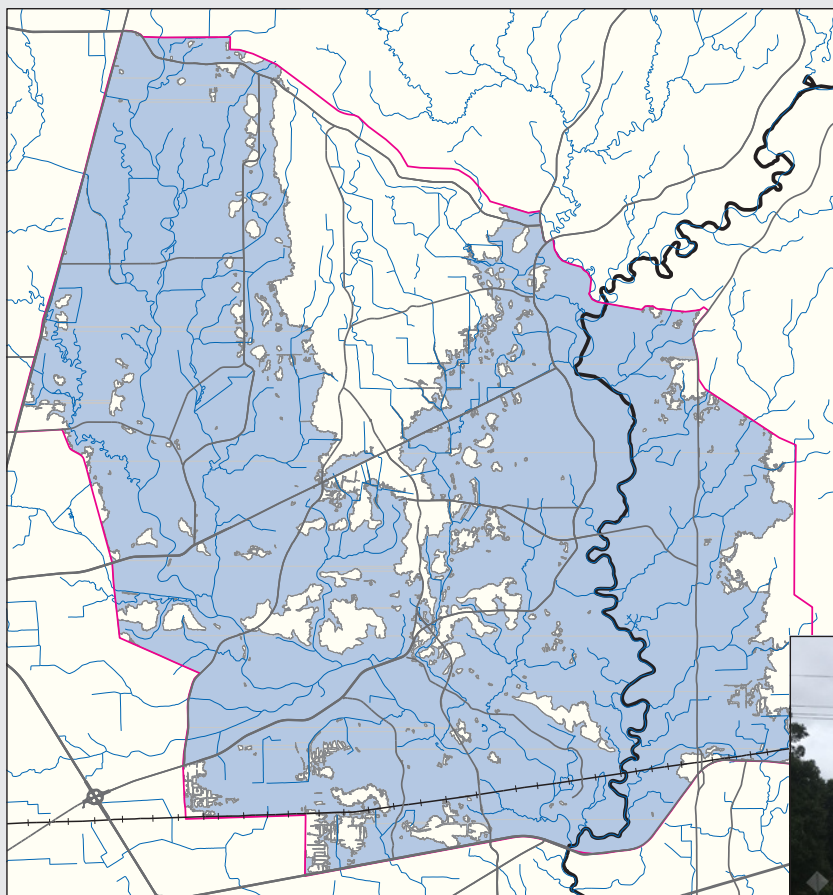


Prepared in cooperation with the City of Central, Louisiana

Flood-Inundation Maps for the Amite and Comite Rivers From State Highway 64 To U.S. Highway 190 at Central, Louisiana



Scientific Investigations Report 2019–5028

Cover. Upper left: Flood-inundation map for the Amite and Comite Rivers at Central, Louisiana, corresponding to stages of 59.0 ft and 35.0 ft at the U.S. Geological Survey streamgages Amite River at Magnolia, La., and Comite River near Comite, La., respectively. Further details provided on figure 8 of this report.

Lower right: Photograph showing backwater flooding across Florida Boulevard near the Amite River Bridge in Denham Springs, Louisiana. Photograph by James Fountain, U.S. Geological Survey.

Flood-Inundation Maps for the Amite and Comite Rivers From State Highway 64 To U.S. Highway 190 at Central, Louisiana

By John B. Storm

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Scientific Investigations Report 2019–5028

**U.S. Department of the Interior
U.S. Geological Survey**

U.S. Department of the Interior
DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2019

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
Length		
inch (in)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi ²)	2.590	square kilometer (km ²)
Flow rate		
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second (m ³ /s)
Hydraulic gradient		
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

Datum

Vertical coordinate information is referenced to (1) stage, the height above an arbitrary datum established at a streamgage, and (2) elevation, the height above the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

