SECTION IV

MR&T OPERATION AND EMERGENCY ACTIVITIES

A. INTRODUCTION

Under the authority of Public Law 84-99, the Corps executed its responsibility to support local interests in all phases of flood fighting. The MR&T System was approximately 11 percent incomplete at the time of the 2011 Flood; however, in combination with extensive emergency flood fight efforts, it generally performed as designed.

Emergency flood fight measures included ringing sand boils, constructing water berms, blocking culverts and ditches to prevent inflow of floodwaters, constructing erosion control measures, and raising deficient sections of the mainstem Mississippi River Levee to authorized grade. Crest stages during the 2011 Flood varied between levels 9 feet below the Project Design Flood (PDF) flowline to stages exceeding the PDF flowline. For the first time, the Morganza, Bonnet Carré and BPNM floodways were operated during a single event. The BPNM Floodway operation was the first since 1937 and only the second in its history, while the Morganza operation was the first since 1973 and also the second in its history. The Bonnet Carré Spillway was operated for the tenth time in its history. Each of these floodway operations reduced stages by several feet, both downstream of the floodways and for varying distances upstream, while operations at many reservoirs also provided stage reduction benefits. Although backwater effect occurred on several rivers, none of the MR&T authorized backwater areas were operated during the 2011 Flood because river stages remained below their operation level and the backwater levees did not overtop.

The following sections summarize the plans used to guide operation of the MR&T System and the actions taken in response to the 2011 Flood. They also present the results of an assessment of the successes and vulnerabilities of each major MR&T System component based on the 2011 Flood. Later, the Summary and Conclusions Section presents a coordinated analysis of the conclusions that can be drawn from the overall systems perspective. The Recommendations Section compiles all recommendations, based on broad-based considerations and presents them within the context of the performance and operation of the entire system.

B. EMERGENCY OPERATIONS PLANS

Each District maintains an Emergency Operation/Action Plan for the operation of MR&T System components within its AOR. Water control structures are operated in accordance with approved Water Control Plans. These plans contain the process information, roles and responsibilities; decision criteria, communications guidance, and detailed information to address known trouble spots and the operation of a variety of features and activities specific to each district. They also include plans/manuals, flood fight rosters, standard operating procedures and phased flood fight deployment guidance. Emergency Operation Plans are generally reviewed and updated annually and as new information becomes available. MVD also maintains plans for actions and components for which it has operational or oversight responsibilities. In addition to Corps' plans, local levee districts, states, counties and similar authorities also have emergency plans that are used, adapted, and adjusted for each flood event. The Emergency Response community evaluates plans and continually incorporates new ideas and new information in preparation for flood seasons. All of these plans are tested during events like the 2011 Flood and the lessons learned are used to improve responses to future challenges. The significant issues that arose and the deficiencies and vulnerabilities exposed during the 2011 Flood are discussed along with the associated MR&T System components in Section IV.D.

C. FLOOD FIGHT SUMMARY BY DISTRICT

Each district knew, from experience with past high water events, where known trouble spots were and began monitoring these problem areas and remediating them as needed. This allowed the districts to respond more quickly to problems in new areas as well as the historic problem areas. Each district closely monitored and documented the issues with both new and historical trouble spots so that post-flood inspections and damage assessments would be well informed. The following sections summarize flood fight activities and related deficiencies and damages. Additional details are provided for each MR&T System component in the Appendices.

1. St. Louis District

a. Flood Fight Summary. MVS Commander, signed a Declaration of Emergency at 15:00 April 21, 2011, due to a significant flood threat on the Upper Mississippi River. This initiated Phase I of the MVS Emergency Response Plan. The MVS EOC was activated at Level I on April 21, Level II on April 25 and Level III on May 1 in response to rising water levels along the Mississippi River and at Wappapello Lake. Phase II of the flood fight began April 25 when the Mississippi River exceeded 59 feet on the Louisiana, MO gage. The MVS EOC returned to Level I activation June 20, and the flood fight ended June 23, when the stage at Louisiana receded below 19 feet. At that time, the MVS EOC was deactivated.

b. Funding Details

3112 MR&T Appropriation Direct	$ 687,000
3125 FCCE Emergency Operations	$1,540,000
Total Flood Fight	**$2,227,000**

c. Chronology of Flood Fight Activities. Table IV-1 shows the chronology of MR&T flood fight activities in the St. Louis District. All times are CDT.

Table IV-1. Chronology of MR&T Flood Fight Activities – St. Louis District

Date	River Events	MVS Events	Other Events
21-Apr	Louisiana stage exceeds 19 feet (forecast crest 21.0 on 27 Apr)	MVS Commander signs emergency declaration; MVS enters Phase I flood fight in Louisiana & Missouri, activates EOC to Level II, requests and receives $225k of 210 funds.	
24-Apr	Wappapello Lake elevation 361.87	Wappapello Lake- evacuated Greenville and Peoples campground; preparing to release 10,000 cfs when they reach elevation 380, in accordance with Water Control Plan.	
25-Apr	Wappapello Lake elevation 372.88	COL O'Hara visits Wappapello Lake	
26-Apr	Wappapello Lake elevation 382.65	Yesterday's rainfall threatens to push lake levels to exceed overflow section, el 397.74. MVS is evaluating two options - get a deviation from MVD Water Control to release more water now and/or flood fight the spillway. An additional inch of rain would make flood fight feasible; additional 2 inches of rain would make it a questionable option.	
27-Apr	Wappapello lake elevation 389.91	MVS working to construct rock dike to flood fight the spillway. Contract initiated 27 Apr	
28-Apr	Wappapello lake elevation 393.99	Rock berm will be raised to 398.5 by tonight. 16" pump will be placed to reduce water between rock berm and spillway.	
29-Apr	Wappapello lake elevation 396.39	Forecasted crest is 397.0. Two additional pumps will be placed to reduce the water between the rock berm and spillway. Rock dike has been degraded to el 397.3 from 398.5 after a deviation was disallowed by Dam Safety during the deviation coordination process.	
30-Apr	Wappapello lake elevation 396.63	Preparing for high water; moving equipment, materials, and supplies from Admin building to Visitors Center and Redman Creek picnic area. Redman Creek picnic shelter will be used as one of the command centers if Admin building becomes inaccessible. Personnel placing walls at the shelter. The drainage path for the predicted flow over the spillway is still being graded. Evacuation plans are in place and ready to be executed if/when needed.	
1-May	Wappapello Lake elevation is 396.63	Preparing for high water; rolls of plastic provided to field office. Media updated every 2 hrs	MG Walsh, congressional delegates Blunt and Emerson visit to SE MO
2-May	Wappapello Lake elevation 399.12	Rock berm overtopped at 0200. Project office evacuated but not threatened by discharge flows. Command Centers in Visitors Center and at Redman Creek being utilized. Lake stage at 1630 is 399.12. Spillway fully functioning w/ flows expected to increase from 22,850 to 25,700 cfs.	The state highway across the dam was destroyed along with the fiber optics and water lines going across the dam.
3-May	Wappapello Lake crests record level of 400.04	Spillway fully functioning with flows from 30,300 cfs.	MG Walsh visits Lake Wappapello
4-May	Wappapello Lake elevation- 399.81	Lake release 27, 200 cfs	Congresswoman Emerson visits Wappapello and Cape Girardeau area
5-May	Wappapello Lake elevation 398.48	Lake release 18,500 cfs, expected to be back to 10,000 cfs by Saturday. MVS working with MO Dept of Transportation in discussing re-opening downstream bridge/road.	Power lines are being re-established across the spillway.
6-May	Wappapello Lake elevation 398.09	Lake release 14,150 cfs. MVS continues to work with MO Dept of Transportation regarding re-opening of downstream bridge/road, scheduled for Sunday. Visitors Center has power. Open for public visits to observe the overflow.	Power lines re-established across the spillway.
7-May	Wappapello Lake elevation 397.60	Lake release 10,000 cfs	
8-May	Wappapello Lake elevation 397.06	Lake release 10,000 cfs	
9-May	Wappapello Lake elevation 396.77	Lake release 10,000 cfs.	Presidential disaster declaration DR-1980 for MO flooding

2. Memphis District

a. Flood Fight Summary. MVM Commander signed a Declaration of Emergency at 15:00 March 7, 2011, due to a significant flood threat on the Mississippi River, initiating Phase I of the Emergency Response plan of the MVM. The MVM EOC was activated at Level I on March 7 and Level III on March 14 in response to the rising water levels along the Mississippi River. Phase II of the flood fight began March 14 when the Mississippi River exceeded 52 feet on the Cairo, IL gage. The MVM EOC returned to Level I activation March 22, and the flood fight ended March 24, when the stage at Cairo receded below 49 feet, and the MVM EOC was deactivated.

MVM Deputy Commander signed a Declaration of Emergency on behalf of MVM Commander at 09:00 April 20, 2011, due to a renewed significant flood threat on the Mississippi River, reinitiating Phase I of the Emergency Response plan of the MVM. The MVM EOC was activated at Level I April 20 and Level III April 24 in response to the rising water levels along the Mississippi River. Phase II of the flood fight began April 24 when the Mississippi River exceeded 52 feet on the Cairo, IL., gage. Phase II 24-hour patrols began April 26 and continued until May 11. The MVM EOC began Level IV 24-hour operations April 26 and remained at this level of activation until May 12. The MVM EOC returned to Level I activation on May 29. The flood fight ended June 5, when Phase I monitoring of the White River was discontinued, and the MVM EOC was deactivated.

b. Funding Details

March Flood Fight

MR&T Total	**$118,000**
MRL Maintenance	$118,000
St. Francis Maintenance	$0
White River Maintenance	$0
FC&CE Total	**$310,000**
21M MRL – M	$310,000
21M St. Francis – M	$0
24M St. Francis – M	$0
March Subtotal:	**$428,000**

April-June Flood Fight

MR&T Total	**$7,591,000**
MRL Maintenance	$6,718,000
St. Francis Maintenance	$128,000
White River Maintenance	$745,000
FC&CE Total	**$8,100,000**
21M MRL – M	$2,355,000
21M St. Francis – M	$4,670,000
24M St. Francis – M	$1,075,000
April-June Subtotal:	**$15,691,000**

TOTAL FLOOD FIGHT:	**$16,119,000**

c. Chronology of Flood Fight Activities. Table IV-2 on pages IV-5 through IV-11 shows the chronology of flood fight activities in the Memphis District. All times are CDT.

Table IV-2. Chronology of Flood Fight Activities – Memphis District

Date	River Events	MVM Events	Other Events
26-Feb	Stage at Cairo exceeds flood stage (40')		
27-Feb	Cairo stage: 41.4		St. Johns Levee and Drainage District closes St. John's Bayou floodgates
7-Mar	Cairo stage exceeds 49' (forecast crest 50.5 on 3/11).	MVM Commander signs emergency declaration. MVM enters Phase I flood fight in Cairo, MO and Reelfoot-Obion areas, activates EOC to Level I. MVM requested and received $35k of 210 funds. Cairo Area reports sinkhole at 11th and Commercial in Cairo (later determined to be from city pumping operations at the 10th St. station); numerous pin boils along Hwy 51 in Future City.	
9-Mar	Cairo stage: 50.2 (forecast crest 52.0 on 3/13). Slide riverside on BPNM frontline levee (Sys. 16), Levee Mile 84/0+00.	Two slides on landside of BPNM setback levee (Sys 2, Seg. 10), LMs 34/22+85 and 34/24+35.	
10-Mar	Cairo stage: 50.8 (forecast crest 52.5 on 3/15).	Backwater inside BPNM Floodway over MO Hwy. WW. Slide at BPNM frontline levee enlarged.	
11-Mar	Cairo stage: 51.4	MVM requested and received $25k of 210 funds.	
14-Mar	Cairo stage: 52.6.	MVM enters Phase II flood fight in Cairo, MO and Reelfoot-Obion areas, activates EOC to Level III. MVM requested and received $250k of 210 funds. Pin/sand boils reported in Hickman sector at Island No. 8 in KY.	
15-Mar	Cairo stage: 53.0.	Numerous boils in Cairo sector along Hwy 51 (Sys.1, Seg. 2). Some flowing readily and transporting silt.	
18-Mar	Cairo crests at 53.41.	Sand boils reported near Island 8 in KY. (Sys. 3, Seg. 11, Levee Mile 6).	
20-Mar	Cairo stage: 53.1.	Sand boils reported near Island 8 in KY. (Sys. 3, Seg. 11, Levee Mile 8, 6, & 11)	
22-Mar	Cairo stage drops below 52	MVM ends Phase II flood fight in Cairo, MO and Reelfoot-Obion areas, lowers EOC activation to Level I	
24-Mar	Cairo stage: 51.3 (forecast to continue falling below 49)	MVM ends Phase I flood fight in Cairo, MO and Reelfoot-Obion areas, deactivates EOC. Stages would exceed Phase I levels in Memphis, West Memphis, Helena, and Clarksdale; Levee Districts and Wynne Area Office monitored water levels without initiating Phase I flood fight.	
3-Apr	Cairo stage drops below 40		
9-Apr	Cairo stage exceeds 40 again		
20-Apr	Cairo stage exceeds 49' again. Based on NWS forecast of 52 on April 30 (contingency of 58)	MVM Deputy Commander, signs emergency declaration on behalf of MVM Commander. MVM reenters Phase I flood fight in Cairo, MO and Reelfoot-Obion areas, activates EOC to Level I. MVM begins coordination calls with LRD. MVM requested and received $100k of 210 funds.	

Table IV-2. Chronology of Flood Fight Activities – Memphis District

Date	River Events	MVM Events	Other Events
21-Apr	Cairo stage: 49.8 (forecast crest 52.0 on 4/30). Forecast of daily rounds of moderate to heavy rains from Caruthersville to Hannibal including Ohio Valley. (4-8"thru 4/26). Cairo may expect 10 foot rise on gage NWS contingency forecast of 61.1 Cairo gage on 5/4.	Pin boils are active where noted in March flood fight (Cairo, Island 8). No change to levee slides noted in March.	
22-Apr	Cairo stage: 50.3 (forecast crest 52.0 on 4/30)		LRD began increasing Kentucky-Barkley discharges a total of 50,000 cfs and will continue thru the weekend to clear storage space in the reservoirs
23-Apr	Cairo stage: 51.0		
24-Apr	Cairo stage: 52.4 (forecast crest 58.5 on 5/3) St. Francis, Ark., stage exceeds 24 Up to 6"over lower Ohio during past 24 hours. Forecast predicts 8"of rain over next 5 days. Tornado touches down near Cairo Regional Airport.	MVM enters Phase II flood fight in Cairo, MO, and Reelfoot-Obion areas, Phase I in Upper St. Francis area. EOC activated to Level III. Coordinated coordination that had begun in March with City of Cairo to get city pumps operational.	Tennemo private levee artificially crevassed
25-Apr	Cairo stage: 54.6 (forecast crest 60.0 on 5/3) St. Francis, Ark., stage: 25.02 3-8" rain forecast north of Ark City (includes Ohio Valley).	MVM enters Phase II flood fight in Upper St. Francis area. Cairo team patrolling levees, floodwalls, pump stations and all sand boil locations. Barge loading commences, completed at 19:30. MVM press release "COE prepares to operate BPNM". Initiated Dutchtown, MO, emergency levee plan, contracting process. Seepage occurring under and through Cairo floodwall. Street collapse from March at 11th and Commercial in Cairo expanded.	Mississippi County Sheriff's Department declared a state of emergency in the Floodway and orders evacuation. KMOX radio reports Gov. of MO objects to BPNM operation.
26-Apr	Cairo stage: 56.5 (forecast crest 61.0 on 5/3, remain above 60 for 10 days). St. Francis, AR. stage: 26.0 2-5"expected from Ark City to Cape on 4/26-4/27; another 1.5 over Ohio 5/6-5/7.	Cairo, MO and Reelfoot-Obion areas begin 24-hour levee patrols. EOC activation increased to Level IV, 24-hour operation. MVM determines mainline levee at Lake County will not pass flood of 61' on Cairo gage and makes recommendation to raise low spots in the levee near Tiptonville 2' using 12K tons of crushed limestone. MVD Commander orders movement of barges to Hickman Harbor; M/V Mississippi departs Ensley Engineer Yard. MVD Commander orders land-based crews to deploy 4/27 and prepare Floodway for operation. MVM requested and received an additional $400k of 210 funds. At Fulton Co., pin boils continue to develop in the Island 8, KY area and they are ringed as necessary. Two sand boils flowing at Mile 6. Three large boils flowing at Mile 7 near existing house. Two boils flowing at Mile 8. Levee Board delivering sand bags at each location. Sand boils at Future City (Sys. 1, Seg. 5) beginning to pipe material.	Floodway evacuation continues. MO National Guard is assisting with this effort and preventing unauthorized personnel from entering floodway. Dyer County Little Levee board approved plan to intentionally breach levee as it will overtop when Caruthersville reaches 44 feet.

Table IV-2. Chronology of Flood Fight Activities – Memphis District

Date	River Events	MVM Events	Other Events
27-Apr	Cairo stage: 58.0 (forecast crest 60.5 on 5/1). St. Francis, Ark. stage: 26.5 1-3"expected between Ark City and Cape, with heaviest over Tenn/Cum. Another rain event expected over MO/ARK/lower OH on 4/30-5/1.	M/V Miss. arrives at Hickman Harbor (will take 6 hours to position at 1st loading site. MVM establishes Joint Information Center in Sikeston, MO, staffed 07:00-19:30 daily. Contractor begins delivery of rock for Dutchtown emergency levee.	East Prairie public meeting; Rep. Emerson (MO-8), Sen. Blunt (MO), Sen. McCaskill (MO) sent letter to president looking for alternative
28-Apr	Cairo stage: 58.7 (forecast crest 60.5 on 5/1). St. Francis, Ark. stage: 26.8 Memphis stage exceeds 37	Memphis, and West Memphis areas entered Phase I activities. M/V Miss. continues to hold at Hickman. All 46 access wells located and uncovered. MVM requested and received additional $740k of 210 funds. Major sand boil showed up west of the Cairo water plant and 500' from the floodwall. Operations to ring it went on through the night. 40-man construction crew delivered 4000+ cy of fill to construct ring. Appears to be piping less material and under control.	Mayor urging people to evacuate Cairo. State of MO presents request for Temporary Restraining Order (TRO) before US District Court Judge. Dyer Co. (TN) Little Levee artificially breeched after board approves action, with MVM concurrence. Private levee inside BPNM overtopped.
29-Apr	Cairo stage: 59.0 (forecast crest 60.5 on 5/1) Memphis stage: 38.4 St. Francis, Ark. stage: 26.8 Helena stage exceeds 46 Des Arc stage exceeds 25	Memphis and West Memphis areas entered Phase II activities, Clarksdale, Helena and White River areas entered Phase I. The Engineer Research & Development Center explosives team and MVM pump crew on site and awaiting further instructions. MVM Commander holds news conference at BPNM—all prepared but still holding. MVM requested and received an additional $650k of 210 funds. MVM requested and received an additional $90k of 240 funds. Numerous sizeable sand boils at Fulton Co. (Sys. 3, Seg. 11). Sheep's Ridge spur levee (Tiptonville, TN) breeches, 75' gap, 5.5' initial head differential.	US District Court Judge denies TRO. MO appeals to 8th Circuit Court of Appeals. MO NG arrives in Caruthersville to monitor floodwall. 108 USGS on site in support of Floodway operation; sheriff, state police, NG, and private security in place. USGS place sensors in Floodway. Benyaurd and quarter boats arrive.
30-Apr	Cairo stage: 59.1 (forecast crest 60.5 on 5/3) St. Francis, Ark. stage: 26.4 Memphis stage: 38.4 Helena stage: 46.6 Des Arc stage: 25.1 Front stationary along Ohio and Ark rivers 4/30-5/2. 5 day QPF 3.5-7.5"from Helena-Chester.	MVM engineering assessment to MVD Commander; 3rd large boil at Cairo and more at Fulton Concerns about stress, advising evacuation of Cairo. MVM Commander recommends move to H-21 (move barges to levee). MVD Commander orders movement to H-24 (move barges to Wickliffe from Hickman). M/V Miss. arrives Wickliffe 22:00. Street collapse on Commercial Ave between 11th and 12th Streets is still expanding with the street closed off completely. Two large sand boils were found in the bottom of one of the holes. A load of sand bags was dumped into the hole downstream of the sand boils. Backwater in BPNM floodway over MO Hwy. 80.	8th Circuit Court denies State of MO TRO appeal. Evacuation of floodway completed. City of Cairo issues mandatory evacuation.

Table IV-2. Chronology of Flood Fight Activities – Memphis District

Date	River Events	MVM Events	Other Events
1-May	Cairo stage: 59.7 (forecast crest of 61.5 on 5/5) St. Francis, Ark. stage: 26.0 Memphis stage:40.9 Helena stage: 48.03 St., Francis, Ark. stage: 26.0 Lake City stage exceeds 12 Des Arc stage:29.9 Stage at Cairo surpasses previous record of 59.51 at 02:00. 3-5"over Ohio next 24 hours. Bill Frederick reports that Cairo will surpass 60 in about 4 hours. NWS concerned localized	White River area enter Phase II, Lower St. Francis area enters Phase I. MVD Commander directs loading of pipes at 1630. Severe thunderstorms and lightning delay loading. Press conference at BPNM with Gov. of MO at 1900. Contractor began operation to supply material for the water berm near Fulton County Levee Mile 7. Seepage reported in Caruthersville, but no pin/sand boils.	Supreme Court denies request by State of MO to hear TRO. Memphis – Shelby Co. Airport Authority constructs 3-5' high temporary berm on 2nd St. to protect Dewitt Spain Airport.
2-May	Cairo stage: 61.0 at 07:00 (forecast 63.5 on 5/5). Cairo stage: 61.6 at 19:00 Cairo stage: crest of 61.72 at 22:00. BPNM Floodway operated. Cairo stage: 61.3 at 23:00, 0.4 foot stage drop despite rising river in other locations. Memphis stage: 42.1 Helena stage: 49.3 St. Francis, Ark. stage: 26.9 Lake City stage: 13.5 Des Arc stage: 33.5 2-4" last night, additional 2-2.5 forecasted today.	Helena, Clarksdale, and Lower St. Francis areas enter Phase II. Closely Monitoring the Commerce to Birds Point Levee for rising water levels. Len Small private levee is placing additional stress on the Commerce to BP levee. Received word that the Len Small levee has overtopped and possibly has been breached. Weather breaks; crews begin loading pipes at 07:20. MVM Commander briefs Walsh on Upper St. Francis overtopping potential, Fulton Co water berm, and Caruthersville overtopping potential. MVD Commander announces decision to operate Floodway at 18:30 press conference. BPNM artificially crevassed at 22:00 CDT. Frederick delivers new NWS forecast 60.5 on 5/3, 60.0, 59.9, 59.7, 59.4 on 5/7 (Deborah Lee (LRD) later reports that Cairo gage would have hit 66.73 without BPNM and KY/B ops and 65.5 without KY/B only, Banks reports that Commerce levee would have overtopped without BPNM and KY/B operation. Fuse plug levee begins overtopping at 07:00. MVM requested and received an additional $30k of 210 funds.	Blunt, Emerson and McCaskill send letter to McHugh and Grisoli asking the Corps to put the levee back as soon as possible if the BPNM floodway is operated. MVS commander reports that rock berm overtopped at emergency spillway at Wappapello. MG Peabody reports Ohio River situation deteriorating at Smithland and Paducah; Smithland mayor ordered evacuation; Patoka reservoir reaching spillway crest. Len Small Levee (IL) overtopped, breeched. Presidential disaster declaration DR-1975 for AR flooding (Craighead Co. not declared). Powers Island Private Levee (MO) breached.
3-May	Cairo stage: 60.5 Memphis stage: 43.5 Helena stage: 50.7 St. Francis, Ark. stage: crest at 27.25 Lake City stage: crest record 14.37 Des Arc stage: 35.8 Floodway operation inflow of 404,000 cfs reported (maximum); outflow 130,000 cfs)	MVM reports Cairo boils under control, Fulton Co water berm 3/4 complete. Inflow/outflow #2 near New Madrid opened at 12:37.	Barnett reports 25 landowners have filed suit against the Corps for taking of land

Table IV-2. Chronology of Flood Fight Activities – Memphis District

Date	River Events	MVM Events	Other Events
4-May	Cairo stage: 59.8 (original forecast prior to opening was 62.8 this a.m.) Memphis stage: 44.3 Helena stage: 51.8 St. Francis, Ark. stage: 27.2 Lake City stage: 14.1	MVM Commander reports 400 kcfs going into floodway; 17 kcfs out through #2 and 113kfcs thru gap.	Presidential disaster declaration DR-1976 for KY flooding. MO NG constructed rock dike to prevent overflow water from Ditch 81 from inundating homes near Hornerville, MO.
5-May	Cairo stage: 59.6 (river would have crested at 63.0 this morning without BPNM operation) Memphis stage: 45.1 Helena stage: 51.6 St. Francis, Ark. stage: 27.2 Lake City stage:13.7 Des Arc stage: 38.4	Tiptonville and Caruthersville 1 foot of freeboard, building 3' high setback levee at Caruthersville and pump to combat concerns about wave wash and overtopping. MO NG proposal to increase wall height was evaluated and deemed unsafe. Fulton Co. water berm complete and working as designed; Cairo boils in stabilized condition. Inflow/outflow #1 opened using alternative explosive agent at 14:35. Contractor placed gravel to raise low spots of St. Francis levee south of Lake City. Contractor delivered 1,000 tons of gravel to raise White River levee near Biscoe, AR 18". New slide reported on riverside of setback levee (Sys. 2, Seg. 9) Levee Mile 12/42+50. Numerous small sand boils noted at Ensley Levee in Memphis (Sys.7, Seg. 24).	Due to freeboard issues at Caruthersville, CG to close Miss R. to navigation at 1200 on 5/6 near Caruthersville for 8 days. (Closure deferred until stages reach 48.0 on Caruthersville gage; river crested at 47.61 on 5/7). AR DOT closed I-40 at White River due to high water. Temporary berm constructed by Memphis–Shelby Co. Airport Authority on 2nd St. breeched after water mail broke under berm; Dewitt Spain Airport flooded.
6-May	Cairo stage: 59.4 New Madrid stage: record crest of 48.35 Memphis stage: 45.6 Helena stage: 53.6 St. Francis, Ark. stage: 27.0 Lake City stage: 13.5 Des Arc stage: 39.2	MVM ends Phase II flood fight in Lower St. Francis area. Contractors continued delivery of materials to raise low spots in the TN levee near Tiptonville (Sys. 3, Seg. 13). West Memphis team reports two large sand boils, numerous pin boils, and small slides at Levee Mile 198 (Sys. 2, Seg. 17). White River overtops Sys. 15, Seg. 51 north of Biscoe, AR, flooding agricultural land.	
7-May	Cairo stage: 59.0 Caruthersville stage: record crest of 47.61 Memphis stage: 46.8 Helena stage: 54.5 St. Francis, Ark. stage: 26.7 Des Arc stage: record crest of 39.43 Lake City stage: 13.4		
8-May	Cairo stage: 58.7 Caruthersville stage: 47.4 Memphis stage: 45.5 Helena stage: 55.2 St. Francis, Ark. stage: 26.1 Des Arc stage: 38.9 Lake City stage: 13.2	MVM Commander reports that Memphis flooding on news is backwater flooding from Wolf and Loosahatchie rivers. MVM requested and received an additional $600k of 210 funds. Floodway inflow matching outflow indicating that volume is starting to tip toward outflow.	

Table IV-2. Chronology of Flood Fight Activities – Memphis District

Date	River Events	MVM Events	Other Events
9-May	Cairo stage: 58.3 Memphis stage: 47.8 Helena stage: 55.9 St. Francis, Ark. stage: 25.5 Des Arc stage: 38.0 Lake City stage: 13.0	White River no longer overtopping Sys. 15, Seg. 51 near Biscoe, AR.	Presidential disaster declaration DR-1979 for TN flooding. Presidential disaster declaration DR-1980 for MO flooding. AR DOT reopens eastbound lanes of I-40 at White River after it was closed because of high water.
10-May	Cairo stage: 57.8 Memphis stage: crest of 48.03 Helena stage: 56.2 Des Arc stage: 36.9 St. Francis, Ark. stage: 25.1 Lake City stage: 12.6	MVM ends Phase II flood fight in Upper St. Francis.	
11-May	Cairo stage: 57.3 Memphis stage: 47.6 Helena stage: 56.4 Des Arc stage: 35.7 St. Francis stage drops below 24 Lake City stage drops below 12	24-hour levee patrols end in Cairo, MO and Reelfoot-Obion areas. MVM ends Phase I flood fight in Lower St. Francis area. Dutchtown, MO emergency levee removed.	Presidential disaster declaration DR-1983 for MS flooding. AR DOT reopens all lanes of I-40 at White River after it was closed because of high water.
12-May	Cairo stage: 56.7 Helena stage: crest at 56.59 Des Arc stage: 34.7 St. Francis stage: 24.5	Crest has passed MVM and river is now in a steady fall. System still under a lot of stress. EOC lowers activation to Level III (12-hour operations).	
13-May	Cairo stage: 56.0. Helena stage: 56.5 Des Arc stage: 33.7 St. Francis stage: 24.2	New sand boils discovered piping material near Mound City, IL (Sys. 1, Seg 2). Sand boils continue to develop in Caruthersville, MO.	
14-May	Cairo stage: 55.2 Helena stage:56.4 Des Arc stage: 32.8 St. Francis stage: 24.4	Sand boils continue to develop Levee Mile 90-92 of Sys. 8, Seg. 26 (Rena Lara area). Levee District constructed several water berms after ringing with sandbags failed to contain the boils.	
15-May	Cairo stage: 54.4 Helena stage: 55.9 Des Arc stage: 31.9 St. Francis stage: 24.2	Sand boils continue to develop behind Ensley Levee (Sys. 7, Seg. 24).	MODOT closes right northbound and southbound lanes of I-55 miles 58-60 because of backwater from St. Johns Bayou over the road.
16-May	Des Arc stage: 31.0 St. Francis stage drops below 24	MVM ends Phase I flood fight in Upper St. Francis area.	
17-May	Des Arc stage: 30.1		
18-May	Cairo stage drops below 52 Clarendon gage (White River) drops below 35	MVM ends Phase II flood fight in Cairo, MO, Reelfoot-Obion, and White River areas.	

Table IV-2. Chronology of Flood Fight Activities – Memphis District

Date	River Events	MVM Events	Other Events
19-May	Cairo stage: 51.3		St. John's gates open at 02:00.
21-May	Cairo stage drops below 49 Memphis: 40.3 Helena: 52.2	MVM ends Phase I flood fight in Cairo, MO and Reelfoot-Obion areas.	
22-May	Memphis: 39.1 Helena: 51.4	MVM ends Phase II flood fight in Memphis and West Memphis areas.	
24-May	Memphis stage drops below 37	MVM ends Phase I flood fight in Memphis and West Memphis areas.	
26-May	Helena stage drops below 48	MVM ends Phase II flood fight in Helena and Clarksdale areas. MVM requested and received an additional $520k of 210 funds.	
28-May	Helena stage drops below 46	MVM ends Phase I flood fight in Helena and Clarksdale. EOC ends Level III activation, returns to Level I.	
29-May	Des Arc: 27.8	All gages below flood stage or falling with no issues.	
2-Jun	Cairo stage: 46.0	Water stops flowing into the Floodway inflow crevasse.	
5-Jun	Des Arc stage: 28.1	MVM ends Phase I flood fight monitoring in White River area, deactivates EOC.	
7-Jun	Cairo stage drops below flood stage (40)		Presidential disaster declaration DR-1991 for IL flooding.
23-Jun	Cairo stage: 39.8	MVM completes construction of emergency berm at BPNM center crevasse to EL 301.0 to prevent rising river from reentering Floodway.	
24-Jun	Cairo stage exceeds flood stage (40)		
30-Jun	Cairo crests at 41.94 Helena stage drops below flood stage (44)	Emergency berm prevents water from reentering Floodway	
3-Jul	Cairo stage drops below flood stage (40) for last time until 12/2/11		

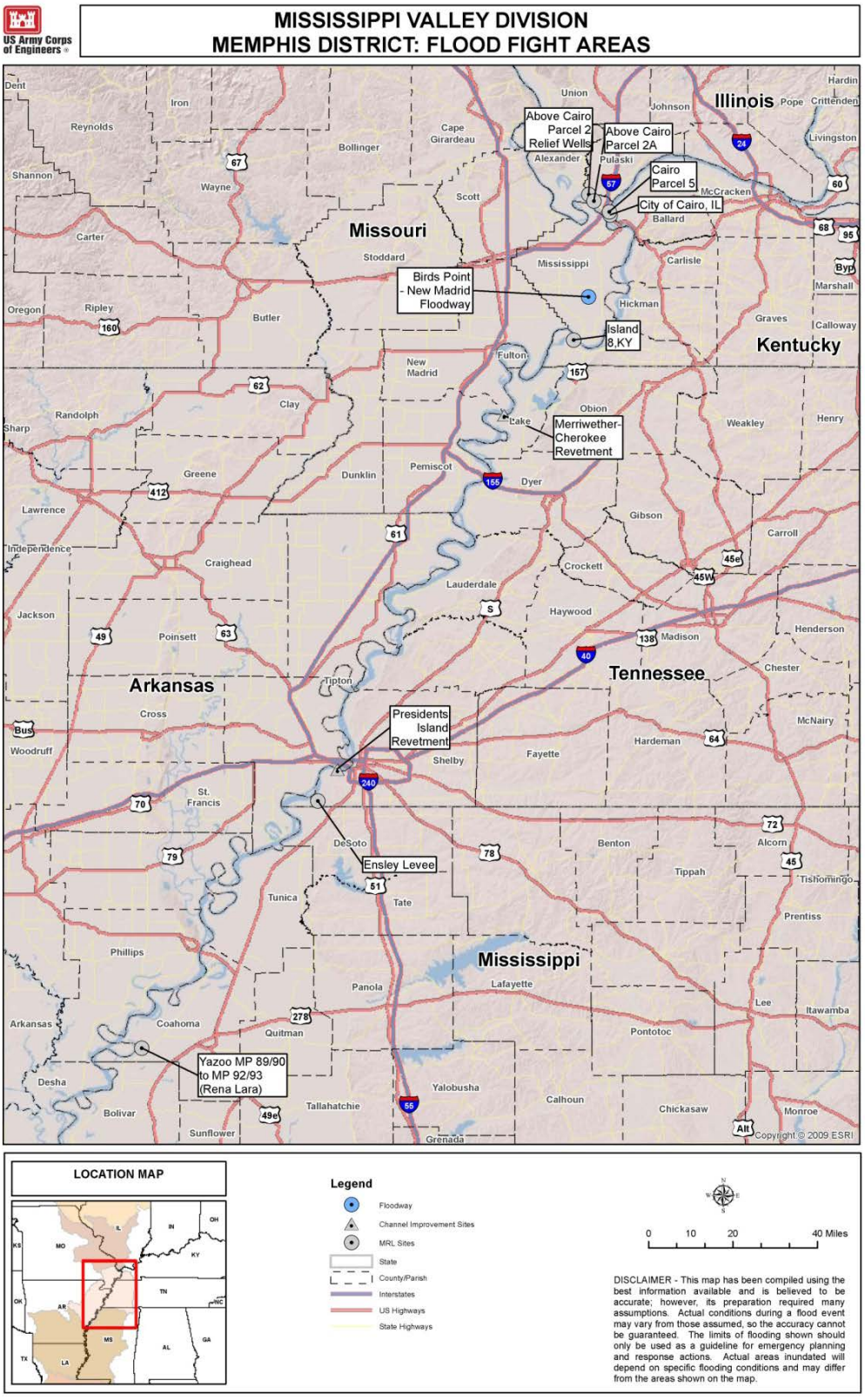


Figure IV-1. Key Flood Fight Locations in the Memphis District

d. Key Flood Fight Locations

i. City of Cairo, IL. Known seepage issues existed in Cairo (figure IV-1) near System #1, Segment #3, levee mile 8/30+48 [(Ohio River, right descending bank (RDB)]. During the 2011 Flood, major seepage in the form of three high energy sand boils with sand cones from 8 to 15 feet in height occurred in this area. Major flood fighting efforts were required starting at approximate river stage reading of 52.3 feet (10-year event) and higher. A history of repeated very large, high energy sand boils were recorded in this area starting at river stages of 54 feet in 1995, 1997, 2002 and 2011. Throughout the flood fight, issues were noted with the city being unable to operate pumping stations due to poor maintenance. This resulted in localized flooding due to impounded rainwater near the inoperable pumps.

ii. Cairo, IL, Parcel 5. During the 2011 event, major seepage was observed near Mound City and Cairo near System #1, Segment #2 (Ohio River, RDB) in the form of multiple large, high energy sand boils in the sump area of the Goose Pond Pumping Station. Historically, a great number of sand boils have been observed here starting at river stages of 52 feet during high water events exceeding the 10-year event. Considering the number and size of the sand boils, the only means of fighting the uncontrolled seepage in this area is to increase the depth of water within the sump area of the Goose Pond pumping station and flood adjacent lands. During the 2011 event, this strategy resulted in some flooding of adjacent neighborhoods.

iii. Above Cairo, IL, Parcel 2A. Major seepage was observed near Future City and Cairo near System #1, Segment #5 [(Mississippi River, left descending bank (LDB)] in the form of hundreds of small to medium sand boils during the 2011 Flood. Most of these boils had throat diameters of greater than 4 inches and cone diameters of 3 to 6 feet or greater. During the 2011 event, significant flood fighting was required starting at an approximate river stage of 52.3 feet (10-year event) and higher. A history of hundreds of medium to large sand boils within 50 feet of the toe of the levee are recorded for every event exceeding the 10-year event. Considering the number and size of the sand boils, the only means of flood fighting the uncontrolled seepage in this area is to establish the necessary height of water within the ditches and culverts near Highway 3. Only a relatively low head can be maintained however, without flooding the highway.

iv. Fulton Co., KY, Island 8. Seepage was observed in System #3, Segment #11 from levee mile 1/0+00 to 15/0+00 near Island 8 (Mississippi River, LDB) during the 2011 event. From mile 5/35+00 to mile 15/0+00, the majority of the area had heavy seepage with pin boils and small boils with at least 3 areas having large to large high energy boils. This area required significant flood fight efforts to ensure and maintain the integrity of the levee. Multiple large to very large high-energy sand boils approximately 100 feet from levee toe and three large sand boils at the levee toe were flood fought in mile 5. A rock dike was installed and the area was flooded (water berm) to control seepage here when the stage exceeded 59 feet.

v. Birds Point New Madrid Floodway. The Floodway was operated for only the second time in its existence in 2011. The inflow at Birds Point was artificially crevassed May 2 at 22:00, at a stage of 61.72 feet. Inflow/Outflow #2 near New Madrid was artificially crevassed May 3 at 12:37, and inflow/outflow #1 near Seven Island Conservation Area was artificially crevassed May 5 at 14:35 (all times CDT). Operation lowered the stage at Cairo by 0.5 foot in the first hour, and lowered the expected crest by 3.5 feet. Maximum flow through the Floodway was 403,000 cfs. Water ceased entering the inflow crevasse June 3, 30 days after operation. A temporary berm was constructed in June to prevent water from reentering the Floodway. A detailed description and timeline for the operation of the floodway is provided in Section IV.E of this report.

vi. President's Island, Memphis, TN. Bank failure and scour occurred at about RM 732 (LDB) where the river attempted to straighten the bend at President's Island. Top bank scour was 2,500 feet wide and 20 to 25 feet deep. Overbank scour was approximately 50 feet deep and extended inland approximately 3,000 to 3,500 feet.

vii. Sheep's Ridge Road / Meriwether-Cherokee Revetment, Tiptonville, TN. Bank failure and breach of spur levee occurred at about RM 869 (LDB) where the river attempted to straighten a bend. Top bank scour was approximately 2,200 feet wide and 50 to 60 feet deep. Overbank scour was approximately 80 feet deep and extended inland for 3,000 to 4,000 feet.

viii. Rena Lara, MS. Seepage was observed in System #8, Segment #26 from levee mile 89/34+70 to 90/0+00 (Mississippi River, LDB). Numerous small to medium size boils developed in the area. Several water berms were constructed to control seepage.

ix. Ensley Levee, Memphis, TN. Major seepage was observed in South Memphis in System #7, Segment #24 (Mississippi River, LDB), in the form of numerous small to medium size sand boils. Some of the boils had throat diameters of greater than 4 inches and cone diameters of 3 to 6 feet or greater. Significant flood fighting effort was required when river stage readings were 45 feet and higher. The most active area was near Levee Mile (LM) 9.1-9.4. Small to medium boils developed there when stages reached 45 feet and continued to grow even after the crest. Boils stopped piping material when the river dropped below 44 feet, but were still flowing clear when Phase I monitoring ended at 37 feet. The boils developed near the toe of the seepage berm. More than 22 boils were ringed in the vicinity. To mitigate the sand boils, the City of Memphis ceased operations at the Ensley Pumping Station (LM 12) per a request from MVM between May 5 (stage exceeding 45 feet) and May 20 (stage below 40 feet). Smaller pin boils developed at LMs 2.8 and 11.1 to 11.6 after the river crested.

