a flood because of this levee district not overtopping would also include raises in other districts downstream of the Columbia Levee District.

2. The Bois Brule levee district has the highest damage to acre ratio on the Mississippi River. The reason for this high acre ratio is that industry located inside this district would result in high dollar/structural damages if the levee overtops.

3. A portion of the Bois Brule levee containing the industrial section and the highway that connects to the Chester Bridge was raised in one trial of Alternative B. This trial was identical to the selected trial except that this trial removed storage area from the Bois Brule district and shifted the levee district's upstream overtopping point further downstream. This trial resulted in a water surface increase 0.1 foot greater at Thebes than the increase caused by selected trial. These results reiterate the need for maximizing the volume of storage below St. Louis. This additional 0.1 foot would result in a significant raise at Thebes which is in violation of the second modeling criteria.

4. In most of the study alternatives, all agricultural levees were raised to the same level of protection unless the computed water surface increase exceeded 1.0 foot for the 1% annual chance flood (100-year) event. At that point, select agricultural levees were left at existing levels or were degraded, starting with the districts with the lowest ratio of economic damages to area protected. For future consideration, an alternative could be designed in which the agricultural levee districts with the highest ratio of average annual damages to acres protected are raised first and then the remaining levees are raised in decreasing order of ratio until the threshold of water surface increase is exceeded.. As noted above, raising the levee with the highest ratio results in a noticeable impact at Thebes. That observation may end up proving that Bois Brule cannot be raised for any alternative without exceeding the specified water surface increase.

5. Raising all the Illinois River levees to a .2% annual chance flood (500-year) protection level does not increase the computed 1% annual chance flood (100-year) profile more than 1 foot.

6. Raising all the Mississippi River levees above and below L&D 19 at Keokuk, IA to the .2% annual chance flood (500-year) protection level does not increase any of the computed stage frequency profiles upstream of L&D 19. Dam 19 is a high head dam. Stages above the dam are not influenced by stages below, even during the highest flood events. Also, most the levees upstream of L&D 19 currently have relatively high level of protection, as compared with those downstream. Raising them further has limited effect on river stages.

7. MVP unprotected areas have had enough time to put up temporary flood protection measures during previous flood fighting activates.

8. Removing bridge obstructions along the Mississippi River will only decrease local flood elevations and the decrease will taper to the existing bridge condition a few miles upstream and downstream.

9. Location of the levee overtopping (upstream or downstream) and overtopping height 2% annual chance flood (50-year), 1% annual chance flood (100-year), and.2% annual chance flood (500-year)) does effect water surface elevations upstream and downstream.

10. Setback or realignment of levee segments along the Mississippi River has only a minor localized impact in computed water surface elevations.

11. The criteria of minimum impact to the MR&T levee system curtailed the potential levee raises on the Middle Mississippi River.

12. The 1,000-year stochastically-produced inflow record helped in reducing the influence of levee overtopping on the computed frequency water surface profiles. Levee overtopping impacts the computed water surface of each flood event differently, affected by the duration and volume of the event. In this study, simulating numerous levee-overtopping flood events minimized the influence of any one flood event.

13. Using the stochastically produced 1,000-year inflow record greatly simplified the systemic hydraulic model simulations and frequency analysis for the study. The computed stage and flow frequency for each alternative could be simulated with one hydraulic model run. This allowed for the hydraulic analysis of more alternatives than would be possible using the FFS method or a series of design events.

IX. SUMMARY AND CONCLUSIONS

The hydrologic and hydraulic assessments used in the study incorporated existing resources and introduced new methodology to systemically analyze hundreds of miles of complex river system. The UNET hydraulic models developed for the Upper Mississippi River Flow Frequency Study (FFS) were the foundation for the hydraulic analyses of study alternatives. These models cover more than 1,100 miles of the Mississippi and Illinois River and are capable of simulating a wide array of physical and hydrologic study alternatives.

Through the ingenuity of Dr. Robert Barkau, the hydrology used for the FFS frequency analysis was replaced in this study by a stochastically-generated 1,000 years of inflow record which reproduces the flow frequency relationships computed in the FFS. This long flow record allows for a stage frequency analysis through a range of frequencies between 50% annual chance flood (2-yr) and .2% annual chance flood (500-yr) reoccurrence interval for each study alternative using a single hydraulic model simulation. This simplified method of hydraulic simulation allowed for frequency analyses of many more study alternatives than the FFS method.

Most of the alternatives focused on reducing systemic flood damages by raising existing levees and by adding new levees for currently unprotected urban areas. However, other modifications to the existing levee systems, including levee removal and levee relocation, employed in various combinations, were necessary to achieve results within the bounds of the study criteria. These criteria were selected to limit increases to frequency stages, maximize economic benefits, and minimize negative stage and flow impacts to existing flood control projects downstream of the study reach.

The results of the alternative analyses show that the study reaches of the river respond differently to the structural measures employed in each alternative. Generally, raising levees in the upper reaches of the study had little impact to frequency river stages. This is largely due to the relatively low number and high existing protection levels of levees in these reaches as compared with those of the lower reaches. Conversely, levee raises in the lower reaches showed much greater impact to frequency river stages. For some alternatives, little improvement could be made to the lower river levee districts while meeting the pre-established modeling criteria.

While the hydraulic analyses did not cover every possible hydrologic and physical modification, they provide sufficient insight into the water surface impacts that could be expected from systemic changes to the levee systems along the Upper Mississippi and Illinois Rivers.

X. STUDY LIMITATIONS AND RECOMMENDATIONS

1. Reservoir regulation analysis could not be incorporated into the hydrology and hydraulic frequency analysis used.

2. While potentially valuable for flood damage reduction, upland wetlands, detention and retention reservoirs could not be investigated because of funding and time constraints.