2D	two-dimensional
AHPS	Advanced Hydrologic Prediction Service
DEM	digital elevation model
FEMA	Federal Emergency Management Agency
FESWMS-2DH	Finite Element Surface-Water Modeling System: Two-Dimensional Flow in a Horizontal Plane
FIM	flood inundation mapper
FIS	flood insurance study
GIS	geographic information system
GPS	Global Positioning System
HEC-RAS	Hydrologic Engineering Center River Analysis System
lidar	light detection and ranging
NOAA	National Oceanic and Atmospheric Administration
NWIS	National Water Information System
NWS	National Weather Service
RTN	real-time network
SMS	Surface-Water Modeling System
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Flood-Inundation Maps for the Amite and Comite Rivers From State Highway 64 To U.S. Highway 190 at Central, Louisiana

By John B. Storm

Abstract

Flood-inundation maps for a 14.5-mile reach of the Amite River and a 20.2-mile reach of the Comite River from State Highway 64 to U.S. Highway 190 were created by the U.S. Geological Survey (USGS) in cooperation with the City of Central, Louisiana. These maps, which can be accessed through an interactive mapper at the USGS Flood Inundation Mapping Program website and from a companion USGS data release, depict estimates of the areal extent and depth of flooding corresponding to selected water levels (stages) at the USGS streamgages Amite River at Magnolia, La., (07377300) and Comite River near Comite, La. (07378000).

Flood profiles were computed for the Amite and Comite River reaches by using the two-dimensional (2D), finite-volume numerical modeling options in the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (USACE HEC-RAS) software version 5.0.3. Models were calibrated to the current (2018) stage-discharge relations at the Amite River at Magnolia, La., and Comite River near Comite, La., streamgages, water-surface profiles from the March and August 2016 floods, and documented high-water marks from the flood of August 2016.

The hydraulic models were used to compute 37 individual water-surface profiles (21 for the Amite River and 16 for the Comite River) at 1.0-foot intervals ranging from the National Weather Service flood stage to the highest peak on record at the two streamgages. The 37 simulated water-surface profiles were used with a light detection and ranging-derived digital elevation model to delineate the flood extent and associated depth at each water level. The delineated areas (inundation maps) were merged into 127 combinations or possible flooding scenarios based on annual peak stage information from the two streamgaging stations.

The availability of these maps, along with real-time data delivered via the internet, will provide emergency management personnel and residents with information that is critical for flood-response activities such as evacuations and road closures, as well as for recovery efforts after floods.

Introduction

The City of Central, Louisiana, is located in East Baton Rouge Parish (fig. 1) above the confluence of the Amite and Comite Rivers and has an estimated population of 26,864 (U.S. Census Bureau, 2010). The Amite River forms the eastern boundary of the city and the Comite River forms its western boundary. The city's location and low-lying floodplains make it susceptible to flooding from each river individually and combined. Backwater-affected flows along the Comite River can exist for approximately 8.7 miles (mi) from its confluence to the streamgage at Comite River near Comite, La. (station number 07378000), depending upon the level of the Amite River. The U.S. Geological Survey (USGS) began monitoring the Amite River at Denham Springs, La. (station number 07378500), in 1938 just below the confluence with the Comite River at U.S. Highway 190. Based on current flood stage categories established by the National Weather Service (NWS), the Amite River at Denham Springs, La. (07378500), streamgage has exceeded flood stage at least 57 times since 1938 (NWS, 2018a). In 2016, Central, La., experienced two major flood events including the peak of record flood of August 2016. This flood was the result of a slow-moving inland tropical depression releasing record amounts of rainfall across southern Louisiana, with amounts exceeding 31 inches (in.) in some areas (Di Liberto, 2016). The April 1983 flood had been considered the peak of record flood prior to the August 2016 flood in the Central, La., area. The August 2016 flood peak eclipsed the April 1983 peak by 2.2 feet (ft) at the Comite River at Comite, La., streamgage, 7.6 ft at the Amite River at Magnolia, La., and 4.7 ft at the Denham Springs, La., streamgages. Damages throughout Louisiana resulting from the August flood event were estimated to be \$10 billion and resulted in at least 13 fatalities (National Oceanic and Atmospheric Administration [NOAA], 2016).