3. Vicksburg District

a. Flood Fight Summary. The MVK Commander signed a Declaration of Emergency at 0700 hours on 25 April 2011 due to a significant flood threat on the Mississippi River, initiating Phase I of MVK's Emergency Response Plan. The MVK Emergency Operations Center (EOC) was activated at Level I on 25 April 2011 and at Level II on 30 April 2011 in response to the rising water levels along the Mississippi River. Phase II of the flood fight began on 4 May 2011 when the Mississippi River rose to over 44 feet on the Arkansas City gage. Phase II 24-hour levee patrols began on 7 May 2011 in all sectors and continued until 12 June 2011. The MVK EOC began Level III 24-hour operations on 8 May 2011 and remained so until 4 June 2011. The MVK EOC returned to normal operations on 20 June 2011. Flood fight operations in the MVK required 238 Corps personnel. 1,415,000 sandbags were issued, and 11,110 linear feet of HESCO bastions were used to execute flood fight efforts.

The MVK EOC developed many new processes and changes to existing processes during the 2011 Flood:

- Area Action Officer (AAO) positions were established. The AAOs acted as liaisons between the EOC and their respective area offices, providing one point of contact between the two.
- A Project Manager was used to create and implement a system to make personnel requests more formal and efficient, and to revise the organization chart specifically for this event.
- The FreeBoard database system was used by the MVK for this event. This system was used to report and track inspection points along the levee systems, and also to track flood fight supplies and equipment.
- The EOC used a dedicated GIS specialist throughout the event in order to coordinate all mapping and imagery products.
- The EOC implemented a new report called the Hot Spot Brief, which was updated daily and provided to the District Commander. The report detailed the current status of all significant projects and incidents within the District.

A further challenge posed during this event was the simultaneous FEMA mission regarding debris removal and demolition related to a severe storm and tornados that produced extensive damage across Mississippi on

27 April, most notably in Smithville, MS and Monroe County. This mission called for a total of 38,500 tons of debris to be removed and a total of 2,900 tons of demolition debris. The MVK EOC was engaged in both the flood fight and in the tornado mission throughout the duration of the flood fight.

The MVK EOC was also involved in a flood fight effort along the Coldwater River near Marks, MS due to a significant rainfall event 24-28 April over the upper portion of the Yazoo Basin. The Coldwater River basin received most of this precipitation, with 12 to 15 inches falling over the entire watershed and Arkabutla Dam receiving 15.16 inches of rain. The Coldwater River rose to near record stages in Sarah, Birdie, Darling, and Marks, MS and crested at Marks on 2 May. The gates at Arkabutla Dam remained closed during this event, and water flowed over the spillway producing approximately 250 cfs flow on 13-29 May. Greenwood Area Office was engaged with this flood fight during the beginning stages of the flood fight along the Mississippi River and Yazoo River Backwater. The Marks Sector Commander began coordinating flood response efforts with local officials in Marks on 27 April. City officials requested sandbags and technical assistance regarding inspection of levees and improvements to a portion of the levee that protects the City.

The MVK established a Rapid Response Team during this event to plan for and respond to levee breaches and other failures of the levee system. The Team used breach inundation maps for seven locations throughout Louisiana and Arkansas to plan for response to a levee breach, based on locations with the highest potential for breach or the highest potential for damage to critical infrastructure in the event of a breach. Those locations were Vidalia, LA; Kings Point, LA; Tallulah, LA; Lake Providence, LA; Waterproof, LA; Transylvania, LA, and Willow Lake, AR.

A Rapid Response Team was created and split internally into two teams that planned for and would respond to events north and south of Vicksburg, MS. The team coordinated with sector leads and county / parish leaders to develop an action plan and to determine capabilities such as manpower, equipment, and supplies. Coordination included preparing legal documents such as ROE forms and lease agreements that could be put into effect quickly. Coordination was also made with the Louisiana National Guard to determine its capabilities and to plan for air support if required. The team collected information regarding the location of equipment and supplies available to the District, but did not pre-stage any equipment or supplies except for the Engineer Research and Development Center (ERDC) PLUG, which is an emergency breach repair consisting of a fabric tube that inflates in place.

Geotechnical Branch created High Water Inspection Teams to conduct a high water inspection of the levees during this event. Three teams of three geotechnical engineers traveled downriver on foot and using UTVs following the crest and capturing all of the data they could in order to document seepage performance along the length of the levees. This information will be consolidated and used for future designs and to document the actual performance of the levees. Preparatory projects consisted of providing protection at known hot spots and addressing any known deficient areas of the system. There were three main efforts in preparing for this flood: the Buck Chute hot spot; protection and repair along the Yazoo Backwater Levee; and protection and repair near Vidalia, LA.

b. Funding Details

3112 MR&T Appropriation Direct	$10,172,729
3125 FCCE Reprogrammed from MR&T	$3,470,422
3125 FCCE Emergency Operations	$1,350,000
Total Flood Fight	**$14,993,151**

c. Chronology of Flood Fight Activities. Table IV-3 on pages IV-16 through IV-18 shows the chronology of flood fight activities in the Vicksburg District. All times are CDT.

Table IV-3. Chronology of Flood Fight Activities – Vicksburg District

Date	River Events	MVK Events	Other Events
25-Apr	Predicted crest at Vicksburg: 52.5	Declaration of Emergency signed by COL Jeffrey Eckstein	
	Steele Bayou control structure closed	EOC activated at Level I, duty hours 0730 – 1600 MVK requested and received $25k of 210 funds	
26-Apr	Predicted Crests updated: Arkansas City - 48.5 / 14 May Greenville - 60.0 / 15 May Vicksburg - 53.5 / 18 May Natchez - 60.0 / 20 May		
27-Apr	MVK requests permission to deviate from the water control plan at Muddy Bayou in order to raise the water level at Eagle Lake		
29-Apr	Mississippi River entered Phase I at Arkansas City and Greenville gages	MVK requested and received $225k of 210 funds	MVK begins installing stoplogs at the floodwall
		MVK received request from Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP) to evaluate possible flood protection options for the Vidalia Convention Center	
30-Apr	Muddy Bayou control structure opened to let water into Eagle Lake	EOC activated at Level II, duty hours 0700 - 1930	
1-May	Mississippi River entered Phase I at Vicksburg and Natchez gages		
2-May	Crests revised upwards significantly Arkansas City - 53.5 / 14 May / +5.0 Greenville - 64.5 / 15 May / +4.5 Vicksburg - 57.5 / 18 May / +4.0 Natchez - 65.0 / 20 May / +5.0	Phase I levee patrols begin at all sectors	SR 465 to Eagle Lake closes
	Coldwater river crests at 41.0 ft in Marks	Marks sector begins Phase I response in upper Yazoo R. Basin	
3-May			BPNM Floodway operated
4-May	Mississippi River entered Phase II at Arkansas City and Greenville gages		President declares disaster: 14 counties in MS declared for public assistance
	Crest dates revised Arkansas City - 16 May / +2 days Greenville - 17 May / +2 days Vicksburg - 20 May / +2 days Natchez - 22 May / +2 days		
5-May	Natchez crest gage revised - 64.0 / 22 May / -1.0		
6-May	Mississippi River entered Phase II at Vicksburg and Natchez gages	MVK requested and received $600k of 210 funds	President declares disaster: 26 parishes in LA declared for public assistance (9 are in the MVK AOR)
		Stabilization work at Buck Chute complete	

Table IV-3. Chronology of Flood Fight Activities – Vicksburg District

Date	River Events	MVK Events	Other Events
7-May	Anticipated overtopping of abandoned levee occurs near Grand Lake, AR	Phase II (24 hr) levee patrols begin at all sectors	
		MVK requested and received $600k of 210 funds	
		MVD receives FEMA Mission Assignment (Verbal) COE-MVD-01 for 3322-EM-LA – Regional Activation funded at $50,000	
		MVD receives FEMA Mission Assignment (Verbal) COE-MVD-01 for 3320EM-MS – Regional Activation funded at $10,000	
8-May		MVK EOC begins 24-hr operations	Vicksburg completes closure of floodwall
		ECCV 5 arrives in the MVK AO, stationed at the Yazoo River bridge on US 61N	
9-May	Crest dates revised Arkansas City - 15 May / -1 day Greenville - 16 May / -1 day Vicksburg - 19 May / -1 day Natchez - 21 May / -1 day		Bonnet Carré Spillway opened
10-May		Significant sand boil identified in the Rosedale sector	
11-May	Greenville crest gage revised - 65.0 / 16 May / +0.5	ECCV 5 moved to Lake Chicot Pumping Plant to support SEAPO	Presidential disaster declaration: 14 counties in MS declared for individual assistance
		MVK receives funding increase for FEMA Mission Assignment (Verbal) COE-MVD-01 for 3320EM-MS of $10,000 to $20,000	
12-May	Anticipated overtopping of abandoned levee occurs near Wilson Point, LA		US 61 south of Vicksburg, SR 16, and SR 149 close
			N. Washington Street is inundated
13-May	Water begins flowing over spillway at Arkabutla Dam, approx. 250 cfs	Erosion protection for landside of Yazoo Backwater Levee complete	US 61N north of Vicksburg closes
14-May	0.5 foot drop at the Greenville gage determined to be from crevasse at Wilson Point abandoned levee overtopping	All levee raises in the Yazoo Backwater Levee and near Vidalia are complete	Morganza Control Structure opened
	Greenville / Natchez crests revised Greenville - 64.8 / 16 May / -0.2 Natchez - 63.5 / 21 May / -0.5		
15-May	Greenville crest gage revised - 64.5 / 17 May / -0.3		HESCO failure at the Vidalia Convention Center due to pipe seepage
16-May	Mississippi River crests at Arkansas City, gage reading 53.14	MVK requested and received $500k of 210 funds	
	Natchez crest gage revised - 63.0 / 21 May / -0.5	Natchez requests assistance with erosion protection at Silver St.	

Table IV-3. Chronology of Flood Fight Activities – Vicksburg District

Date	River Events	MVK Events	Other Events
17-May	Mississippi River crests at Greenville, gage reading 64.22	Sand boil and levee slide identified in Mayersville Sector near Station 8170+00 (Albermarle)	Yazoo Backwater Levee is closed to all vehicle traffic
18-May	Vicksburg / Natchez crests revised Vicksburg - 57.1 / 19 may / -0.4 Natchez - 62.5 / 21 May / -0.5		
19-May	Mississippi River crests at Vicksburg, gage reading 57.1	Erosion protection at Silver St. Natchez complete	
	Mississippi River crests at Natchez, gage reading 61.95		
20-May		Android devices are fielded to Vidalia Area Office	
23-May		MVK receives FEMA Mission Assignment COE-MVD-02 for 1983DR-MS – Regional Activation funded at $40,000	
25-May		Work completed on Albermarle levee slide	
29-May		Significant sand boil found in St. Joseph sector near levee station 6185+75	
1-Jun	Mississippi River gage at Arkansas City falls below Phase II		US 49W, US 61/SR 3 north of Vicksburg and SR 16/SR149 open
3-Jun	Mississippi River gage at Greenville falls below Phase II	SEAPO ceases 24 hr levee patrols	US 61 south of Vicksburg opens
4-Jun		MVK EOC ceases 24 hr operations, reducing to 12 hr operations	Vicksburg begins removal of stoplogs in the floodwall
6-Jun		MVK receives funding increase for FEMA Mission Assignment COE-MVD-02 of $18,000 to $58,000	
8-Jun	Mississippi River gage at Vicksburg falls below Phase II	GAO ceases 24 hr levee patrols	
12-Jun		VAO ceases 24 hr levee patrols	
15-Jun	Mississippi River gage at Natchez falls below Phase II		
17-Jun		All 21M class funds revoked from MVK; total is $529,577.97	
18-Jun	Steele Bayou control structure opens		
20-Jun	Muddy Bayou control structure opened to let water out of Eagle Lake	Final MVK SITREP for this event submitted	

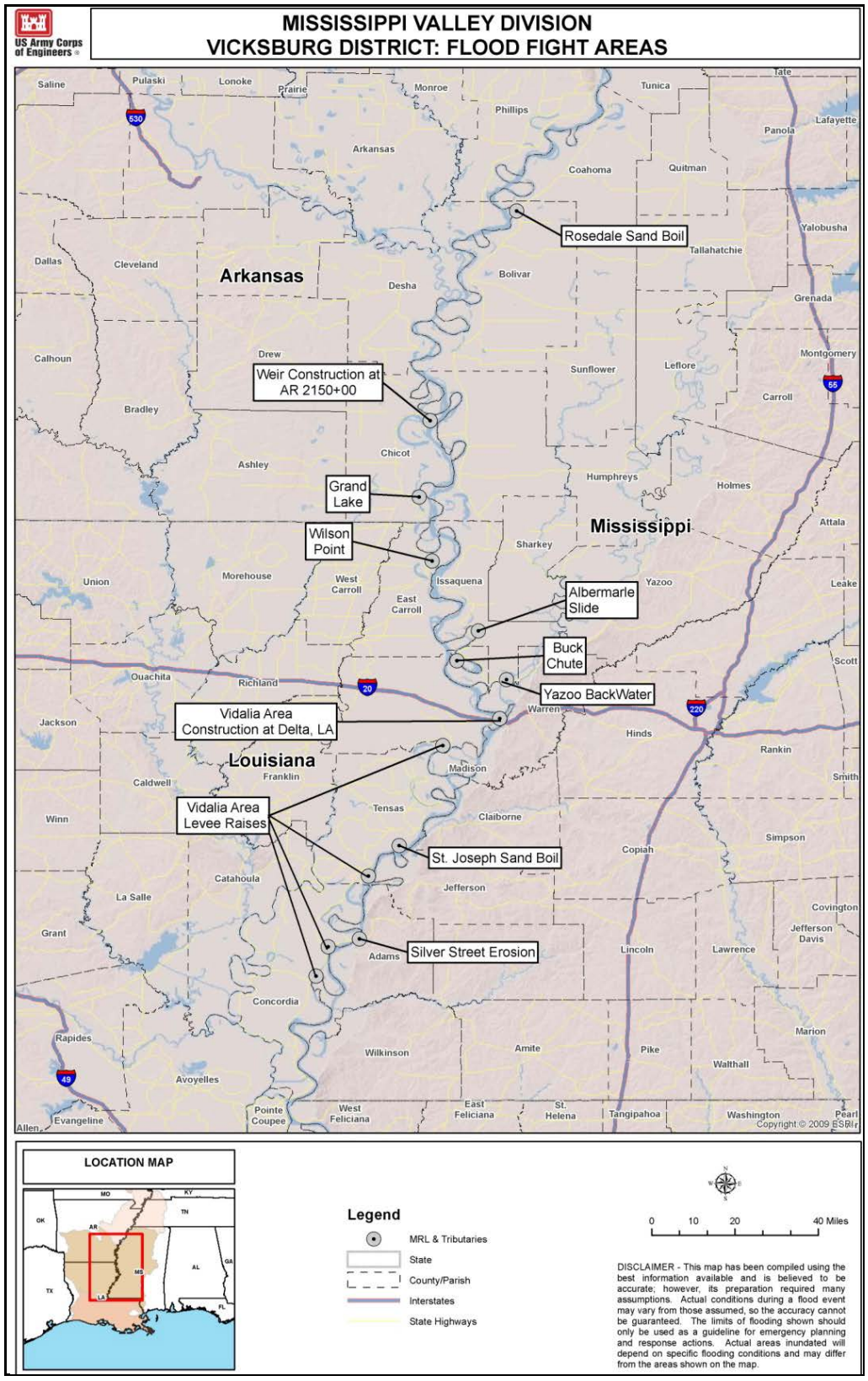


Figure IV-2. Key Flood Fight Locations in the Vicksburg District

d. Key Flood Fight Locations

i. Buck Chute. In February 2010, the MVK was notified of boils that occurred in an area along the berm toe north of Buck Chute, near Eagle Lake, MS (figure IV-2). The District began designing a repair for this area in the summer of 2010 based on that notification and on experience gained during the 2008 flood. By the time the Flood occurred, a stabilization berm was already scheduled to be constructed in the fall of 2011 at the location where sand boils were prevalent.

MVK addressed this known hot spot using two methods: constructing an emergency stabilization berm (using a different design from the final design discussed above) in the area where boils had been identified in 2010, and raising the water level at Eagle Lake to lower the hydraulic head. The improved stabilization at Buck Chute included clearing the area around the boils, constructing a dike around the boils to enclose approximately 2 acres, filling the enclosed area with sand, and providing a clay cap. This berm was intended to control seepage pressures on the land side of the levee and prevent the transport of materials under the levee system. Construction was completed by hired labor on 6 May 2011.

In addition to supplying contracts for gravel and other materials, an emergency contract was issued to transport approximately 25,000 cubic yards (CY) of sand from the Mat Casting Field at Delta, LA to the Buck Chute site. The Federal government took possession of this sand and quickly transported and stockpiled it at the Buck Chute site to meet the immediate need for use in the stability berm. The sand had been stockpiled at the Mat Casting Field by Fordice Construction, but mat casting work was suspended due to the approaching flood waters. The mat casting contract was later modified to replace the sand.

MVK requested and the MVD Commander approved a deviation from the established Eagle Lake water control plan on 28 April in order to raise the water level at Eagle Lake to 90.0 feet, in order to offset pressure caused by high riverside water levels. On 29 April, prior to opening the Muddy Bayou control structure in accordance with the deviation, the water level at Eagle Lake was 77.6 feet. The Muddy Bayou control structure was opened on 30 April to allow water to enter the lake, which reached a stage of 89.8 feet at crest due to lower than average rainfall across the watershed. Muddy Bayou was opened on 20 June to let water out of the lake. Due in part to these emergency operations, there were no significant issues with seepage or sand boils at Buck Chute during this high water event. However, raising the water level at Eagle Lake caused damage to piers and boat houses around the lake and impacted boating and fishing in the area.

ii. Yazoo Backwater Area Levee. The Yazoo Backwater Area is located in west central Mississippi in portions of Warren, Issaquena, Sharkey, Yazoo, Humphries, and LeFlore Counties, near the confluence of the Yazoo and Mississippi Rivers (figure IV-3). Several measures were required at the Yazoo Backwater Area Levee during this event. This flood was forecasted to overtop this levee and put the Yazoo River Backwater Area into operation for the first time since its completion, and a great amount of work went into preparing the levee for that predicted overtopping. The total cost of preparations on the Yazoo Backwater Area Levee was $1.94 million.

a. Erosion Protection. As an authorized backwater area within the MR&T system, the Yazoo River Backwater Area is designed to store floodwaters during very large floods through overtopping of the Yazoo Backwater Area Levee, which is intentionally constructed to a lower grade than the mainline Mississippi River levee. The Yazoo Backwater Area levee system consists of two segments, a 26 mile segment that is a flat 107.0 elevation (approximately 5 feet below the mainline levee grade) which serves as an outlet to allow water to enter the backwater area under PDF conditions, and the sloped Whittington Right Bank levee, which provides headwater flooding protection from the Yazoo River. In addition to the two connected levee segments, the Yazoo Backwater area has two drainage structures on the Little Sunflower

River and Steele Bayou. These levee segments and drainage structures protect approximately 1,550 square miles of land lying between the east bank Mississippi River levee and the Yazoo Backwater Levee System.

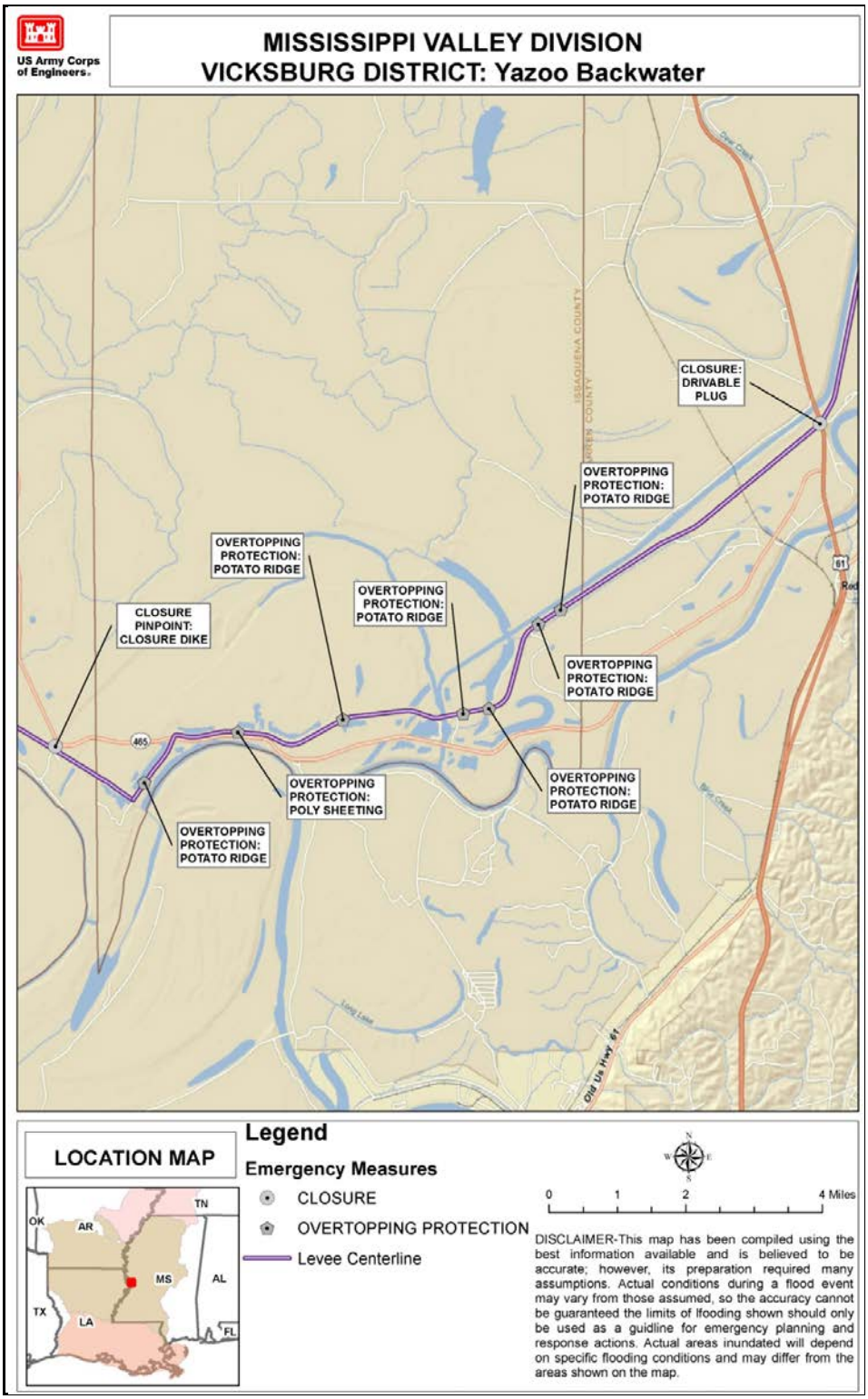


Figure IV-3. Yazoo Backwater Area

The Yazoo Backwater levee ties into the lower end of Mississippi River levee near Eagle Lake and ties to high ground near Morgan City. The area is subject to flooding from the Mississippi River backwater which can enter the area by overtopping the lower portion of the Yazoo Backwater Area levee. It can also receive flood waters from headwater flooding of the Yazoo River.

By late April, forecasts indicated that crest stages on the Mississippi River would cause elevations at the intersection of the mainline levee and the Yazoo Backwater levee (MS East Sta. 9314 + 71) to exceed 107 feet NGVD29, overtopping the levee and putting the backwater area into operation. In preparation of this event, MVK installed polyethylene sheeting for erosion protection along the land side of the levee to prevent damage to the levee slope and berm during the forecasted overtopping, mitigating the risk of catastrophic crevassing and failure of the levee while still providing for the feature's intended function. Polyethylene sheeting was placed along a 4 mile section of the Yazoo Backwater Levee land side slope starting approximately 1,700 feet from the junction of the Mississippi River Levee and the Yazoo Backwater Levee and extending approximately 4 miles to 2,700 feet west of the Steele Bayou control structure. A small trench was excavated at the land side crown and the sheeting was anchored within the trench and draped down the land side slope of the levee. Polyethylene sheeting was provided by GSE Lining Technology, Inc. for $700,000.

GSE Lining Technology also provided approximately 60 personnel to assist in installation, including special equipment and trained technicians to seal 100 percent of the seams on the fabric. Supplies, labor, equipment, and installation guidance and assistance were provided by American Environmental Group, Ltd. for $493,000. Installation of the erosion protection was accomplished by Fordice Construction for $315,000. With a potential for overtopping forecast for 15 May, the scope of work was developed on 5 and 6 May. Engineering and Construction and Contracting met with Fordice Construction on-site near the Steele Bayou structure and contracts were awarded in the early afternoon on Friday, 6 May. Work began immediately to mobilize equipment, assemble the contractor workforce, and ship materials. Fabric was delivered over a three day period and staged at the harbor for transport to the site by Fordice Construction.

Fabric installation began on the morning of Saturday, 7 May as soon as the first materials arrived in Vicksburg. Fabric was installed and seamed during daylight hours and materials were staged along the levee at night for placement the next day. The Mississippi National Guard was on alert for possible deployment to assist with this work if necessary, but was cancelled on Sunday, 8 May once the contractor's capabilities and progress were confirmed. Access along the levee was very congested during the fabric installation, and a one-way traffic plan was developed to ensure traffic flow during construction. All fabric was essentially installed by the evening of 11 May, with all work completed on 13 May.

b. Overtopping Protection. In order to direct the predicted overtopping water away from landside toe of the mainline Mississippi River Levee, protection was placed along the crown of the Yazoo Backwater Levee extending from the junction with the Mississippi River Levee east for 2,000 feet. The protection was planned to be 4 foot high Rapid Deployment Floodwall, but due to a shipping delay was changed to 4 foot HESCO bastions. The HESCOs were placed by hired labor starting on 10 May and were completely placed on 13 May.

c. Pinch Point Closure Dike. In order to prevent overtopping water from flowing north along the toe of the Mississippi River Levee, a 7 foot dike was constructed on the section of PawPaw Road between the mainline Mississippi River Levee and Highway 465. This dike consisted of approximately 2,000 CY of material borrowed from the Muddy Bayou borrow area. Construction was done by Hired Labor starting on 6 May and completing on 12 May.

d. Yazoo Backwater Levee Low Spots. Several deficient areas were identified along the Yazoo Backwater Levee, including cattle guards and portions of the levee below design grade. One site was located between the Mississippi River Levee and the Steele Bayou control structure; four sites were located between Steele Bayou and US 61. This area posed a significant traffic risk as that portion of the levee was still open to public traffic. Hired Labor placed fill and potato ridges (i.e., small earthen berms) on the levee crown starting 6 May and completing on 16 May. The Board of Mississippi Levee Commissioners also raised several low spots along the Yazoo Backwater Levee north of US 61.

e. 61N Driveable Plug. The portion of the Yazoo Backwater Levee at the intersection with US 61 was closed with a drive-able plug. This closure was designed to ensure traffic access along the levee, and also allow vehicles to enter and exit the levee from US 61. Construction was done by Hired Labor starting 13 May and completing 14 May.

Although several sections of US 61 were predicted to overtop during this event, MDOT did not request assistance to flood fight those sections in order to keep the highway open.

iii. Vidalia Area Levee Raises. Several locations along the Mississippi River Levee near Vidalia, LA were identified as deficient and in need of raising. Between 4 May and 14 May, these areas were repaired using HESCOs and potato ridges.

a. 357-R, 350-R, 365-R. An ongoing construction contract for enlargement of Item 365-R on the Mississippi River Levee with Kingridge Construction was modified to perform emergency measures on Items 365-R, 357-R, and 350-R. Chancellor and Sons was a major subcontractor involved in this work. Each deficient area required potato ridge, HESCO, or both in order to raise the levee to the required grade and provide a minimum freeboard based on the predicted water level. Potato ridges are small temporary earthen berms and HESCOs are large metal baskets lined with cloth that are filled with sand. Work on these items began on 4 May and continued 24-hours per day until completed on 14 May.

- Item 357-R. 13,800 LF of potato ridge and 5,100 LF of HESCO Bastions
- Item 365-R. 675 LF of potato ridge
- Item 350-R. 700 LF of potato ridge

b. 420-R, 379-R, and Delta, LA. A construction contract for enlargement of Item 420-R with CKY, Inc. was modified to perform emergency measures on items 420-R, 379-R, and adjacent to the old Highway 80 at Delta, LA. Construction related to Item 420-R was ongoing for a portion of the Flood. The contractor was constructing a haul road on the landside toe of the levee using landside borrow material from the old front line levee. Seepage issues increased within the construction limits, and the contractor was directed to suspend work as a precaution to assure construction activity did not adversely affect seepage concerns. Work was suspended for approximately 3 weeks.

- Item 420-R. 310 LF of potato ridge
- Item 379-R. 400 LF of potato ridge
- Delta, LA. 150 LF of potato ridge

iv. Rosedale Sand Boil. On 10 May a significant sand boil was identified in the Rosedale sector near Station 151+00. The Board of Mississippi Levee Commissioners along with convict labor constructed a sand bag ring around the boil. Additional containment was required, and on 11 May Hired Labor and contractors began constructing a dike around the boil. The dike was completed on 12 May.

v. Grand Lake Seepage Berm. On 10 May MVK's Southeast Arkansas Project Office SEAPO was notified by the levee board that moderate seepage and small boils were developing off the toe of the landside berm located in the vicinity of Station 3542 near Grand Lake in Arkansas. This area is adjacent to the mainline levee, which was rapidly loaded when the abandoned front line levee crevasse occurred. The mainline levee on the river side has been historically dry and protected by the abandoned front line levee, therefore never subjected to river loading. Full loading conditions on the mainline levee were experienced 12 hours after the crevasse of the old abandoned levee. The seepage area was sandbagged by the levee board with assistance from the local fire department, but the SEAPO Area Commander decided that the seepage area required an earthen ring levee in order to be stabilized. Construction of a 900 foot long by 3-foot tall levee with plastic lining was completed by the levee board on 11 May.

vi. Silver Street Erosion Protection, Natchez, MS. Significant erosion of the river bank began occurring near Silver Street in Natchez, MS on the week of 8 – 14 May. By 15 May the erosion had begun to threaten the temporary protection measures at Natchez, and the City of Natchez requested assistance from the MVK. The City of Natchez had previously emplaced HESCO bastions near the site, and had used engineering fabric and sandbags to stabilize the river bank.

On 16 May MVK entered into an agreement with the City of Natchez to construct emergency repairs at the site, consisting of emplacement of R200 stone on top of the existing fabric and sand bags along a 350 foot section of eroded river bank. Work was completed by Hired Labor between 16 and 19 May. The City of Natchez removed the top row and one of the bottom rows of HESCO between 18 and 19 May in order to reduce bank loading.

vii. Albemarle Levee Slide. On the evening of 16 May three significant sand boils were discovered in the Mayersville sector near Station 8170+00 on the Mississippi River Levee, which is approximately 8 miles north of Eagle Lake. Additional small boils were identified in that same area on 17 May. The boils were repaired by ringing them with stone and sand, creating a filtered exit. This work was completed on 17 May.

On the afternoon of 16 May a slide was also discovered immediately downstream of the sand boils. The levee slide was 200 feet long with an approximately 3- to 4-foot vertical face. On 18 May another slide occurred upstream of the boil. This slide was approximately the same size as the earlier slide. In order to repair this slide a stone dike was emplaced around the slide area and was backfilled with sand. Hired Labor began work on 19 May by emplacing the stone dike. On 21 May movement of the slide necessitated increasing the quantities of stone and sand required. The northern (upstream) dike and backfill was completed on 22 May, and the southern (downstream) dike and backfill was completed on 24 May.

viii. St. Joseph Sand Boil. On 28 May a very large sand boil was discovered in the St. Joseph sector near Station 6185+75 on the Mississippi River Levee, which is approximately 5 miles south of St. Joseph, LA. This sand boil had a throat diameter of 13 feet and a depth of approximately 18 feet, and was 700 feet from the levee toe. The boil had moved an estimated 100 CY of material.

The Fifth Louisiana Levee District repaired this sand boil by emplacing sandbag dams at both ends of the ditch in which the sand boil formed. These repairs were completed on 30 May.

ix. Wilson Point Levee Overtopping and Crevasse. On 12 May an anticipated overtopping occurred on the abandoned front line levee near Wilson Point north of Lake Providence in Louisiana. The overtopping was expected to impact approximately 10,000 acres of farmland. Because the abandoned levee was lower than the Mississippi River Levee there was no anticipated impact to the levee system except for a rapid loading of the main line levee.

At approximately 2215 on 13 May the MVK was notified that the Greenville gage was slightly falling. Patrols were sent to the Greenville gage area and to the opposite side of the river. The patrols verified the drop based on water marks but could not find a cause of the drop. The immediate concern was that a levee had crevassed.

Levee patrols were conducted along the Mississippi River Levee to identify the cause of the drop, and after verifying that the main line levee was intact suspicion fell on the overtopping levee near Wilson Point. On the morning of 14 May levee patrols verified that the water level on the land side of the abandoned levee was equal to the level on the river side, indicating that a crevasse had occurred in the levee and quickly inundated the land between the abandoned levee and the main line levee. The Greenville gage began falling at 1500 on 13 May and resumed climbing at 0300 on 14 May after a drop of 0.4 feet. The initial actions of the EOC and Greenwood Area Office were to verify the gage drop and to verify the integrity of the main line levees. The gage falling was indicative of a levee failure, and even though the abandoned levee was known to be overtopping it was initially overlooked as the cause of the gage drop.

x. Construction of Weirs in Southeast Arkansas. During this event SEAPO constructed several weirs to control sand boils. These weirs were constructed of sand bags and were lined with polyethylene sheets anchored with sand bags. The first weir was constructed at Station 2150+00 on the Mississippi River Levee northeast of Lake Chicot in a 5,000 foot diversion ditch. Two weirs were constructed on either end of a series of sand boils on 12 May. On 14 May the weirs were raised to increase the water level in the ditch. On 15 May the water level in the ditch was further raised by closing off discharge laterals in the ditch. Clear water flowed over the weirs for most of the duration of the event. SEAPO also constructed weirs at Station 1550+00, north of the Lake Chicot Pumping Plant and at Station 3550+00, north of Grand Lake.

Repairs were made at the weir at Station 1550+00 when soil was washed away from under the plastic, by replacing the eroded soil with sand bags and replacing the plastic sheet. Clear water then flowed over these weirs for most of the duration of the event.

4. New Orleans District

a. Flood Fight Summary. COL Edward R Fleming, the MVN District Commander signed a Declaration of Emergency initiating Phase I of the Emergency Response plan of the MVN, due to a significant flood threat on the Mississippi and Atchafalaya Rivers on 14 March when the water rose to over 11 feet on the Carrollton Gage in New Orleans. On March 15, the MVN EOC elevated the activation to Level II. Phase II of flood fight and level III EOC activation began May 6, 2011 when the water rose to over 15 feet on the Carrollton Gage and remained so until June 26. The MVN EOC returned to normal operations on August 5.