3. Missouri River flood damage reduction measures were not considered. The Missouri River flows have a major influence on the flows downstream of the confluence with the Mississippi River.

4. Digital floodplain topographic data is not available for the Illinois River between river miles 43 and 80. Due to the missing data, older floodplain information is used in this portion of the Illinois River hydraulic model. This missing topographic data should be acquired to fill a gap in the dataset that covers most of the Upper Mississippi, Missouri and Illinois River floodplains.

5. Funding for the Standard Project Flood is recommended to ascertain the effect of the largest flood capacity on the Mississippi and Illinois Rivers.

6. Future changes in land use, population, and climate were not considered in the alternatives of this study.

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GLOSSARY

100-year flood: a term commonly used to refer to the 1% annual chance flood; the 100-year flood is the flood that is equaled or exceeded once in 100-year on the average, but the term should not be taken literally as there is no guarantee that the 100-year flood will occur at all within a 100-year period or that it will not recur several times

controlled failure of levee: set a controlling weir elevation that a levee will overtop usually at the downstream end of a levee system

diversion channel: a waterway used to divert water from its natural course

dry detention: the temporary storage of water in an area which is normally dry and outflows are unregulated

flood control reservoir: a body of water impounded by a dam and in which water can be stored and outflow regulated for the purpose of reducing downstream discharges

floodproofing: to construct or modify individual buildings, facilities, and their sites to prevent or reduce the effects of water entry

flow diversion: movement of floodwater from one area to another by means of an alternate route

improved interior drainage / pumping capacity: improving the interior drainage of a levee district by reducing the flooding that occurs during exterior high water stages

levee and floodwall raising: increasing the effective height of the levee protection by permanent structural or floodfighting methods

levee removal: the removal of all or portions of the earthen levee footprint from the floodplain to allow conveyance and storage

levee set-back: relocation of a levee away from the river channel a specific distance from the existing levee alignment

low profile berms to protect environmentally sensitive areas: an area protected by a low frequency (example a 2-year) embankment to protect environmentally sensitive areas from unfavorable flooding

modifying/reducing constrictions: improving the conveyance of the river system by removing the constrictions caused by obstructions bridges and levees

re-alignment of levee: the adjustment of the levee alignment which can affect the conveyance of the flood plain

wetlands restoration: the reestablishment and/or creation of wetlands in areas where wetlands been removed or modified from the natural condition

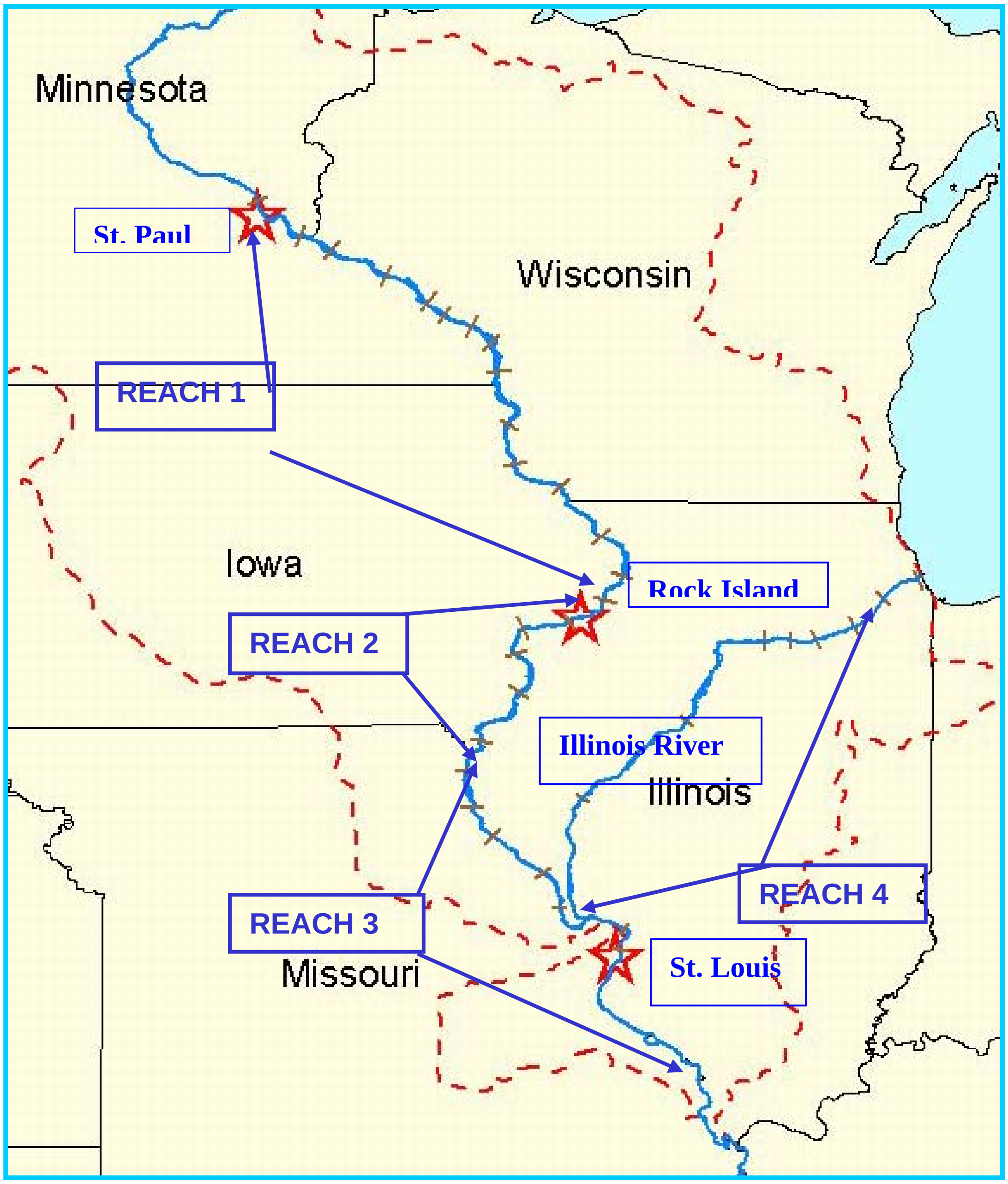

Minnesota
St. Paul
Wisconsin
REACH 1
Iowa
Rock Island
REACH 2
Illinois River
Illinois
REACH 4
REACH 3
St. Louis
Missouri