Prior to this study, the city's emergency responders relied on several online information sources to make decisions on how to best alert the public and mitigate flood damages. These sources all have static information that are limited in

2 Flood-Inundation Maps for the Amite and Comite Rivers From State Hwy. 64 To U.S. Hwy. 190 at Central, Louisiana

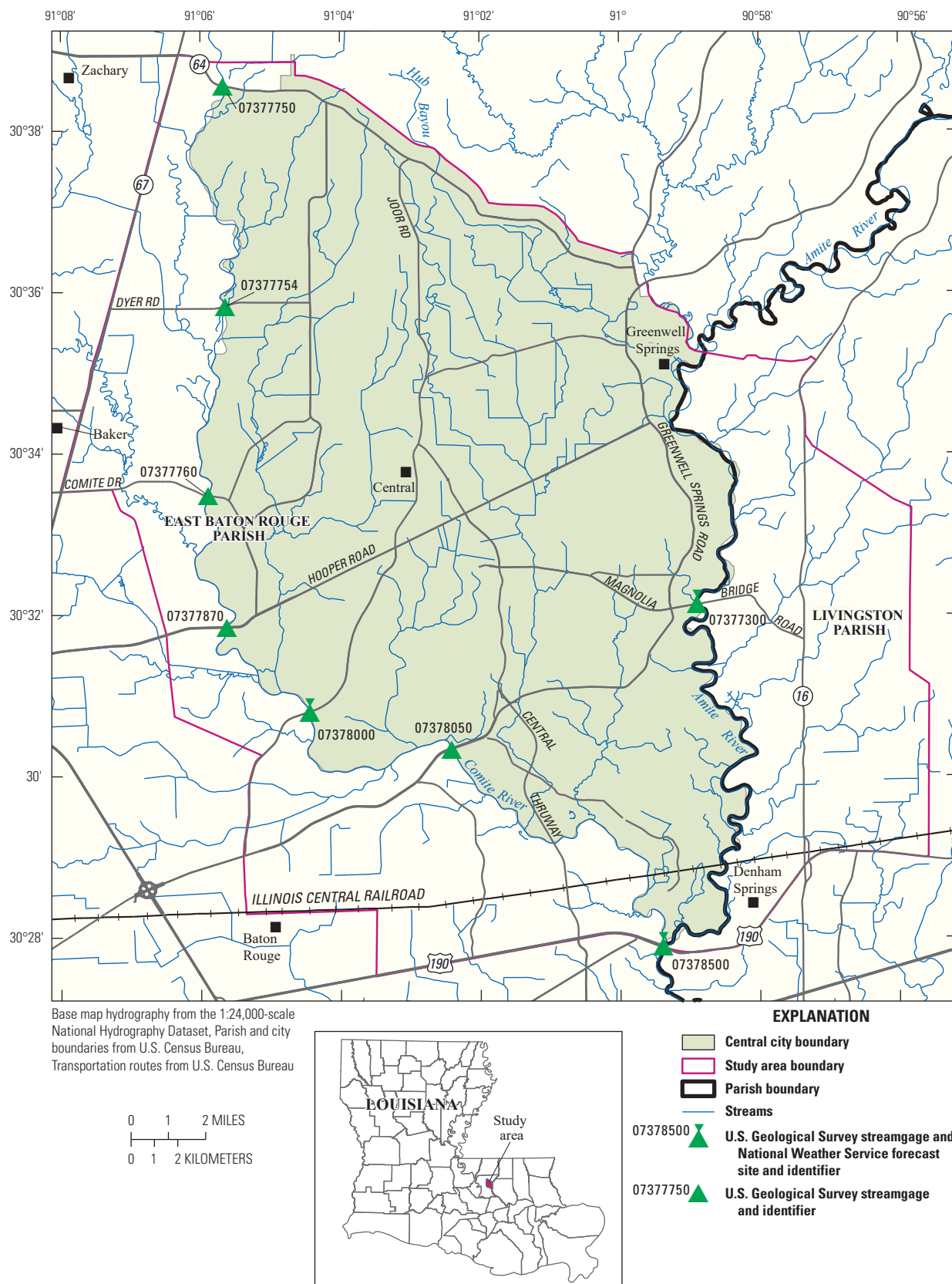


Figure 1. Location of study reach for the Amite and Comite Rivers at Central, Louisiana, and location of U.S. Geological Survey streamgages and National Weather Service forecast sites.