Mississippi and Atchafalaya River peak stages during the 2011 Flood set new records at Knox Landing, Red River Landing, and St. Francisville, and ranked among the top five in most areas throughout the System. This historic Flood required the operation of the Bonnet Carré spillway for only the 10th time since its construction and the operation of the Morganza Floodway for only the second time since its construction. The Old River Control Complex diverted the highest peak flow in its history using only the Hydropower, Low Sill, and Auxiliary Structures; the Overbank Structure was not operated.

Flood Fight mission required over 600 personnel assembled from every department within MVN. During the 2011 Flood, MVN issued or used 1,229,650 sand bags (9,850 large/1,219,800 small), 29 pumps, 524 rolls of polyethylene sheeting, and 44,990 linear feet of HESCO bastions.

The Mississippi River levees experienced an extended period of high water stages. Many seepage and sand boil sites appeared and were flood fought. Damage Assessments were performed for 667 points in all 13 Flood Fight sectors.

The 2011 Flood was an historical event throughout the MR&T Project. Overall, the flood fight was executed successfully in the MVN AOR. Historic flows were safely passed to the Gulf of Mexico in large part due to the exhaustive inspection and response efforts of the Corps as well as the local levee districts.

b. Funding Details

3112 MR&T Appropriation Direct	$7,040,903
3125 FCCE Transferred to MR&T Project	$13,249,130
3125 FCCE Emergency Operations	$3,843,418
Total Flood Fight	**$24,133,451**

c. Chronology of Flood Fight Activities. Table IV-4 on pages IV-27 and IV-28 shows the chronology of flood fight activities in the New Orleans District. All times are CDT.

Table IV-4. Chronology of Flood Fight Activities – New Orleans District

Date	River Events	MVN Events	Other Events
8-Mar	Water level rose at the Carrollton Gage to 8.54 ft	The fore bay of Bonnet Carré Spillway was flooded.	
14-Mar	Water level rose at the Carrollton Gage to 11.0 ft	Declaration of Emergency signed by COL Edward R. Fleming. .	
15-Mar		EOC activated at Level I, emergency watch operation duty hours 0700 - 1730. Lower portions of Mississippi R. activated to phase I flood fight	
17-May	Water level rose at the Carrollton Gage to 11.9 ft	Water was over topping the concrete weir at Bonnet Carré Spillway. Big Mamou sand boil inspected.	
24-Mar	Water level at the Morgan City gage reached 5.0 ft.	The lower Atchafalaya Basin sectors were activated for Phase 1.	
30-Apr	Water level rose at the Carrollton Gage to 12.45 ft	Seepage at Duncan Point; MVN places 122,000 sandbags to form a berm.	
30-Mar	Water level at the Red River Landing gage reached 51.0 ft.	The upper sectors w/in Mississippi River activated for Phase 1.	
4-May	Water level at the Knox Landing gage reached 55.0 ft.	ORCC Hired Labor began sandbagging the Morganza lower guide levee and intersection of lower guide levee with main line levee.	M/V Fred Lee was provided to MVN as a picket boat to monitor inflow channels.
5-May	Water level at the Red River Landing gage reached 54.21 ft.	Phase II flood fight for sectors w/in the entire Mississippi River activated. MVD Commander approved operation of Bonnet Carré Spillway.	
5-May	Monitoring of the scour at the Low Sill Structure was initiated	The Low Sill Structure was fully staffed to monitor and supervise the boom surveys being performed to detect scour upstream of the structure	
6-May	Water level rose at the Carrollton Gage to over 15.0 ft	Phase II flood fight was activated for sectors within the upper Mississippi River. An announcement by MRC was made that the Morganza Control Structure may be opened and the Morganza Floodway may be operated.	Presidential disaster declaration: 26 parishes in Louisiana are declared for public assistance
7-May	Water level rose at the Carrollton Gage to over 15.39 ft	Seepage was noticed by the Chalmette Ferry on Paris Road. Local levee district placed a temp HESCO basket berm on protected side.	
8-May	Water level at the Morgan City gage reached 6.0 ft. Water level of Red River Landing gage reached 55.0 ft.	Phase II flood fight was activated for lower sectors of the Atchafalaya. Approximately 190 sand boils located in the Angola area; 87 were bagged. The others were observed.	
9-May	Water Level rose at the Red River Landing gage to 58.05. Water level rose at the Carrollton Gage to 16.8 ft.	Bonnet Carré Structure was opened. Sand boils were located at Oak Alley. A sand boil was discovered by the Old River Lock.	
10-May		Levee district placed sandbags at intersection of Morganza lower guide and main line levee; placed super bags w/ visqueen in 2 reaches near Waterloo. 1st reach was a 260-ft stretch between Stations 2463+30 and 2461+70; 2nd second reach was 780 ft long between Stations 2475+44 and 2483+24.	
	Water level rose on the Baton Rouge gage to 41.75 ft.	Many sand boils were discovered in a ditch near Port Allen, LA. Weirs were constructed in the ditch to develop a head.	
11-May	Water level rose at the Carrollton Gage to 17.04 ft.	Clear seepage at the toe of the levee was noticed near the Domino Sugar Refinery in Arabi, LA. Seepage also appeared at the Conoco-Philips Plant under the railroad track w/in the plant.	
12-May		Old River Lock closed to navigation	

Table IV-4. Chronology of Flood Fight Activities – New Orleans District

Date	River Events	MVN Events	Other Events
13-May	Water level at the Red River Landing gage reached 61.82 ft.	MRC concurred with operation of Morganza Floodway on 14 May. Pointe Coupee Drainage Structure Closed.	
14-May		MVN activated Phase II for all sectors in the district. Morganza Control Structure opened. Emergency scour repairs completed at ORCC. A 1,600 foot potato ridge levee constructed on the south side of Airline Hwy.	BPNM Floodway operated.
15-May	Water level rose at the Carrollton Gage to 16.96 ft.	2 sand boils appeared at the Algiers area. 330 bays at Bonnet Carre open.	M/V William James arrived to assist the M/V Fred Lee.
16-May	Water level rose at the Carrollton Gage to 16.96 ft.	Seepage discovered in the concrete parking lot at the Port of New Orleans.	
	Water level on the Red River Landing gage reached 62.27 ft.	Sand boils were located in at the James Audubon Bridge near Waterloo, LA. The ditch was bagged to provide head for the sand boil. GIWW Alternate Route closed	
16-May	First detection of scour observed	Standing waves in the tailbay	
17-May	Water level on the Red River Landing gage reached 62.76 ft.	Boil area at Port Allen continued to worsen and road began collapsing.	
18-May		Morganza Control Structure had 17 gates open.	
18-May	First scour Buoy was checked	Scour buoys were only checked once the gate changes began.	Buoys couldn't be checked near open gate.
20-May	Water level at the Carrollton gage read 17.2 ft.	LADOTD closed 1/4 mile of River Rd near Duncan Point due to seepage.	Safety Zone initiated around ORCC.
		Port Allen Lock closed	
21-May	Water level at the Carrollton gage read 16.97 ft.	National Guard added 360 sand bags to the Duncan Point sand bag berm.	
		Berwick Lock closed	
23-May		Port Allen Lock reopened	
24 May		Begin closure of Morganza Floodway structure	
27-May	Water level at the Carrollton gage read 16.8 ft.	2 large sand boils and 4 smaller boils were located on LSU farms. Multiple sand boils were located at Farr Park Equestrian Center and also behind Riverbend Subdivision.	
28-May	Water level at the Red River Landing gage read 61.83 ft.	Erosion due to wave wash was identified near Sugar Lake. Sand bags were placed at water level to decrease erosion.	
31-May		Old River Lock reopened for navigation.	
3-Jun		Berwick Lock reopened	
8-Jun	Last scour buoy was checked	Once discharges were reduced, buoys couldn't be easily checked.	
11 Jun		Begin closure of Bonnet Carre Spillway structure.	
13-Jun		GIWW Alternate Route reopened	M/V William James departed ORCC. Safety Zone around ORCC lifted.
20-Jun		Final needles of Bonnet Carré Spillway Structure closed.	M/V Fred Lee departed ORCC.
21-Jun		Bonnet Carré Spillway was reopened to the public	
23-Jun	Last day on monitoring for scour at the Low Sill Structure.		
25-Jun	Water level at Carrollton gage read 12.4 ft	Seepage through needles of Bonnet Carré Spillway ceased.	
7-Jul		Final gates closed at Morganza Floodway Structure.	
5-Aug	Water level at Carrollton gage read 5.6 ft, Morgan City read 2.9	Flood fight operations ceased in the MVN.	

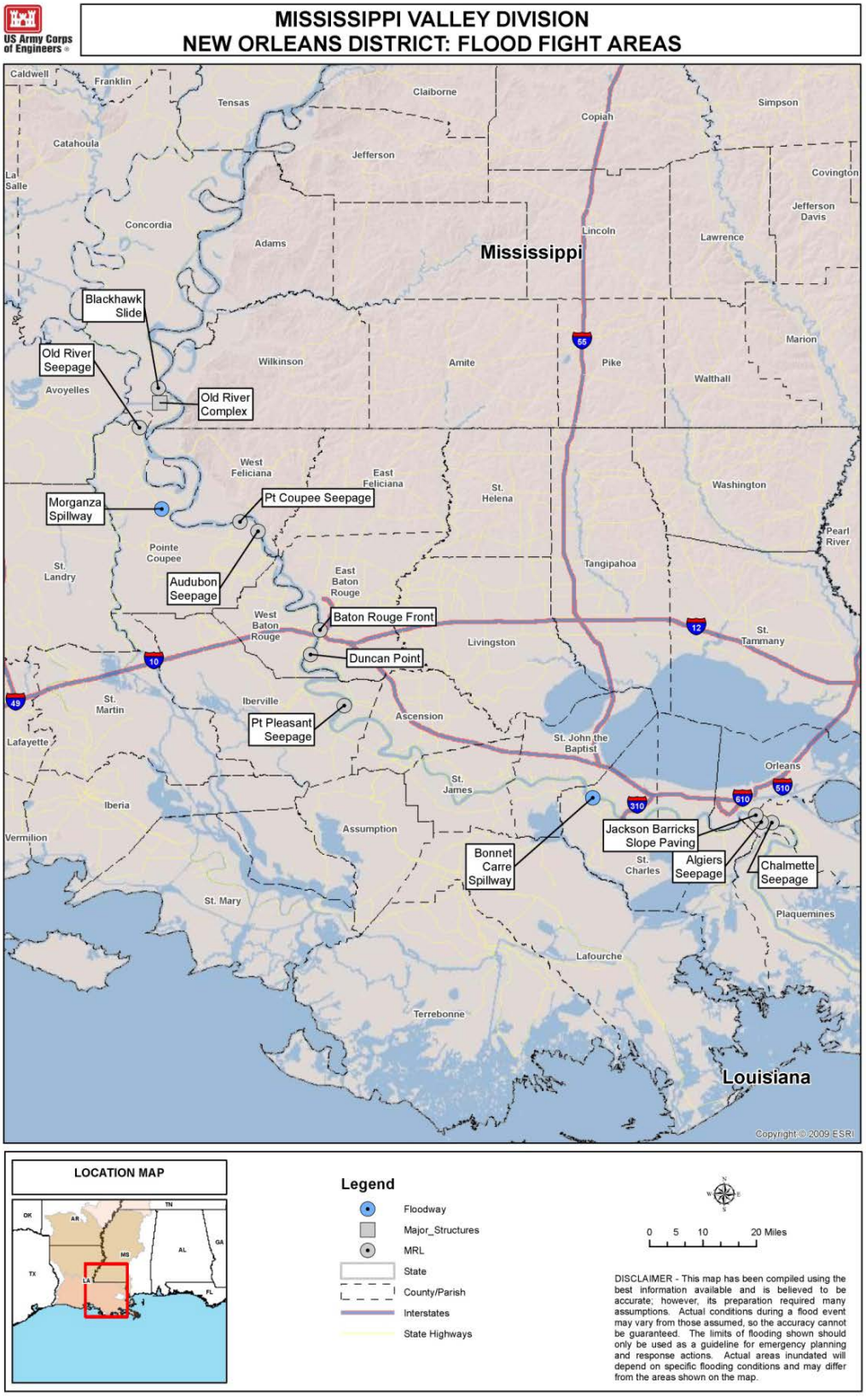


Figure IV-4. Key Flood Fight Locations in the New Orleans District

d. Key Flood Fight Locations

i. Baton Rouge Front. The unstable flood side slope at *Baton Rouge Front* (figure IV-4) has been visibly moving riverward since 2002. Flood side stability was monitored 24/7 during recent high water to assess potential loss of levee slope (which includes a major railroad atop of crown). The Canadian National railroad was restricted to the use of the landside track only with a reduced speed limit of 10 mph.

ii. Duncan Point. The Duncan Point seepage area contained through-seepage and a sand boil at the landside toe of the levee which also occurred during both the 2008 and 2009 high water events. The seepage at Duncan Point had been getting progressively worse with each event. The lower 1/3 of the landside slope was saturated during these events and has required intensive flood fight efforts. During the 2011 event, head at the levee toe was greater than 10 feet. Spongy conditions developed along the adjacent highway resulting in its closure. A temporary, berm was constructed using 12,000 sandbags to reduce seepage in the most critical reach of the site. A massive aquifer in exceeding 300 feet in depth exists beneath the levee overlain by a thin blanket of confining material, this blanket has been ruptured and the situation continues to deteriorate with successive high water events. The Factor of Safety at the levee toe with water at flowline is 1.15 (vs. 1.6 required).

iii. Chalmette Seepage. The Chalmette Seepage is located at station 175+00.00 Lake Borgne Basin Levee District. There was extensive seepage at this site to include soft, spongy conditions at the levee toe, requiring flood-fight efforts by the local sponsors (construction of a temporary seepage berm using HESCO baskets). Site had to be continually monitored during the flood fight, while an acceptable level of seepage still continued to flow.

iv. Jackson Barracks Slope Paving. The Jackson Barracks Slope Paving is located at Station 690+00.00 OLD. Concrete slope pavement for storm water discharge pipe is cracked, with the potential to undermine slope pavement and discharge foundation during high water events

v. Old River Seepage. Sand boils are on the protected side of the levee at the base of the electric poles that supply electricity to Old River Lock.

vi. Blackhawk Slide. The Blackhawk Slide is located at station 180+00.00 5TH. The Flood Fight team inspection remarked, *"Historical slide from Jan 2010 that was not repaired but was dressed and seeded by MVK hired labor. It is located on the Mississippi River Levee across from Blackhawk on the right descending bank."*

vii. Audubon Seepage. The Audubon Seepage project is located at station 2310-00.00 Atchafalaya Basin Levee District (ABLD). The Flood Fight team inspection remarked, *"3-4 small sand boils in the L/S ditch along the highway directly under the John James Audubon Bridge."*

viii. Pointe Coupee Seepage. The Pointe Coupee Seepage project is located at station 2085+00.00 ABLD. The Flood Fight team inspection remarked, *"Seepage popping up in fresh tractor tracks just upstream of the old New Roads/St.Francisville Ferry. Not sand boil but a seepage hole; Historic seepage popping up beneath the limestone reservation area for a communication tower just above the New Roads/St.Francisville ferry landing and coming out of the edges of the limestone. The seepage is on the levee slope only."*

ix. Point Pleasant Seepage. The Point Pleasant Seepage project is located at station 4950+00.00 ABLD. The Flood Fight team inspection remarked, *"These are historic sand boils in a drainage ditch at Point Pleasant; LA located approximately 900 feet landside of the centerline of the levee. Of 40 visible boils 37 are flowing, 32 are carrying minor amounts of sand material. 14 have 1-inch cones; 6- have 2-inch cones; 5 have 2- to 4-inch cones; 6 have 4- to 6-inch cones; 8 have 6 to 8-inch cones; and 1 has an 8- to 10-inch cone. Standing water in ditch both sides of road LA-405; Large seepage area which*

includes the area behind a church 1/10 mile wide. Location is H Lewis St. at Hwy 405; Seepage at GSU Gas Pipeline. Water is collecting in L/S ditch along River Road. Water is clear. Sand boil is present at the levee toe. Blanket has been fractured.

x. Algiers Seepage. The Algiers Seepage project is located at station 260+00.00 Algiers Levee District (ALD). This is a known historical seepage area. The Flood Fight team inspection remarked, "*0260+00 ALD: Located in front of mailbox No. 11803. Water is coming from curb at edge of road and from levee toe. Water is mostly clear, brownish color in some locations along curb.*"

xi. West of Berwick. The flood fighting activities that occurred in the areas West of Berwick, LA consisted of placing sheet pile closures across primary gravity drainage canals to prevent any impacts of backwater effects due to high water in Wax Lake Outlet at Calumet. These closures were placed on Hansen Canal, Yellow Bayou Canal, and Franklin Canal.

xii. Bayou Chene. The closure on Bayou Chene was constructed by sinking a barge in the channel and placing HESCO baskets on the top of the barge. The barge was tied in to the channel banks by sheet pile section, with riprap placed on either side.

xiii. Old River Control Complex. The ORCC was constructed to prevent the Atchafalaya River from capturing the flow of the Mississippi River. This objective is achieved by maintaining the distribution of total latitude flow (defined as the sum of the Atchafalaya and Mississippi Rivers flows at the latitude of Red River Landing, LA) between the Mississippi River and the Atchafalaya River at 70 percent and 30 percent, respectively. The ORCC consists of three large water control structures and is located on the RDB of the Mississippi River between RM 304 and 317. These structures include the Old River Low Sill and Overbank Structures that began operation in 1962 and the Auxiliary Structure completed in 1986. A privately owned and operated Hydroelectric Power Station (S.A. Murray, Jr.) is located immediately upstream of the overbank structure. The Old River Lock is located about 8 miles downstream of the ORCC.

Emergency Operations at the ORCC are triggered by readings at the Knox Landing gage, located between the Low Sill and Auxiliary Structures. When stages at Knox Landing reach 52.0 feet, flood fight surveys begin. On 15 March, flood fight surveys where requested to begin on 22 March when the Knox Landing gage was predicted to exceed 52.0 feet. When Knox Landing exceeded 52.0 feet on 29 March, the frequency of the structure surveys was increased.

When Knox Landing reaches 55.0 feet, MVN requests a boat be sent to monitor the Mississippi River for vessels in distress that could be pulled towards the ORCC and assist these vessels in avoiding the structures if needed. On 25 April, the ORCC contacted MVK about picket boat availability since the MVN Motor Vessel (M/V) Kent was already at the Bonnet Carré Structure. MVK provided the M/V Fred Lee which arrived on 4 May as requested. As the Knox Landing continued to rise past 55.0 feet, additional assistance for the Fred Lee was requested. The turbulent waters and extreme currents called for backup by a larger vessel. On 15 May, M/V William James arrived from MVK. Due to turbulent waters and strong current at the confluence to the ORCC inflow channels and the Mississippi River, field personnel requested through the EOC to have the Coast Guard implement a safety zone in the vicinity of the ORCC starting on 20 May.

The ORCC diverted flows exceeding PDF flow of 620,000 cfs for 9 days due to high flows on the Mississippi River and relatively low flows on the Red River, but the design flow for the Federal structures was not exceeded. Only the Low Sill, Auxiliary, and Hydropower Structures were operated during the event. Operation of the Overbank Structure was considered but its operational constraints limited the conditions under which it could be operated. Operation of the Overbank Structure is limited to a head differential of 13.0 feet or lower, and flows are also limited until tailwater stages rise (due to operation of the

Low Sill Structure) to submerge the resulting hydraulic jump and prevent damage to the gabion weir. Consequently, the Overbank Structure, if closed, can only be opened during a short window after tailwater stages have risen but before the differential head exceeds 13 feet.

At one point during the event, the increased flows through the ORCC and the unusually low flow down the Red River caused the Red River to flow backward (northward). Eventually, storage in the overbank areas of the Red River was filled and water again began to flow downstream.

Wave wash erosion was spotted behind the Low Sill Structure on the North and South banks behind the wing walls. On May 13 when Knox Landing read 64.13 feet, Contracting Division issued a verbal notification for a contractor from the Lafayette Area Office to perform emergency scour repairs at these walls. The work was performed overnight and completed on 14 May. 471 tons of rock were placed on the north bank, and 633 tons of rock were placed on the south bank. The area was monitored for the remainder of the event. The rock repair was deemed adequate and prevented any further erosion. Minor erosion was also seen at the at the rock dyke tie-in on the inflow side, where the 1973 failure occurred. The wave action moved small rocks and no emergency repairs were necessary.

On 13 June, when the Knox Landing gage read 59.30 feet, the M/V William James departed. The ORCC Team requested through the EOC that the Coast Guard lift the navigation safety zone. On 20 June, the M/V Fred Lee departed the ORCC. By 27 June, when the Knox Landing gage read 59.34 feet, high water surveys were partly discontinued.

Surveys on 17 June, when the Knox Landing gage read 56.99 feet, indicated scouring on the south bank of the inflow channel at the Auxiliary Control Structure. No emergency repairs were required. The same survey also showed significant shoaling of the first 3,000 feet of the channel near the Mississippi River. No emergency repairs were required. Upon further analysis, the erosion at the guide levee banks was attributed to this shoaling, as sedimentation reduced the flow capacity through the inflow channel and redirected flow toward its banks. An inspection on 02 August determined that the continued erosion led to isolated bank failures.

e. Morganza Floodway. The Morganza Floodway is located at RM 280 in central Louisiana. The Morganza Floodway begins at the Mississippi River, extends southward to the East Atchafalaya River levee, eventually joining the Atchafalaya River Basin Floodway near Krotz Springs, Louisiana. The purpose of the floodway in conjunction with the Atchafalaya Basin Floodway is to carry flood water from the Mississippi River to the Gulf of Mexico via the lower Atchafalaya River and the Wax Lake Outlet. The floodway feature, at twenty miles long and five miles wide, consists of a stilling basin, an approach and outlet channel, and two guide levees. The control structure contains a concrete weir, two sluice gates, and 125 gated openings. On 9 May 2011, seventeen scour indicators were installed in the tailbay of the Morganza Control Structure by MVN Hired Labor Units. The structure is designed to pass up to 600,000 cfs of water to the Gulf of Mexico, alleviating stress for mainline levees downstream along the Mississippi River. Operation of the floodway is highly affected by the Mississippi River water level readings at Red River Landing gage located 20 miles north of Morganza.

On 11 March 2011, MVN mailed the annual written notices to all interests and landowners within the Bayou Des Glaises Loop, Old River Control Structure Project, West Atchafalaya Floodway, Atchafalaya Basin Floodway, and Morganza Floodway, reminding them of the possibility of the floodway operation. By 30 March 2011, Phase I of flood fight was initiated for the Upper Mississippi Area as the Red River Landing gage reached 51.0 feet.

As the waters began to rise, flood notification letters were prepared for the landowners within the Morganza Floodway advising them of the possibility of the need to evacuate all people and livestock as well as the removal of personal belongs. By 28 April 2011, the letters were delivered.
The decision to operate the floodway is the responsibility of the MVD Commander. On 6 May 2011, an announcement was made that the Morganza Control Structure may be opened and the Morganza Floodway may be operated. The following day a request for rangers from Port Barre Office was made to assist with structure opening. The Morganza Team as well as the Mississippi Sector Command teams communicated regularly with the Coast Guard, levee district, and parishes including: ABLD, St. Mary Levee District, Town of Berwick, Morgan City, Pointe Coupee Parish, Iberville Parish, St. Martin Parish, Iberia Parish, St. Mary Parish, and Terrebonne Parish. Requests to the Kansas City Southern Railroad to slow train traffic to 10 mph once Baton Rouge gage reaches 40 ft. NGVD was also made due to seepage area at north abutment of the Morganza Control Structure. Navigation notices were also issued announcing major impacts to the waterways including the closing of the Old River Lock (ORL_11-40, 6 May 2011); and closure of the Port Allen Lock (PAL_11-43, 10 May 2011).

On 11 May 11, 4500 ft of sand bags and Hesco baskets were placed to shore up the southern guide levee at Morganza Control Structure, which was being overtopped by flood waters. On 17 May 11, the equipment tally at this location was 1720 large sandbags, 7000 small sandbags, and 30 Hesco Baskets.

At 1500 hours on 13 May 2011, the MVD Commander concurred with the MVN Commander's recommendation for operation of the Morganza Floodway and directed the Commander to be prepared for operation within 24 hours. A detailed description and timeline for the operation of the floodway is provided in Section IV.E of this report.

f. Atchafalaya Floodway. During the 2011 Flood, the opening of the Morganza Floodway was a concern for its impacts in the middle and lower Atchafalaya Basin. Beginning on May 24, 2011 the Hydraulics Branch in the New Orleans District began monitoring the water levels in the Atchafalaya Basin Floodway to observe the affects of the additional water introduced to the basin floodway from the operation of the Morganza Floodway. The New Orleans District utilized USGS to install gages in the Atchafalaya Basin Floodway and in the backwater areas east and west of the floodway to better monitor water levels.

The areas of concern were the community of Butte La Rose, the areas west of Berwick, LA, and the areas east of Morgan City, LA. The Hydraulic Branch scheduled teams of hydraulic engineers to go to these areas each day as the forecasted flood crest neared to monitor the actual water levels and to observe any impacts that were occurring as a result of the high water.

i. Butte La Rose, LA. The area of most concern was the community of Butte la Rose, because of its location in the middle of the Atchafalaya Basin. The Atchafalaya River forecast showed that the river would be above flood stage in this area at the time the Morganza Floodway was operated. The concern was that the additional water from the Morganza Floodway, would further raise the water elevations in the community. The hydraulic engineers began monitoring the water elevations on the Atchafalaya River near Butte la Rose and on the back side of the Butte la Rose ridge. It was observed that the high water elevations in the Atchafalaya River were wrapping around the downstream end of the Atchafalaya River Levee and coming back up through the West Atchafalaya Basin Protection Levee Borrow Channel. Water in the borrow channel was flowing north past Butte La Rose into the Henderson Lake area and further into the West Atchafalaya Floodway. During the peak of the flooding, backwater was observed in the West Atchafalaya Floodway as far north as Krotz Springs, LA. The Butte La Rose area experienced only minor flooding. The water elevations on the Atchafalaya River at Butte La Rose crested at 23.1 feet NAVD 88. On the backside in Butte La Rose, peak water elevation reached 19.0 feet NAVD 88, a difference of approximately 3 feet.

ii. Morgan City – Backside. Weeks before the river levels reached flooding conditions, the Mayor of Morgan City, LA asked the New Orleans District to provide him with estimated water elevations of Lake Palourde, based on the NWS latest Atchafalaya River forecast at Morgan City. His concern was that prolonged high water elevations on the Lower Atchafalaya River would flank the lower Avoca Island levee and cause flooding on the backside of the City. Lake Palourde is hydraulically connected to the Atchafalaya River. The MVN's Hydraulics Branch performed an analysis based on historical river data. The purpose of this investigation was to provide best estimated water elevations on Lake Palourde, northeast of Morgan City, based on forecasted water elevations on the Atchafalaya River near Morgan City. The NWS is the official forecasting agency and they produce the forecasted stages for Morgan City. This analysis was performed by applying hydrologic statistical methods to historical data for Lake Palourde in order to determine if a correlation exists with water elevations on the Atchafalaya River near Morgan City. This correlation would provide a tool able to estimate lake stages based on a forecasted stages on the Atchafalaya River.

The results of this analysis illustrated that prolonged elevated stages in the Atchafalaya River could result in stage increases on areas located east of the floodway. When the flows in the Atchafalaya Floodway get high, the stages at the end of the Avoca Island Levee, which extends to about twelve river miles downstream of Morgan City, become elevated. The backwater effects from these elevated stages extend to the Amelia area and eventually up to the Lake Palourde area. With the construction of the Bayou Chene closure by St. Mary Parish Levee District, the backwater effects did not occur.

iii. West of Berwick. Elevated stages in the Atchafalaya River in Morgan City and in Wax lake Outlet can also cause stage increases on the GIWW west of Berwick. High stages on the GIWW in this area have the potential to increase the chance of backwater flooding in many outfall drainage canals for some of the local communities in the area. In order to prevent any possible backwater effect from impacting these areas, the local communities placed closures in three of the largest gravity drainage canals in this area. Hansen Canal, Franklin Canal, and Yellow Bayou were closed to prevent high stages in the GIWW from moving into populated areas.

The Hydraulic Branch of the New Orleans District began monitoring water levels on this three canal closures as well as along the levees in the Bayou Sale Ridge area. The monitoring effort began on 24 may and concluded on 29 May 2011. During this monitoring effort, the stages on the three canal closures were reported as well as the conditions on Bayou Sale Ridge.

g. Bonnet Carré Spillway. The Bonnet Carré Spillway is located 32.8 miles above New Orleans, near the Jefferson Parish and St. John the Baptist Parish borders. It extends from the Mississippi River to Lake Pontchartrain for a length of 5.7 miles. The structure consists of 350 bays, each 20 feet wide, for a total width of 7,000 feet at the weir opening. The structure is designed to divert 250,000 cfs to Lake Pontchartrain under the conditions of the PDF for the MR&T Project. The peak flow through the spillway was 314,000 cfs.

On 8 March, the forebay at the Bonnet Carré Structure was flooded when the Carrollton gage reached 8.54 feet NGVD. By 17 March, water was overtopping the concrete weir of the structure and flowing through the closed needles (The Bonnet Carré Spillways is closed with timber posts, or "needles" rather than gates. These do not provide a watertight seal, so leakage through the structure occurs whenever water levels are above the weir crest). Water typically overtops the low bays at 11.8 feet NGVD and the high bays at 17 feet NGVD. Recreational and borrow activities at the Bonnet Carré Spillway were restricted. Borrow pits remained active until water impacted operations, and the closing of these borrow pits did not impact any levee contracts or completion dates.

Several preparatory measures were taken prior to the opening of the spill way. One bay was tested on 5 April 2011 as part of an emergency preparedness exercise. The M/V Kent arrived at the downstream end of the spillway structure a day prior to the spillway opening to perform picket duty. The USCG implemented a Safety Zone on the Mississippi River in front of the structure. Based on experience during the flood of 1997, 500 CY of sand for sand bags was stockpiled offsite for protection of Airline Highway (US 61). The sand was stockpiled adjacent to the maintenance facility at the Bonnet Carre Floodway.

Safety precautions were taken in expectance of large crowds. Under normal operations, the spillway has contracted law enforcement personnel from St. Charles Parish that cover night and weekend shifts. As a result of the structure opening and high level of public interest, the contract was modified to cover two months of additional personnel at both ends of the structure from 1800 hours to 0600. Park rangers from the Atchafalaya Basin were brought in as well to assist during day light hours. In addition to park rangers and St. Charles Parish law enforcement, the Louisiana Department of Wildlife Fisheries (LDWF), Louisiana Department of Transportation and Development, and Louisiana State Police provided regular patrols on guide levees and public viewing areas.

Stakeholder meetings were held the week prior to opening the structures and the MVN Public Affairs Office put out a press release. The Bonnet Carré team communicated regularly with the Pontchartrain Levee District, St. Charles Parish, Pontchartrain Basin Foundation, US Coast Guard, and the USGS.

The decision to operate the spillway is the responsibility of the MVD Commander. On 9 May 2011, the Bonnet Carré Structure was opened; by 15 May, 330 bays were open. Per the Water Control Manual, the structure was operated to prevent flows on the Mississippi River from exceeding 1,250,000 cfs and to maintain safe levels of freeboard on downstream levees. On 14 May, additional material was placed on the upper guide levee, along Airline Highway (US 61) for additional freeboard. This upper guide levee was under construction when the Bonnet Carre Floodway was operated. A 1,600- foot potato ridge levee was constructed on the south side (front side) of Airline Highway. Approximately eight minor seepage areas were reported along the guide levees. The spur levee at the far end of the spillway was overtopped into the lake, though this resulted in no major consequences. A few gages and four of the original structure needles were lost during operation of the structure. These needles were replaced with new ones

On 22 May 2011, a 26-foot section of the Canadian National railroad bridge within the Bonnet Carré spillway was damaged, leaving the rails suspended without a trestle. Amtrak shuttled passenger between Hammond and New Orleans by bus while the structure was inoperable. Further investigations were conducted by the railroad to ensure no further damage was imminent and the Department of Transportation and Development was contacted to ensure debris from the failure would not threaten the integrity of the piers at Interstate 10. No further damage occurred as a result of this incident. The temporary repairs to the railroad bridge were complete on 28 May and the line was fully reopened to rail traffic. Inspections to the rail bridge continued throughout the event and ongoing work was performed on the line amid traffic.

Throughout the event, park rangers issued citation for unauthorized entry or use of the structure. No vehicles were permitted to ride on the levees or park on the crowns. The railroad was prohibited from stockpiling any materials or parking equipment trucks on the crown of the levee while conducting repairs at the rail bridge. Recreational access to the water was prohibited. Law enforcement and park rangers issued citations and citizens assisted in reporting restricted activities. Approximately 20 citations were issued, 6 for unauthorized entry into the water, the rest for ATV usage or riding/parking on the levees. As a result of events with unauthorized entry into the water, a secondary navigation zone was implemented at the Spillway on 27 May. Both ends of the Spillway, the river end and the Lake Pontchartrain side, were patrolled by the Coast Guard to prevent unauthorized entry.

The Bonnet Carré spillway structure closure began on 11 June, and the structure was completely closed by 20 June. The M/V Kent departed and the Coast Guard lifted the safety zones. The Spillway was reopened to the public on 21 June. By 25 June, when the Carrollton gage read 12.43 feet, water was below the concrete weirs and leakage through the needles stopped.

D. SYSTEM BASED SUMMARY

This section builds on the district flood fight information in the prior section by incorporating knowledge gained from MR&T areas of operation after emergency response activities were complete. Some information is repeated from the previous section to provide a foundation for this increased knowledge. This section of the report is organized by MR&T component and presents the information from a system-based perspective to document overall performance. The assessment of the successes and vulnerabilities of MR&T System components provides insights into potential concepts and actions necessary to better manage future flood risks across district boundaries and throughout the system.

1. Reservoirs. During the 2011 Flood, reservoirs were utilized to attenuate the flood crests and reduce overall impacts. MR&T authorized reservoirs, as well as other reservoirs outside the MR&T project, were utilized. A map showing reservoir travel times to the MR&T system can be found in Appendix A, *Reservoirs.* Table IV-5a lists the reservoirs within MVD and LRD that were utilized, their locations, and the extent to which available storage was utilized. Within LRD, all 79 reservoirs in the Ohio Valley played a role in reducing flood levels. Table IV-5b includes a subset of these reservoirs within LRD that set record pool elevations or were instrumental in the regulation of the Tennessee-Cumberland River system.

Table IV-5a. Reservoirs Utilized

Reservoir	Location	District	Division	Operator		Maximum Flood Control Storage 2011
Saylorville Lake	Johnston, IA	MVR	MVD	Corps	non-MR&T	55%
Lake Red Rock	Knoxville, IA	MVR	MVD	Corps	non-MR&T	82%
Coralville Lake	Iowa City, IA	MVR	MVD	Corps	non-MR&T	18%
Lake Shelbyville	Shelbyville, IL	MVS	MVD	Corps	non-MR&T	24%
Carlyle Lake	Carlyle, IL	MVS	MVD	Corps	non-MR&T	68%
Mark Twain Lake	Monroe City, MO	MVS	MVD	Corps	non-MR&T	25%
Lake Barkley	Grand Rivers, KY	LRN	LRD	Corps	non-MR&T	92%
Kentucky Lake	Grand Rivers, KY	TVA	LRD	TVA	non-MR&T	92%
J Percy Priest	Nashville, TN	LRN	LRD	Corps	non-MR&T	76%
Center Hill	Lancaster, TN	LRN	LRD	Corps	non-MR&T	25%
Dale Hollow	Celina, TN	LRN	LRD	Corps	non-MR&T	75%
Wolf Creek	Jamestown, KY	LRN	LRD	Corps	non-MR&T	7%
Rough River Lake	Falls of Rough, KY	LRN	LRD	Corps	non-MR&T	115%
Patoka Lake	DuBois, IN	LRN	LRD	Corps	non-MR&T	112%
Monroe Lake	Bloomington, IN	LRN	LRD	Corps	non-MR&T	109%
Taylorsville Lake	Taylorsville, KY	LRN	LRD	Corps	non-MR&T	101%
Cave Run Lake	Morehead, KY	LRN	LRD	Corps	non-MR&T	81%
Nolin Lake	Bee Spring, KY	LRN	LRD	Corps	non-MR&T	99%
Brookville Lake	Brookville, IN	LRN	LRD	Corps	non-MR&T	67%
Wappapello Lake	Wappapello, MO	MVS	MVD	Corps	MR&T	100%
Sardis Lake	Sardis, MS	MVK	MVD	Corps	MR&T	55%
Arkabutla Lake	Coldwater, MS	MVK	MVD	Corps	MR&T	100%
Enid Lake	Enid, MS	MVK	MVD	Corps	MR&T	43%
Grenada Lake	Grenada, MS	MVK	MVD	Corps	MR&T	38%

Figure IV-5 illustrates the flood storage available within MVD and LRD in mid-February 2011 relative to the average available at that time during other years.