PLATE B-1

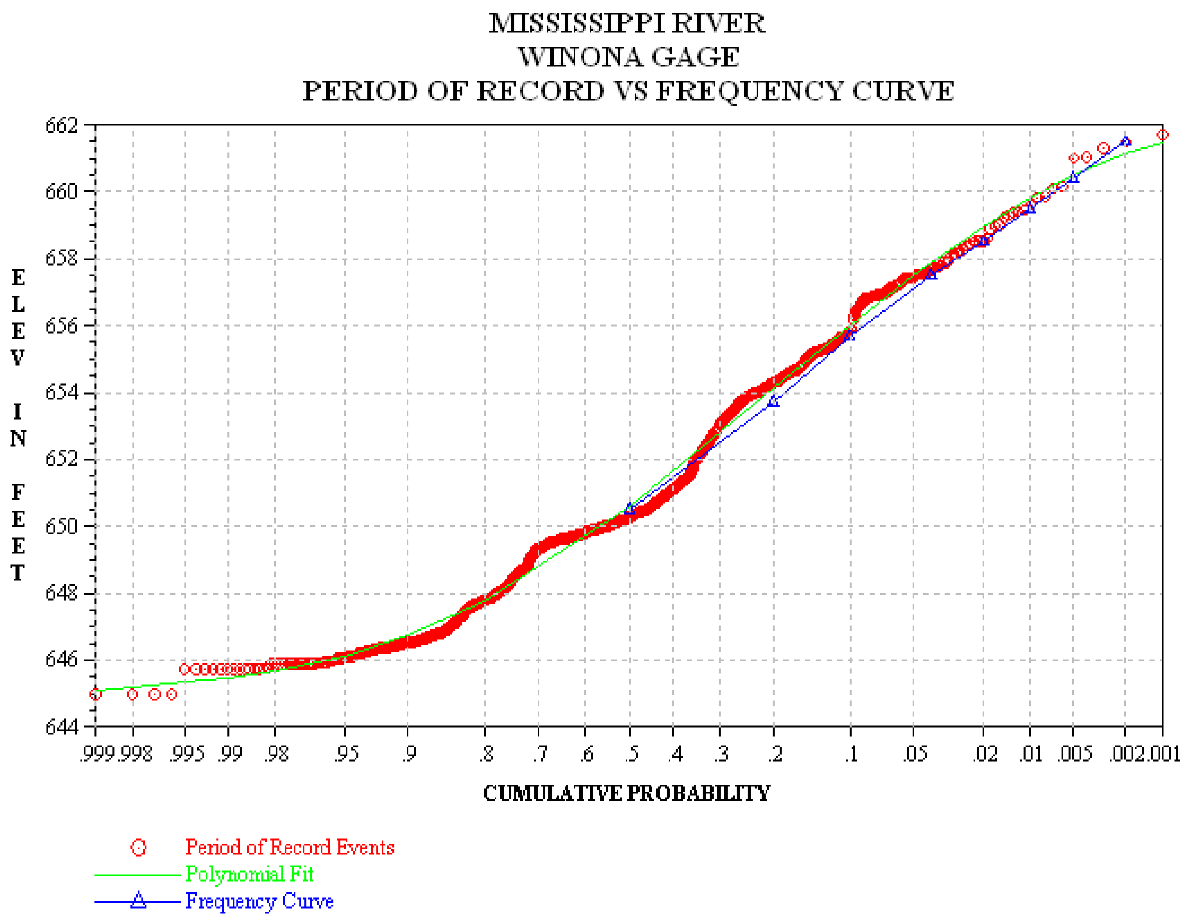
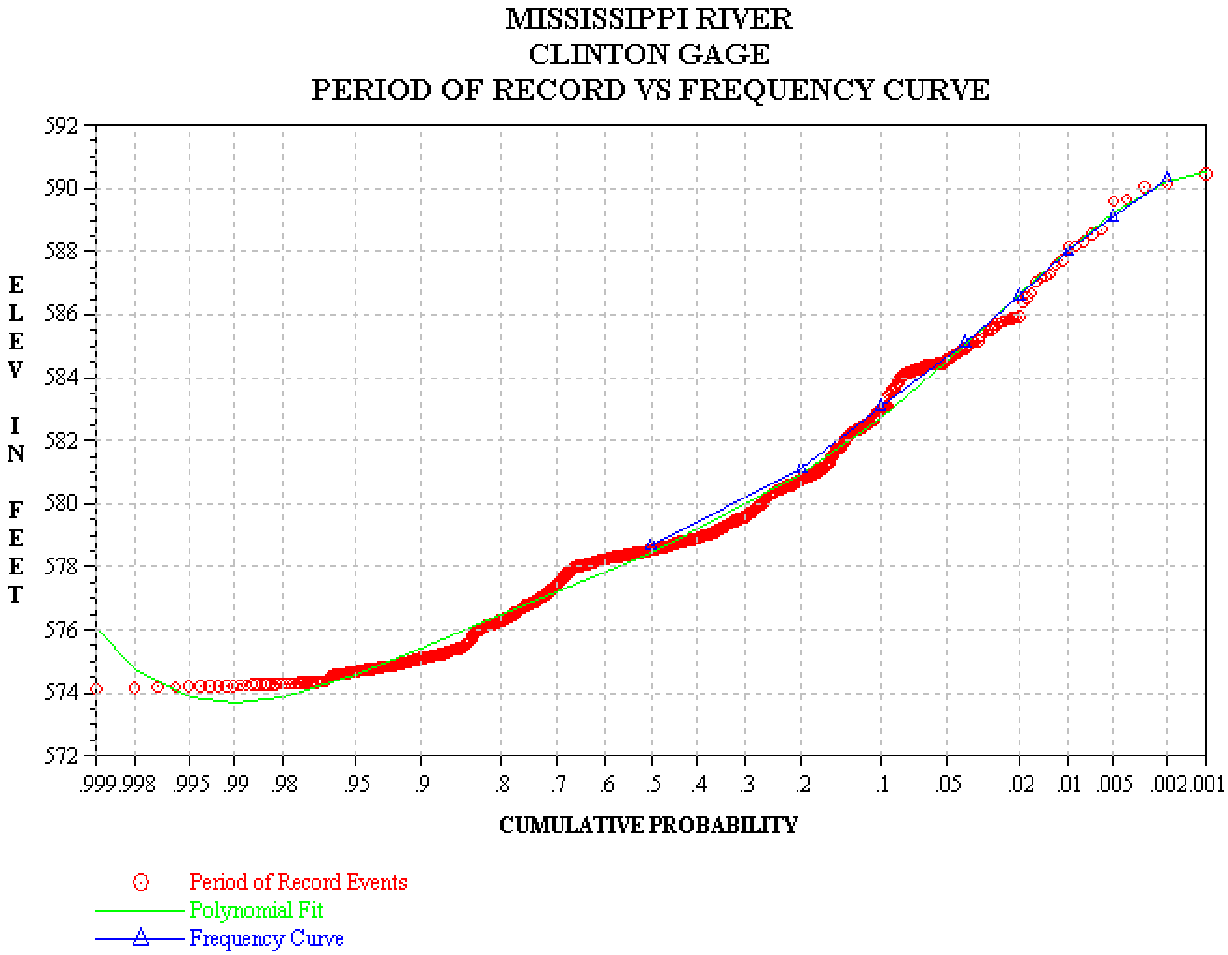