their application during an emergency. One source is the Federal Emergency Management Agency (FEMA) flood insurance study (FIS) for East Baton Rouge Parish and incorporated areas (FEMA, 2012). A second source of information is the eight USGS streamgages located within the study reach (table 1). Current and historical information for these streamgages—including water levels, discharges, and annual peak flows—can be obtained from the USGS National Water Information System (NWIS) Web interface (USGS, 2018a). A third source of flood-related information is the National Weather Service Advanced Hydrologic Prediction Service (AHPS), which displays the USGS stage data and also issues forecasts of stage for the Amite River at Denham Springs, the Amite River at Magnolia, and the Comite River near Comite Joor Road (NWS, 2018b).

Although the current stage at a USGS streamgage is particularly useful for residents in the immediate vicinity of a streamgage, it is of limited use to residents farther upstream or downstream because of the sloping water surface. Knowledge of a water level at a streamgage is difficult to translate into depth and areal extent of flooding at points distant from the streamgage. To address these data gaps that exist away from a streamgage, a library of interactive flood-inundation maps that are referenced to the stages recorded at the USGS streamgage can be produced that cover the entire reach/study area.

In 2017, the USGS, in cooperation with the City of Central, initiated a study to produce a library of

flood-inundation maps for the Amite and Comite Rivers at Central, La. By referring to the maps, emergency responders can discern the severity of flooding (depth of water and areal extent), identify roads that are or will soon be flooded, and make notification or evacuation plans for some distance upstream and downstream from a USGS streamgage. In addition, the capability to visualize the potential extent of flooding can motivate residents to take precautions and heed warnings that they previously might have disregarded.

Purpose and Scope

The purpose of this report is to describe and document the development of a series of estimated flood-inundation maps that represent flooding scenarios for the Amite and Comite Rivers at Central, La. The flood-inundation maps along with USGS real-time stage data and NWS flood-forecast data are made available for interactive viewing, planning, and/or decision support through the USGS Flood Inundation Mapping Program (FIM) at https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-fim-program?qt-science_center_objects=0#qt-science_center_objects. Flood extent polygons and depth grids are publicly available from Heal and Storm (2019).

Table 1. U.S. Geological Survey streamgage information for Amite and Comite Rivers at Central, Louisiana.

[Station location is shown in figure 1. mi², square mile; ft, foot; NAVD 88, North American Vertical Datum of 1988; ft³/s, cubic foot per second; NA, not available]

Station name	Station number	Drainage area, (mi ²)	Latitude	Longitude	Datum (ft, NAVD 88)	Period of peak-flow record (water years ¹)	Maximum recorded stage (ft), and elevation (ft, NAVD 88) and date	Maximum discharge (ft ³ /s) and date
Amite River at Magnolia, La.	07377300	884	30° 32' 05"	90° 58' 50"	−1.43	1949–83; 1993–2018	58.56 (57.13) August 13, 2016	202,000 August 13, 2016
Amite River at Denham Springs, La.	07378500	1,280	30° 27' 50'	90° 59' 25"	−1.35	1939–2018	46.20 (44.85) August 14, 2016	266,000 August 14, 2016
Comite River near Zachary, La.	07377750	230	30° 38' 35"	91° 05' 40"	58.58	1951–62	31.99 (90.57) August 13, 2016	NA
Comite River near Baker, La.	07377754	² 238	30° 35' 46'	91° 05' 39"	48.20	NA	26.91 (75.12) August 13, 2016	NA
Comite River at Comite Drive near Baton Rouge, La.	07377760	² 261	30° 33' 29.1"	91° 05' 53.4"	36.43	NA	29.36 (65.79) August 13, 2016	NA
Comite River at Hooper Road near Baton Rouge, La.	07377870	² 271	30° 31' 50"	91° 05' 37"	28.49	NA	31.96 (60.45) August 14, 2016	NA
Comite River near Comite, La.	07378000	284	30° 30' 45"	91° 04' 25"	21.51	1944–2018	34.22 (55.73) August 14, 2016	71,000 August 14, 2016
Comite River at Greenwell Springs Road near Baton Rouge, La.	07378050	² 304	30° 30' 20"	91° 02' 24"	−0.95	NA	54.06 (53.11) August 14, 2016	NA

¹Water year is the 12-month period from October 1 of one year through September 30 of the following year and is designated by the calendar year in which it ends.