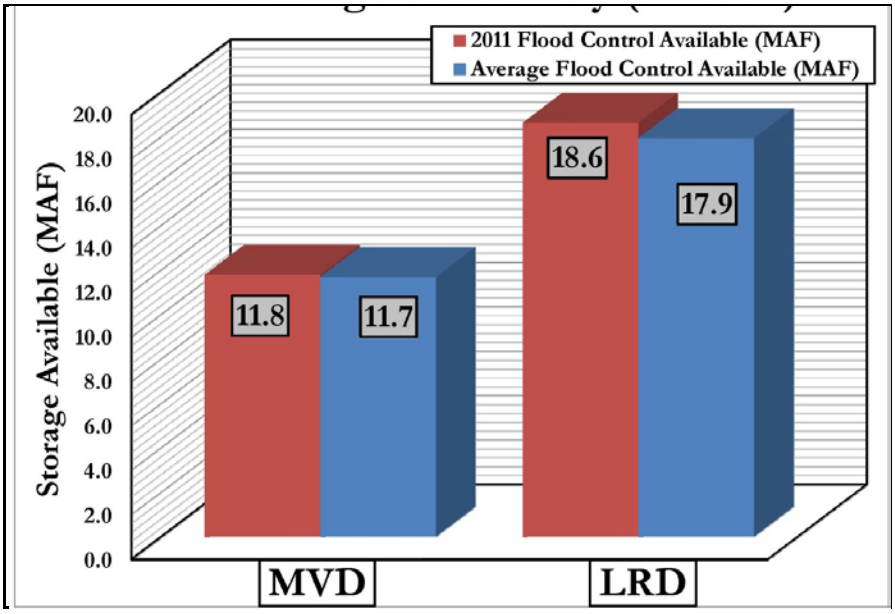


Figure IV-5. Relative Flood Storage Availability – Mid February, 2011 (Million Acre Feet)

a. MR&T Reservoirs. Table 5b lists MR&T reservoirs that were utilized with greater than 50 percent Flood Control Storage during the 2011 event:

Table IV-5b. MR&T Reservoirs Utilized with Greater than 50% Flood Control Storage

Reservoir	Location	District	Division	Maximum Flood Control Storage 2011
Wappapello Lake	Wappapello, MO	MVS	MVD	100%
Sardis Lake	Sardis, MS	MVK	MVD	55%
Arkabutla Lake	Coldwater, MS	MVK	MVD	100%

Additional detailed reservoir information can be found in Appendix A, *Reservoirs*. Due to the record-breaking flood at Wappapello Lake, details related to that event are discussed as follows:

Leading into the 2011 Flood at Wappapello Lake, on April 1 the pool level (355.2 feet) was in the transition range from 354.74 NGVD to 356.74 NGVD, as called for in the Wappapello Lake water control manual. From April 22 through May 3, the St. Francis River Basin received record breaking rainfall. Due to rising pool elevations and forecasts indicating that overtopping of the auxiliary spillway resulting in major damage to downstream roadway and utility infrastructure was probable, a major deviation was requested for Wappapello Lake on April 26, 2011. The deviation plan consisted of constructing a berm at elevation 397.3 feet across the auxiliary spillway. The purpose of the berm was to allow the entire scheduled release discharge of 10,000 cfs to be discharged through the gated outlet structure, and none over the spillway. The berm was located sufficiently upstream of the auxiliary spillway so that it would not impede discharges over the spillway if the berm would be overtopped. The major deviation was approved and was in effect from April 26 through May 2. The pool level crested at 396.7 on April 29 and the deviation was successful.

As a result of a second record rainfall, multiple peak inflows of greater than 100,000 cfs raised Wappapello Lake to a record pool level of 400.04 NGVD on May 3, 0.95 ft above the previous record and 5.30 ft above the auxiliary spillway. The berm which had been constructed across the auxiliary spillway was overtopped (photographs IV-1 and IV-2). Spillway overtopping resulted in significant damages downstream. By June 1, the pool level was down to 377.2 ft and 42 percent of the flood control storage utilized. By July 1, the pool level was successfully approaching rule curve level of 359.74 ft.

Photograph IV-1. Prior to 2011 Overtopping of Spillway

Photograph IV-2. Post 2011 Overtopping of Spillway

The Wappapello Reservoir monthly pool elevation and percent utilization status for 2011 is provided in table IV-6. Figure IV-6 shows a comparison of pool elevations and associated inflow and outflow hydrographs.

Table IV-6. Wappapello Reservoir Pool Elevation & Percent Utilization - 2011

Item	Data	1/1	2/1	3/1	4/1	5/1	6/1	7/1	8/1	9/1	10/1	11/1	12/1
1	Pool Elevation, ft	355.18	354.9	356.96	355.2	396.37	377.2	360.94	360.06	359.87	359.84	359.93	360.82
2	Target Elevation, ft	354.74	354.74	354.74	356.74	359.74	359.74	359.74	359.74	359.74	359.74	359.74	354.74
3	Flood Control Storage % Utilization	0.3	0.1	2.1	0.4	100	41.7	5.9	5.9	5.7	5.6	5.7	7.1
4	All-Time High Pool Elev, ft	389.04	377.14	373.14	395.24	396.37	385.95	389.44	374.24	364.57	366.13	378.67	386.5
5	Period of Record Avg Pool Elev	360.45	358.08	358.1	359.95	363.24	362.82	360.51	359.61	359.15	359	359.7	362.13
6	Average % Flood Control Storage Utilization for Period of Record	6.5	3.4	3.4	5.8	10.9	10.2	6.6	5.3	4.7	4.5	5.4	9.1

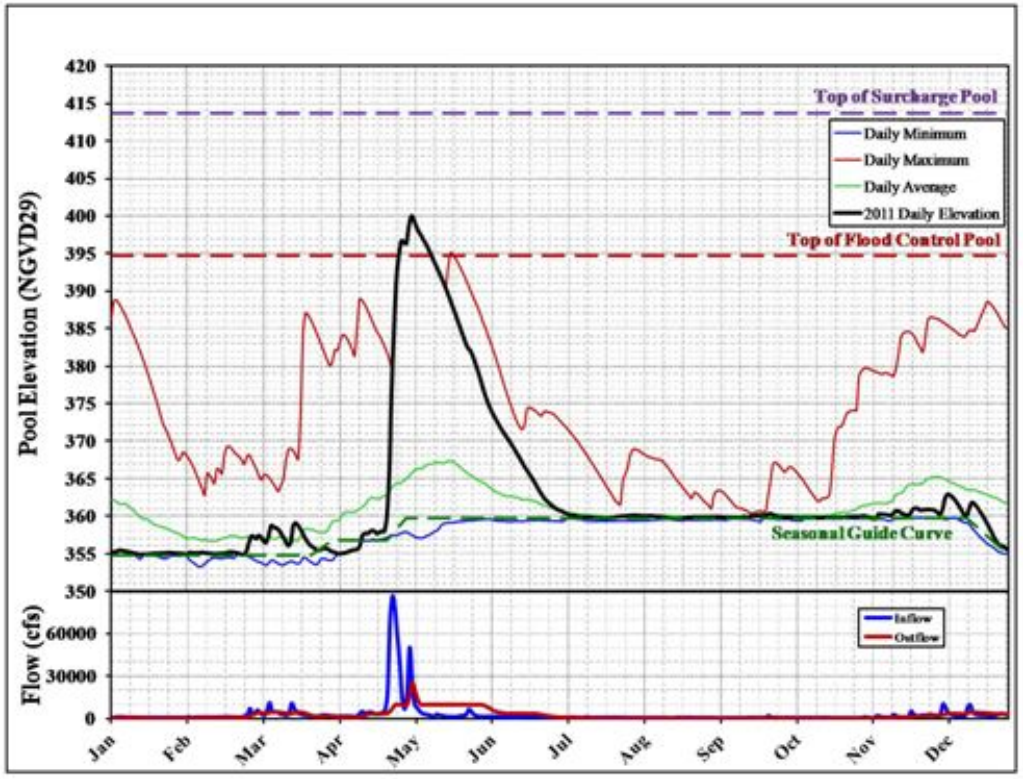


Figure IV-6. Wappapello Lake Elevation, Inflow, and Discharge Comparison Hydrograph

b. Non-MR&T Reservoirs. Several non-MR&T reservoirs located within MVD and LRD were utilized during the 2011 Flood in an attempt to lessen impacts to the MR&T system of their releases. The non-MR&T reservoirs helped to reduce peak Mississippi River stages during the flood. Modeling scenario 3 (section V of this report) included the effect of all reservoirs. Scenario 3 results showed that significant damages were avoided during the flood, due in part to the non-MR&T reservoir effects. At LRD, storage at Lake Barkley and Kentucky Lake was utilized up to the pool of record to reduce stages at Cairo in an attempt to avoid activation of the BPNM Floodway, and protect the lower MR&T system. At Lake Cumberland/Wolf Creek Dam (DSAC I), while only 7 percent of flood control storage was used, the pool reached 45 feet above its interim risk reduction measure lowered pool of 680 feet. This is the highest Lake Cumberland has been allowed to rise since the pool lowering was put in effect as a dam safety interim risk reduction measure. The 7 percent does not truly reflect the large amount of storage that was utilized relative to other issues. These and other reservoirs in LRL contributed significantly to the reduction in the flood crest at Cairo (about 0.53 feet). In addition, several reservoirs with the MVR and MVS Districts operated during the 2011 Flood under a Directive issued by MVD to deviate from their approved Water Control Plans. Those reservoirs, their locations, and the maximum flood storage utilized with and without Directive are provided in table IV-7.

The MVR and MVS Districts were directed to perform deviations from their approved Water Control Plans for Red Rock and Saylorville Reservoirs in the MVR District and Carlyle, Shelbyville and Mark Twain Reservoirs in the MVS District to maintain reduced releases during the Flood in an attempt to minimize flows entering the Mississippi River to effect reductions on the ultimate stages of the Mississippi River. See Appendix A for a copy of the Directive. In addition, releases from Saylorville and Shelbyville Lakes were curtailed due to the need to balance flood control storage with downstream reservoirs.

These Directives were initiated as early as April 25, 2011 through coordination with the Watershed Division. The extraordinary floods which occurred on both the Upper Mississippi and Ohio Rivers were expected to push the stage at Cairo, IL, to exceed the 1937 peak of 59.51 feet by as much as a foot on or about May 1. Record stages were forecasted to occur on the Mississippi River below Cairo as well. The historic flood placed tremendous pressure on the entire FRM system requiring water management measures beyond the normal water control plans.

The MVR and MVS Water Management Offices expressed to the Watershed Division Office that they were not in favor of the Directive because local flood control was “lost” to attempt to provide reduced risk downstream, and because commensurate off-setting positive impacts were not communicated to the Districts. Subsequent analysis during this PFR effort indicates that compared with modeled stages without Directive operations, the crest at Cairo IL with the Directive was reduced by 0.01 feet, a slight positive impact (figure IV-7). Due to the travel time of releases from the reservoirs to Cairo and the timing of the directive, the effect of flow reductions reached Cairo after the crest had already passed for three of the four reservoirs operating under the directive, and on the same day for one reservoir (table IV-8).

Table IV-7. Non-MR&T Reservoirs Utilized

District	Division	Reservoir	Location	Operator	Maximum % Flood Control Storage 2011	Est. Max. % Flood Control Storage 2011 w/out Deviation Directive	Notes
MVR	MVD	Saylorville Lake	Johnston, IA	USACE	55	54	Operated under normal conditions, no change in storage used.
MVR	MVD	Lake Red Rock	Knoxville, IA	USACE	82	79	Difference equivalent to increase of 0.9 feet in pool elev impacting flowage easement agricultural landowners in pool
MVR	MVD	Coralville Lake	Iowa City, IA	USACE	18	18	Operated under normal conditions, no change in storage used.
MVS	MVD	Lake Shelbyville	Shelbyville, IL	USACE	24	18	Difference equates to 1.8 feet of pool elevation.
MVS	MVD	Carlyle Lake	Carlyle, IL	USACE	68	60	Difference equates to 1.2 feet of pool elevation.
MVS	MVD	Mark Twain Lake	Monroe City, MO	USACE	25	25	No difference in peak elevations, but opportunity to operate for fish spawn was lost due to directive operation.
LRN	LRD	Lake Barkley	Grand Rivers, KY	USACE	92	92	Operated under normal conditions, no change in storage used.
TVA	LRD	Kentucky Lake	Grand Rivers, KY	TVA	92	92	Operated under normal conditions, no change in storage used.
LRN	LRD	J Percy Priest	Nashville, TN	USACE	76	44	Deviated 4/26 to 5/5. 44% assumes no flood threat to Nashville, may have been higher if QPF/stage forecasts had indicated a need to reduce flows.
LRN	LRD	Center Hill	Lancaster, TN	USACE	25	0	Deviated 4/24 to 5/7. Operating under IRRM, peak without reductions would have been below bottom of flood pool.
LRN	LRD	Dale Hollow	Celina, TN	USACE	75	50	Deviated 4/25 to 5/6.
LRN	LRD	Wolf Creek	Jamestown, KY	USACE	7	0	Deviated 4/25 to 5/7. Operating under IRRM, peak would also have been below bottom of flood pool.
LRL	LRD	Rough River Lake	Falls of Rough, KY	USACE	115	115	Record Pool; Flow through uncontrolled spillway
LRL	LRD	Patoka Lake	DuBois, IN	USACE	112	112	Record Pool; Flow through uncontrolled spillway
LRL	LRD	Monroe Lake	Bloomington, IN	USACE	109	109	Record Pool; Flow through uncontrolled spillway
LRL	LRD	Taylorsville Lake	Taylorsville, KY	USACE	101	101	Record Pool
LRL	LRD	Cave Run Lake	Morehead, KY	USACE	81	81	Record Pool
LRL	LRD	Nolin Lake	Bee Spring, KY	USACE	99	99	Record Pool
LRL	LRD	Brookville Lake	Brookville, IN	USACE	67	67	Record Pool

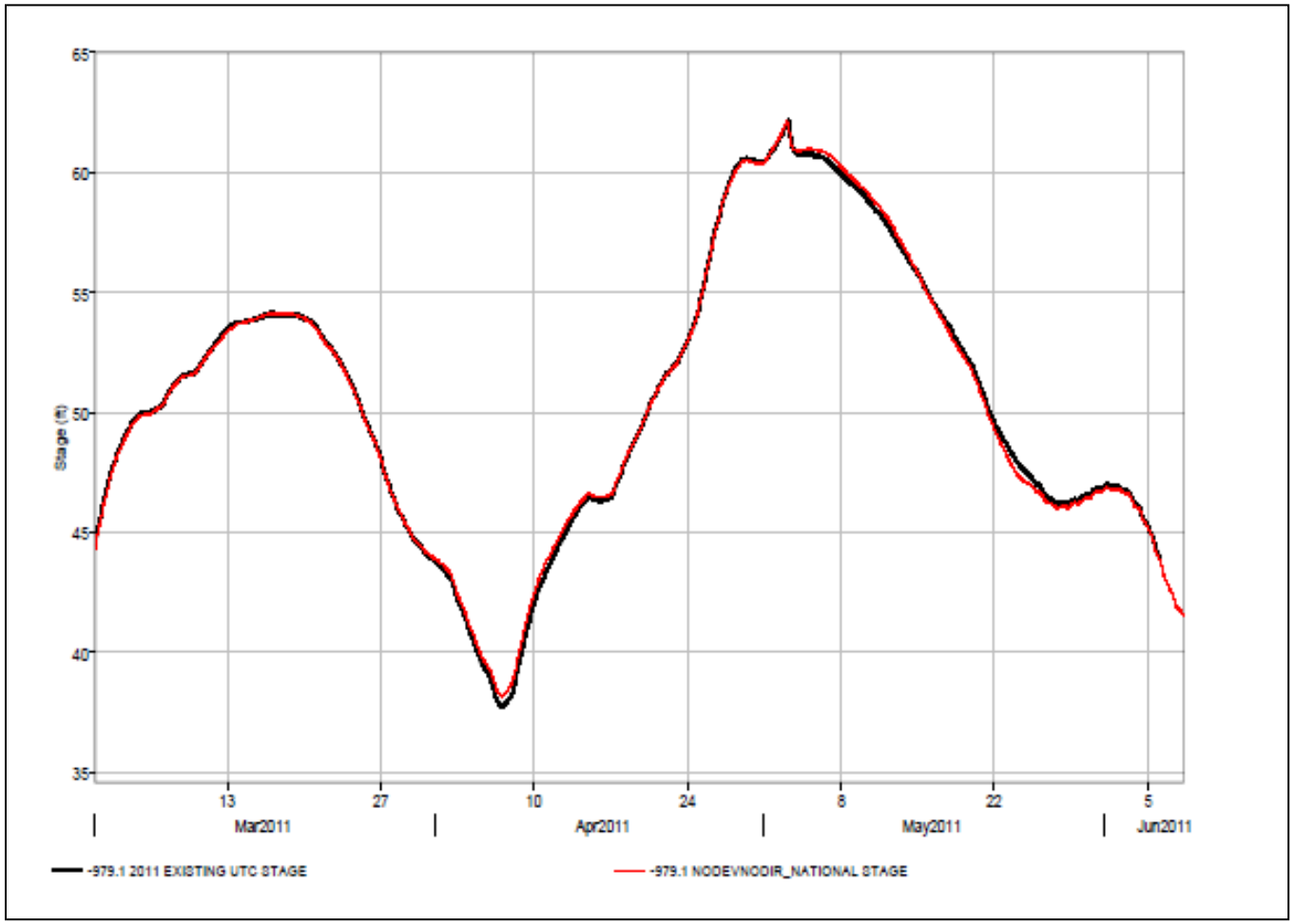


Figure IV-7. Impacts of the Directive on the Stages at Cairo, IL

Table IV-8. Travel Time to Cairo, Deviation-Directed Reservoirs

Reservoir	Date Directive Initiated	Reservoir Flows Est. Travel Time	Arrival Date of Reservoir Flows	Mississippi River Crest Date at Cairo	Reservoir Flows Arrival Relative to Cairo Crest
Mark Twain	4/26/2011	7 days	May 3, 2011	May 2nd @ 2100	After
Shelbyville	4/26/2011	9 days	May 5, 2011	May 2nd @ 2100	After
Carlyle	4/26/2011	6 days	May 2, 2011	May 2nd @ 2100	Same Day
Red Rock	4/27/2011	11days	May 8, 2011	May 2nd @ 2100	After

Negative impacts of the Directive at Lake Red Rock (MVR) included the inundation of about 1,000 occasional flowage easement (not fee title) acres. The 1,000 acres of flowage easement land flooded in Lake Red Rock's flood pool were flooded due to conditions not considered in the water control plan. At Carlyle Lake (MVS), operation under the directive contributed to the lake reaching its second-highest elevation for the period of record, in spite of proactive early-season MVS efforts with local stakeholders to prepare for anticipated heavy spring rains by utilizing deviations for higher than normal releases. Due to the impact of the directive, MVS requested and was granted a deviation to release up to the maximum allowable release of 10,000 cfs until the end of May 2011. This resulted in more available flood control storage at Carlyle, which in turn allowed releases to be increased from Lake Shelbyville (located higher in the watershed).

Stakeholders found it difficult to understand why changes to reservoir operation was needed during the 2011 Flood, and additional time was required to explain why this was being done to attempt to balance flood risks throughout the Mississippi River Basin. Additional details related to how the reservoirs operated under a directive to attempt to minimize flows into the Mississippi River can be found in Appendix A, *Reservoirs*.

2. Levees and Floodwalls. During the 2011 Flood, each District deployed personnel to patrol and monitor the levees and floodwalls that comprise the protection system for their respective District. These personnel are trained by their Districts to identify problematic phenomena that occur during a riverine flood event and report these inspection sites back to their District's EOC. The EOC, in conjunction with District Engineers, develop courses of action to remediate the damaged areas, coordinate the efforts through various local entities, and manage the overall flood fight effort for their District. Typical sites of concern along levee and floodwalls during a high water event are seepage, sand boils, levee sloughing or sliding and freeboard deficiencies. Remedial action for these phenomena can range from merely monitoring the site to an expedited emergency repair.

During the Flood, each system in the MVD was monitored closely and damage was observed and recorded. A summary for each system follows. A more detailed report is found in Appendix B, *Levees and Floodwalls*.

a. SYSTEM #4001 – Mississippi and Ohio River Levees at Cairo and Vicinity

i. Cairo, IL. Three large high-energy sand boils with sand cones from 8 to 15 feet high developed due to major seepage.

ii. Cairo, IL Parcel 5. Major seepage was observed in the form of multiple large, high energy sand boils along the levee toe and in the sump area of the Goose Pond Pumping Station.

iii. Above Cairo, IL Parcel 2A – Relief Wells. Hundreds of small to medium sand boils were observed during the 2011 event. Most of these boils had throat diameters of greater than 4 inches and cone diameters of 3 to 6 feet or greater. Boils were ringed with sandbags.

iv. Above Cairo, IL Parcel 2 – Slurry Trench. Major seepage was observed in the form

of hundreds of small to medium sand boils. Most of these boils had throat diameters of greater than 4 inches and cones diameters of 3 to 6 feet or greater.

b. SYSTEM #4002 – Commerce, MO to St. Francis River

Sand Boils at Gammon Water Berm. Heavy seepage and small to large boils occurred and were rung at the landside toe of the Gammon Water Berms. In addition one large boil was discovered.

c. SYSTEM #4003 – Mississippi and Ohio River Levees at Cairo and Vicinity

Island 8 (Mile 1/0+00 to Mile 15/0+00). Heavy seepage and hundreds of large, high energy sand boils within 100 feet of the levee toe was flood fought in this area.

d. SYSTEM #4006 – Mississippi and White Rivers Below Helena. During the 2011 event, six areas of uncontrolled seepage were observed in this system, including sheet seepage, pin boils and small to medium boils moving moderate amounts of material.

e. SYSTEM #4016 - New Madrid Floodway Levee

i. Segment #75 and Segment #76 – BPNM Floodway – Make Safe and Stable. Following the operation of the Floodway, the crevassed sections of the levees were no longer functional. The MVD Commander issued a memorandum directing the MVM to implement *make safe and stable* operations based on a target elevation (stage) of 51 feet on the Cairo gage to provide a stable base for flood fight operations and subsequent reset operations by 30 November 2011. Restoration of the crevassed sections for *make safe and stable* was later expanded to include reconstruction of the levee at the upper inflow crevasse to provide FRM to a Cairo gage reading of 55 feet (photographs IV-3 through IV-6).

ii. The Birds Point New Madrid Floodway. The restore project consisted of rebuilding the System #4016 levees to full height. At the defined *make safe and stable* elevations, the level of protection for the floodway is minimal compared to the pre-operation level of protection. Full reconstruction of the floodway levees requires other elements of the MR&T system, located adjacent to and upstream of the floodway, be remediated to ensure that they can provide full PDF protection.

Photograph IV-3. Upper Inflow Crevasses Prior to Repairs

Photograph IV-4. Levee Crown Damaged Due to Overtopping

Photograph IV-5. Northern End of the Lower Inflow/Outflow Crevasse Prior to Repairs

Photograph IV-6. Scour Hole at Center Crevasse Extending into Agricultural Field.

f. SYSTEM #4021 – Little River Drainage District of Missouri. During the 2011 event, numerous medium sand boils formed within the collector ditches for the Nash Relief Wells while the relief wells were actively flowing. Based on a survey, it appears that the ditches have been over excavated by up to several feet, allowing the sand boils to form. Multiple areas of shallow slope movement and one levee slide that was categorized as possibly impacting levee performance were present on the landside slope prior to the event.

g. SYSTEM #5901 – West Bank Mississippi River Levee

i. Segment #24 - Lake Bruin (LA 5715+00, 5776+00 - 5800+00). Seven boils with cone diameters varying from 2 to 5 feet were located just off of the bank of Lake Bruin at Melancon Camp. These boils produced a total of approximately 10 yards of silty sand and contributed to the removal of material from behind a concrete seawall. These boils are approximately 250 feet from the levee toe.

ii. Segment #62 - Leland Chute (AR 2150+00). Moderate seepage (photograph IV-7) exiting at the toe of the levee and beyond as well as numerous small to medium sized boils located in a ditch (photograph IV-8) approximately 100 feet beyond the toe of the levee were identified in an approximately 1-mile long reach.

Photograph IV-7. Aerial View Showing Extent of Seepage

Photograph IV-8. Bagged Sand Boil in Ditch

iii. Segment #62 – Lake Chicot (Fish Bayou-AR 2575+00). The site has historically been an area with large boils. Two large, high energy sand boils were exiting the lake bank one foot above the water surface at the south end of Lake Chicot. These boils were located within 15 feet of each other.

iv. Segment #24 - Henderson (LA 2062+00 - 2132+00). This has historically been an active seepage and sand boil area. The site is located in and around an old borrow area that was used to raise levee Item 464-R. There were numerous boils ranging in size from small to medium located in a ditch that runs parallel to the berm toe. The ditch is located approximately 20 feet from the toe of the berm.

v. Segment #24 – Ice Box Hole (LA 1910+00 - 1925+00). Historically, this has been an active area. Multiple boils ranging in size from pin boils to large boils are located in the area. Boils are located 75 to 200 feet from the toe of the existing 150- to 200-foot seepage berm.

vi. Segment #62 – Willow Lake (AR 3750+00). The site has historically been an area with numerous small to medium sized boils; there were numerous medium sized boils and one large boil identified in 2011.

vii. Segment #24 – Lake St. John (LA 6940+00). The site has historically been an area with numerous small to medium sized boils. There were six medium sized, moderate energy boils sand bagged during this event. Several of these were boils that reappeared in existing sandbag rings from the 2008 High Water event.

viii. Segment #24 – Lake St. Joseph (Davis Landing - LA 5220+00-5275+00). The site has historically been an area with numerous small to medium sized boils with heavy seepage. There were several medium sized boils that were bagged.

ix. Segment #62 – Grand Lake (AR 3550+00). This area is located along a stretch of levee that had never been loaded by high water until 2011. The loading of this stretch of levee occurred rapidly as a result of the breaching of an abandoned frontline levee. Two medium sized, moderate energy sand boils were located approximately 50 feet beyond the 400-foot seepage berm toe.

x. Segment #24 –St. Joe (LA 6185+75). A large high energy boil, approximately 4 miles south of St. Joe, LA was located approximately 950 feet landside from toe of levee at Station 6185+75 downstream of a drainage ditch culvert. The boil produced over 100 yards of material.

xi. Segment #24 –Wilson Point (LA 590+00-650+00). This area is located along a stretch of levee that had never been loaded by high water until 2011. The loading of this stretch of levee occurred rapidly as a result of the breaching of an abandoned frontline levee. There are hundreds of pin boils with some larger boils that were bagged in order to raise the head over the boils. There are boils beginning at the toe of the berm, which is approximately 300 feet wide and extends out approximately 1,000 feet.

xii. Segment #62 – AR Station 2250+00. Multiple boils were located in the north end of Lake Chicot and in low lying sloughs that drain into the lake. The boils closest to the levee (greater than 500 feet from the toe) were found several days after the river crested and had moved what appeared to be more than 100 yards of silt and fine sand.

xiii. Segment #24 –Kemp Bend (LA 6442+00). Historically, this has been an active boil site that was addressed with the installation of relief wells. Multiple boils were noted at the upstream end of the line of relief wells in 2008 and with the 2011 Flood. Many of the 2008 boils could not be accessed due to water, but active boils were noted in vicinity. These boils are located approximately

1,500 feet from the levee. Throat sizes range from 2 to 6 inches. These boils have each moved approximately ½ yard of material.

iv. Segment #62 – Lake Chicot Pumping Plant (AR Station 1570+00). Historically, this ditch has required flood fighting by placement of water berms to control sand boils in the bottom of the ditch. Numerous sand boils are located in the collector ditch that empties into the diversion canal northwest of Lake Chicot Pumping plant. There was also seepage exiting the toe of the berm at the northern end of the ditch. The ditch is located approximately 150 feet from the toe of berm. The ditch is 20 feet wide and 7 feet deep. The berm is 90 feet wide at the northern end of the ditch and is 300 feet wide at the southern end.

h. SYSTEM #5921 - East Bank Mississippi River Levee (EBMRL)

i. Segment #34 - Buck Chute – [Station 110+00 Brunswick Extension Levee (BEL)]. In February, 2011, when conditions in the project area were dry, two large sand boils were pumped and inspected revealing voids at boil sources as wide as 20 feet and as deep as 10 feet. The voids revealed no obvious "pipes" that continued downward or laterally from the void bottom. The sides and bottom of the voids appeared to be top stratum, fine grained material. As Mississippi River levels continued to rise and approach flood stages in March 2011, the boil area voids were backfilled with sand material, covered with a nonwoven filter fabric, and either sandbagged or earthen dams were constructed around them. These flood fighting measures were sufficient for the 2009 and 2010 flood seasons; however, in May 2011, with predictions of higher stages on the Mississippi River (eventually cresting at 57.1 feet at the Vicksburg gage on May 19), an emergency berm was constructed over the area which encompassed the worst known boil areas. The berm was a clay dike around the perimeter of the boils area, 3 feet of clean sand material within the dike, and capped with approximately 2 feet of clay fill.

At the toe of the berm, a 10-foot wide, 2-foot thick layer of stone was placed in lieu of the clay fill cap to alleviate pressures in the sand material layer. The toe of the berm was constructed to an approximate elevation 85.0 feet. Because of the high exit gradients for the predicted stages, the known boil areas, and the consequences of failure at this location, it was decided to flood the entire project site by raising water levels in Eagle Lake to approximate elevation 90.0 feet through the use of Muddy Bayou Control Structure. Severe damages were prevented at this site through the use of the aforementioned flood fighting measures; however, the extensive flood fighting measures that were used to get through the 2011 Flood are not a sustainable option for annual flood fighting.

ii. Segment #34 - Albemarle - East Bank Mississippi River Levee (EBMRL Station 8170+00). The initial site assessment identified five medium sized, high energy sand boils at the toe of the levee in an area with no berm. Also found was a significant landside slide immediately downstream of the boils. An additional slide developed over the second night immediately upstream of the sand boils. Both slides were accompanied with and were possibly the result of heavy seepage exiting the slide face and on the slope below. The slides were present in the lower 1/3 of the levee embankment and were relatively shallow in depth. A small slide near the levee toe formed immediately above the sand boils on the third day that connected the two larger slides.

iii. Segment #34 - Francis (EBMRL Station 151+00). A large, high energy sand boil was identified moving significant quantities of silt and fine sand material at the toe of a 200 foot seepage berm. Flow from the boil was estimated at approximately 300 gals/min. This boil appeared to have the potential to result in backward erosion and piping that could eventually lead to loss of berm and levee foundation material. Two additional sand boils were identified approximately 100 – 150 feet from the berm toe. These boils were classified as moderate energy levels and moved

approximately 5to 7 CY of material. Heavy seepage and numerous pin boils were noted and monitored along the slope and toe of the berm upstream and downstream of these boils for a reach of approximately 2,000 feet.

iv. Segment #34 - Winterville (EBMRL Station 3714+00). A large, high energy sand boil approximately 30 feet from the toe of a 200 foot berm was identified. The boil was estimated to be flowing approximately 300-350 gals/min and was moving significant quantities of silt and fine sand material (approximately 100 cubic yards). This boil appeared to have the potential to result in backward erosion and piping that could eventually lead to loss of berm and levee foundation material. Four additional medium sized boils were identified within 250 feet of the berm toe. The extent of the boils is from Station 3711+00 to Station 3718+00.

v. Segment #26 - Yazoo MP 89/0+00 to MPO 92/0+00 (Rena Lara). During the 2011Flood, heavy seepage with one large high energy boil, about 40 medium boils, 12 small boils, and hundreds of pin boils were observed in this area.

vi. Segment #34 - Tara – (Station 208+00 BEL-327+00 BEL). Moderate to heavy under seepage and numerous active, medium sized sand boils and pin boils were observed within 50 feet of the levee toe between BEL Stations 208+00 and 327+00 near and around Tara Hunting Camp. Two to three large, high energy sand boils with 12- to 16-inch throats were identified between Stations 210 and 220 that flowed 100+ gallons per minute and transported 5+ CY of fine sand/silt before and during remedial action. These boils were located between 10 and 20 feet from the toe of the levee (photographs IV-9 and IV-10).

Photograph IV-9. Sand Cone on Flowing Boil

Photograph IV-10. Sandbagged Boils Flowing

i. Segment #34 - Avon (EBMRL Station 4917+00). Moderate thru seepage exiting several feet up the levee slope and numerous small to medium sized boils at and beyond the toe of the levee were identified with heavy seepage. Each boil moved silt and fine sand; however none of the boils moved a significant quantity of material.

i. Segment #34 - Leota (EBMRL Station 5615+00). Multiple sand boils were located in and on either side of a drainage ditch at the toe of the existing approximate 200- to 250-foot berm. Three of the boils were medium in size and high energy. Multiple pin boils and heavy seepage were noted to the north and south end of the area. The boils at the toe of the berm appeared in the area first and as the river level increased, multiple boils became active out in the field further from the toe.

ii. Segment #34 – Lake Jackson (EBMRL Station 6050+00). Multiple boils were found in a drainage ditch and low areas located approximately 35 to 75 feet from the toe of the existing 250-foot seepage berm.

iii. Segment #34 – Greenville (EBMRL Station 4035+00). Multiple moderate to high energy sand boils were identified moving large quantities of fine sand in two separate areas on the east side of the railroad tracks approximately 400 feet from the levee toe. There is no seepage berm in this area. Heavy seepage, numerous pin boils and saturated, soft ground was identified in and around the boil areas. The throats on these boils ranged from 3 to 6 inches in diameter and several yards (5 to 8 cy) of material had been transported over a 1000 square foot area; however, most of these boils were producing clear water. There were approximately three high flowing sand boils at approximately 100 to 200 gallons per minute each, and were transporting a significant quantity of fine sand and clay/silt balls. Over 15 to 20 yards of material had already been transported from the boils and material was still being moved. Throat diameter of the boils ranged from 12 to 18 inches.

iv. Segment #34 – Ben Lomand (EBMRL Station 7150+00). Several medium to large sand boils were identified moving moderate quantities of fine sand and silt in a drainage ditch along the toe of the seepage berm and in an open area east of the ditch. All of the sand boils were within 10 to 20 feet of the seepage berm toe.

j. SYSTEM #4401 – Mississippi River East Bank Above Bonnet Carre

Duncan Point. Duncan Point is an area of historic seepage. A massive aquifer in excess of 300 feet deep exists beneath the levee overlain by a thin blanket of confining material. This blanket has been ruptured and the situation continued to deteriorate with successive high water events. The area was previously a historic sand boil; but in 2010, a stabilization berm was constructed. As a result, the seepage moved from the berm to an area north along the protected side toe of the levee. There was extensive seepage at this site to include a sand boil at levee toe and soft, spongy conditions one-third up the levee slope, requiring extensive flood-fight efforts. A temporary, berm was constructed using 12,000 sandbags to reduce seepage in the most critical reach of the site. Adjacent highway experienced spongy conditions requiring closure.

k. SYSTEM #4405 – St. Bernard Polder

i. Chalmette Seepage. The site was first reported on 07 May when the Carrollton gage read 15.39feet. The local levee District placed a temporary HESCO Basket berm on the protected side, but a small amount of seepage still appeared underneath the baskets. There was no flow but the seepage remained at the bottom of the baskets throughout the event. The point site was closed out on 15 July when no visible signs of seepage remained and the Carrollton gage read 10.63 feet. This site has been permanently repaired as of March 2012. The repair incorporated a sheet pile cutoff and approximately 300 CY of embankment.

ii. Jackson Barracks Slope Paving. The cracked concrete slope pavement near Jackson Barracks was a known issue prior to this Flood. The cracked slope pavement is located under the storm water discharge pipes approximately twenty feet downstream from where Delery Street meets the river. The broken slope pavement has been replaced by the New Orleans Sewage and Water Board.

l. SYSTEM #4415 – Mississippi River Westbank – Above Old River

Old River Lock Sand Boils. The sand boils by the Old River Lock were first inspected on 09 May when the Red River Landing gage read 58.05 feet. Sand boils had never been reported in this area prior to this event. Backwater from the Atchafalaya River flowed into Keller's Lake and covered the boils near the light poles.

m. SYSTEM #4425 – Atchafalaya Basin

Audubon Seepage. Sand boil and seepage locations were discovered near Waterloo, Louisiana on 16 May when the Red River Landing gage read 62.27 feet. The seepage sites were located in a highway ditch directly underneath the John James Audubon Bridge.

Significant flood fight activities were required at Charenton Floodgate, Bayou Sorrel Lock, and the East and West Calumet Floodgates. Hesco baskets were added to all these structures and steel plates were welded to the East and West Calumet Floodgate superstructure.

While not tested in the 2011 event, some of the floodwalls are believed to be deficient. In 2010, an assessment of approximately 37 miles of I-wall in the Atchafalaya Basin was performed. Evaluations performed included global stability (considering water to the top of wall and flowline + freeboard.), pile tip penetration, and stickup. At that time approximately 3.1 miles of I-wall indicated some form of deficiency. Since that time, both the flowline (2011) and criteria (2012) have changed. These changes tend to further reduce factors of safety.

n. SYSTEM #4452 – Westwego-Harvey-Algiers

Algiers Seepage. Two sand boils sites were reported within this sector: one at Oak Alley Plantation and one in *Algiers* (photograph IV-11). The Oak Alley sand boil was first reported on 09 May when the Carrollton gage read 16.51 feet. It is located at the intersection of Bessie K Road and River Road. There was no moving material reported and the water flowed clear for the duration of the event. The boil was downgraded to a seepage site on 16 June when the Carrollton gage read 14.62 feet, and the area began to dry on 28 June when the Carrollton gage read 11.48 feet.

Photograph IV-11. Algiers Seepage

3. Floodways. The four MR&T Floodways reduce risk by diverting excess floodwaters from the main channel at key locations and increase floodplain area, lowering crest stages in their vicinities and downstream. Performance of the floodways was assessed through interviews with regulators, operators, and stakeholders, and through analysis of stage and discharge data collected during the flood. The following provides details on the emergency operation activities involving floodway areas. The general locations of

the floodways are shown in Section II, Figure II-2 of this report. A more detailed illustration is provided in Plate A-1 of Appendix A.

a. Bird's Point – New Madrid Floodway. The BPNM Floodway is located on the right descending bank of the Mississippi River in Mississippi and New Madrid Counties, Missouri, just below the confluence of the Ohio and Mississippi Rivers. The Floodway is about 33 miles long and 10 miles wide. Its area comprises about 205 square miles of alluvial valley land and is enclosed by Mississippi River project levees, except for a 1,500 foot authorized but uncompleted closure at the lower end which provides a drainage outlet and allows flood backwaters to enter the Floodway. The Mississippi River project levees enclosing the Floodway are the lower portion of the upper St. Francis Levee (hereinafter called the Frontline Levee) which forms the eastern boundary and the Birds Point-New Madrid (BPNM) Floodway Levee (hereinafter called the Setback Levee) which forms the western boundary. The Frontline Levee consists of three parts: the upper fuseplug section, 11 miles in length; the lower fuseplug section, five miles in length; and the section between the two fuseplugs. The fuseplug sections are about 2 feet lower in grade than the remainder of the Frontline Levee except for 12,500 feet in the upper fuseplug for the Inflow Crevasse and 7,500 feet in the lower fuseplug for Inflow/Outflow No. 2. The Setback Levee extends from its junction with the Frontline Levee at Birds Point, Missouri, directly across the Mississippi River from Cairo, Illinois, southwesterly for a distance of about 36 miles and ties in with the St. Johns Bayou Levee near New Madrid, Missouri.