MISSISSIPPI RIVER
WINONA GAGE
PERIOD OF RECORD VS FREQUENCY CURVE
ELEV IN FEET
662
660
658
656
654
652
650
648
646
644
.999 .998 .995 .99 .98 .95 .9 .8 .7 .6 .5 .4 .3 .2 .1 .05 .02 .01 .005 .002 .001
CUMULATIVE PROBABILITY
Period of Record Events
Polynomial Fit
Frequency Curve

PLATE B-2


MISSISSIPPI RIVER
CLINTON GAGE
PERIOD OF RECORD VS FREQUENCY CURVE
ELEV IN FEET
592
590
588
586
584
582
580
578
576
574
572
.999
.998
.995
.99
.98
.95
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CUMULATIVE PROBABILITY
Period of Record Events
Polynomial Fit
Frequency Curve

PLATE B-3

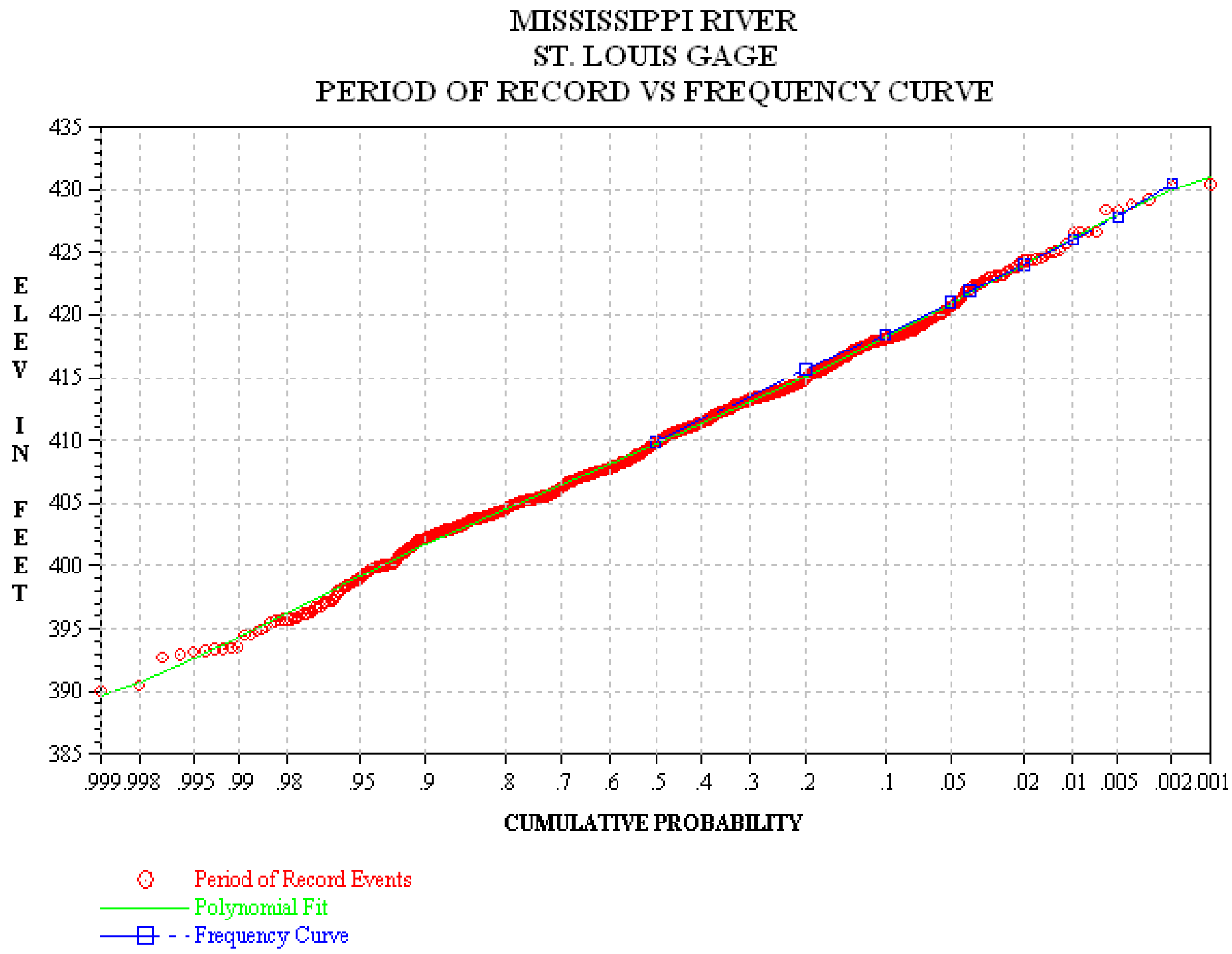
MISSISSIPPI RIVER
ST. LOUIS GAGE
PERIOD OF RECORD VS FREQUENCY CURVE
ELEV IN FEET
435
430
425
420
415
410
405
400
395
390
385
.999 .998 .995 .99 .98 .95 .9 .8 .7 .6 .5 .4 .3 .2 .1 .05 .02 .01 .005 .002 .001
CUMULATIVE PROBABILITY
Period of Record Events
Polynomial Fit
Frequency Curve