²Drainage area not published; computed by using ESRI ArcGIS.

Flood inundation map extents for this study were required to incorporate the city limit boundaries of Central, La. These extents were expanded to also include inundated tributaries outside of the city boundaries to at least the first bridge crossing when possible. Model boundary extents included an even larger area of the stream reaches. The scope of the maps included a 14.5-mi reach of the Amite River from the northern city limit boundary of Central above the community of Greenwell Springs, La., to U.S. Highway 190 at Denham Springs, La., and a 20.2-mi reach of the Comite River from State Highway 64 near Zachary, La., to its confluence with the Amite River above U.S. Highway 190 (fig. 1).

Incremental flood-inundation maps were created for possible flooding scenarios referenced to the recorded stages at the USGS streamgages Amite River at Magnolia, La. (07377300), and Comite River near Comite, La. (07378000) (USGS, 2018a). The inundation maps cover a range in stage on the Amite River from 39 to 59 ft, gage datum. The Amite River range begins 9 ft below the NWS flood stage, defined as the stage at which a rise in water levels begins to create a hazard to lives, property, and commerce (NWS, 2018c). The purpose for starting the range below the flood stage at the Amite River streamgage is to account for possible coincident flooding on the Comite River based on annual peak stage comparisons (fig. 2). The inundation maps also cover a range in stage from 20 to 35 ft, gage datum on the Comite River. The 20-ft stage corresponds to the flood stage at the Comite River streamgage as defined by the NWS. The maximum stages covered by the inundation maps correspond to approximately the highest recorded water level at the respective streamgages during the peak of record flood of August 2016.

Study Area Description

The Amite River has its headwaters in southwestern Mississippi and flows for approximately 117 mi to its confluence with Lake Maurepas in southeastern Louisiana. The Amite River Basin has a total drainage area of approximately 2,200 square miles (mi²) and includes the Comite River, contributing approximately 334 mi² of drainage. Major urban areas within the basin include Baton Rouge, Central, Zachary, and Denham Springs (U.S. Army Corps of Engineers [USACE], 2012).

Located within the East Gulf Coast and Mississippi Alluvial Plain sections of the Coastal Plain Province (Renken, 1998), the basin transitions from the Southern Pine Hills characterized by rolling hills and narrow, well-defined floodplains in the upper third of the basin to alluvial floodplains with seasonally inundated bottomland hardwoods and tupelo swamps in the lower third (Gulf Engineers and Consultants, Inc., 2015).

The Amite River reach length within the study area is about 14.5 mi, average channel bed slope is approximately 1.5 feet per mile (ft/mi), and top of bank widths average about 410 ft. The length of the Comite River reach within the study area is about 20.2 mi, average channel bed slope is approximately 2.9 ft/mi, and top of bank widths average about 300 ft. There are 2 major road crossings of the Amite River, 7 major road crossings of the Comite River, and 1 railroad crossing both rivers within the study area.

Previous Studies

The current FIS for East Baton Rouge Parish (FEMA, 2012) was completed by FTN/Taylor Joint Venture in 2008 and revised by Risk Assessment, Mapping, and Planning Partners in 2012. The FIS presents estimates of the peak discharges with 1-percent annual exceedance probabilities (table 2) and their associated water-surface profiles for the Amite River. Comite River flood profiles for the 0.2-, 1.0-, and 10-percent annual exceedance probabilities are also presented in the current FIS, but the associated discharges are not presented and could not be determined.