The BPNM Floodway reduces flood stages and prevents the PDF from exceeding the design elevation on the Mississippi River at and above Cairo, IL, and along the east bank levee opposite the floodway. The PDF at Cairo is 62.5 Feet or 332.97 Feet NGVD. The BPNM Floodway is designed to divert 550,000 cfs from the Mississippi River during the PDF and provides an estimated 7 feet of stage lowering in the vicinity of Cairo, with smaller reductions above Cairo and through the floodway reach. Under the current operating plan developed in 1986, the floodway is operated when sections of the frontline levee naturally overtop or are artificially crevassed. The floodway requires a timely operation to ensure it performs as designed during a flood approaching the PDF magnitude. In addition to natural overtopping, the plan of operation involves the placing and detonation of explosives at critical locations. The operation of the floodway is directed by the president of the MRC after consultation with the Chief of Engineers.

During the 2011 Flood, the BPNM Floodway was operated in accordance with the approved Water Control Plan. A detailed description and timeline for the operation of the floodway is provided in Section IV.E of this report.

Overall, the floodway operation was successful in conveying the 2011 Flood. However, by its nature, the operation of the floodway results in significant damage to the frontline levees.

b. Morganza Floodway. The Morganza Floodway extends from the Mississippi River at about RM 280 Above Head of Passes (AHP) southward to the East Atchafalaya River levee, and thence southward to join the Atchafalaya River Basin Floodway at the latitude of Krotz Springs, LA. The Floodway consists of a control structure in the RDB of the Mississippi River levee just above the town of Morganza, Louisiana; a guide levee along the upper side of the Floodway between the Mississippi and Atchafalaya River Levees with a drainage structure (Pointe Coupee Drainage Structure, at the Bayou Latenache crossing); that part of the East Atchafalaya Basin Protection Levee from the Mississippi River to about 3 miles below Lottie (latitude of Krotz Springs); high level crossings for the Texas and Pacific Railway; the New Orleans, Texas, and Mexico Railroad; Louisiana State Highways 1 and 190 (the Texas Pacific Railway and LA Hwy 1alignments are on the control structure itself); a lower guide levee extending from just above Morganza to Lottie, Louisiana; and miscellaneous drainage improvements.

The purpose of the Floodway is to divert water from the Mississippi River into the Atchafalaya Basin Floodway. The Morganza Control Structure and the Morganza Floodway are required to pass up to 600,000 cfs of Mississippi River floodwater, under PDF conditions, to the Gulf of Mexico via the Atchafalaya Basin Floodway and the lower Atchafalaya River and Wax Lake Outlet. The Morganza Floodway is operated to divert sufficient floodwater from the Mississippi River to avoid unacceptable stress to the levees along the main stem of the Mississippi River below the Morganza Floodway. Normal operation includes preventing flood stages from encroaching on freeboard requirements, limiting flows to design discharge of 1,500,000 cfs between the Morganza Floodway and the Bonnet Carré Spillway and limiting flow below the Bonnet Carré Spillway to the design flow of 1,250,000 cfs.

Normal operational procedures for the Morganza Floodway are intended to minimize its impacts on the natural environment. The Morganza Floodway Water Control Manual page 5-10, paragraph 5-04c states:

> *The floodgates should be opened gradually and well in advance of the time full Floodway use is needed so more of the animals have time to escape the rising waters. The USFWS and the Louisiana Department of Wildlife and Fisheries recommend that structure gates should be opened slowly, so that waters rise in the Floodway at a rate of about one foot per 24 hours.*

On May 14, as flood flows approached the design discharge of 1.5M cfs, the Morganza Control Structure was opened due to water levels on the Mississippi River side of the structure threatening to overtop the gates of the structure at elevation 60.0 feet. This overtopping would have made it difficult if not impossible to open gates with water rushing over the top. The gantry crane operators at the structure were directed to take hold of the structure gates in advance of the official opening authorization, because if water had begun overflowing the structure before the opening was authorized it would have been nearly impossible to grab the gate hooks. Initially, one gate was opened to keep the water level in the Floodway from rising too quickly, but later in the evening a second gate was opened. .

The Floodway was operated in accordance with the Morganza Floodway Water Control Manual (updated Feb 2000). Section IV.E details the description and timeline for the operation of the floodway.

Although the Morganza Floodway performed as designed, several areas experienced minor damage. Scouring occurred along the toe and up the slope of the East Atchafalaya River Levee at Sherburne which also washed away the highway located at the levee toe. Significant scouring also occurred on the tailbay side of the structure beyond the limits of the scour protection, along the stilling basin end sill wall and in the concrete plunge pond. If allowed to continue unimpeded this scouring could have affected the integrity of the structure. Additionally, some of the stone from the scour protection area adjacent to the stilling basin was washed out and displaced. The Morganza Forebay South Guide Levee had scoured damage in low sections where sandbags were placed during the flood due to overtopping of the levee. Other scour areas developed along forebay levee slopes due to wind-driven wave action. These levee damages were generally localized and did not significantly affect flood risks for communities along the Mississippi or Atchafalaya Rivers.

The 2011 Flood revealed several deficiencies in the operation of the Morganza Floodway. Although floodway operation is tied to a defined discharge in the Mississippi River, in 2011 Floodwaters nearly overtopped the structure before the discharge reached the level that dictates Floodway operation. Due to geomorphologic changes that are occurring in the Mississippi River, the discharge threshold for operation of the Morganza Structure is resulting in river water elevations that are very close to the top of the structure. Future geomorphic changes could result in operational discharge triggers that result in water surface elevations that exceed the elevation of the structure.

The scour protection in the tailbay was revealed to be insufficient to prevent significant scour damage during operation. A serious scour threat remains because of the type of gates on the structure along with the lack of a means to dissipate the energy of such a high head differential due to the changes in the stage-discharge relationships being observed in the Mississippi River. The South Guide Levee was also shown to be deficient during this event, requiring sandbagging to prevent overtopping. Furthermore, several structure piezometers, scour indicators, and relief wells also failed to function properly.

Many operational deficiencies were revealed by the flood; one required deviation from the Water Control Manual and/or Operations and Maintenance Manual. Some of the scour damage in the tailbay was due to the gate opening sequence required in the Water Control Manual; changing this sequence required an approved deviation in 2011. The Water Control Manual also does not include a stage/storage curve, discharge formulas, or weir coefficients, giving almost no information for how to calculate structure flow. Similarly, the size and inverts of the sluice gates at the structure are not listed in the Water Control Manual, so the discharge through those gates is also difficult to compute. Finally, the pertinent data in the Manual does not reflect the latest staff gage locations, hydrologic data, support agencies, or scour damages and corresponding repairs, if any, due to the 2011 Flood. Operational deficiencies revealed during the flood can only be understood and corrected through an engineering assessment or study, which is warranted for this key structure.

Similarly, the size and inverts of the sluice gates at the structure are not listed in the Water Control Manual, so the discharge through those gates is also difficult to compute. Finally, the pertinent data in the Manual does not reflect the latest staff gage locations, hydrologic data, support agencies, or scour damages and corresponding repairs, if any, due to the 2011 Flood.

c. Bonnet Carré Spillway. The Bonnet Carré Spillway is located in St. John Parish, Louisiana. The Spillway structure is located on the Mississippi River between RM 127 and RM 129 AHP. The spillway itself extends from the Mississippi River to Lake Pontchartrain, approximately 5.7 miles away. The project is part of the MR&T Project in the Lower Mississippi River Basin and operational responsibility belongs to the MVN.

The purpose of the Bonnet Carré Spillway is to divert floodwater from the Mississippi River to the Gulf of Mexico via Lake Pontchartrain. The spillway is required to pass 250,000 cfs of Mississippi River floodwater to Lake Pontchartrain under PDF conditions. The ORCC, Morganza Floodway, and Bonnet Carré Spillway are operated together as needed to divert sufficient floodwater from the Mississippi River to minimize the flood damages in the lower river reaches and prevent discharge in the Mississippi River from exceeding 1,250,000 cfs at New Orleans. Bonnet Carré is normally operated when the flow in the Mississippi River below Morganza exceeds 1,250,000 cfs on a rising hydrograph or to preserve a desired level of freeboard on deficient levees through the New Orleans Area. The spillway is controlled so that the flow below Bonnet Carré in the Mississippi River does not exceed 1,250,000 cfs.

The Bonnet Carré Spillway consists of the following elements: a control structure in the LDB of the Mississippi River levee just above the town of Norco, LA; an upper guide levee extending 5.7 miles from the Mississippi River, with an elevation of approximately 27.0ft, to Lake Pontchartrain, with a levee elevation of approximately 15.0 ft., and a lower guide levee extending 5.7 miles from the Mississippi River, with a levee elevation of approximately 28.0 ft, to Lake Pontchartrain, with a levee elevation of approximately 15.0 ft, ; high level crossings for the Yazoo and Mississippi Valley Railroad, Louisiana and Arkansas Railroad, and the Illinois Central Railroad; and high level crossings for US Highway No. 61 and Interstate 10. The high level crossing for US Highway No. 61 is a bridge crossing with abutments that extend out into the floodway. The west abutment extends approximately 2,700 feet into the floodway with a

minimum elevation of approximately 16 feet. The east abutment extends into the floodway approximately 2,300 feet, with a minimum elevation of approximately 16.5 feet.

Significant decisions associated with the 2011 operation of the Bonnet Carré Spillway are as follows:

May 5 – MVD Commander concurred with MVN Commander's request to operate the Bonnet Carré Spillway and consulted with the MRC, who approved it unanimously. MVD Commander contacted Louisiana and Mississippi officials to inform them of the possibility of operation.

May 9 - The first bays were opened at the Bonnet Carré Spillway structure based on a computed discharge of 1,240,000 cfs at Red River Landing on 8 May and an assumed one-day lag time between Red River Landing and New Orleans.

May 12 - it was determined that floodwaters were encroaching on the freeboard of deficient Mississippi River levees downstream of New Orleans. In order to preserve desired freeboard for levees and structures in the New Orleans area from prolonged exposure to high stresses, MVN considers increasing the flow through the Bonnet Carré Spillway beyond the 250,000 cfs it would be required to divert under the Water Control Manual.

May 14. The discharge through the spillway was increased above the design discharge of 250,000 cfs to preserve a desired level of freeboard on these deficient levees, in accordance with the Water Control Manual. This increase above the 250,000 cfs design discharge was approved by the District Commander and a white paper titled "Commanders Assessment" was written to document the reasons for this increase (Appendix C, *Floodways and Backwaters*).

May 17 - at peak operation, 330 of the 350 total bays were open and 316,000 cubic feet of water per second passed through the Spillway.

June 8 – MVN Commander requested a deviation from the Bonnet Carré Spillway Water Control Manual to allow structure closure to begin only after stages at New Orleans had fallen to 15 feet, rather than closing as quickly as possible without exceeding the flow limitation at New Orleans. The purpose of this deviation was to allow stages along levees below New Orleans to fall more quickly, permitting inspection of levees and reducing risk due to a potential hurricane storm surge in the river. This deviation request was disapproved to prevent further water quality impact to Lake Pontchartrain.

June 11 - the MVN began closing the Bonnet Carré Spillway structure.

June 20 - the final gates were closed at the Spillway structure.

Neither the Bonnet Carré structure nor the spillway was significantly damaged during the 2011 Flood. The spillway experienced significant sedimentation over the course of its operation, theoretically reducing the amount of flow it can safely discharge to Lake Ponchartrain, but this is an expected occurrence and an issue to be investigated rather than damage incurred. This sediment will be removed over time by sand hauling companies.

The Spillway performed as needed, passing more flow than its assumed allocation as part of the MR&T system. More flow could have passed through the structure if all bays had been opened, but it is unknown how much more flow the guide levees could have held without overtopping. The effects of greater discharge on velocities in the Spillway are also unknown. Nevertheless, these are not considered deficiencies as they concern discharges greater than the required capacity. There were however deficiencies with the floodway, downstream of the structure. A potato ridge had to be constructed to prevent Airline

Highway from being flooded during spillway operations. It was constructed between the Bonnet Carre Upper Guide Levee and the west abutment of the Airline Hwy Bridge crossing the spillway. This is a major deficiency within the Spillway. The Bonnet Carré Spillway carried more water than its assumed allocation under PDF conditions in order to protect deficient Mississippi River levee sections downstream. These deficient sections could be considered deficiencies of the MR&T system's present state, rather than of the Spillway itself.

d. West Atchafalaya Floodway. The West Atchafalaya Floodway is located immediately west of the Atchafalaya River, paralleling it from the latitude of Simmesport in the north to approximately Krotz Springs in the south. Averaging 5 to 7 miles wide, it is bordered by the West Atchafalaya Basin Protection Levee on the west and the West Atchafalaya River Levee to the east. Across the northern end of the Floodway between Simmesport and Hamburg is a 7.5-mile long fuseplug levee. The purpose of the West Atchafalaya Floodway is to lower stages in the Atchafalaya River, the Red River backwater area and the Mississippi River through the natural overtopping or artificial crevassing of the 7.5-mile long fuseplug levee, and/or through the natural overtopping of the West Atchafalaya River levee below Simmesport. Operational responsibility belongs to the MVN. The West Atchafalaya Floodway was not utilized during the 2011 Flood because of low stages on the Red River. The Floodway was not damaged during the 2011 Flood and no physical or operational deficiencies in the Floodway were revealed.

e. Old River Control Structure Complex (ORCC). Although the ORCC is not a Floodway, its operation is integral to the MR&T system and the potential operation of the West Atchafalaya Floodway and the Red River Backwater Area, and operations at the ORCC both influence and are influenced by operations at the Morganza Floodway. The project is located on the west bank of the Mississippi River between RM 304 and RM 316 AHP and 50 miles northwest of Baton Rouge, LA. The project provides for the control of flows from the Mississippi River into the Atchafalaya River and Basin. The primary purpose of the project is to prevent the Mississippi River from changing its course to that of the Atchafalaya River, which it achieves through regulation to provide a distribution of flow and sediment from the Mississippi to the Atchafalaya River equivalent to that which occurred naturally in 1950. Specifically, the ORCC is regulated to maintain a distribution of total flow in the Mississippi and Atchafalaya Rivers such that 70 percent of that flow is contained in the Mississippi River and 30 percent in the Atchafalaya River.

The project consists of an Auxiliary Structure, a Low Sill Structure, an Overbank Structure, an integrated levee system, and a navigation lock and highway bridge. A privately owned hydroelectric power station is allowed to divert some of the required flows for power generation.

The ORCC performed as needed during the 2011 Flood, but several unexpected effects occurred. The ORCC is regulated based on the flow in the Mississippi River at Red River Landing and in the Atchafalaya River at Simmesport, both of which are downstream of the ORCC. When the Red River rose out of its banks and began occupying side-channel and overbank storage, excess flows from the ORCC flowed north up the Red River rather than south down the Atchafalaya River, causing the Atchafalaya's share of latitude flow to trend lower than the typical 30 percent. Similarly, when the flood was receding and water was draining out of storage on the Red River, the opposite effect occurred, causing flows at Simmesport to tend to be higher than 30 percent of latitude flow; further decreases in ORCC discharge only served to draw more water out of storage.

Late on the night of 13 May, the Engineering Division and Hydraulics and Hydrologic Branch Chiefs were monitoring freeboard at the Morganza structure and became concerned about possible overtopping there during the night, so the decision was made to perform a gate change at the Auxiliary Structure to increase the flow through the complex for the sole purpose of ensuring that overtopping would not occur at the Morganza Control Structure. The areas of the Morganza Structure called curtain walls were especially vulnerable

because there was no overtopping resiliency there. Overtopping in these areas had the potential to propagate into greater distress at the structure with the further potential to compromise the operation. This decision resulted in an increased total ORCC flow. This had the desired effect of preventing overtopping at Morganza but also altered the distribution of flows between the two rivers for several hours until the next gate change at ORCC on 14 May.

Scouring of the bank occurred behind the wing walls on the outflow side of the Low Sill Structure. Construction Division issued an emergency stone placement contract and was able to stabilize the banks. Additionally, issues and concerns were raised regarding sediment build-up in the inflow channels of the Auxiliary and Low Sill Structures. A large scour hole formed just behind top of bank On the LDB of the Auxiliary inflow channel near its mouth.

Old River Lock was closed due to high water stages. Electrical equipment for the operation of the lock was removed in the affected areas until the water stages drop to a safe operation level. Plates were added to the top of the Mississippi River end gates and sandbags were placed on the guide walls to maintain required freeboard.

Two major operational deficiencies at the ORCC were identified during the 2011 Flood. The ORCC is regulated to maintain a flow balance, with flows measured through the use of stage-discharge rating curves. These curves relate a change in stage to a change in discharge, as plotted based on measured stages and discharges. However, once the Morganza Floodway was operated, stages at the nearby ORCC almost ceased to change, though the discharge continued to change, since the Morganza structure was being regulated to prevent further rises. This made the rating curve method unusable and therefore made regulation of discharge highly uncertain until the Morganza structure was again closed.

The other operational deficiency relates to the Overbank Structure. This structure was designed to be operated under a limited differential head (8 feet when fully open, 13 feet when used in staggered-panel configuration). Furthermore, to avoid damage to the gabion field downstream of the structure, flows through this structure are limited to minimum outflow channel stages to prevent a hydraulic jump from forming. The decision not to use the Overbank Structure was predominately based upon a lack of confidence in the downstream weir. The use of the Overbank Structure is essential to provide operational flexibility to the ORCC to adjust for unforeseen emergencies. Ability to fully utilize the Overbank Structure would allow reducing flows through the Low Sill Structure resulting in less stress on the inflow training walls and adjacent embankments, and the inflow and outflow channels near the structure. .

4. Backwaters. The four major backwaters of the MR&T system serve to reduce flood crests on the Mississippi River and some of its tributaries by storing excess water under severe flood conditions. They function through the use of fuseplug levees, which are intentionally constructed to a lower grade than mainline Mississippi River levees, so that when overtopped they store water off of the main channel and thus lower stages nearby and downstream. However, because these backwater areas were constructed in areas of natural overbank and side-channel storage, natural backwater effect can store water and lower crests even when the fuseplug levees of the authorized backwater areas are not overtopped.

a. St. Francis River Backwater Area. The St. Francis River Backwater Area is located near the confluence of the St. Francis and Mississippi Rivers in Lee and St. Francis counties, Arkansas. The area is bounded by the St. Francis Levee system on the east and Crowley's Ridge on the west. The levee includes a 9 mile long fuseplug section near the W. G. Huxtable Pumping Plant, both located near Marianna, AR. The purpose of this backwater area is to store excess floodwaters from the St. Francis and Mississippi Rivers under PDF conditions, lowering peak stages on the Mississippi River. The backwater area is placed into operation by overtopping of the fuseplug levee when stages start to approach PDF elevations. This fuseplug

levee has an elevation three feet below the MR&T PDF flowline and one-half foot above the stages experienced in the backwater area during the Flood of 1937. The 12,000 cfs W. G. Huxtable Pumping Plant is designed to remove runoff impounded within the backwater area by the levees flanking the Mississippi and St. Francis rivers by pumping when gravity flow through its gates is insufficient to drain the backwater area. Its four gates, each 28 feet wide by 27 feet tall, are closed when the elevation of the Mississippi River approaches 177 feet above sea level or exceeds the elevation of the St. Francis River. Under such conditions, the pumps are placed into operation until the level of the St. Francis River drops below an elevation of 175 feet above sea level.

Although flooding occurred outside the levees in the vicinity of the mouth of the St. Francis River, the fuseplug levees at the St. Francis River Backwater Area were not overtopped and the backwater area was not operated during the 2011 Flood. Crest stage at the Huxtable Pumping Plant during the 2011 Flood was 202.6 feet NGVD29, whereas the fuseplug levee elevation at the same location is approximately elevation 209 feet NGVD29 for most of its length, with a section at its lower end that is below the 207 foot design grade. Crest elevation on the landside at the Huxtable Pumping Plant during the 2011 Flood was 192.4 feet NGVD29.

b. White River Backwater Area. The White River Backwater Area is located in Desha and Phillips counties, Arkansas, near the confluence of the White and Mississippi Rivers. It consists of a 40-mile-long backwater levee stretching from the frontline levee at Laconia Circle, AR along the east side of the White River until it reconnects with the frontline levee near Old Town, AR, as well as floodgates on Little Island Bayou (draining to the White River) and on Deep Bayou (draining to the Mississippi River), and the 1,500 cfs Graham Burke pumping station. The backwater area is placed into operation by overtopping of two fuseplug levee sections on the White and Mississippi rivers when stages on those rivers start to approach PDF elevations. The two floodgates serve to evacuate impounded runoff within the backwater area, with the pumping station operating when stages on the White River do not permit gravity drainage through the Little Island Bayou structure.

Although there was significant flooding in the White River floodplain, some of which was caused by backwater from the Mississippi, the White River Backwater Area was not operated during the 2011 Flood, as stages did not reach sufficient height to overtop the fuseplug levee sections. Crest stage at the Graham Burk Pumping Plant during the 2011 Flood was 168.5 feet NGVD29, whereas the fuseplug levee elevation at the same location is approximately elevation 177.5 feet NGVD29. Stages on the interior of the backwater area peaked at 149.7 feet NGVD29.

Significant deficiencies revealed for the White River Backwater Area include areas of under-seepage into the backwater area, debris deposition in unprotected areas, and overtopping of a short reach of the Augusta-Clarendon levee. This levee is approximately 39 miles long, extending from RM 192 to 115 along the LDB of the White River and protecting approximately 650,934 acres of agricultural land. The Augusta to Clarendon project flowline is based on the 1938 flood on the White River. High water data from the 2011 Flood indicate that the crest elevation along the overtopped section of levee exceeded the project flowline by about 1 foot. This overtopping caused damage to the levee during the period of 25 April to 30 May 2011. Landside levee crown material was windrowed on the riverside levee crown to create a taller flood barrier structure to prevent further overtopping. A short section of levee was unable to be protected from overtopping. Minimal damage occurred to the levee along the overtopped portion and very few additional acres were inundated on the landside of the levee, because significant flooding was already occurring along the Cache River.

c. Yazoo River Backwater Area. The Yazoo River Backwater Area is located in Warren and Issaquena counties in Mississippi, near the confluence of the Yazoo and Mississippi Rivers. It consists of a

backwater levee connecting with the frontline Mississippi River levee near Vicksburg and extending along the west bank of the Yazoo River to Yazoo City, as well as drainage structures on the Little Sunflower River and Steele Bayou. The backwater area is placed into operation by overtopping of the backwater levee, which is lower than the mainline Mississippi River levee.

The Yazoo River Backwater Area was not utilized during the 2011 Flood, as the backwater levee was not overtopped. However, the protected side of the backwater levee was armored and some deficient sections were brought up to authorized grade in anticipation of overtopping, as crest stages reached within inches of the levee crown. The peak stage on the interior of the Backwater Area was 90.0 ft NGVD 29, just over 16 feet below the riverside elevation. Section IV. E, *Key Operational Decisions* provides further details on the Yazoo River Backwater Area efforts during the 2011 Flood.

d. Red River Backwater Area. The Red River Backwater Area is located in Avoyelles and Concordia Parishes in Louisiana, near the confluence of the Red and the Black Rivers. It consists of a 93-mile backwater levee along the east banks of the Red, Black, and Tensas Rivers, the lower 38 miles of which are built three to four feet below the grade of the Mississippi River Levee at Red River Landing and serve as a fuseplug to allow water to enter the backwater area under PDF conditions. There is also a drainage structure through the levee at the mouth of Bayou Cocodrie (draining to the Red River) and a combination drainage structure and 4,000 cfs pumping plant at the mouth of Wild Cow Bayou (draining to the Black River). The purpose of the backwater area is to store excess water from the Mississippi, Red, Ouachita, Boeuf, and Tensas Rivers during extreme floods. Under the original MR&T flood control plan adopted by the 1928 Flood Control Act, this area would also have stored water from the Boeuf and/or Eudora floodways, which were never constructed.

The Red River can store large amounts of water in its overbanks even without overtopping the fuseplug levee. Typically, the Red River will overflow its banks when stage at Barbre Landing, LA (at the confluence of the Atchafalaya River and the Old River Lock Channel) exceeds 40 feet.

The Red River Backwater Area was never operated during the 2011 Flood, as the fuseplug levee was never overtopped. However, a significant amount of floodwater was stored in the overbank areas of the Red River, between the backwater levee and the Marksville, LA area. This storage was evidenced by the relatively unchanged flow of the Atchafalaya River at Simmesport, LA, despite rapidly increasing discharge through the ORCC. The storage effect was also measured in the field as crews from both the Corps and the USGS measured negative (northward) flow in the Red River during the period of greatest discharge through the ORCC. The peak stage on the interior of the Red River Backwater Area in 2011 was 34.1 feet NGVD29, measured on Bayou Cocodrie at Shaw.

No damages were detected at the Red River Backwater Area as a result of the 2011 Flood. No operational or physical deficiencies were detected at the Red River Backwater Area as a result of the 2011 Flood.

5. Interior Drainage Systems. Throughout the basin, there are many areas protected from headwater and backwater flooding which rely on gravity drainage structures as interior drainage outlets. During floods, these structures are closed and the impoundments of seepage and rainwater can cause interior flooding of serious proportions. In some cases, pumping stations which would address the problem are authorized. In other cases, areas are allowed to become inundated, or portable pumps are utilized by the Corps or others.

There was variance in the amount of rainfall within the three lower districts. Rainfall in the MVK was higher than the annual average which impacted the operation of interior drainage structures. Conversely, the MVN was experiencing a drought and therefore experienced limited impact to interior drainage. Any

additional rainfall during the flood would have resulted in greater impacts and, as a result, a greater need for emergency measures.

In addition to the following issues, interior drainage was impacted throughout the LMRV by seepage and blockage in locally operated drainage canals. In regards to seepage, the impacts were limited because it could be pumped into adjacent bodies of water or back into the Mississippi River. Nonetheless, seepage was an issue during the height of the event and proper resources had to be allocated for response. During the 2011 Flood, there were instances of blocked drainage due to debris in drainage canals. Clearing and snagging is the responsibility of the local sponsor and must be done prior to the floods.

a. St John's Bayou – New Madrid Floodway. The St. John's Bayou project is located in the Bootheel area of Missouri. It covers two drainage basins adjacent to the Mississippi River: the St. Johns Bayou Basin (450 sq mi) and the New Madrid Floodway (203 sq mi). The St. Johns Bayou Basin is bounded on the east by the BPNM Floodway Setback Levee and on the west by Sikeston Ridge and the Farrenburg Levee. St. Johns Bayou is the drainage outlet of the basin and empties into the Mississippi River through the St. John's Bayou Gravity Structure (SJBGS). The structure crosses State Highway P and is located approximately ½ mile upstream from the Mississippi River. The SJBGS contains six 10 by 10 foot box culverts.

During high water events on the Mississippi River, floodwaters back into the BPNM Floodway thru a 1,500-foot opening at the southern end of the floodway. The SJBGS is closed to prevent Mississippi River backwater flooding. Interior rainfall/runoff is stored in the sump area until gravity flow is permissible.

During the 2011 Flood, the SJBGS was closed. Multiple major rainfall events which contributed to the high Mississippi River stages were also impacting interior drainage. More than two thirds of the BPNM Floodway was inundated due to backwater flooding when it was operated for the second time in its history. The SJBGS prevented flood waters from entering into St. Johns Bayou Basin, but Mississippi River water levels did not permit gravity drainage through the structure for approximately 70 days.

b. St. Francis River Basin. The St. Francis River flows from Lake Wappapello, MO, to the confluence with the Mississippi River, approximately 10 miles north of Helena, AR. The St. Francis River Basin project contains levees and channels which are 100 percent federally maintained. The drainage design capacity was approximately a 10 year frequency during the crop season and the levee design was approximately a 25-year frequency with 3 feet of freeboard. Recent analysis indicates that levees have approximately a 100-year level of protection with 2 feet of freeboard.

Within this basin, there are two pumping stations—Drainage District #17 (DD#17) and W.G. Huxtable Pumping Plant—built, maintained and operated by the Corps. DD #17 is located east of the Big Lake Floodway and is the outlet for a 33 square mile area. The pumping station removes interior runoff from DD#17, which includes the communities of Gosnell and Blytheville, AR. This runoff flows into DD#17 Pump Station and is pumped over the levee into State Line Outlet Ditch. It has three pumps with a total capacity of 700 cfs. Huxtable Pumping Station is the outlet of 2,013 square mile area and removes impounded interior runoff during high stages along the Mississippi River reach near Helena, AR. It is located southeast of Marianna, AR and discharges into the St. Francis Floodway approximately 13 miles upstream of the Floodway's confluence with the Mississippi River.

Due to high rainfall and effects of the Flood, the pump stations exceeded normal operation periods. Average pumping operations for Huxtable and DD#17 Pumping Stations is approximately 50 and 30 days respectively. During the 2011 Flood, Huxtable Pumping Plant operated for 102 days and DD 17 operated for 30+ days. The stations exceeded the expected operation without any major damage to the structures

c. Yazoo River Area. The Yazoo River Backwater Area is located in Warren and Issaquena Counties, Mississippi, near the confluence of the Yazoo and Mississippi Rivers. It consists of a backwater levee connecting with the frontline Mississippi River levee near Vicksburg and extends along the west bank of the Yazoo River to Yazoo City. Collins Creek Drainage Structure is a gravity drain outlet for the Collins Creek ring levee system that protects several thousand acres of farm land in the Yazoo River flood plain. The Yazoo City Pumping Plant Complex consists of a pump station and a gravity flow section. It contains three 8x8-foot conduits with a total structure capacity of 540 cfs. It is further upstream on the Yazoo River, and gravity drains interior rain water from Yazoo City and surrounding protected areas into the Yazoo River.

During the 2011 Flood, there was backwater up the Yazoo River due to the high stages on the Mississippi River. The Collins Creek Drainage Structure and Yazoo City Pumping Plant Complex were closed on 17 April 2011 and 20 April 2011, respectively; and prevented back waters from entering the protected area. The two structures, however, were not able to gravity drain interior areas that are enclosed by levees. Both structures were closed for approximately 2 months during the 2011 event. The pump station was not operated during the Flood due to lack of rainfall. Because of these drought conditions, there were no impacts due to interior drainage.

d. Lake Chicot Pumping Plant Complex. Lake Chicot, the largest natural lake in Arkansas, is a 16-mile-long oxbow lake created about 400 years ago. During the Flood of 1927, the pattern of drainage was altered and the lake began to fill with silt-laden water. The Flood Control Act of 1968 authorized the Vicksburg District to improve water quality in Lake Chicot through the construction of several structures. The Connerly Bayou Dam regulates water coming into the lake, and the Ditch Bayou Dam maintains the lake at desired levels. The Lake Chicot Pumping Plant Complex is part of the MR&T levee system and diverts water into the Mississippi River from Connerly Bayou when the bayou is turbid with agricultural runoff. Thus, the silted waters go into the Mississippi River, and Lake Chicot is fed only during the winter when Connerly Bayou is relatively clean. When the Mississippi River is low enough, gravity allows Connerly Bayou to flow into the river. The gravity structure contains three 26 feet by 20 feet gates with a max capacity of 10,000 cfs. When the Mississippi River is high, the pumps carry the water over the closed gates of the pumping plant. There are 10 pumps with 600 cfs capacity and 2 pumps with 250 cfs capacity for a total capacity of 6,500 cfs.

The system protected a vast area of agricultural land from flood waters. There was no gravity flow through the Lake Chicot Pumping Plant Complex for most of spring and summer of last year because of high river stages on the Mississippi River. Due to the drought conditions, there was little to no need for pumping during the event. If interior rainfall had occurred during the event, the structure could have been operated to pump excess water into the Mississippi River.

e. Upper Pointe Coupee Parish Loop. Pointe Coupee Drainage Structure (PCDS) is located at the intersection of the Morganza Floodway upper guide levee and Johnson Bayou. The PCDS is ½ mile east of the Atchafalaya River and consists of two motor operated steel lift gates, each 10.5 feet wide and 15.0 feet high. The Pointe Coupee Pumping Station (PCPS) is located on the east bank of the Atchafalaya River approximately 15 miles northwest of New Roads, LA. It consists of an inlet channel, pump-house, discharge piping, outlet structure, and outlet channel. It has three pumps each with a capacity of 500 cfs. The drainage structure, pumping station, and Johnson Bayou are the main components of the drainage system for this area in the northern portion of Pointe Coupee Parish, known as the Upper Pointe Coupee Loop.

Prior to the operation of the Morganza Floodway, the PCDS is required to be closed to prevent water in the floodway from entering the Upper Pointe Coupee Parish Loop. When the PCDS is closed normal internal drainage for approximately 80,000 acres in the Upper Pointe Coupee Loop is cut off. In the event that a rainfall occurred with the PCDS closed, the Corps operates the PCPS to evacuate rain water from the Upper

Pointe Coupee Loop into the Atchafalaya River. During the 2011 Flood, the PCDS operated as intended. The PCDS was closed and no rain fell into the Upper Pointe Coupee Loop. The PCPS was operable although not needed for this event. There were no significant drainage issues to indicate that Johnson Bayou was silted or plugged.

f. Bayou Courtableau Drainage Structure and Darbonne Drainage Structure. The Bayou Courtableau Drainage Structure (BCDS) and Bayou Darbonne Drainage Structure (BDDS) are normally operated to divert rainwater from the landside (Courtableau /Port Barre areas) into the flood side (West Atchafalaya Basin Floodway). The BCDS is located in St. Landry Parish about 1.5 miles southeast of Courtableu, LA. It is a 220-foot long reinforced concrete box frame culvert with five 10 foot wide x 15 foot high water passages. The operating tower, located on the outlet end of the structure, contains five 10-foot, 8 inch x 15-foot, 8 inch hydraulic operated structural steel slide gates. The maximum discharge is 12,000 cfs. The BDDS is located in St. Landry Parish, LA within the West Atchafalaya Basin Protection Levee about one-half mile north of US Highway 190. It is a 10-foot x 20-foot reinforced concrete box culvert with a length of 265 feet and an invert elevation at 6.0 feet mean sea level. The sluice gate is a vertical lift steel gate 10 feet, 8 inches x 10 feet, 8 inches. The drainage structures are approximately 2 miles apart and operate in conjunction. The drainage structures are operated according to the revised Operation & Maintenance guidance letter which dictates that the controlling landside water elevation be maintained at elevation +17.63 feet NGVD during the months of March 1 through November 30, elevation +15.63 feet from December 1 through December 31, and elevation +16.63 feet from January 1 through February 28/29.

During the 2011 Flood, the floodside stages at the structures were higher than the landside stages. The structures operated as intended, and no rain event occurred that would have caused internal flooding on the landside of the drainage structures.

g. Hanson Canal. The Hanson Canal flows from Bayou Teche at Mile 15 to Bayou Portage and is approximately 10 miles west of Calumet along US 90 between Garden City and Franklin, LA. It was originally deepened and widened in the mid 1920's as part of an USACE navigation project that would connect Franklin, LA to the Mermentau River. This project was later superseded by the Gulf Intracoastal Waterway (GIWW) project and thus the Hanson Canal is primarily used for drainage from Bayou Tech and the Franklin area through the Franklin Pump Station. For approximately 8,000 feet—from Bayou Teche to the Franklin Pump Station—the Canal is lined on each side by levees built as part of the West of Atchafalaya Basin project. The Hanson Canal Lock, located at the head of the canal, was abandoned and transferred to St. Mary Parish in 1959.

As a result of operation of the Morganza Floodway, there was concern that backwater effects east of Wax Lake Outlet could raise water levels in the Hanson Canal such that levees along the canal would be overtopped and the surrounding areas would experience flooding. To prevent this flooding scenario, two locations of sheet pile and sand bags were placed by St. Mary Parish across the Hanson Canal as flood fighting measures. To protect from flood waters in Bayou Teche, 76.5 feet of sheet pile was driven immediately north of Highway 90 on 17 May 2011. The sheet pile was driven in the canal to an elevation of ±9 feet using a standard excavator with a vibratory hammer. Work was completed the same day.

Further downstream on the Hanson Canal, near the Centerville Pump Station, 105.6 feet of sheet pile was driven to protect against flood waters entering from the GIWW. Driving began on 18 May 2011 and was completed 19 May 2011. It was done by barge mounted crane with a vibratory hammer to an elevation of ±11 feet. All sheet piles were 45 inches long and tied into the banks on either side using 3,000 pound sand bags. In between the two sheet pile locations, there is a stretch of levees with low crown elevations. Portions of the canal bank were also lined with HESCO baskets for additional stability. The emergency

measures were successful in preventing backwater flooding as intended. Pumping for interior drainage from the Hanson Canal was not required due to drought conditions.

h. Franklin Canal. The Franklin Canal carries storm water from Franklin, Louisiana and the surrounding areas to the lower lying areas of the outfall marshes and the Gulf of Mexico. The canal begins within the Franklin city limits, runs southwest, passes under Chatsworth Road and Highway 90 and flows towards the Gulf Intracoastal Waterway. Franklin Canal is lined on the north end by approximately 800 feet of West of Atchafalaya Basin Protection Levees. The levee system runs southeast, crosses the canal at the Chatsworth Road Draw Bridge, turns, and runs north to south. Because the alignment of the canal also turns and runs north to south, the south side of the canal is lined by approximately 10,000 feet of West of Atchafalaya Basin levees. Because of the alignment of the canal and location of the protected areas, there is no levee alignment other than the 800-foot stretch along the northern end of the canal.