PLATE B-4

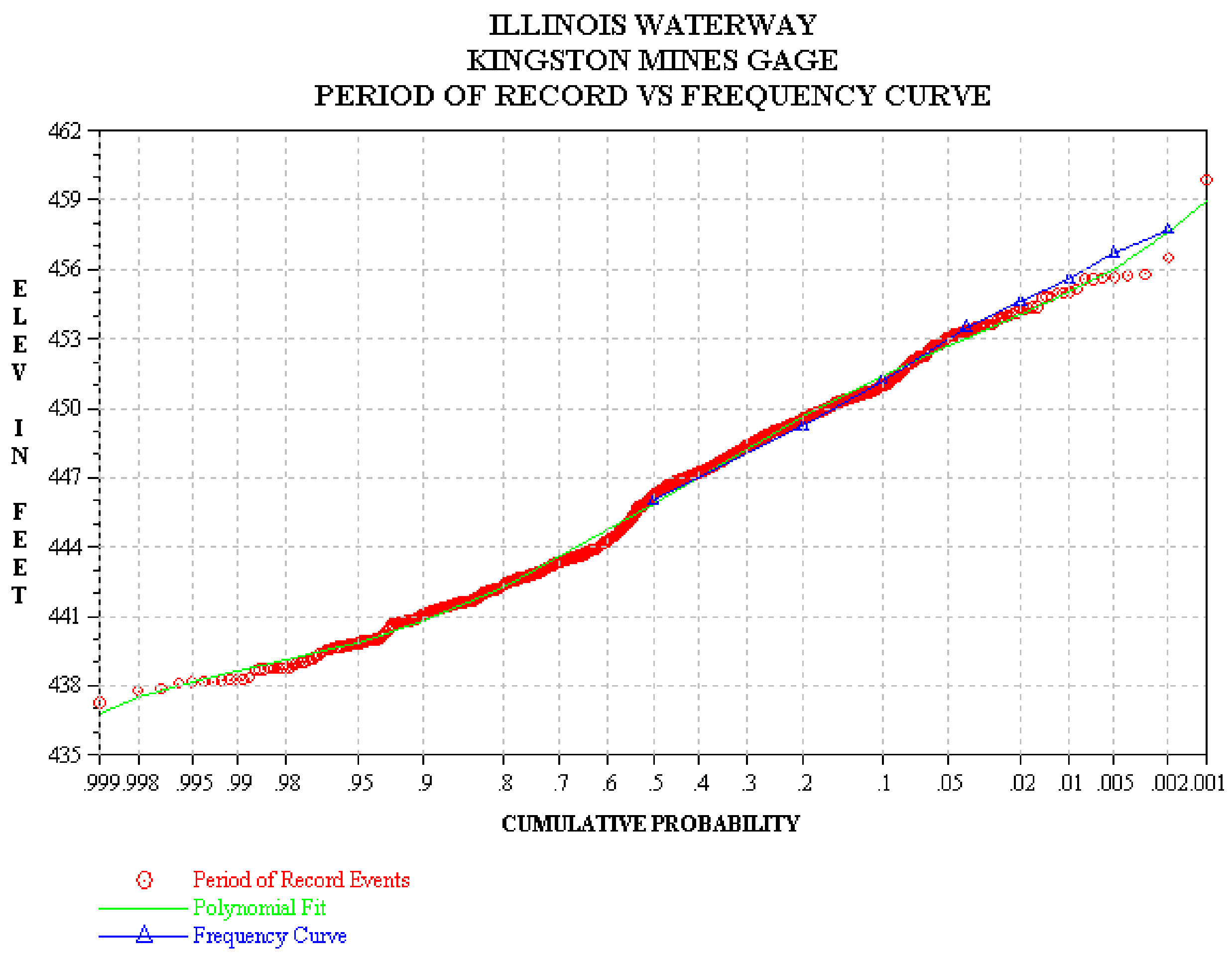
ILLINOIS WATERWAY
KINGSTON MINES GAGE
PERIOD OF RECORD VS FREQUENCY CURVE
ELEV IN FEET
462
459
456
453
450
447
444
441
438
435
.999
.998
.995
.99
.98
.95
.9
.8
.7
.6
.5
.4
.3
.2
.1
.05
.02
.01
.005
.002
.001
CUMULATIVE PROBABILITY
Period of Record Events
Polynomial Fit
Frequency Curve