Hydraulic Model Development and Flood-Inundation Map Library Creation

The USGS has standardized procedures for creating flood-inundation maps (USGS, 2018b) so that the process and products are consistent among USGS offices. Tasks specific to the development of the flood inundation maps for Central, La., were as follows:

- Upgrade USGS streamgage 07377300 to a stage/discharge gaging station.
- Review current and historical hydrologic data at USGS streamgaging stations 07377300, 07378000, and 07378500.
- Collect topographic data for cross sections at major bridge crossings within the study area.
- Estimate energy-loss factors (roughness coefficients) in the stream channels and floodplains,
- Develop and calibrate two-dimensional (2D) hydraulic models by using USACE Hydrologic Engineering Center-River Analysis System (HEC-RAS) modeling software (Brunner, 2016a).
- Compute incremental water-surface profiles along the Amite and Comite River reaches by using the calibrated 2D hydraulic models.
- Produce incremental estimated flood extent and associated depth layers by using the HEC-RAS Mapper module within the modeling software (Brunner, 2016a) and geographic information system (GIS) software.
- Merge the incremental flood extent and depth layers into polygon feature classes and depth rasters to represent 127 possible flood-inundation map scenarios between the two study reaches.
- Serve and display derived inundation map scenarios in the USGS Flood Inundation Mapper.