Similar to the Hanson Canal, as a result of operation of the Morganza Floodway, there was concern that backwater effects east of Wax Lake Outlet could raise water levels in the Franklin Canal such that the banks of the canal would be overtopped and the surrounding areas would experience flooding. There is no structure across the canal to stop flood waters coming up from the south and the levees on either side stop at the Chatsworth Road Draw Bridge. Flood waters coming up the Franklin Canal would flood the city of Franklin and the surrounding area. To mitigate the effect of the floodwaters, St. Mary Parish installed 128.5' of steel sheet pile with a barge mounted crane and vibratory hammer. Sand bags and HESCO baskets used as a tie- in to the levee system had been placed prior to the sheet pile. Driving began on May 16, 2011 and was completed on May 18, 2011. Sheet pile was 45 inches long length and driven to an elevation of ±11 feet. To allow for drainage and navigation, a 30.16 linear foot section of sheet pile was removed within the canal once flood conditions subsided.

Closing of the canal with sheet pile and other emergency measures was expected to impact the interior drainage for the City of Franklin and the surrounding area. To mitigate the impact and create storage capacity, the protected side of the canal was pumped down approximately 18 inches. A tractor pump was placed on the south side levee near the sheet pile, and interior water was pumped from the protected side of the sheet pile to the flood side. The pumps ran on May 25 and 26 for 18 hours each day. The emergency measure held in place throughout the duration of the event and no additional pumping was required because of drought conditions.

i. Yellow Bayou. Yellow Bayou runs from Cane Road east towards State Route 317down into Thurguson Bayou and eventually flows into the GIWW. Yellow Bayou serves as interior drainage for Centerville, LA and the Centerville Pump Station.

As with the Hanson and Franklin Canals, as a result of operating the Morganza Floodway, there was concern that backwater effects east of Wax Lake Outlet could raise water levels in the Yellow Bayou such that levees along the canal would be overtopped and the surrounding areas would flood. To reduce the flood risk to Centerville, approximately 56.6 feet of sheet pile was driven downstream of Parish Road 16 and upstream of the Centerville Pump Station by St. Mary Parish as a flood fighting measure. A standard excavator and vibratory hammer were used to drive the sheet pile to an elevation of ±8 feet. Driving began on 14 May 2011 and was completed on 15 May 2011. The sheet pile was 45 inches long and tied into the banks of the canal with HESCO baskets and 3,000 pound sand bags. This measure remained in place for the duration of the Flood and performed as intended. No pumping for interior drainage was required because it did not rain.

j. Bayou Chene. Bayou Chene is a large waterway that serves as the main drainage artery for the Lake Verret Watershed. Bayou Chene intersects the Atchafalaya River where the East of Atchafalaya Basin Guide Levee ends. When the Morganza Control Structure is opened, water flows down the floodway and

ties into the Atchafalaya River. In major flood event, flood waters exiting at the mouth of the Atchafalaya River back up within Bayou Chene and transport floodwaters into Lake Verret Basin. During the 1973 Flood, this effect in Bayou Chene resulted in backwater flooding within Amelia, Morgan City, Stephensville, Pierre Part, and other local communities east of the Atchafalaya Basin.

Due to the imminent threat of the Flood causing backwater flooding in the Atchafalaya River, on 6 May 2011, St. Mary Parish Levee District (SMLD) submitted a closure plan for Bayou Chene to both the Corps and the Louisiana Office of Coastal Management. On 9 May 2011, an emergency permit was granted, and SMLD began procuring equipment and material for the closure. Construction began on 11 May 11 (photograph IV-12).

Photograph IV-12. Bayou Chene Closure

The closure included 1,000 linear feet of steel sheet pile, 17,000 tons of rip-rap, and the temporary placement, sinking, and mooring in place of a 500-foot long by 120-foot wide deck barge. The water bottom was dredged to a -26.0 ft. (NAVD88) elevation on both ends of the barge. Sheet pile driving operations began on 13 May 11. On 18 May 11, as the sheet pile wall neared completion, the increased water flow and hydraulic forces caused a toe failure of approximately eight pairs of sheet pile. The sheet piles were removed from the channel and on 20 May 11 SMLD requested Corps assistance to close the resulting hole with rock. The Corps responded and placed five barges of 600-pound stone in the failure gap to close the bayou off. Construction was completed 25 May 11.

Aside from the sheet pile failure during placement, the emergency flood fighting measure functioned as intended. By 29 May, the water level crested in Bayou Chene and measured +4.91 feet (NAVD88) on the flood side of the closure and +1.95 feet (NAVD88) on the protected side. No pumping for interior drainage was required because it did not rain. Any rainfall in Amelia or the surrounding area normally drained through Bayou Chene could be drained through the eastern portion of the GIWW. However, some level of pumping would be needed to aid in draining rainfall from the area with the closure in place.

6. Channel Improvements. The Channel Improvement Project on the Mississippi River extends from Head of Passes to RM 956 AHP. The Project is a key element of the MR&T FRM system, maintaining the channel to provide proper alignment and depths for navigation and preventing channel migration to ensure levee integrity. The Project uses a number of features to accomplish its purpose:

Dikes. Dikes are composed primarily of rock placed in the channel and extending into the bank with the crest significantly below top bank to have no effect on highwater stages, but high enough to concentrate relatively low flows in a specified width to provide a self-maintaining channel for navigation. Some dikes are constructed in a "W" configuration with a varying crest elevation to provide some diversity of flow conditions in the vicinity. Photograph IV-13 shows a typical dike field.

Photograph IV-13. Typical Dike

In some areas, dikes are constructed with a notch (figure IV-8) to provide conveyance for flows behind the sandbar at stages below the crest for environmental purposes.

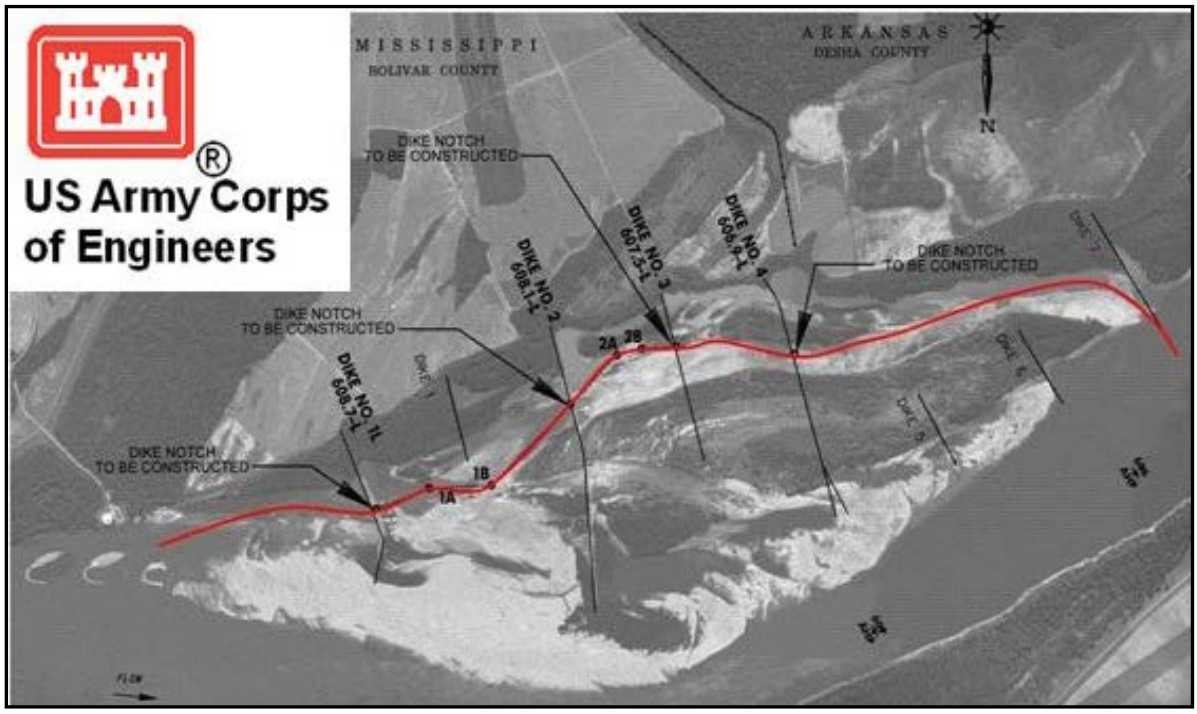


Figure IV-8. System of Notched Dikes

a. Hard Points. Hard points are similar to dikes, but much shorter. In most cases, they have little application for maintaining the low flow channel, but are primarily used to improve channel bank stability in some areas. Typical hard points are shown in photograph IV-14.

Photograph IV-14. Hard Points

b. Chevrons. Chevrons are rock structures constructed in a "U" configuration with the closed end in the upstream direction located a specified distance from the bank. These structures function similar to dikes to concentrate flow in the channel while providing diversity of flow conditions and channel bottom configurations. Typical chevrons are shown in photograph IV-15.

Photograph IV-15. Chevrons

c. Bendway Weirs. Bendway weirs are rock structures constructed in the navigation channel with crest elevations low enough to allow navigation to travel above them. They are angled in the upstream direction from the bank to redirect the flow to provide adequate width for navigation. A schematic example of bendway weirs is shown in figure IV-9.

Figure IV-9. Illustration of Bendway Weirs

d. Articulated Concrete Mattress Revetment (ACM). An ACM revetment is a flexible structure constructed with connected concrete blocks placed on a sloping river bank. The connected blocks are tied to cables that allow the revetment to conform to minor changes in the bank configuration. Upper bank paving composed of riprap is placed on the bank above the concrete blocks. The revetment provides protection from the erosive forces of the river which maintains the bank in its desired location. Prior to placement of the concrete blocks and riprap, the bank is cleared of vegetation and graded for a stable slope to accept the upper bank paving. A typical revetment that has been in operation for a number of years is shown in photograph IV-16.

Photograph IV-16. Revetment

Photograph IV-17 shows an ACM revetment under construction. Note the concrete blocks just above the water surface and the graded bank to accommodate the placement of the upper bank paving.

Photograph IV-17. ACM Revetment Under Construction

e. Use of the Features During the 2011Flood. In the majority of cases, the features of the Project performed as designed. There was damage to some of the individual features, but no catastrophic failures. There were no shifts in channel location and no excessive bank erosion that threatened the integrity of levees. However, there were at least two locations where there was major damage in the form of overbank erosion and, if the duration of the flood had been longer, the river would have very likely changed course and threatened the integrity of nearby levees. One of these locations is at approximate Mile 869.0 at the Merriwether-Cherokee revetment. A private levee overtopped and failed. The resulting crevasse scoured a significant amount of material creating a deep hole. The revetment was damaged but its existence prevented the erosion from being more serious. The other location is at approximate Mile 732.0 at the President's Island revetment. The flood attempted to short circuit the bendway by eroding the overbank area. As at Merriwether-Cherokee, the revetment was damaged but its existence prevented the damage from being much worse.

f. Use of the Features During Non-flood Events. The channel improvement features perform during non-flood flows, as well as, during flood events. The non-flood flows have sufficient forces to erode the channel banks which could have a negative effect on the integrity of the levees and the navigation channel. The dikes contract the non-flood flows to a width and in an alignment that facilitates the development of an efficient navigation channel which also contributes to flood risk management. Each year, approximately 500 million tons of commodities, such as grain and coal, are transported in this channel, making use of the most cost effective and environmentally friendly method of transportation available. The dikes, in conjunction with the articulated concrete mattress revetment, have dramatically reduced the dredging required to maintain the navigation traffic, making the channel essentially self-maintaining. Figure IV-10 indicates the reduction in required dredging as the cumulative length of dike has increased through time. The other features of the channel improvement project (i.e., hard points, chevrons, and bendway weirs) also serve as parts of the system that ensures the integrity of the flood risk management system and navigation channel, both of which are critical to the Nation's economy.

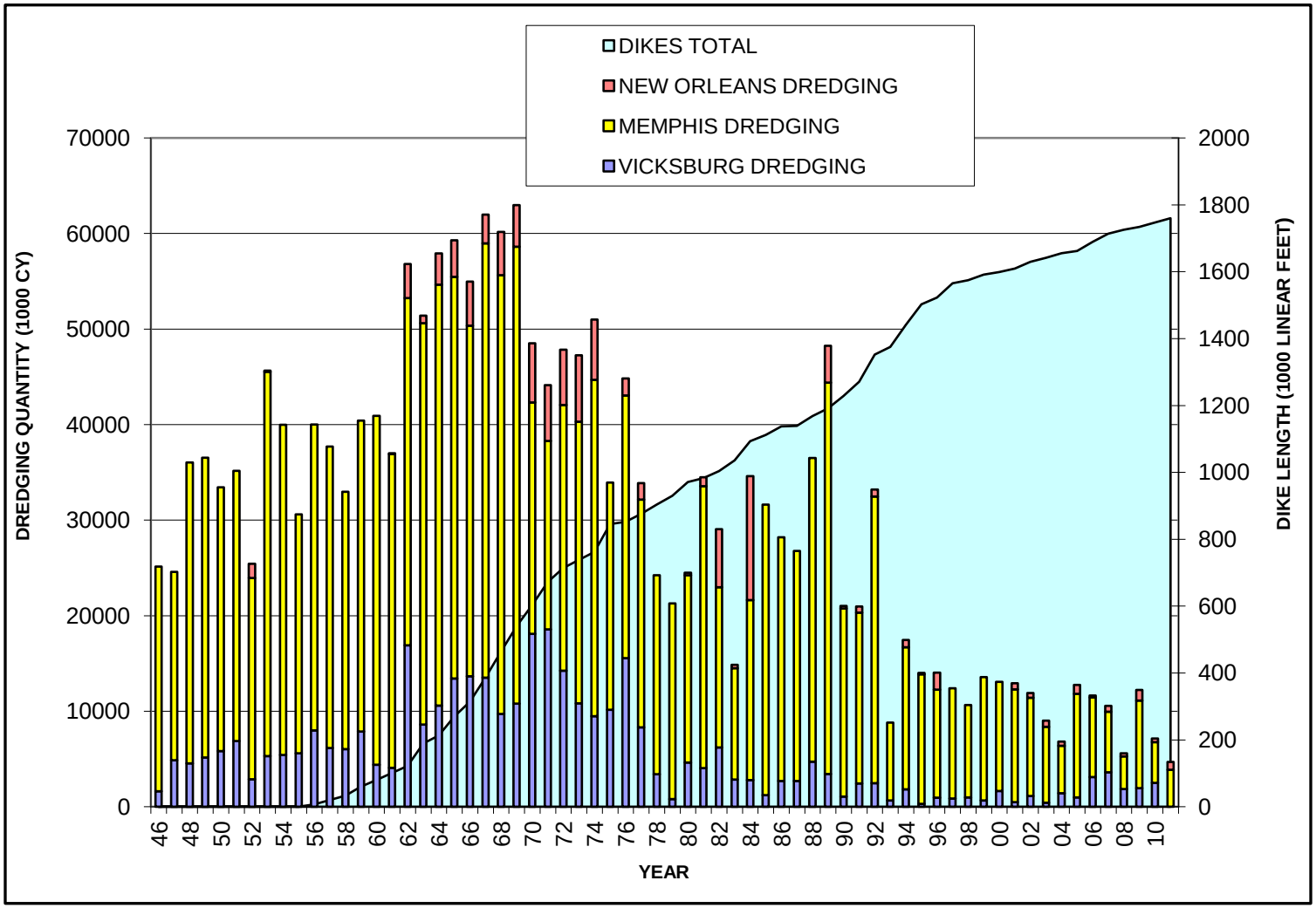


Figure IV-10. Cumulative Dike Lengths and Dredging on Mississippi River

7. Streamflow/Channel Capacity. Table IV-9 shows the locations where flow rates were routinely measured during the 2011 Flood.

In addition to the stream flow measurements identified in table IV-8, measurements were taken at several locations. At the request of the Corps, the USGS collected within channel measurements along the Old River Outflow Channel and Red River Backwater on May 20 and May 26. The idea was to better understand where water enters and exits the overbank areas. Additionally, the Corps measured flow rates on the Mississippi River at the Huey P. Long Bridge to update velocity and depth information and four sets of flow measurements in the Mississippi River above and below Bonnet Carré Spillway, where similar measurements were made in 2008. The Corps also performed measurements on May 28 in the Mississippi River at West Pointe a la Hache, Port Sulphur, Buras, and Empire, in an effort to determine if significant flow was exiting the Bohemia Spillway, located on the LDB of the Mississippi River.

All flow measurements were made with ADCP equipment, with the exception of Morganza Floodway and Bonnet Carre Spillway, where measurements were taken with a Price meter, measuring velocity at 60 percent depth and computing discharge using the mid-section method (referred to as the conventional method). For part of the flood, the Corps performed auxiliary flow measurements at Tarbert Landing using the conventional method. When flow in the Mississippi River at Tarbert Landing exceeds 1,000,000 cfs, the two methods produce different results. The two sets of measurements are taken to better understand the differences in methodology. Because of equipment issues on the discharge boat, it was not possible to make the conventional measurements until May 15, 2011.

Table IV-10 shows the provisional 2011 peak flows along with peak flows from other historic floods in the Mississippi River and the Atchafalaya Basin Floodway System and the PDF flow.

Table IV-9. Locations of Flow Rate Measurements

LMR
Approx Mile 950
Hickman, KY range
Near Tiptonville, TN
Memphis, TN
Helena, AR range
Arkansas City, AR
Greenville, MS
Vicksburg, MS
Natchez, MS
Union Point, MS
Tarbert Landing, MS
Baton Rouge , LA (USGS)
Belle Chasse, LA (USGS)

UMR
Just below I-57 Bridge
Atchafalaya River
Simmesport (Corps and USGS)
Lower Atchafalaya R. @ Morgan City (USGS)
Wax Lake Outlet at Calumet (USGS)
Red River
Madam Lee
Below Lock and Dam No. 1
Black River
Acme

OHIO RIVER
Approximate Mile 961 and 957
Floodways
BPNM - various locations to measure inflow, middle flow, & outflow
Morganza Floodway at Hwy 190 (USGS)
Bonnet Carré Spillway @ Airline Hwy (USGS)
Old River Outflow Channel
Near Knox Landing
Yazoo River
At Redwood

Table IV-10. Project Design Flood, 2011 Flood, and Historic Peak Flood Flows

Station	PDF	2011[1]	1927	1937[2]	1973
Cairo, IL[3]	2,360,000	2,100,000 [4,5]	1,626,000	2,010,000 [6]	1,536,000
Memphis, TN	2,410,000	2,213,000	NA	2,020,000	1,633,000
Helena, AR	2,490,000	2,130,000	1,756,000	1,968,000	1,627,000
Arkansas City, AR	2,890,000	2,293,000	1,712,000	2,159,000	1,879,000
Vicksburg, MS	2,710,000	2,320,000	1,806,000	2,060,000	1,962,000
Natchez, MS	2,720,000	2,260,000	NA	2,046,000	2,024,000
Red River Landing, LA	2,100,000	1,641,000	1,461,000	1,467,000	1,498,000
Baton Rouge, LA	1,500,000	1,436,000	NA	1,400,000	1,381,000
New Orleans, LA[7]	1,250,000	1,230,000	1,360,000	1,342,000	1,248,000
Old River Outflow Complex	620,000 [8]	671,000	NA	NA	610,000
Simmesport, LA	930,000	692,000	592,000 [9]	465,000 [10]	781,000
Morgan City, LA[11]	920,000	512,000	741,000	493,000	692,000
Wax Lake Outlet, LA[11]	580,000	323,000	NA	NA	292,000

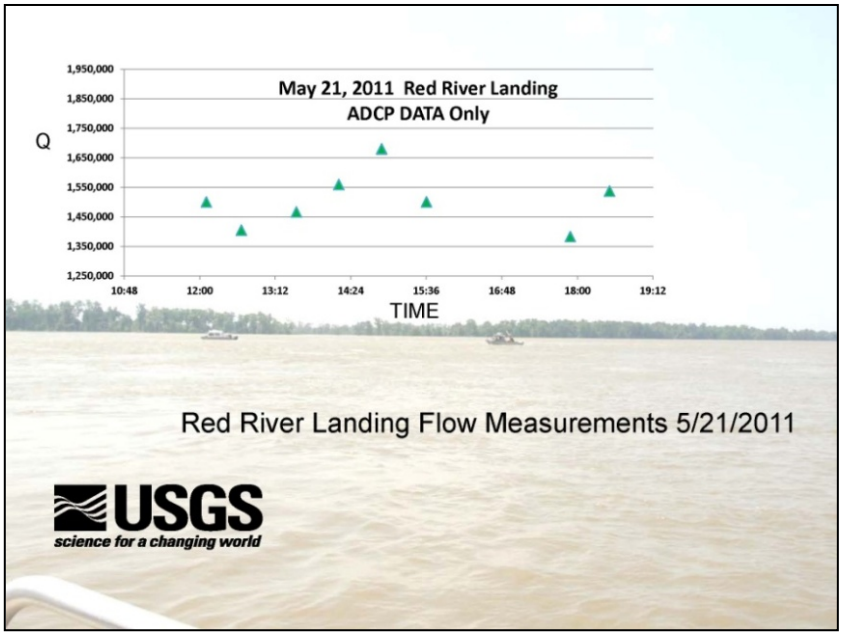
[1] Provisional Flows, Final flows were being coordinated with USGS at the time this report was produced.
[2] From *Annual Maximum, Minimum, and Mean Discharges of the Mississippi River and Its Outlets and Tributaries to 1963*
[3] Discharge Range at Hickman, KY
[4] Total Confluence flow of 1,936,000 cfs measured at approximate mile 950.8 at 1400 CDT on 5/02/2011 near Wickliffe, KY, prior to operation of BPNM
[5] Peak flow measured on 5/4/11 = 1,730,000 cfs at Hickman plus 370,000 cfs flow through BPNM Floodway
[6] Includes flow through BPNM Floodway
[7] New Orleans Mean Daily Flow as determined from gage at Belle Chasse. Readings at this site are tidally influenced. An instantaneous measurement of 1,320,000 cfs was made on 5/17/11.
[8] ORCC design flow is greater than 620,000 cfs PDF flow and considers a low Red River; current capacity of the Federal structures at ORCC is 740,000 cfs
[9] Source: MVN
[10] Source: Rivergages.com
[11] Wax Lake Outlet was constructed from 1937-1942. Prior to that, Lower Atchafalaya R. was the major outlet.

The USGS measurements in the Morganza Floodway and Bonnet Carre Spillway are taken to verify flow computed by the Corps at the structures. The Morganza Floodway measurement site at Highway 190 is over 17 miles downstream of the Morganza structure. The MVN requested USGS to investigate discharge measurement sites closer to the Morganza structure or where ADCP measurements could be made; because of the distance between the Morganza structure and the USGS measurement site, and the travel time between the two locations, there was some difficulty in correlating the flow measurements with the computed flow. Review of the MVN 1973 PFR revealed that there was some kind of flow measurement taken at the structure; after discussions with retirees, it was determined that a Price meter was dropped in each gate bay, and the measured velocity was used with an estimation of the flow area to get a discharge.

After a site visit, USGS concluded that ADCP measurements on the Mississippi River side were not practical because of complex entrance conditions in the forebay; further, for a safe operation, two boats could be required. USGS found one location in the floodway between the structure and Highway 190 where a measurement could be made, and on May 21, 2011, took an ADCP measurement. The USGS took considerably longer to complete the ADCP measurement at this location than at the Highway 190 site because the speed of the boat must be less than the velocity of the stream; therefore, there was no benefit to relocating the range.

On May 12, 2012, prior to the operation of the Morganza Floodway the discharge measurements at Tarbert Landing showed large divergence from the discharge-stage rating curve for Tarbert Landing and a significant

decrease in flow, although the stage had increased 0.7 foot and stages continued to rise upriver. A second measurement was mandated, which was almost 100,000 cfs greater than the measurement taken in the morning and appeared to better represent the flow in the river. It was assumed that there was a problem with the ADCP measurement; however, the same issue arose on May 13, 2011. The ADCP measurement was around 50,000 cfs less than the second measurement taken on May 12 with an increase in stage of 0.4 foot. The Corps began taking ADCP measurements twice a day and continued through June; the Corps enlisted the services of USGS to take additional measurements at Tarbert Landing. USGS crews collected numerous ADCP measurements on May 21-22. Plots of the USGS measurements are shown in figure IV-11.



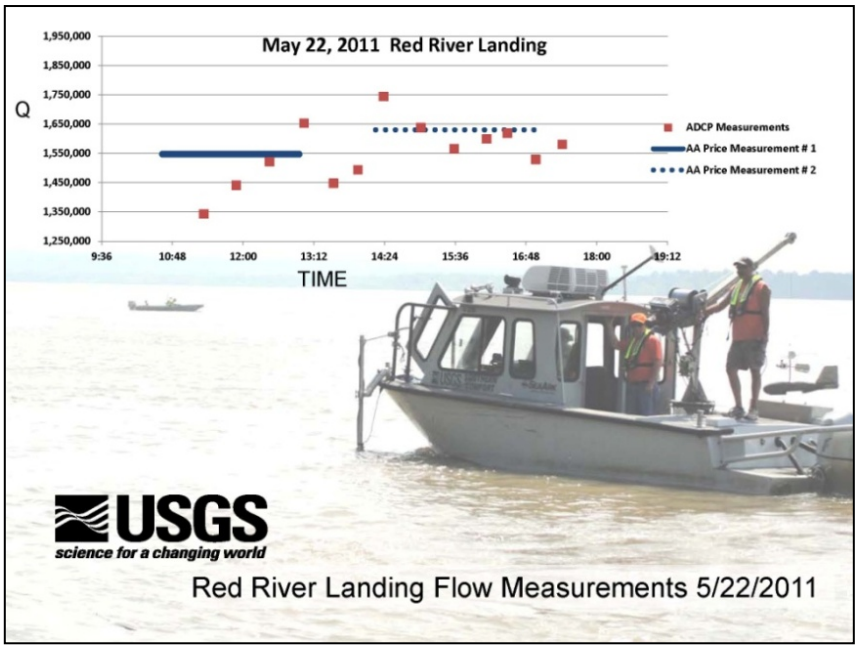


Figure IV-11. Red River Landing Flow Measurements

Additional measurements were taken to provide insight into the difference between ADCP and Price meter measurements on the Mississippi River. Between May 15 and May 30, 12 sets of point measurements were taken in the thalweg of the Mississippi River at Tarbert Landing. One 15-minute ADCP point velocity measurement and 120- and 240-second point velocity samples at 20, 60, and 80 percent depths were taken.

8. Environmental Factors and Cultural Resources

a. Environmental Factors. As the 2011 Flood developed, the environmental and cultural resources specialists assembled interagency teams, kept those teams abreast of new information and developments and set up the protocols and contracts to initiate background monitoring and sampling before the flood affected areas within the watershed.

A list of POCs that were members of the interagency weekly phone calls and the flood response is provided in Appendix A, *Reservoirs*. The list should be updated every 2 years by Emergency Operations personnel.

Environmental data was collected prior to the full impact of flood waters in order to provide a baseline for comparison. Funding and scopes of work were put in place to establish water quality monitoring. During the 2011 Flood, two water quality studies were conducted.

The first was the evaluation of water quality at historically established USGS National Stream Quality Accounting Network sites along the Mississippi and Atchafalaya Rivers. Table IV-11 lists the name and locations of the 15 primary field data collection stations, which were used to measure water quality during the flood period. Figure IV-12 is a map of these stations.

Table IV-11. Water Quality Gaging Stations Along the Mississippi and Atchafalaya Rivers

Station Name	Site #
Mississippi River at Thebes, IL (Upper Mississippi River)	1
Ohio River at Dam 53 Near Grand Chain, IL (Ohio River)	2
Birds Point Levee Breach Inflow (BPNM Floodway)	3
New Madrid Floodway Inflow Outflow No. 2 (BPNM Floodway)	4
Mississippi River at Tiptonville, TN	5
Mississippi River at Memphis, TN	6
Mississippi River above Vicksburg at Mile 438, MS	7
Mississippi River near St. Francisville, LA	8
Atchafalaya River at Melville, LA	9
Atchafalaya Floodway near Ramah, LA North of I-10 F (Morganza Floodway)	10
Mississippi River at Baton Rouge, LA	11
Lower Atchafalaya River at Morgan City, LA	12
Wax Lake Outlet at Calumet, LA	13
Bonnet Carré Spillway at US Hwy 61 near Norco, LA (Bonnet Carré Spillway)	14
Mississippi River at Belle Chasse, LA	15

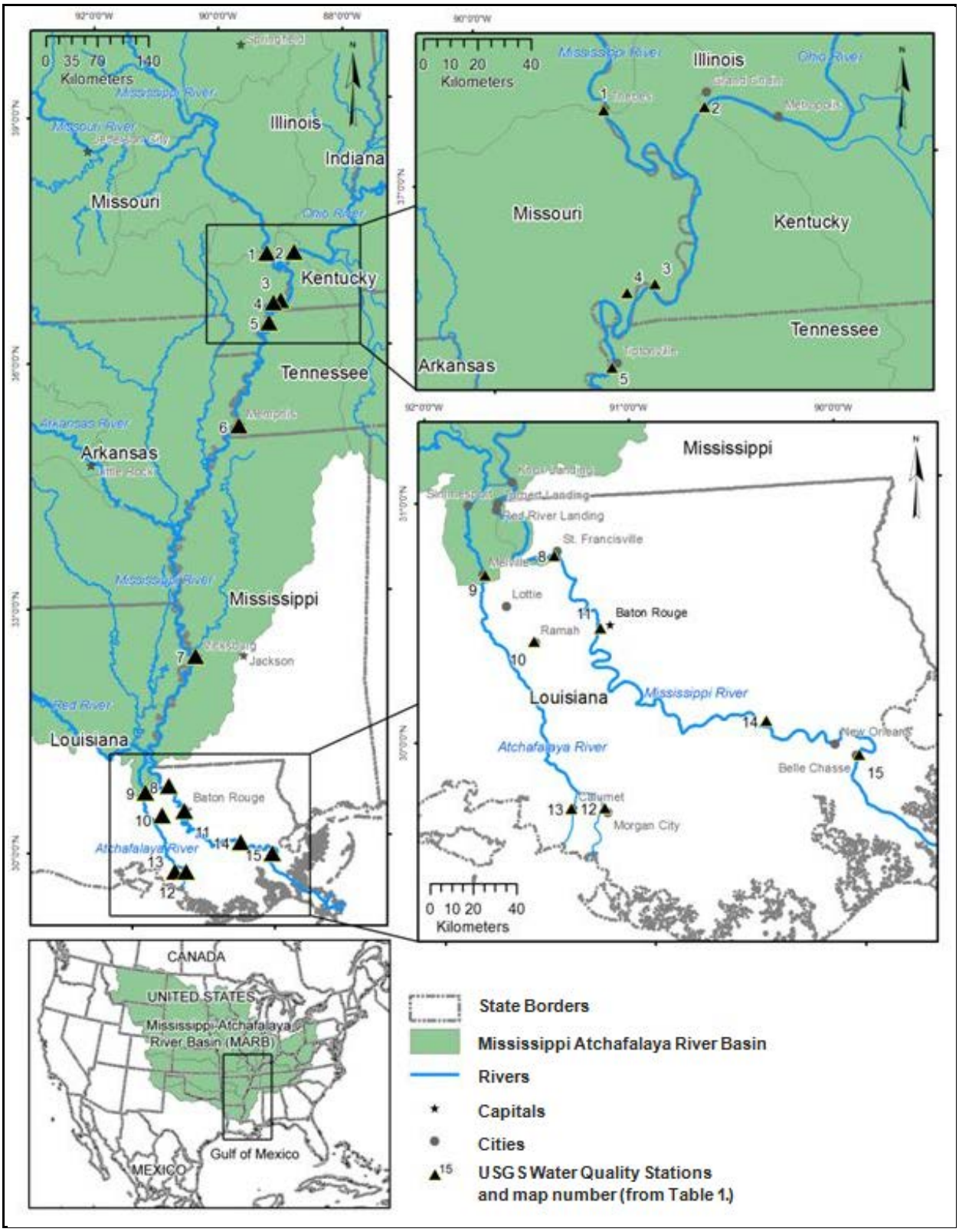


Figure IV-12. Map of LMRV and the Location of the Primary Water Discharge and Quality Measurement Stations (USGS)

A second water quality study focused on the movement of water from the Bonnet Carré Spillway, through Lake Pontchartrain, and into Mississippi Sound. During the 1997 opening of the Spillway, blue-green algae blooms were observed, resulting in the closure of portions of Lake Pontchartrain to recreational activities in order to limit human contact with the potentially toxic algae. There is considerable local interest in the water quality of the lake and interest from local commercial fisherman as the freshwater leaves the lake and enters into Mississippi Sound vicinity.

In order to assemble the data collected from the above efforts, as well as link to data collected by various state agencies, universities and non-governmental organizations, a data viewer was constructed as the flood was developing. The Corps and the USGS have archived water quality data from throughout 2011 Flood in the LMRV and have made it publically available online (http://deltas.usgs.gov/spillway/BonnetCarre2011.aspx; or http://la.water.usgs.gov/MississippiRiverFlood2011.html). A screen capture from the homepage of the data viewer is shown in figure IV-13, which illustrates the geographic extent of the interagency sampling and the range of agencies who participated in the effort.

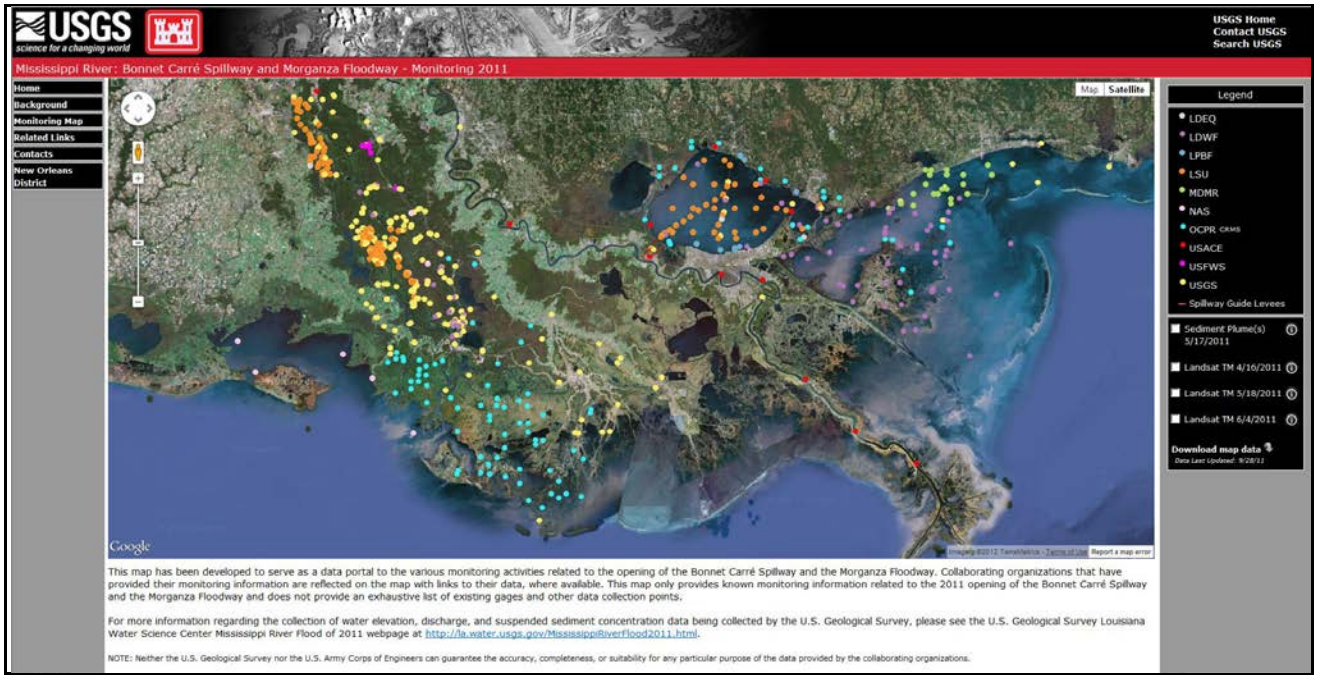


Figure IV-13. Homepage for the Data Viewer Developed by MVN and USGS National Wetlands Research Center During the 2011 Flood to Archive Water Quality Data and Make Available to the Public

b. Cultural Resources. Prior to the activation of the BPNM Floodway, culturally affiliated and federally-recognized tribes were notified of the possibility of activation by telephone and email and then periodically briefed during the activation by follow-up emails and teleconferences. County coroners and sheriffs were advised on the Corps procedures for dealing with inadvertently exposed human remains. Under the revised Missouri statutes (Chapter 194), the Missouri State Historic Preservation Office (MO SHPO) has jurisdiction over human remains associated with prehistoric and historic archaeological sites on non-Federal private lands. In addition, Corps Quality Assurance personnel working on levee restoration were briefed on these procedures and given the telephone numbers and email addresses of the District Archaeologist and Tribal Liaison in the event they made discoveries of human remains. They were advised that if human remains were discovered during the immediate post-flood period, the following actions would be implemented. This would include notification of the respective county coroner and sheriff, the MO SHPO, and the affiliated tribes. The decision to collect exposed remains would not be made without full

tribal consultation and monitoring. If the remains came from privately owned lands and were collected by (or turned over to) the MO SHPO, NAGPRA consultation on the final disposition of the remains would be led by the MO SHPO. If the human remains came from lands held in fee status by the MVM, then the MVM would lead the NAGPRA consultation on their final disposition. In all cases, reburial in place should be regarded as the preferred alternative.

Finally, the MVM should begin aerial flights using LiDAR remote sensing as soon as the floodwaters receded and before revegetation/replanting began. This would ensure that all scour areas could be mapped and incorporated in MVM's GIS database. This would enable the District to prepare a detailed damage assessment independent of the landowners' permission to access private land. Similar procedures for the treatment of inadvertently exposed human remain were developed by MVN for the Morganza Spillway and the Bonne Carré Spillway in compliance with Louisiana state law.