PLATE B-5

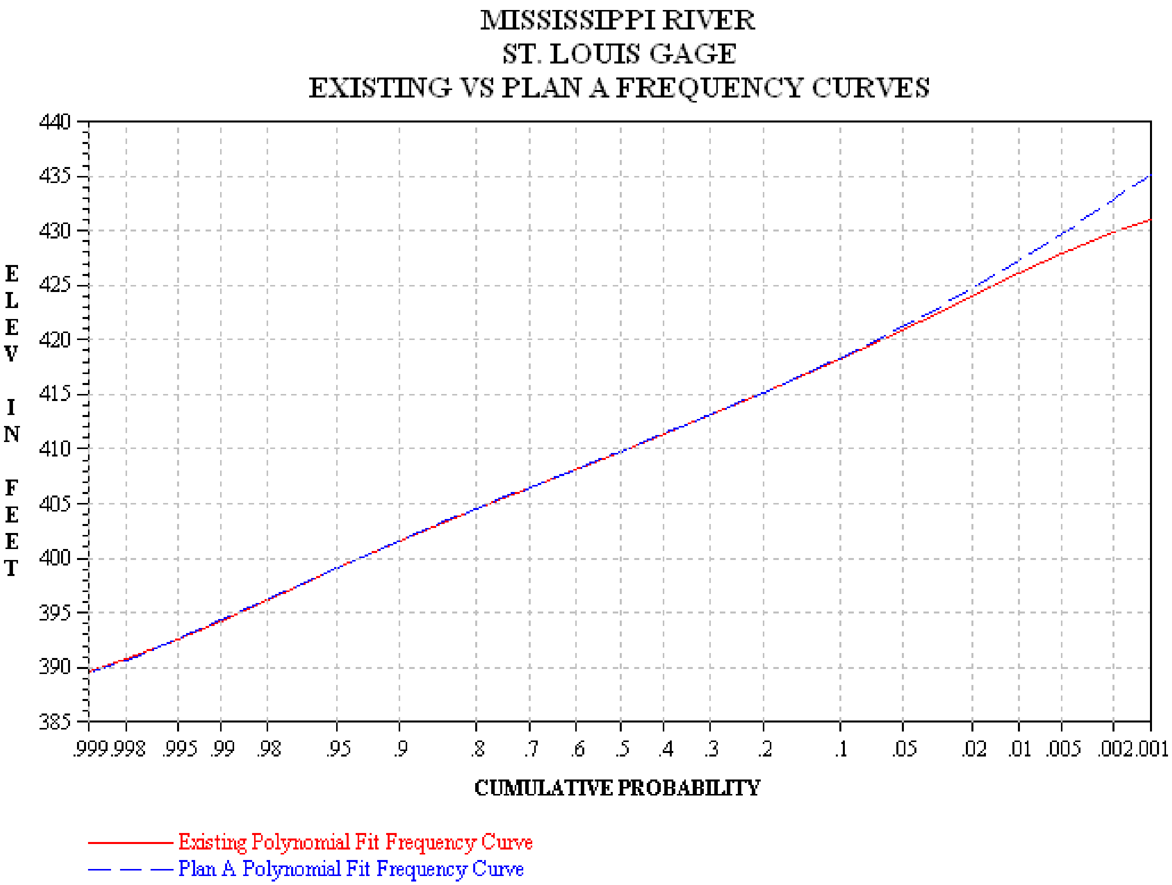
MISSISSIPPI RIVER
ST. LOUIS GAGE
EXISTING VS PLAN A FREQUENCY CURVES
ELEV IN FEET
440
435
430
425
420
415
410
405
400
395
390
385
.999 .998 .995 .99 .98 .95 .9 .8 .7 .6 .5 .4 .3 .2 .1 .05 .02 .01 .005 .002 .001
CUMULATIVE PROBABILITY
Existing Polynomial Fit Frequency Curve
Plan A Polynomial Fit Frequency Curve