9. Forecasting. River stage forecasting provides vital planning and operational information for flood fighters and other people responding to floods. The NWS is the official forecasting agency of the Federal Government. The Corps produces operational forecasts in order to operate our projects and carry out our missions. Before the 2011 Flood, the Corps joined with other Federal agencies to strengthen and improve Federal river stage forecasting. During the Flood, further need for forecasting improvement was identified. The following sections describe river forecasting background and issues.

a. Forecasting Background. River forecasting has played a key role in how society responds to flooding. In some years, forecasting has come under severe criticism, notably during the 2008 UMR Flood and the 2010 Cumberland System Flood. Due to forecasting improvements, the 2011 Flood stands in stark contrast to these two events. However, there were still concerns.

As a result of criticism of the river forecasts before and during the 2008 UMR flood, MG Walsh called for a River Forecasting Summit which was held in St. Louis in October 2008. A major result of this summit was that while the public viewed the Corps operational forecasting as superior, they expected more from the Federal Government's official forecasting agency, the National Weather Service (NWS). The three key agencies—the NWS, the Corps, and the USGS—formed the Fusion Team to improve forecasting capabilities. This team was institutionalized by MG Walsh Commander of MVD; Gary Carter Director, NOAA/NWS Office of Hydrologic Development; and Steven Blanchard, Chief of Surface Water, USGS. The Fusion Team's mission is to improve the accuracy and utility of river/rainfall observations and river forecasts. The team works collaboratively to identify improvements and develop plans to implement them given current science, manpower, and funding constraints. The ultimate goal is to optimize the accuracy and utility of the forecasts provided to the public in accordance with all applicable Federal regulations.

The three agencies that comprise the Fusion Team agree that it has been instrumental in improving the Federal forecast. However, at the time of the 2010 Nashville Flood, many of the same issues were raised and identified as in the 2008 UMR Flood; it became evident that one shortfall of the Fusion Team was its limited geographic scope. Subsequently, the scope of the Fusion Team was expanded to include the Greater Mississippi River Basin.

As indicated in the Spring 2011 Middle & Lower Mississippi River Valley Flood Service Assessment, the forecasting performance was significantly improved from previous floods. It is believed that this can be attributed to several factors:

1. Fusion Team actions
2. HEC-RAS community model for the Ohio River
3. River Forecasters workshop

4. Tri-Agency meeting
5. Increased training of the NWS staff
6. A culture of teamwork among the agencies involved in this Flood

b. Forecasting Issues During the 2011 Flood. While it is generally recognized that the Federal Government, through the NWS, did a much better job of forecasting during the 2011 Flood than during previous floods, multiple users of the river forecasts have pointed out the need for additional improvement. Specifically, there has been a great deal of public confusion about the impacts of the river forecasts as they relate to the operation of the Corps' floodways. The following paragraphs describe areas in which improvements need to be made through coordination /collaboration.

i. Vicksburg District

a. Mississippi River. Based on forecasted rainfall, the crest at the Vicksburg gage was originally predicted to be 52.5 feet on May 13. However, on May 2, the forecasted crest was revised to 57.5 feet on May 18 based on a rainfall event of 3 to 8 inches over northern Arkansas, southern Missouri, and southern Illinois. Due to a collaborative effort between the NWS and Corps, the crest forecasted on May 2 was less than a half foot different than the crest that actually occurred on May 18 (figure IV-14). This is a success story for the flood fighters, decision makers, and others who use these forecasts. There were similar crest revisions along the Mississippi River at all gages inside the Vicksburg District boundaries. The crests at Arkansas City and Natchez gages were both revised upwards by 5 feet, and the crest at Greenville gage was revised upwards by 4.5 feet.

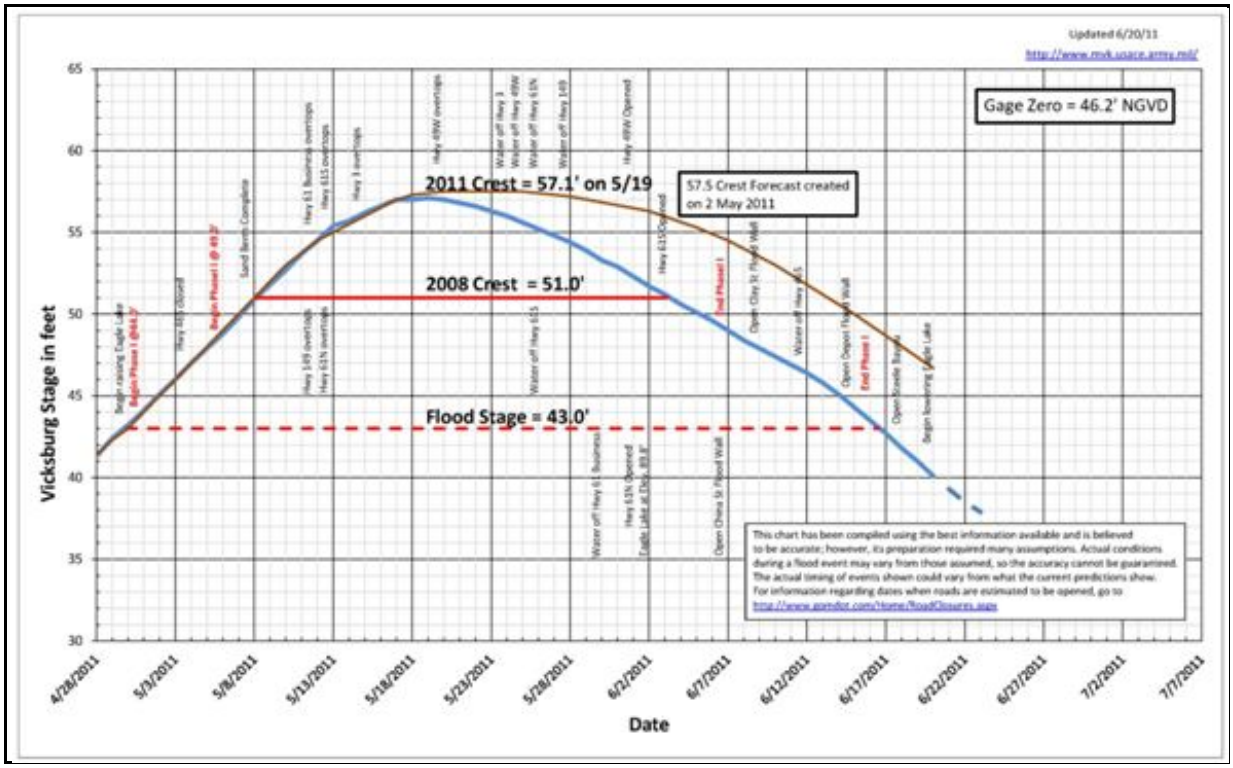


Figure IV-14. 2011 Flood Forecasting Crest for the Mississippi River at Vicksburg
The blue line is the 2011 actual stage; the brown line is the forecasted stage.

b. Red River. The gage at Acme, LA along the Black River is used to determine stages throughout the Red River Backwater area. The gage is located 1/10th of a mile north of the confluence of the Black River and the Red River. From Acme, LA, the Red River flows south into the Atchafalaya River, west of the ORCC.

Based on forecasted crests along the Mississippi River, the forecast crest at Acme, LA was set at 53 feet, 5 feet above the flood stage of 48 feet. The crest prediction was largely due to uncertainty about whether the Morganza Spillway would be operated and whether the watershed would receive normal rainfall. On May 15, the crest was revised to 47 feet, 1 foot below flood stage. The revision was based on the watershed receiving less than normal rainfall which resulted in lower than predicted flows on the Red and Ouachita Rivers, the decision to operate Morganza Spillway and the ORCC diverting less water than planned into the Atchafalaya River Basin. The "over-prediction" of crests caused some public concerns in the unprotected portion of the Red River Backwater area but ultimately did not exceed flood stage.

c. Yazoo Backwater Levee. In order to reduce pressure on the Mississippi River levees during a high water event, the Yazoo Backwater Levee is designed to overtop once floodwaters reach elevation 107 feet. Overtopping was predicted to occur based on crest forecasts. In an effort to prevent erosion of the levee and avoid large repairs after the flood, the Vicksburg District provided erosion protection along the land side of the levee. The actual stages were 0.4 feet lower than forecasted and no levees were overtopped.

ii. New Orleans District. Because the NWS is the official Federal agency responsible for issuing river stage forecasts, MVD's Commanding General instructed MVN to use the official NWS stage forecasts for operation of the MR&T components within the MVN Area of Responsibility (AOR). However, since many of the components—particularly the ORCC, the Morganza Floodway, and the Bonnet Carré Spillway—are operated based on flow rates, MVN staff had to translate the NWS stage forecasts to flow forecasts using stage-discharge rating curves. These curves suffer from known issues such as loop effect or hysteresis[1]. This did not cause a serious challenge until the Morganza Floodway was operated. At that point, further stage rises in the vicinity of Morganza, including at Old River, were dampened by the floodway operation, although flows upriver continued to rise. This impacted stage-discharge relationships and required the use of other techniques to determine flow rates.

c. System-wide Issues. The NWS normally publishes forecasts under the assumption that the Corps will operate water control structures according to approved plans. During the 2011 Flood, the NWS coordinated river forecasts with MVD. Upon request from MVD, NWS published forecasts that did not include Morganza Floodway operation until the MVD Commander made the actual decision to operate the floodway. These forecasts depicted catastrophic stages on the Mississippi River and near-normal stages on the Atchafalaya River. This caused concern in some communities on the Mississippi and may have delayed public preparation for floodway operation along the Atchafalaya River. When flooding first threatened the MVN AOR, the NWS published a forecast showing 17.5 feet at New Orleans. When the NWS contacted MVN to discuss this forecast, MVN told the NWS that their forecast was not likely to be correct, because the

[1] Systems that display loop effect have "memory" that influences how inputs are processed into outputs. In the case of stage-discharge rating curves, a given river stage is associated with one discharge as the river is rising but with a different river stage as the river is falling. This is because as the river is rising, upstream stages are much higher than downstream stages, so the hydraulic grade line is steeper, resulting in higher velocity and therefore higher discharge for a given stage. As the river is falling, upstream stages are still higher than downstream but not by as much; velocities and discharges are correspondingly reduced, even though the river stage is the same. Typical stage-discharge curve show discharge on the x-axis and stage on the y-axis, so rivers tend to "rise on the right" of the overall average curve and "fall on the left." This adds to uncertainty in computing discharge because it's hard to know how much to adjust a curve to account for loop effect when you first receive a discharge measurement - you can only really see it well in hindsight or in actual discharge measurements taken during the event.

Corps would prevent stages from rising to that height by operating the Bonnet Carré Spillway and other features as needed. The NWS subsequently changed the forecast to 17.0 and added a note that it assumed operation of the Bonnet Carré Spillway. Once the decision to operate the Morganza floodway was made, the NWS forecasts included floodway operation. A related circumstance occurred when stages at Cairo, IL approached levels that would trigger operation of the BPNM Floodway and the NWS published a forecast showing 63 feet at Cairo, a level above the trigger that would require operation of the BPNM Floodway and would therefore almost certainly not occur. This situation is different because the stage forecasts affect the decision to operate the BPNM Floodway. The resulting forecasts were both confusing and alarming. They showed unlikely and catastrophic stages in metropolitan Baton Rouge, at the Waterford 3 Nuclear Power Plant, and other locations. This created public communication and public relations issues.

10. Communications/Collaboration. Most communications issues identified during the 2011 Flood were general in nature and applicable to multiple features. Several new technologies presented opportunities to utilize new tools such as Smartphones, and social media sites such as Facebook and Twitter to a greater extent than during previous floods. Although they were not integrated into many pre-flood plans, these tools were generally quickly applied and used successfully to improve internal and external communications during the flood. Field Reconnaissance Emergency Equipment Brokering Operational Assignment Regional Defense (FREEBOARD) and Mobile Information Collection Application software applications were used to efficiently collect and share information more than during any previous floods. Some minor problems were encountered in the field such as poor cell phone reception in some remote areas, a shortage of phones and radios, difficulty in obtaining them, and the fact that few people were trained to use them. However, these problems were overcome and the new field tools were highly successful. Similarly, during and after the Flood, social media were used extensively, with relatively minor problems. Additional details related to the use of these technologies and some of the issues that were encountered are provided in the paragraphs that follow.

Daily communication and collaboration was crucial during the flood. Each District EOC developed a unique Battle Rhythm (table IV-12) to meet its specific communication and collaboration needs.

Table IV-12. Emergency Operations Battle Rhythm

MVS	MVM	MVK	MVN	MVD
0800 • Establish contact w/ flood fight teams • MVD EOC Call • Update to DE via e-mail **1300** Reports from field due to EOC **1400** • DE Brief-MVS flood update • EMA coordination call (when requested) **1600** ENGLink SITREP due	**0800** Area Commander Reports due **1100** Area Coordinator Reports due **1130** Problem Area Map/Material printed **1200** CDR's Briefing Pre-Brief **1230** CDR's Briefing Book updated **1300** CDR's Briefing **1600** SITREPs due **1700** SITREPs available for release **1800** EOC EM Brief	**0700** EOC day shift begins **0800** MVD CDR's Call *Total System Brief* **0830** Field SITREPs due to the EOC **1000** MVD EOC Coordination Call **1100** Change Mgmt Team Staff Briefing **1300** MEMA Coordination Call **1400** GOHSEP Coordination Call **1700** EOC Staff Meeting **1900** Capstone Meeting w/ AAOs	**0700** Internal Daily Briefing **0800** CG Teleconference **0900** MVD EOC call **1300** MVD flood fight supply call **1400** GOHSEP call **1500** Stakeholder teleconference **1900** Freeboard posted/approved **2000** Inventory Report **2100** ENGLink SITREP posted	**0700** EOC day shift begins **0800** MVD CDR's Call *Total System Brief* **0930** EOC Coordination Calls **1000** LRD Update **1300** MVM CMT Briefing **1330** LRD Update **1400** UOC Brief **1500** MVM Birds Point Brief **1600** CMT Brief **1700** CDR's Assessment **1900** EOC Shift Change

MVK's Engineering and Construction, Operations, and Emergency Management branches held a daily meeting at 0800 to coordinate efforts regarding ongoing flood fight projects, which cleared up nearly every communication issue and was overall a great benefit. At the start of the event, there were communication issues among offices regarding the projects. Different offices were reporting different information, and updates were not being communicated to those needing the information. A separate meeting, the Area Commanders Call, was integrated with the Change Management Team (CMT) Staff Briefing. Prior to integration, the Area Commanders briefed the EOC at 1000, and the EOC briefed the CMT at 1100, with the Area Commanders listening in. This change reduced the time the Area Commanders were required for briefings and allowed them to speak directly to the CMT. The CMT Staff Briefing was conducted daily; District personnel provided situation updates and coordinating information to each other and to the MVK Commander. The EOC Staff Meeting was a coordination meeting attended by all EOC members at which EOC leadership addressed administrative issues related to the EOC staff. The Capstone Meeting was a daily update briefing established during this event at which the Area Action Officers provided situation updates to the EOC leadership and the night shift, focusing on high-priority items. The following strengths and weakness were identified in the MVK-AAR regarding internal communication during the Flood:

- The Public Affairs Office (PAO) was receiving great information from the EOC and through the CMT Brief and the AAOs. In particular, the AAOs were an invaluable source of information.
- Coordination between logistics and the EOC was excellent.
- The chain of command was not always used, so employees would take action on behalf of the District without approval and without the proper authority.
- Field offices sent requests for IT support to the EOC, and those requests were not being directed to ACE-IT at the District level.
- It was difficult for the PAO to get access to the pictures that were being sent to the EOC. A plan to set up a share point site for sharing pictures was never completed.
- The PAO was not informed of all public meetings, specifically meetings that were not organized by the Corps and not attended by Public Affairs personnel.
- The Security Office was not informed of all public meetings.
- There was a duplication of effort within the District related to security for the levees. Security began planning for security along the levees only to find out later that another division had begun parallel actions.
- There was confusion regarding the materials being received at the harbor and used for the various projects, specifically information about the timing of shipments of material and which project each shipment was meant for. Overall coordination went well despite some small issues.
- While communication was good throughout the event, it seemed that the District communicated better externally than internally. Throughout the event there were issues with communication between personnel from the field and the District. Some information was reported to either Operations or EOC, but not both. In addition, there was some confusion regarding who had the authority to approve actions in the field.
- MVK's Visitors Center is a poor location to hold a press conference because of the noise from Interstate I-20.

The major communication event to address 2011 Flood activities at MVM was the daily Flood Fight briefing which involved the reporting of all pertinent flood fight activities by each Flood Fight Area/Sector Commander. This briefing was attended by all major staff members, Area Commanders, and MVD supporting team

members. The Flood Fight Commander presented major topics and provided an open forum for questions and answers. Major decisions covering a vast array of flood related issues were made and communicated back to the field and stakeholders.

The MVS held daily coordination meetings to communicate with a PDT consisting of the US Coast Guard, the Corps, the railroad industry (Bridges), the River Industry Action Committee, and mariners. This PDT constantly updated and evaluated requests for emergency vessel movements and developed criteria for timely and orderly reopening of the waterways to commercial navigation.

An MVN battle rhythm was established at the onset of the event. Two of the briefings—the internal daily briefing and the stakeholder teleconferences—were hosted by MVN. Initially, the daily briefing included both internal team members and stakeholders. It was determined that it would be more effective to split the calls into one internal briefing in the morning and one stakeholder call in the afternoon. The morning internal briefing included the District Engineer, Chief of Emergency Management, Division Chiefs or their designees, Area Engineers, Project Managers at the structures, and EOC support staff. Afternoon calls consisted of the MVN personnel from the morning and included local levee Districts, parish representatives, and other Federal agencies. Aside from the battle rhythm, technical offices throughout MVN participated in additional teleconferences as they saw fit. The Hydraulics and Hydrology Branch participated in calls with the NWS, and the Environmental Branch participated in calls with the LDWF and other environmental agencies. ENGLink SITREPs were completed and submitted nightly for use at the morning briefings.

One major challenge throughout the division during any flood fight is ensuring that the most up-to-date information is available and used. Floodway operations are no exception. Accessible only by Corps employees, this website consolidated information related to the flood such as supplies, daily briefs, SITREPs, weather, and other information. More education could have been provided to employees; it seemed everyone had a different awareness level and interpretation of data. An organization chart with contact points would be helpful to establish the POC for specific issues.

MVM faced challenges with outdated standard operating procedures (SOPs) and direct access to enough experienced personnel and communications equipment. Internally, MVM lacked the necessary personnel to respond to the large number of significant issues the 2011 Flood presented. Critical communication equipment needed in remote flood fight locations was in short supply and ACE-IT was unable to provide IT support and other logistical items. This prevented positive communications (landline telephone, internet, email, etc.) from being established early in the event.

The existing BPNM Floodway internal SOP and Operations Plan was outdated. Although tools such as ENGLINK were utilized to acquire the staff needed, a clear delineation of releasing authority and approval of information between the Joint Information Center, staff, and USACE HQ was not delineated. Additionally, the BPNM Operation Plan and SOP did not incorporate more recent social media communication tools and capabilities.

After review of the AARs, it appears the ability to communicate was also hampered by the unfamiliarity with the operations and the finite elements of its operation. The Readiness Branch was balancing the BPNM Operation as a part of the 2011 Flood, although the BPNM Operation was not under the direct supervision of the Emergency Manager. This lack of communication resulted in a quasi hierarchy of experience and rank and created some confusion at times on who either had the technical knowledge, experience, or authority to execute specific tasks and decisions.

a. District to District. There was good communication between MVK, the field offices, and the levee boards related to inspection and remediation of the levees. The EOC instituted AAO positions to act as

representatives of the respective field offices within the EOC. They were responsible for coordinating information between MVK and the field office and for briefing the EOC staff regarding current hot spots for their areas.

During this event both MVK and the MVN District provided information to the State of Louisiana related to the flood fight. At times this information was contradictory, and at other times one District would provide information that the other would not. There were differences in the information reported by MVK, MVK's field offices, and MVN. There was also inconsistent data reported from the District to the different State and local agencies. For future events the "one door to the Corps" concept should be used, establishing one District as the lead regarding Louisiana. It has been recommended to establish a regional communications plan jointly between MVK and MVN that details what information is reported to various State and local agencies, consider dividing communication responsibilities by State to prevent two Districts from communicating with one State agency, and utilize the Silver Jackets relationships to facilitate communication where possible.

Besides the ongoing communication necessary to address critical items, scheduled teleconference calls occurred on a daily basis with affected district and division offices. These calls were conducted to ensure all participating Corps offices were aware of what was going on upstream and downstream (where applicable) and all operational decisions and their resulting actions and/or adverse impacts could be kept at a minimum. Other transfer of information included river forecasts, precipitation forecasts, and FRM operation decisions.

The reservoir releases in Nashville District (LRN), the LRD, and the TVA affected the stages on the Ohio and Mississippi Rivers. The LRN and the LRD, participated in daily calls with MVM and the Districts and all information was transferred in a positive manner. Similar information as above was transferred. The LRD organizes inter-division and interagency teleconferences to coordinate water management operations and NWS forecasting. These calls were conducted daily, twice a day or more as needed during the Flood. This is part of the long-standing procedure contained in the pamphlet *Regulation of Releases From the Tennessee and Cumberland Rivers During Ohio and Mississippi River Flood Control Operations*.

MVM experienced communication issues with ERDC. Communication between ERDC blasting personnel working on the front-line levee and ERDC personnel at the command/control center was required to coordinate various aspects of the firing train preparation and detonation process. The line of communication between operation sites on the levee and the command/control center was primarily provided by the Corps' boat radio network. Communication during operation of the Inflow Crevasse was also facilitated by direct coordination via down-range vehicle access due to site accessibility. However, communication during operation of Inflow/Outflow #1 (I/O #1) and I/O #2 were solely limited to communications over the boat network (and required a relay from boat to command/control for I/O #1). This severely limited direct communication capabilities between forward ERDC personnel and ERDC personnel at command/control. In some instances communications could not be made. Cell phone communications were also used but were not reliable, particularly for I/O #1 and I/O #2. The remoteness of the crevassing sites limited communication capabilities so that only high-power radio networks such as those on the Corps' boats were functional. For operations at I/O #2, even with the Corps' boat radio network direct communication was not available between personnel on the levee and command/control, so that message relays were required.

Stakeholders in MVM complained of inconsistencies between Districts, primarily relating to inundation mapping standards and the floodway. Some agencies said they heard several different elevations for building back the BPNM levee.

b. District to Division. The MVD "Total System Brief" was a daily conference call at which MVD staff and District Commanders provided situation updates to the Division Commander. See table IV-11 for the scheduled times that these occurred.

Since the operations were related to water resources, a substantial amount of communication was conducted within the hydraulics Community of Practice (CoP) across Districts and divisions. Governing water control instructions, complex hydraulic models, precipitation and river stage forecasts, and available real-time data were examined extensively prior to implementation of major command decisions. As the available information was being reviewed and dissimilated, the Commanders were kept informed of river conditions and the need to act on authorized MR&T Project requirements. These requirements affected reservoir release schedules and Mississippi River floodway operations.

c. Corps to Other Agencies. The Districts within MVD pursued coordination internally and with outside agencies during this event in an effort to synchronize efforts and to share information. Coordination was accomplished in many different ways, including establishing direct liaison with certain agencies, establishing internal and external websites, and participating in recurring meetings and conference calls. During the Flood, Districts within MVD were continuously in contact with the following agencies:

FEMA	State Emergency Management Agencies*
NWS	State Departments of Transportation
USGS	Mississippi Department of Environmental Quality
USEPA	State, County, Local officials in affected communities
US National Guard	Delta Council
US Coast Guard	County / Parish and City Leadership
Local Levee Boards	All disaster agencies/drainage levees in the emergency area

MVK provided liaison officers (LNOs) and MVN provided Local Government Liaisons (LGLs) to various agencies. LNOs and LGLs coordinated efforts between the Districts and their respective agencies, provided information to their agencies, forwarded information requests to the Districts, answered questions, and in some cases provided daily update briefs to their agencies. Agencies with liaisons are denoted with an asterisk in the list above. Agencies in the BPNM area requested liaison officers from relevant Districts be set up with State emergency management agencies. Some local agencies contacted Corps employees that they knew at the District, sometimes in divisions that did not have current flood information.

MVK Water control coordinated very well with the NWS, MDOT, and other agencies. The MDOT provided surveys on roads in some of the areas predicted to be affected by the flood and provided that data to MVK water control, and an overtopping date was predicted using inundation maps. This process worked extremely well during this event and allowed for MDOT to plan for road closures.

From late April to mid June, a daily conference call was held with the NWS, LRD, Southwestern Division (SWD), and MVD. The NWS was provided with the forecast discharges for dams/reservoirs, info on spillway operations and collaborated on individual forecast points. Besides individual calls made to the Divisions and District offices throughout the event and a daily coordination call with all Corps/NWS pertinent personnel on the Mississippi and Ohio River drainage was conducted. Personnel from the following agencies participated:

Ohio River Forecast Center (RFC)	NWS Arkansas Basin RFC
Lower Mississippi RFC	NWS Hydrometeorological Prediction Center
LRN, LRL, LRH, LRP Districts	MVM, MVK, and MVN Districts
SWD, MVD, LRD Divisions	

Three State EMAs requested the physical presence of Corps personnel in an effort to streamline the transfer of information. MVM did not have the manpower to dispatch a liaison to the state emergency management agencies. To assist and accommodate the State EMAs requests, Corps personnel from supporting Districts were dispatched to the requesting agencies. Although, the recruited Corps personnel were not extremely

knowledgeable of the area, District personnel or District processes, their familiarity with Corps emergency processes was considered an asset.

The Tennessee Emergency Management Agency (TNEMA) had a daily call with the Corps represented by the MVM and LRN Districts. Others on the call were TVA, NWS, the State of Kentucky and other local governments. As stated above, TNEMA requested a Corps liaison so an employee from the MVN was posted in the Nashville office.

MVS water control staff conducted numerous daily conference calls that provided for situational awareness and information exchange between peers and with interest groups. This process continues during non-flood events, but increased in frequency and intensity as necessary throughout the event. This resulted in the best possible forecast information and opportunities to discuss alternatives (such as deviations) for decisions with other key stakeholders. The MVS AAR recommended that MVS Water Control staff continue to play active role in maintaining and improving interagency cooperation and collaboration.

The following issues were identified through District AARs and post-flood public meetings:

- Many concerns associated with Corps actions in the activation/operation of floodways were identified:
  - decision-making
  - sharing Operation Plans
  - explanation of the procedures
  - open communication.
- There were concerns as to whether the NWS or the Corps had the lead in forecasts.
- Some stakeholders (e.g., levee boards) felt they were neglected as partners—not receiving information, not a partner in decision-making, etc.
- There are some issues with publicizing Operation Plans so impacted parties are in-the-know.
- In some instances, NWS Forecasts assumed that structures would not be operated according to plan, making communication about potential Floodway operations difficult. In some cases more forecast points would also have been helpful.
- Both MVN and MVK had a liaison at LA GOHSEP, but there was inconsistency between the two Districts. There were briefings where Districts reported separately and had different maps, briefs, etc.
- One major deficiency among MVN, EOC, and local government agencies was proper coordination of directives. All directives/instructions should be channeled through the EOC to insure proper funding, communications, and documentation.

There is a need for trained employees capable of performing as District, MVD, or Corps LNOs for other agencies or Districts. During the Flood, MVS provided LNOs to multiple locations in MO and IL, representing both MVS and the Corps in all cases. MVN deployed a team of trained LGLs to various parishes to help the EOC, partner agencies, and communities. Establishing a small cadre of trained personnel that can be used to fill LNO positions at States, or a yearly visit or call in, could benefit future flood fight efforts. MVS (and other Districts) need to maintain contact with LNOs and LGLs and keep them informed to ensure they can adequately represent the District and Corps. In MVS, Silver Jackets are the best candidates. It would be helpful to expand the pool of potential LNOs and LGLs and train prior to next event. These staff need to be provided with District tools and ensured they are included in necessary briefings/updates to remain fully informed.

A majority of communication issues revolved around the activation of the BPNM Floodway and MVM. While most agencies in the area have had successful working relationships with the Corps in the past, several agencies felt as if they were not treated as a partner during the flood and have not heard anything from the Corps since the operation of the floodway. Most stakeholders in the region stated they heard the news about the BPNM Floodway operation on television, despite needing to know the information critical to their operations. Some agencies did not think there was enough vetting of the impacts of the operation.

There were several instances in which agencies needed information from the Corps that they did not receive. Several sources pointed out that they acted on what they saw on TV and never received any information about the operation of the BPNM Floodway from the Corps, not even a phone call. The Governor made decisions based on the reliability of the Corps' information, but there was also a lack of communication and information shared between the State and the Corps. The State asked the Corps many questions, and basic answers took too long to get. Several levee boards/Districts and other agencies felt the Corps was withholding information, particularly in regards to the BPNM Floodway operations.

Information provided to the USCG during the pre-mission planning stage was minimal, including maps of the floodway, predictions of flooding should the mission be aborted, timing and sequence of events, locations for mooring, berthing barge, clearly defined missions of moving safety zone vs security zone on site, etc. Early on in the flood the USCG received conflicting information in regards to expected actions and unclear requirements from the multiple Corps sources that resulted in confusion during the operation. The USCG needed more specific information on what areas of the river were to be closed, how long they would need to be closed before the normalizing, and data showing it was safe to reopen the river by use of the requested survey data. These communication issues between the USCG and Corps were resolved as the flood progressed. Range of radios and cell phones were limited, creating communication problems with the vessel escorts when, due to extreme weather or debris in the water, distance between the escorts and M/V increased beyond the scope of the radios.

Agencies in the region preferred briefings from the Colonel; Colonel Reichling (MVM) was highly commended by the local stakeholders. In some instance however, stakeholders felt the Corps was insensitive and unclear in their briefings, failing to answer the public's questions.

d. Corps to the Public. Several different forms of communication were used to provide information to the public during the flood. Multiple websites were established during this event by the Districts within MVD in an effort to ensure communication and provide information to the public. The result was a series of websites that provided correct and timely information in a consolidated location and allowed for an open dialogue with the public regarding the flood fight. These websites included links to press releases, inundation maps, and other public information.

Social media sites (Facebook, Twitter, and YouTube) were utilized in similar ways during the event. Facebook and Twitter were used to share photographs, link to press releases, and provide opportunities for open dialogue with the public. YouTube was a venue for sharing videos related to the flood fight. This was very effective in correcting rumors and incorrect information, and for informing the public about the flood. Most notably at Wappapello, the use ofFacebook allowed MVS the opportunity to clarify/correct misinformation and be responsive to questions.

The use of social media sites provided challenges. The MVS PAO Social Media Operator eventually moved into the EOC to be able to timely respond to discussion. This was distracting to some EOC staff. It might be possible or preferable to have Subject Matter Experts actually engaged in the discussion rather than PAO if most of the conversation is confirming information. Additional challenges included manning the social media sites since they are 24/7 accessible and their value relies on responsiveness. Ideally, POC and EOC will coordinate social media planning prior to an event and non-PAO employees will be trained on social media operations.

All communication to the media were conducted through the PAO. Within MVM, the PAO was stationed at the EOC and also set up a Joint Information Center at Sikeston, Missouri near the site of the BPNM Operation. The MVM PAO had responsibility for setting up a Joint Information Center and providing all media and journalism support to the BPNM Floodway Operation.

Throughout this event the Districts participated in many meeting with the public, in order to convey information to the public about the flood and the Districts' response, to answer questions from the public, and to dispel rumors and correct false information. They typically took one of three forms: hosted by the Districts; meetings hosted by a state or local agency and attended by the Districts; and meetings called by state agencies or Congresspersons and were generally briefings to emergency response organizations. Many local, state, and Federal agencies were represented at these meetings, and usually all of the agencies would meet prior to the public event in order to share information and coordinate the presentation. The Districts were often involved with planning and organizing the meetings including details such as selecting a location, releasing a public notice about the meeting, and providing presentation materials like podiums and microphones. When possible each meeting was attended by at least three representatives from the related District: a Program Manager (PM), a hydraulics engineer, and a PAO specialist.

In some cases within MVD, the PAO was not aware of public meetings not sponsored by the Corps, which led to some confusion and a lack of coordinated effort. Security was also not informed of some of the meetings and therefore could not ensure adequate security. Additionally, some of the meetings did not have a local sponsor, and due to some coordination issues led to the PAO or Programs and Project Management Division organizing the meeting at the last minute. When a public meeting is identified that will have Corps representation, both PAO and Security should be notified.

MVM used a Staff Action Command Officer who was located in the EOC to address all District incoming "Request For Information" items. Numerous inquiries are processed via the telephone. From the SACO, an Action Officer within the MVM is assigned the "Request For Information" and it is tracked until the response is closed out. It appears the use of the Staff Action Command Officer was extremely productive. First, it ensured stakeholders and customers responses were accurately captured since he was a frontline communicator. Second, it assigned one person the responsibility to seek the proper subject matter expert to address/assess the question. Third, it ensured the action item would be completed by producing a sole employee the responsibility to close the request out.

MVM also used a Sector Area Commander as the first line source of communication to the flood fight area for the public. This process worked well for MVM, but may not be feasible for other Districts where the Sector Area Commander's time is fully committed to coordinating flood fight activities. In these cases, senior staff or PAOs commonly lead the public communication effort. For MVM, major communication was able to occur between the Corps response team and the public at the Sector Area Commander level. Since this was the first line of communication it was probably considered the most reliable because it eliminated the error that is inherent with the transfer of information through a chain of different parties. The Sector Area Commander communicates with the sponsors and stakeholders on a daily basis during the flood fight.

The release of inaccurate or unapproved information to the public was an issue during the 2011 Flood. Most incidents were the result of associates, friends, and/or family seeking inside information about flood conditions. This resulted in some individuals being reprimanded, however a more effective solution has not been implemented. Many residents and communities do not understand how the MR&T is designed to work. As partners, the Corps needs to better educate the public. Not all residents (e.g., Red River backwater area in MVN District) understand how data is reported (i.e., gages vs. stages). Additionally, the public wanted consistency and timeliness in reporting.

11. MR&T System-wide Summary of Operational Performance. The components utilized to manage floodwaters during the 2011 Flood included upstream reservoirs, levees, floodways, backwater areas, and pumping stations. These individual components were operated as a system to reduce and balance overall flood risks as the flood moved through the LMRV. The design and operational strategy for the MR&T System does not entirely exclude the river from its natural floodplain. Instead, at key locations, it accommodates the natural tendency of the river during extraordinary events like the 2011 Flood by incorporating floodway and backwater features that are only utilized during rare and extreme events. For the first time in the MR&T project's history, the BPNM and Morganza Floodways and the Bonnet Carré Spillway were placed in simultaneous operation to relieve the enormous and sustained stress on the levee system.

Emergency flood fight measures were required to pass the 2011 Flood. These measures included ringing sand boils, constructing water berms, blocking culverts/ditches to impound surface waters, constructing erosion control measures, and raising the level of protection in some areas. Although significant flood fight measures were required, the vast majority of the flood fighting efforts were concentrated at weak points that had been identified prior to the 2011 Flood because they were either incomplete features of the MR&T System or areas that experienced issues during previous floods.

Leadership at each District aggressively pursued coordination internally and with outside agencies in an effort to synchronize efforts and to share information. Coordination was accomplished in many different ways, including establishing direct liaison with certain agencies, establishing internal and external websites, using social media to inform the public, and participating in recurring meetings and conference calls.

During the 2011 Flood, the MR&T System successfully performed as it was designed to and the Corps executed its responsibility to support local interests in all phases of flood fighting. However, the 2011 Flood caused significant economic, environmental and structural damages and exposed vulnerabilities in weak and incomplete portions of MR&T System components. It also tested and identified deficiencies in some Emergency Action, Operations, Communication, Water Control, and other pre-flood planning and process documents, and decision-making tools like no flood before had. An analysis of key operational decisions related to the operation of the MR&T System follows in the next section. Details related to economic and environmental damages resulting from the 2011 Flood are presented in Section V. An analysis of the flood's impact on MR&T System components, the damage assessment process, and the repairs that are needed to prepare the MR&T System for future floods are presented in Section VI.

E. KEY OPERATIONAL DECISIONS

Many decisions related to the operation of the MR&T System were made throughout the 2011 Flood. MR&T components are operated as a system to minimize and balance overall risk to lives, property, and the nation's resources. Individual MR&T components are operated and protected during a flood based on operating plans, standard flood fight procedures, and past experience. These processes, along with information on existing and forecasted conditions, guided and supported significant operational decisions as flood waters moved through the MR&T System. Four MR&T components—BPNM Floodway, Muddy Bayou Control Structure, Yazoo Backwater Levee, and Morganza Floodway—and supporting information provide details on complex situations that required key operational decisions during the 2011 Flood. Most of the details presented here were captured through interviews and review of District reports and are further described in the 2012 MRC document, *Divine Providence – The 2011 Flood in the Mississippi River & Tributaries Project*. Section IV. D. of this report also provides additional information on emergency activities conducted at these and other MR&T component locations.

1. Birds Point-New Madrid Floodway

a. Key Decision. Operating the BPNM Floodway

b. Background. The BPNM Floodway is located in southeast Missouri along the west bank of the Mississippi River just below the confluence of the Mississippi and Ohio Rivers. It is designed to be operated at or near specific conditions to pass extreme floods that would otherwise exceed the system's capacity. Prior to 2011, the Floodway had been operated only once before during severe flooding in 1937. The Floodway is operated by detonating explosives within fuseplug pipes installed in three sections of the frontline river levee. The explosives create crevasses to divert up to 550,000 cfs from the Mississippi River through the Floodway. When operated, the Floodway inundates about 130,000 acres along the west flank of the Mississippi River for which the Corps has flowage easements. Operating the Floodway lowers the flood stage by up to 7 feet near Cairo, IL (with smaller stage reductions along the Floodway reach south of Cairo) and lowers the risk of a catastrophic failure or overtopping of mainline levees protecting much larger and more populated areas along the Mississippi River. Section IV.D.3 of this report provides additional details on the BPNM Floodway.

c. Operating Plan. Based on the BPNM design and 1986 Operating Plan, the Floodway normally will not be operated until flood stages in excess of 60 feet are predicted on the Mississippi River gage at Cairo, IL. At approximately 60 feet on the Cairo gage, the upper fuseplug section will be completely prepared for operation. Preparation of the lower fuseplug section follows operation of the upper fuseplug section. Generally, an activation stage of 61 feet on the Cairo gage (with additional stage increases in the forecast) is used by the MRC in operating the Floodway. See the MRC Information Paper *The MR&T Project: Birds Point-New Madrid Floodway*. The BPNM Operating Plan also allows for operating the Floodway sooner (at 58 feet on the Cairo gage) if the levee system is considered to be in danger of failing. Operating the Floodway utilizes existing equipment and approximately 150 MVM personnel, as well as equipment, explosives, and other materials that need to be obtained specifically for the operation.

d. Primary Issue at Hand. Operating the Floodway requires evacuating 230 residents and explosively removing the crevasse portions of the frontline levee, which would then need to be repaired after the flood. Operation would also inundate homes and structures and increase the level of flooding in up to 130,000 acres of productive agricultural land. Not operating the Floodway could result in other mainline levees overtopping or failing with much more significant damages and potential loss of life. Early forecasts put the peak flood stage very close to the Floodway activation stage. In the days leading up to the decision, some decision makers believed it possible to pass the 2011 Flood without operating the Floodway and avoid the associated damages, as rates of rise in river levels were gradually slowing. However, significant additional rainfall occurred on 30 April through 2 May, accelerating rates of rise in stages and causing forecasted stages to exceed 61 feet at Cairo. This late change in conditions resulted in the decision to operate the Floodway.

e The Operational Decision. Preparation for operating the BPNM Floodway was initiated on April 25, 2011 with the loading of barges with materials, equipment, and personnel at Ensley Engineer Yard and culminating with operating the Floodway on May 2, 2011, resulting in successful passage of flood waters through this constricted reach of the Mississippi River. Many factors were considered in making this key operational decision, the most prominent of which included the Floodway operating plan; actual and forecasted flood crests at Cairo, IL; potential damages caused by operating the Floodway and the effects on future MR&T System performance; significant precipitation and saturated hydraulic conditions throughout the Basin; use of all available reservoir storage capacity to influence the flood crest at Cairo; deteriorating conditions of MR&T levees near Cairo, IL and in Fulton County, KY; and the time needed to prepare the Floodway for operation. Severe local weather conditions also influenced the timing of preparation and operation efforts, resulting in the Floodway activation occurring at a stage of 61.72 feet on the Cairo gage. The following detailed information lays out how MVD and MVM made the key operational decision to operate the BPNM Floodway.

Birds Point-New Madrid Floodway

April 20, 2011 (Wednesday)

- Cairo gage exceeds 49 feet
- MVM enters Phase I flood fight in Cairo, Missouri and Reelfoot-Obion areas (for second time this year)

April 21, 2011 (Thursday)

0600: Cairo gage reaches 49.8 feet, NWS forecasted crest is 52 feet on 30 Apr

- NWS contingency forecast (worst-case scenario) calls for 61.1 feet flood crest at the Cairo gage on May 3 or 4
- MRC, MVM, MVD and LRD Commanders are notified of the situation

April 22, 2011 (Friday)

0600: Cairo gage at 50.3, forecasted crest is 52 feet on 30 Apr

- Heavy rains currently falling throughout Mississippi and Ohio River basins will continue to fall over coming days based on NWS forecasts
- LRD increases discharges through Kentucky and Barkley dams to clear additional storage space for upcoming forecasted storms

April 23, 2011 (Saturday)

0600: Cairo gage at 51.0 feet, forecasted crest is 52 feet on 30 Apr

- Significant rainfall continues through the middle Mississippi River Valley

April 24, 2011 (Sunday)

0600: Cairo gage at 52.4 feet, NWS revises projected crest at Cairo to 58.5 feet on 3 May

- MVM enters Phase II flood fight in Cairo, Missouri and Reelfoot-Obion areas
- System-wide flood storage utilization by reservoirs stands at 15%
- Heavy rainfall continues and begins rapidly filling reservoirs
- LRD Div CDR directs LRD District Commanders and senior leaders that flood duty missions take top priority and offices must make all efforts to reduce max. crest at Cairo

April 25, 2011 (Monday)

0600: Cairo gage at 54.5 feet, NWS revises projected crest at Cairo to 60 feet on 3 May

- NWS forecasts another 8 inches of rain for the area over next 3 days
- Small sand boils begin to form across the confluence area, especially in the Cairo, IL and Fulton County, KY sectors
- County Sheriffs order 230 residents within the BPNM Floodway to evacuate
- MVM CDR, following operating plan, orders crews to move forward with loading barges with explosive materials
- LRD begins holding water in reservoirs currently under repair within the Cumberland system after assessing integrity risks
- State of Missouri files suit in the Eastern District Court of Missouri seeking a temporary restraining order to halt the Floodway activation

April 26, 2011 (Tuesday)

0600: Cairo gage at 56.5 feet, NWS revises projected crest to 61 feet on 3 May

- Intense rainfall continues in the confluence area
- Flood fight operations underway throughout the confluence area
- MVD CDR orders movement of barges carrying explosives to a harbor in Hickman, KY and land-based crews to depart on April 27 at 7:30 to begin access well preparations.

Birds Point-New Madrid Floodway

April 27, 2011 (Wednesday)

0600: Cairo gage at 57.9 feet, NWS revises projected crest to 60.5 feet on 1 May

- Forecast calls for rain today and then 2 days of dry weather
- Corps and MRC senior leaders conduct site visit at Birds Point mainstem levee. The following information that was provided for BPNM operational decision making should be assessed for accuracy and added to the floodway operations plan for future decision making on the floodway. MVD CDR and MRC were informed of difficulty of removing explosive material from fuseplug pipes if not detonated. Filling fuseplug levees w/ explosive slurry does not commit MVD CDR and MRC to operate the Floodway, but it would be very complicated and time consuming to remove the material; residents would not be allowed to return to their homes for weeks, maybe months after flood season ends. Commercial navigation may also need to shut down during material removal.

April 28, 2011 (Thursday)

0600: Cairo gage at 58.7 feet, forecasted crest 60.5 feet on 1 May

- No significant rainfall, but forecast calls for additional rain coming 30 Apr to 1 May
- LRD proceeds with storing water in Kentucky and Barkley Lakes and also increases storage in Cumberland system reservoirs. LRD's primary goal is to hold water back long enough to give MVD enough time to load the fuseplug pipes (filling the fuseplug pipes takes approx 18 hours)
- LRD CDR sends e-mail to MVD CDR recommending MVD start filling the fuseplug pipes at the inflow crevasse as soon as possible
- Concern raised about the integrity of the Fulton County, KY levees with large number of sand boils developing
- MVM CDR informs MVD CDR that although the operating manual allows activation of the Floodway at 58 feet on the Cairo gage if levee system is near failure, current conditions at the Fulton County levee did not warrant activation
- MVM CDR recommends holding the barges at Hickman harbor for now and MVD CDR concurs
- MVM discovers high energy sand boil near Cairo, IL in the evening; proceeds with flood fight measures involving building 10 ft high berm around boil
- To address hundreds of sand boils along Fulton County levee, MVM staff constructs 1,500 ft rock berm perpendicular to the levee and cover the boils with a blanket of water

April 29, 2011 (Friday)

0600: Cairo gage at 59.0, forecasted crest 60.5 feet on 1 May

- Weather forecast is for 1.5 to 5 inches of rain over the next 5 days
- Two additional high energy sand boils discovered and addressed near Cairo
- Cairo Mayor issues a voluntary evacuation of the City
- Eastern District Court of Missouri denies State of Missouri's temporary restraining order request to halt activation

April 30, 2011 (Saturday)

0600: Cairo gage at 59.1, NWS revises projected crest to 60.5 feet on 3 May

- Heavy rains begin again in the area, weather forecast calls for 7.5 inches of additional rainfall over Ohio River valley through 2 May
- Due to increased rainfall, LRD increases releases from Kentucky and Barkley dams to stabilize the reservoirs
- Pressure of significant flood water on the mainline levees continues to cause numerous underseepage and sand boil issues
- Landowners complete mandatory evacuation of the Floodway
- MVM CDR recommends H minus 21 (position barges on Floodway frontline levee and hold)
- MVD CDR orders barges to Wickliffe, KY (3 hours closer to operational timeline)
- Cairo, IL proceeds with mandatory evacuation
- Eighth Circuit Court of Appeals denies State of Missouri's appeal to the decision

Birds Point-New Madrid Floodway

May 1, 2011 (Sunday)

0600: Cairo gage at 59.69, NWS revises projected crest to 61.5 feet on 5 May

- Heavy rains continue to push gage higher at Cairo

1000: Col Reichling briefs MVD CDR and MRC on conditions and advises going to hour minus 3 in the BPNM Operating Plan (move barges into position, load pipes with explosive agents, and hold). MVM CDR explains that safety plan calls for crews to be off levee by the time the Cairo gage reached 60.5 ft and based on the current forecast they needed to move soon to make this happen

- MVD CDR orders barges to the levee at Birds Point and asks to be briefed again at 1500 hours
- Significant flood fight activities continue through the Cairo and Fulton County area
- Robert Fitzgerald, MVD Chief of Eng. provides assessment to MVD CDR that the Corps could manage flows under current conditions, but the system is weakening

1500: MVD CDR and MRC briefed on current conditions: Cairo gage 59.93 ft and rising at 1400; would reach 60.5 ft by late a.m. 2 May. NWS forecasted crest now at 61.8 ft on 4 May and expects river to remain above 60 ft for 9 days and 61 ft for 5 days; NWS concerned that heavy rains could cause river stages to spike; LRD reports they may need to increase water releases soon from reservoirs should the heavy rains continue. Cairo and Fulton County levee systems under tremendous stress but holding with intense flood fight measures. Safety of work crews requires completion of 18-hr fuseplug prep prior to 60.5 -ft stage. Col Reichling, MRC, and MVD Sr Leaders recommend going to hour minus 3

- MVD CDR approves going to hour minus 3
- Barges move into position on frontline levee to begin pumping slurry

1930: Crews on hold to load pipes w/ explosive agent due to lightning storm (crews could safely load pipes in darkness and rain, but not during severe lightning storms)

- Supreme Court denies State of Missouri's appeal to the decision
- Stage exceeds 60.5 feet and starts overtopping the fuseplug sections in the late evening/early morning hours

May 2, 2011 (Monday)

0400: Cairo gage at 60.82
0500: Lightning storms shift to west and north allowing crews to proceed with prepping levee for activation
0600: Cairo gage at 60.97, NWS revises projected crest to 63.5 feet on 5 May
1000: Cairo gage at 61.08
1030: MVD CDR advised that explosive pumping operations would be completed in 12 hrs, at 2230 hours; MVD CDR requests plan to complete work in 8 hrs
1050: Governors, congressional members, and Chief notified of delay

- During mixing and transferring of explosive components, it is found that storage tanks containing the components cannot be completely emptied w/ equipment on site; this reduces the amount of mixture that can be generated so amount of mixture available is insufficient to fill fuseplug pipes at all 3crevasse sites. Plan developed to reduce explosive needed in middle crevasse & maintain crevasse large enough for needed stage reduction, shortening prep time needed for activation.

1515: Chief, MVM Project Management Branch directs teams to run equipment at higher rate to reduce fill time from 60 to 20 minutes for each 1,000 ft pipe section; MVD CDR presented with accelerated plan (Running the mix pump units at about 3 times the recommended rate may have affected detonation efficiency)
1630: MVD CDR officially notifies congressional members and Governors, including MO Gov Jay Nixon, that he would operate the Floodway between 2100 and 2400 hrs
1900: Cairo gage at 61.55; pumping operation complete; ERDC commences with 3-hour process to charge the lines and establish a blasting site
2030: MVM CDR informs MVD CDR the Floodway will be operational in 45 minutes
2100: Cairo gage at 61.67
2125: MVM CDR informed that Floodway is ready to operate; requests permission to operate the Floodway; MVD CDR approves the operation and proceeds to the blasting site
2200: Cairo gage at 61.72; BPNM Floodway is operated, opening the upper crevasse site with explosive material
2300: Cairo gage at 61.29
2400: Cairo gage at 61.13

Birds Point-New Madrid Floodway

May 3, 2011 (Tuesday)
0300: Cairo gage at 60.81 **0600:** Cairo gage at 60.62 **1100:** MRC briefed on status of remaining Floodway crevasse preparation. Lower crevasse is ready to operate, but there is no remaining explosive agent to fully prepare the middle crevasse. MVD CDR directs the team to procure additional explosives to open the middle crevasse. **1240:** Lower Floodway crevasse site is opened
May 4, 2011 (Wednesday)
0600: Cairo gage at 59.8
May 5, 2011 (Thursday)
0700: Cairo gage at 59.65 (May 2 NWS forecast projected the river to crest at 63.5 feet on Cairo gage on May 5) **1435:** Middle Floodway crevasse site is opened using alternative explosive agent

2. Muddy Bayou Control Structure

a. Key Decision. Whether to deviate from the Muddy Bayou Water Control Plan to help protect the Buck Chute Mainline Levee

b. Background. The mainline levee at Buck Chute is located near Eagle Lake, Mississippi 15 miles northwest of Vicksburg. This levee is part of a sub-system that protects over 1,400 square miles in the lower Mississippi River Delta from flooding. The Buck Chute levee is a chronic problem area with underseepage and sand boils commonly forming at low flood stages. Relief wells were installed to address the problems in 1999 and 2007, but new problems areas developed upriver from the improvements in 2010. Several massive sinkholes (10 to 15 feet wide and 6 to 8 feet deep) detected at the toe of the levee were caused by prior sand boil activity. The sand boils appeared at a fairly low stage (less than 1 foot above bank full) which meant that this levee issue was significant. Repairs to this levee section including a 1500 x 200-foot seepage berm and 25 relief wells were being designed, but construction was not anticipated to begin until May 2011. Temporary measures were put in place in March 2011 to address an earlier flood pulse, but these were not sufficient for the higher forecasted flood stages. When significant flooding was forecast for the Mississippi River in April 2011 the levee at Buck Chute was considered by MVK to be the weakest link in the MR&T system. A deviation from the Muddy Bayou Water Control Plan was examined as part of the emergency measures being put in place to keep the Buck Chute Mainstem Levee from failing during the 2011 Flood.

c. Operating Plan. The Muddy Bayou Water Control Structure and Operating Plan were developed as a fish and wildlife mitigation feature for the Yazoo Basin Project to prevent agricultural runoff from Steele Bayou from entering Eagle Lake. During dry periods the control structure also prevented lake water from draining into Steele Bayou. The operating plan allows for flooding of Eagle Lake to an elevation of 76.9 feet NGVD29 during 1 January – 15 June to support fish and wildlife. The need to raise the water above this level in Eagle Lake to protect the Buck Chute Levee represented a change in operation of the control structure and would require a deviation from the Muddy Bayou Water Control Plan.

d. Primary Issue at Hand. Deviating from the water control plan to raise the level of Eagle Lake would reduce the risk of levee failure at Buck Chute, but it would also potentially impact 800 residents and their property along Eagle Lake. Not deviating from the plan would result in much higher head differential between the wet and dry sides of the degraded Buck Chute mainline levee and high risk of levee failure, potentially inundating 1,450 square miles and impacting up to 3,000 homes.

e. The Operational Decision. Approval to deviate from the Muddy Bayou Operating Plan was given by the MVD Commander on 28 April 2011 and resulted in successful passage of the 2011 Flood waters through this part of the MR&T System. Many situational factors and inputs were considered in making this key operational decision. Some of the most prominent include: actual and forecasted flood crests at Vicksburg, MS; the poor condition of the Buck Chute Mainline Levee and impacts of levee failure; potential emergency measures to reduce the risk of failure of the Buck Chute Levee and; and the Muddy Bayou Operating Plan and possible impacts of deviating from the plan.

f. Play-by-Play Leading up to Key Decision. The following detailed information lays out how MVD and MVK made the key operational decision to deviate from the Muddy Bayou Water Control Plan.

Muddy Bayou Control Structure

April 22, 2011 (Friday)

- MVK staff participates in Lower-Ohio Mississippi River coordination teleconference which includes NWS forecasters and the Corps water control managers. Meeting participants are informed that the NWS forecast calls for 59 feet on Greenville gage on May 11 and 53.5 feet on Vicksburg gage on May 13. A gage reading of 53.5 feet would equate to the second highest stage ever recorded on the gage and represents a massive flood.
- MVK staff move forward with preparation for the flood, including work on the mainline levee at Buck Chute, considered the weakest link in the MR&T system.
- MVK team of geotechnical, hydraulics, operations, and project management staff begin analyzing various options to address the Buck Chute levee problems
- MVK staff deploy to the site to further assess the conditions, available resources, and move forward procuring a workforce and equipment

April 23, 2011 (Saturday)

- District equipment is on site moving forward with constructing a large clay berm surrounding the 2 acre problem area along the Buck Chute levee

April 25, 2011 (Monday)

- Vicksburg gage at 39.2 feet
- MVK multi-discipline team assess the situation at the Buck Chute are not confident the berm alone will be sufficient to address the levee sand boil and underseepage issues that could result in the levee being undermined during the forecasted flood. Geotechnical engineers on the team advise creating a similar levee head differential that was seen during the 2008 flood where the levee did not fail
- MVK develops a plan to create the needed head differential using both the sand/clay berm and covering this with a blanket of water to add extra weight and pressure to the landside of the levee. Based on forecasted crest of 53.5 feet, they will need to raise the berm and water to 87 feet (10 feet higher than the existing ground).
- MVK determines that placement of the water behind the levee will require a deviation from the water control plan for the Muddy Bayou Control Structure to raise the elevation of Eagle Lake.
- MVK begins coordinating the deviation request with MVD, USFWS, MS and LA Depts. of Wildlife, the Warren County Board of Supervisors, the Madison Parish President, and state and local entities

April 27, 2011 (Wednesday)

- MVK formally sends the deviation request to MVD CDR who would have to approve it

April 28, 2011 (Thursday)

- Vicksburg gage at 41 feet
- MVK CDR and staff meet with MVD CDR to discuss the deviation request: The mainstem levee at Buck Chute is considered the weakest link in the MR&T system. Based on Buck Chute Levee's current degraded condition, MVK staff does not think it can withstand the forecasted flood crest pressure w/out added hydraulic counter pressure. The elevated water levels needed to achieve the counter pressure could be provided by deviating from the Muddy Bayou Water Control Plan. The deviation could impact up to 800 residents around Eagle Lake, however, not deviating would very likely result in the Buck Chute Levee failing and inundation of approx 3,000 homes and 1,450 square miles. MVK asserted that the deviation is absolutely necessary because there are no other available options.
- MVD CDR concurs with the MVK CDR and approves the deviation request

April 29, 2011 (Friday)

- MVK CDR MVK CDR and the Levee Board Chief Engineer, conduct a public meeting in Eagle Lake to explain the need and consequences of raising lake levels. The approximate 500 attendees are more concerned with potential Buck Chute levee failure than raising lake levels. MVK CDR reports that the Eagle Lake raise would reduce risk of levee failure, but not eliminate it. He urges meeting attendees to take appropriate steps to protect their lives and property.

Muddy Bayou Control Structure

April 30, 2011 (Saturday)
• Vicksburg gage exceeds flood stage at 43 feet • MVK opens gates at the Muddy Bayou Control Structure and begins raising Eagle Lake to the elevation needed to protect the Buck Chute levee. The water levels will rise to 80 feet by May 2 and 1.5 feet higher per day until it reaches the needed 87 feet
May 4, 2011 (Wednesday)
• Eagle Lake residents told to evacuate by Sheriff Martin Pace
May 7, 2011 (Saturday)
• Construction of the sand/clay berm is complete at Buck Chute
May 10, 2011 (Tuesday)
• Eagle Lake level is raised to 89.8 feet to maintain the needed levee head differential with the higher forecasted crest. The original deviation request allows this because it was worded to be flexible and permit a raise up to 90 feet if the forecasted crest changed.
May 19, 2011 (Thursday)
• Vicksburg gage crests at 57.1 feet and Buck Chute mainstem levee passes flood waters without failure

3. Yazoo Backwater Levee

a. Key Decision. Whether to perform flood fight measures at the Yazoo Backwater Levee

b. Background. The Yazoo Backwater Levee is located ten miles north of Vicksburg, Mississippi and extends 28 miles from the Mississippi River mainline levee along the west bank of the Yazoo River to Yazoo City. It is one of several backwater levees in the MR&T System that are designed to slowly overtop and take pressure off the system during extremely high flood stages (approaching PDF elevations) on the Mississippi River. Up to this stage the Yazoo Backwater Levee protects 1,900 square miles of land within the Yazoo Basin. Prior to construction of this backwater levee, the most recent flood to significantly affect this area occurred in 1973 and resulted in over 1,000 square miles of the Yazoo Basin being inundated. The 1941 Flood Control Act authorized the Yazoo Backwater Levee to be built to a height equivalent to 56.5 feet on the Vicksburg gage, as long as the levee did not push river levels to within five feet of the top of mainline MR&T levees. Construction of this levee height was completed in 1978 and is what exists today. Subsequent authorization has allowed for an additional six feet of height on mainline levees and the Yazoo Backwater Levee, but the backwater levee has not been raised yet due to additional work needing to be done on mainline levees first.

c. Operating Plan. Backwater levee systems are meant to take pressure off the MR&T System mainline levees by overtopping during extreme floods. The Yazoo Backwater Levee was designed to overtop when the Vicksburg gage reached a stage of 56.2 to 56.6 feet. Further analysis by the MVK refined this estimate to 56.3 feet using updated data collected during the 2008 Mississippi River Flood.

d. Primary Issue at Hand. Based on the high forecasted flood stages in early May 2011, it was determined that the Yazoo Backwater Levee could be overtopped by as much as a foot of water for up to 10 days, which put the levee at high risk of failure. Full levee failure would result in much more significant life safety issues and damages in the backwater area than a slow overtopping event. It was estimated that if the levee overtopped without failing approximately 450 square miles would be inundated. If the levee failed, the area inundated would increase to approximately 1,900 square miles and impact more than 3,000 people. Flood fighting on the Yazoo Backwater Levee would reduce the risk of full levee failure at this location, but doing this may also increase risk to mainline MR&T levees by raising the Mississippi River flood stage. Also, there was question about the type and extent of flood fighting the Corps was allowed to do under current authorization.

e. The Operational Decision. Approval to perform flood fight measures along a four-mile stretch of the Yazoo Backwater Levee (forecasted to overtop) was given by the MVD Commander on 4 May 2011. The approved flood fight measures were fully completed by 11 May and included filling deficient low spots to authorized levels and armoring the landside of the levee with polyethylene plastic sheeting to reduce the risk of erosion and potential levee failure. Many inputs and situational factors were considered in making this key operational decision. The most prominent include: examination of authorized flood fight activities for this backwater levee; actual and forecasted flood crests at Vicksburg, MS; potential impacts of full levee failure compared to levee overtopping without failure; 2008 flood data and observations; and additional flood fight measure effects on mainstem flood levels.

f. Play-by-Play Leading up to Key Decision. The following detailed information lays out how MVD and MVK made the key operational decision to perform flood fight measures at the Yazoo Backwater Levee.

Yazoo Backwater Levee

May 2, 2011 (Monday)

- NWS forecasts a flood crest of 57.5 feet on the Vicksburg gage on 20 May
- MVK water control engineers realized that the Yazoo Backwater Levee would overtop by more than 1 ft based on the forecast (overtop begins at 56.3 on the Vicksburg gage)
- MVK contacts Mississippi Levee Board Office to inform them that they expect the 28-mile backwater levee to overtop by more than a foot for at least 10 days
- The Mississippi Levee Board was not greatly concerned with the additional water the overtopping would bring, but they were concerned with the integrity of the levee under duration and magnitude of the forecasted overtopping conditions and the significant flooding that could result from full levee failure

May 3, 2011 (Tuesday)

- MVK conducts further analysis of data collected during the 2008 flood and determines that only a 4-mile stretch of the backwater levee (from mainline levee to Steele Bayou Control Structure) would overtop based on the current forecasted crest
- MVK team examines impacts of temporarily raising the backwater levee

May 4, 2011 (Wednesday)

- During the morning Commanders briefing, MVK CDR informs MVD CDR that Mississippi Gov. Haley Barbour was assembling a task force to assist in the flood fight. The Mississippi Levee Board and state were prepared to formally ask the Corps to raise or armor the four-mile stretch of levee at risk of overtopping.
- MVD CDR states further information is needed on the potential impacts of flood fighting on the MR&T system
- Further discussion takes place on the Yazoo Backwater Levee at a meeting with the MVD CDR, MRC, and MVK CDR after the morning briefing
  - Subsequent authorizations allow for the levee to be raised by almost 6 feet, but that was most likely contingent upon work not finished yet on the mainline levees
  - Sections of the backwater levee were currently deficient, being as much as one foot lower than currently authorized levels (based on the 56.3 stage at Vicksburg). These areas needed to be raised to prevent premature overtopping
  - MVD CDR asks MVK CDR to prepare and present a decision briefing later in the evening
  - MVD CDR reminds meeting participants that the MR&T must be operated as a system and the integrity of the mainline levee is crucial
- MVK engineers determine that the Corps does not have authority to perform flood fight measures along the backwater levee that raise mainstem flood waters
- Flood fighting along the backwater levee was beyond the MS Levee Board's current resources due to current flood prep work by the Board's crews across the system
- Mississippi Levee Board sends official request to MVK CDR asking MVK to assume leadership of any flood fight on Yazoo Backwater Levee west of Hwy 61
- MVK staff (Simrall and Parish) conduct public meetings in Rolling Fork and Yazoo City to keep public informed of developments, answer questions, and eliminate rumors
  - The public was worried because of the forecast being 6 ft higher than 1973 flood and not understanding the capability of the current backwater levee to reduce impacts
  - 1,500 people attend Rolling Fork meeting and 700 attend Yazoo City meeting
  - Rumors include idea that the Corps would blow the levee similar to Birds Point
  - Staff discuss potential impacts of overtopping, full levee failure, the Corps preparation for the flood, and gave instructions on preparations for evacuation

2100: MVK CDR briefs MVD CDR and MRC members on the Yazoo Backwater area. MVK CDR provides background information on the backwater area and how its operation relates to the Vicksburg gage. He then shows two inundation maps comparing the extent and impacts of flooding. The first map shows the 450 square miles being impacted with a levee overtopping event based on the current forecasted crest of 57.5. The second map shows the 1,900 square miles inundated due to full levee failure during the current crest. MVK CDR further explained that over 3,000 people would be impacted by a levee failure.

- MVK CDR finishes his briefing with a request to raise deficient low spots to elevation 107 (equates to the authorized level of 56.5 feet on Vicksburg gage) and armor the landside of the backwater levee along the four-mile overtopping stretch to reduce the risk of erosion and levee failure.
- MRC members concurred with the Col's request and MVD CDR approves the recommendation

Yazoo Backwater Levee

May 5, 2011 (Thursday)
• MVK proceeds with work to fill deficient low spots and armor Yazoo Backwater Levee with landfill liner (40 mm thick and more durable than standard poly sheeting)
May 7, 2011 (Saturday)
• Liner delivered to location and installation begins
May 11, 2011 (Wednesday)
• Vicksburg gage has surpassed 1973 and 2008 levels and is approaching 54 feet • Liner installation complete along with all other levee preparation activities
May 19, 2011 (Thursday)
• Vicksburg gage crests at 57.1 feet • Flood crest comes within inches of the levee crown, but does not overtop the Yazoo Backwater Levee

4. Morganza Floodway

a. Key Decision. Operation of the Morganza Floodway in conjunction with conditions at Bonnet Carre spillway and Old River control structure

b. Background. The Morganza Floodway is located in central Louisiana near RM 280 on the western bank of the Mississippi River. The Floodway begins at the Mississippi River, extends southward to the East Atchafalaya River levee, eventually joining the Atchafalaya River Basin Floodway near Krotz Springs, Louisiana. The purpose of the Floodway in conjunction with the Atchafalaya Basin Floodway is to operate during extreme floods to carry flood water from the Mississippi River to the Gulf of Mexico via the lower Atchafalaya River and the Wax Lake Outlet. The structure is designed to pass up to 600,000 cfs of water to the Gulf of Mexico, alleviating stress for mainline levees downstream along the Mississippi River. Prior to 2011, the Floodway had been operated only once before during severe flooding in 1973 and it passed approximately 170,000 to 180,000 cfs at its peak operation.

c. Operating Plan. Based on the Morganza Floodway design and Water Control Plan, the Floodway is to be operated when the flow of the Mississippi River at Red River Landing, Louisiana (located 20 miles north of Morganza) reaches 1,500,000 cfs and is rising.

d. Primary Issue at Hand. Up to 300,000 cfs of water would need to be diverted through the Morganza Floodway based on the water control plan and forecasted Mississippi River flow of 1,800,000 at Red River Landing. The forecasted flow conditions on the Atchafalaya River combined with operating the Morganza Floodway could impact nearly 2,500 people and 2,000 homes in the Floodway and up to 22,500 people and 11,000 homes in backwater areas. Not operating the Floodway could result in other mainline levees overtopping or failing with much more significant damages and potential loss of life. If operated, the timing and magnitude of Floodway operation also required careful examination to balance the needed reduction in flood flows on the Mississippi River with minimizing the damages in the Floodway and on the control structure itself (which could be damaged if operated too quickly). Scenarios comparing the potential impacts of operating the Floodway against the impacts to the MR&T System below Morganza needed to be examined. Finally, the timing of Floodway activation was called into question as the flood flow neared the activation point of 1,500,000 cfs at Red River Landing. It was found that the stage at the Morganza Floodway structure was higher than anticipated given the current flow conditions at Red River Landing which could require earlier than anticipated Floodway activation. As the flood flow neared the activation point the lack of remaining freeboard and initial overtopping of the structure could make the gate opening more difficult.

e. The Operational Decision. Operation of the Morganza Floodway was initiated at 1500 hours on 14 May and resulted in successful passage of 2011 Flood waters through this part of the MR&T System with a peak flow of 186,000 cfs through the floodway. Conditions at the Old River Control Complex played a major part in activating the floodway along with several other important situational factors and inputs. The most prominent include: the Floodway water control plan; actual and forecasted discharges at Red River Landing, Louisiana; stages and remaining freeboard at the Morganza Spillway structure; potential impacts of activating the structure on the Floodway; potential impacts of not activating the structure on MR&T mainline levees and the areas they protect; and potential impacts based on how quickly the Floodway is operated.

f. Play-by-Play Leading up to Key Decision. The following detailed information lays out how MVD and MVN made the key operational decision to operate the Morganza Floodway.

Morganza Floodway

March 11, 2011
• MVN mailed annual written notices to all interests and landowners within the Morganza Floodway reminding them of the possibility of the floodway operation.
April 28, 2011 (Thursday)
• MVN sends flood notification letters to Morganza Floodway landowners advising them of the possibility of needed evacuation
May 2, 2011 (Monday)
• NWS forecasts the flood flow at Red River Landing, Louisiana will reach 1,800,000 cfs in early May
May 3, 2011 (Tuesday)
• MVN CDR informs MVD CDR and the MRC that the NWS and MVN water control managers anticipate the Mississippi River will quickly surpass the activation point (1.5 million cfs at Red River Landing) to operate the Morganza Floodway by as early as 11 May • MVN CDR sends memorandum to MVD CDR and MRC requesting permission to open the Bonnet Carré Spillway • MVD CDR acknowledges receipt of the Bonnet Carré Spillway request and that the MRC had it under advisement • MVD CDR requests that MVN CDR provide a briefing on the Morganza Floodway
May 4, 2011 (Wednesday)
• MVN CDR provides briefing detailing the layout, trigger points, and operation of the Floodway. The CDR lays out the timeline for Floodway activation based on current forecast, including activating the Floodway at 1,300,000 cfs (rather than 1,500,000) to allow for a slower, less damaging activation process (environmentally and structurally) • Initial Floodway inundation modeling was performed
May 5, 2011 (Thursday)
• MRC votes unanimously to give MVN CDR authority to open Bonnet Carré Spillway in accordance with the approved water control manual • MVN staff meet with LA Gov., parish presidents, levee boards, and other stakeholders to discuss Morganza Floodway operation and land owner preparation and evacuation
May 6, 2011 (Friday)
• MVN CDR sends memorandum to MVD CDR and MRC requesting approval to operate the Morganza Floodway • MVN informs MVD CDR and MRC of mainline levee concerns between Baton Rouge and Bonnet Carré if Floodway is not operated during current forecasted flood. This included significant underseepage at Duncan Point, and the Morganza structure itself could be overtopped and the resulting scour could jeopardize its stability • MVN CDR provides second decision briefing on Morganza Floodway and an updated timeline of operation. MVN CDR cites 1973 PFR recommendations to support need to slowly operate the Floodway to reduce environmental and structural impacts (e.g., extensive scour damage during 1973 operation) • Updated inundation modeling and maps show a potential impact to nearly 2,500 people and 2,000 homes in the Floodway and up to 22,500 people and 11,000 homes in backwater areas • MVD CDR contacts Corps HQ to inform them of potential impacts • Corps HQ requests assessment of alternate scenarios comparing potential impacts of operating the Floodway vs impacts to MR&T System below Morganza if it is not operated • MVD CDR instructs the Chief of MVD's Watershed Division to work with MVN to develop assess various scenarios. Three scenarios are examined: (1) adhering to the approved water control plan and diverting 300,000 cfs through Morganza; (2) not operating the Floodway and attempting to pass 1,800,000 cfs through the mainline MR&T with increased flood fight measures; and (3) avoid operating the Morganza Floodway and pass an additional 300,000 cfs through the ORCC.

Morganza Floodway

May 7, 2011 (Saturday)

0700: Flow at Red River Landing is 1,180,000 cfs

May 8, 2011 (Sunday)

0700: Flow at Red River Landing is 1,240,000 cfs

May 9, 2011 (Monday)

0700: Flow at Red River Landing is 1,320,000 cfs

- Bonnet Carré Spillway is opened
- MVN CDR conducts briefing with MVD CDR and MRC and presents the 3scenarios related to the Morganza Floodway operation. The CDR discusses the pros and cons of the scenarios and emphasizes that the scenario of operating the Morganza Floodway poses the least risk to the MR&T system. He also communicates recent issues brought to the attention of MVN regarding the potential closing of the system to commercial navigation and shutdown of a nuclear power plant if the Morganza Floodway is not operated
- MVD CDR concurs with MVN CDR 's recommendation to operate the Morganza Floodway and confirms that he will operate the Floodway according to the water control plan (when 1,5000,000 cfs is reached at Red River Landing)

May 10, 2011 (Tuesday)

0700: Flow at Red River Landing is 1,360,000 cfs

- MVN staff identify that the discharge trigger of 1,500,000 cfs at Red River Landing is not correlating to the proper stage at the Morganza Floodway structure (1.5 million cfs originally corresponded to no more than 56 feet at the spillway, leaving 4 feet of freeboard). Previous floods had shown a progressive deterioration of discharge capacity in this reach of the system. The result was higher stages were now being observed at the Morganza Floodway structure during lower flood discharges at the Red River Landing. This put the Morganza Floodway structure in danger of overtopping and being extremely difficult to open before the activation discharge of 1,500,000 cfs was reached. Overtopping also threatened the integrity of the structure itself.

May 11, 2011 (Wednesday)

0700: Flow at Red River Landing is 1,394,000 cfs

- NWS adjusts forecast for Red River Landing from 1,800,000 cfs to 1,626,000 cfs in mid May
- Stage is 57 feet at the Morganza Floodway structure (1 foot higher than assumed design stage for activation)
- MVN CDR informs MVD CDR that the Morganza gates are within three feet of overtopping and discusses the concerns associated with this
- MVD CDR requests MVN run the three scenarios again with the new NWS forecast
- Volunteer evacuation of the Floodway is proceeding slowly

May 12, 2011 (Thursday)

0700: Flow at Red River Landing is 1,423,000 cfs

Morganza Floodway

May 13, 2011 (Friday)

0700: Flow at Red River Landing is 1,449,000 cfs

- MVN CDR informs MVD CDR and MRC that the Bonnet Carré Spillway would reach its design capacity discharge sometime that day
- Stage is 58.6 feet at the Morganza Floodway Structure (1.5 feet from overtopping)
- MVD CDR sends official order to MVN CDR to prepare to operate the Floodway within 24 hours upon MVD CDR's order to execute and IAW with the approved operational plan
- MVN staff at Morganza Floodway structure monitors situation and gages around the clock

2200: River stages at Morganza start to increase more rapidly and would most likely overtop the floodway structure gates during the evening

- MVN instructs gate operators at Old River auxiliary structure to divert more water to keep the Morganza gates from overtopping

May 14, 2011 (Saturday)

0700: Flow at Red River Landing is 1,470,000 cfs

- Forecast for Red River Landing is 1,480,00 cfs for 14 May
- Stage is 59.4 feet at the Morganza Floodway structure (waves are spilling over the Floodway gates)
- MVD CDR and MRC arrive at Morganza Floodway structure to directly inspect conditions
- MVN CDR conducts briefing with MVD CDR and MRC at the Morganza Floodway, going over current and forecasted conditions. Although the activation stage would most likely be reached on 15 May, current and increased gate overtopping was leading to a serious problem of making the gate opening much more difficult. To address the overtopping and gate opening issue, MVN would most likely have to deviate through Old River if the Morganza Floodway was not going to be operated until 15 May.
- MVN CDR requests permission to operate the Morganza Floodway at 1500 hours on 14 May
- MRC members concurred with MVN CDR's recommendation
- MVD CDR approves MVN CDR 's request to operate the Morganza Floodway at 1500 hours due to Mississippi River flows approaching 1,500,000 cfs and rising at Red River Landing
- MVD CDR calls the Governor of Louisiana to notify him of the decision
- The governor informs him that the Floodway is clear

1500: The Morganza Floodway is operated with the first gate being opened. A second gate was opened later in the evening.

May 15, 2011 (Sunday)

0700: Flow at Red River Landing is 1,495,000 cfs

- Nine more bays opened at the Morganza Structure directing 100,000 cfs into the Morganza Floodway. Additional bays would continue to be opened daily until 18 May, when a total of 17 bays were open, resulting in a peak flow of 186,000 cfs.