PLATE B-6

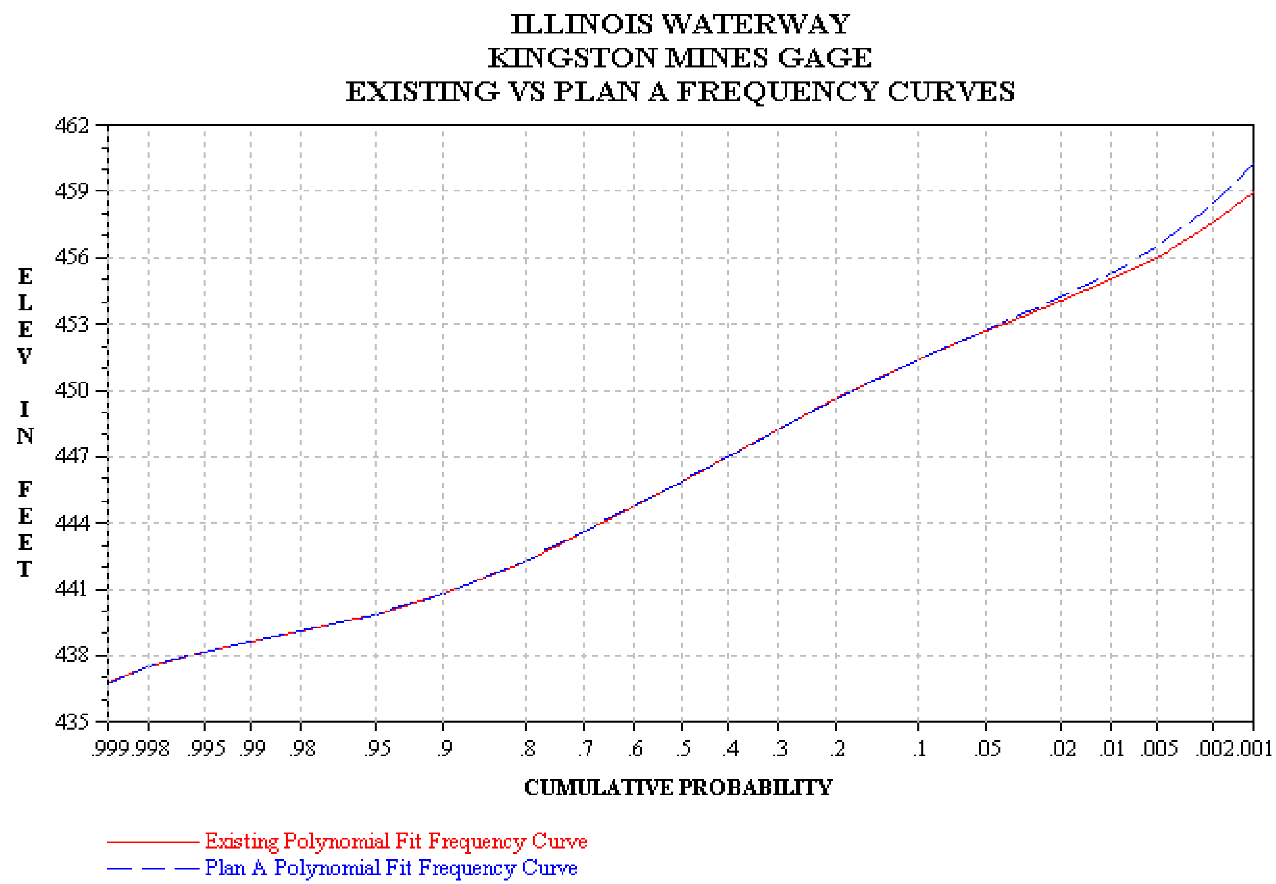
ILLINOIS WATERWAY
KINGSTON MINES GAGE
EXISTING VS PLAN A FREQUENCY CURVES
ELEV IN FEET
462
459
456
453
450
447
444
441
438
435
.999 .998 .995 .99 .98 .95 .9 .8 .7 .6 .5 .4 .3 .2 .1 .05 .02 .01 .005 .002 .001
CUMULATIVE PROBABILITY
Existing Polynomial Fit Frequency Curve
Plan A Polynomial Fit Frequency Curve

PLATE B-7

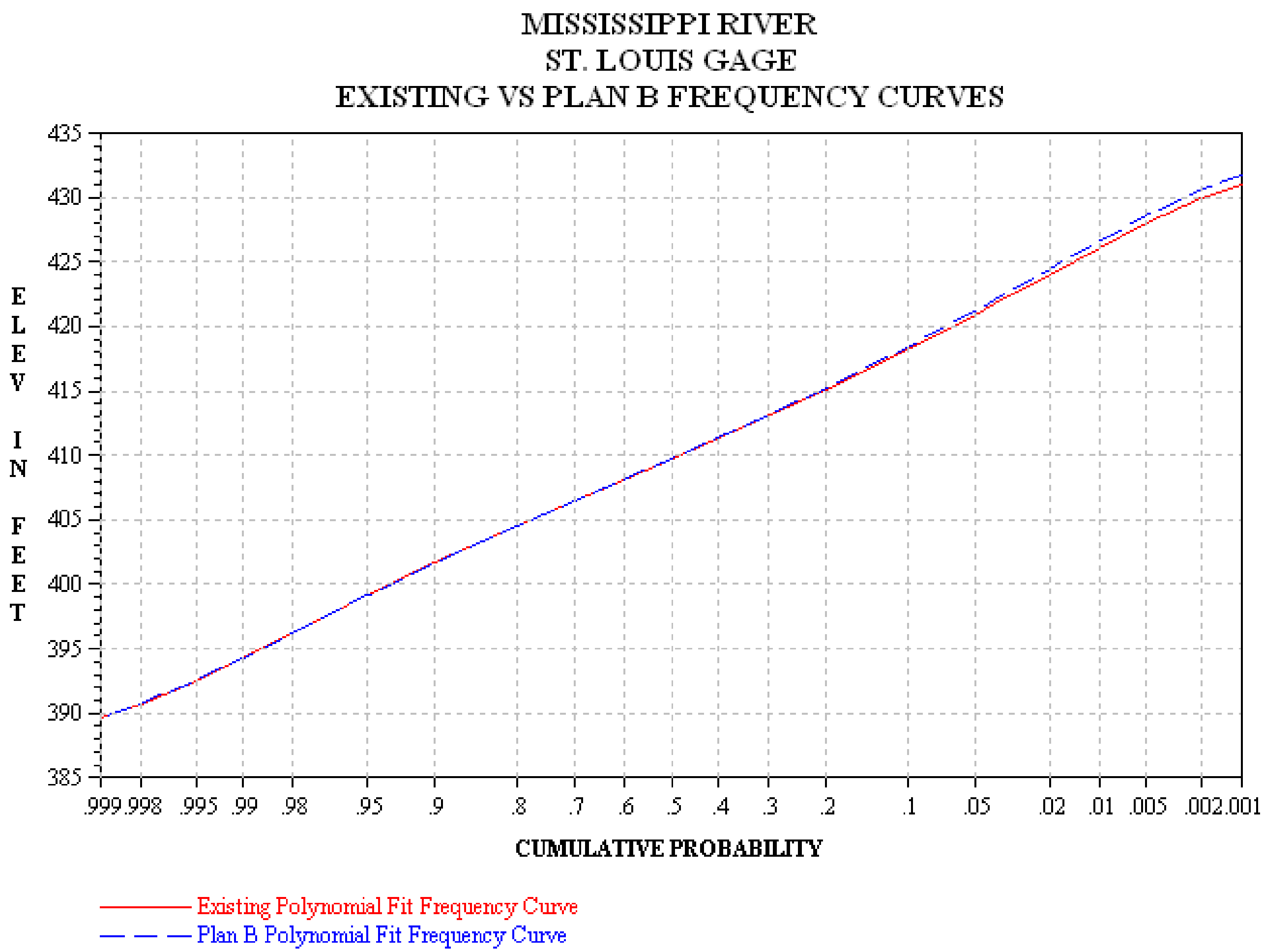
MISSISSIPPI RIVER
ST. LOUIS GAGE
EXISTING VS PLAN B FREQUENCY CURVES
ELEV IN FEET
435
430
425
420
415
410
405
400
395
390
385
.999 .998 .995 .99 .98 .95 .9 .8 .7 .6 .5 .4 .3 .2 .1 .05 .02 .01 .005 .002 .001
CUMULATIVE PROBABILITY
Existing Polynomial Fit Frequency Curve
Plan B Polynomial Fit Frequency Curve

PLATE B-8

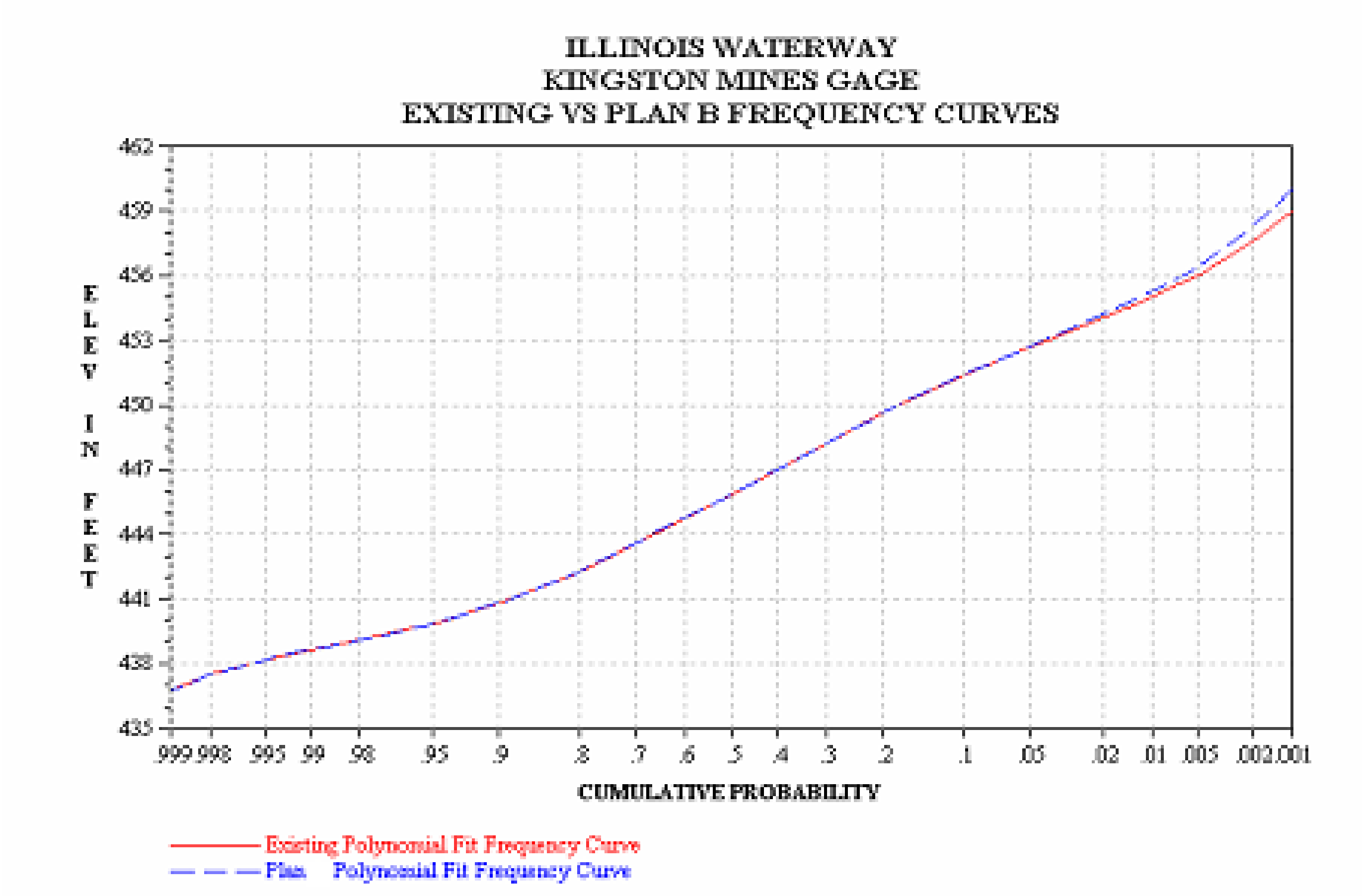
ILLINOIS WATERWAY
KINGSTON MINES GAGE
EXISTING VS PLAN B FREQUENCY CURVES
ELEV IN FEET
462
459
456
453
450
447
444
441
438
435
.999 .998 .995 .99 .98 .95 .9 .8 .7 .6 .5 .4 .3 .2 .1 .05 .02 .01 .005 .002 .001
CUMULATIVE PROBABILITY
Existing Polynomial Fit Frequency Curve
Plan Polynomial Fit Frequency Curve

PLATE B-9#