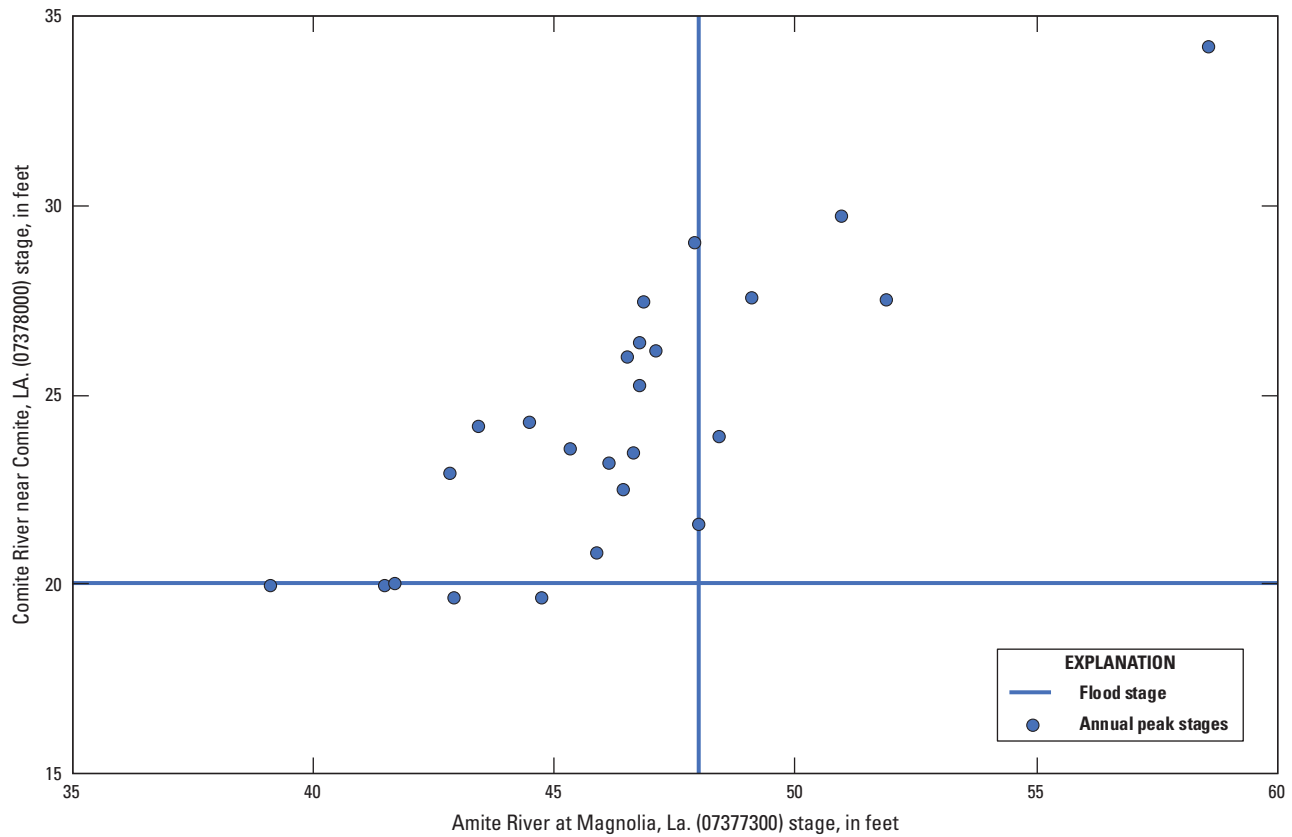


Figure 2. Corresponding annual peak stages 1964–2018 for Amite River at Magnolia, Louisiana (07377300), and Comite River near Comite, La. (07378000).

Table 2. Peak discharge estimates for the 1.0-percent annual exceedance probability for selected locations on the Amite River in Louisiana.

[ft³/s, cubic foot per second; mi², square mile; n.d., no data. Data from Federal Emergency Management Agency (2012)]

Location on Amite River	Drainage area (mi ²)	Discharge estimate (ft ³ /s)
Confluence of Comite River	1,286	140,138
Confluence of Hub Bayou	910	116,685
At State Route 64	n.d.	114,409

Hydrologic Data

The study-area hydrologic network contains eight USGS streamgages (fig. 1; table 1) composed of two streamgages on the Amite River and six streamgages on the Comite River. Five of the streamgages on the Comite River measure continuous stage only with the Comite River near Comite, La. (07378000), being the only station computing continuous streamflow (discharge). Both gaging stations on the Amite River measure stage and compute continuous streamflow. The Amite River at Magnolia, La. (07377300), streamgage was upgraded in January 2017 to compute continuous streamflow and is being upgraded to a flood forecast gaging station by the NWS at the writing of this report (2018). Stage is measured every 15 minutes, transmitted hourly by a satellite radio in the

streamgage, and made available from NWIS (USGS, 2018a). Stage data from these streamgages are referenced to a local datum but can be converted to water-surface elevations referenced to the North American Vertical Datum of 1988 (NAVD 88) by adding the local datum (table 1). Continuous records of streamflow are computed from a stage-discharge relation at Amite River at Magnolia, La. (07377300) and are available from NWIS (USGS, 2018a).

Variable backwater effects exist on the Comite River above its confluence with the Amite River. The water-surface elevation at the confluence is considered the control, and continuous streamflow computations at the Comite River near Comite, La., streamgage are complex. Continuous streamflow computations incorporate the stage-discharge rating with water-surface slope below the gage (Rantz and others, 1982) and are available from NWIS (USGS, 2018a).

6 Flood-Inundation Maps for the Amite and Comite Rivers From State Hwy. 64 To U.S. Hwy. 190 at Central, Louisiana

The peak flows used in the model simulations (table 3) were taken from preliminary stage-discharge relations that were developed after the August 2016 flood event. These flows differ slightly from the approved (effective) ratings because of adjustments for smoothing of the rating and rounding. Differences in discharges are less than 3 percent and are therefore considered within the range of acceptable modeling accuracy requirements and correspond with target stages. The stage-discharge ratings in effect at the time of this report are as follows:

07378000 Comite River near Comite, La.

Rating 32.0 effective October 1, 2017

07377300 Amite River at Magnolia, La.

Rating 2.0 effective October 1, 2017

The August 2016 floodflow peaks were estimated outside of this study effort by using the two-dimensional, depth-integrated, surface-water flow model Finite Element Surface-Water Modeling System: Two-Dimensional Flow in a Horizontal Plane (FESWMS-2DH) (Froehlich, 1989) in conjunction with Surface-Water Modeling System

(SMS) (Aquaveo, 2018). SMS was used to construct a finite element grid for the study reach, and FESWMS-2DH was the computational engine for all model simulations. Input floodflows were increased incrementally until simulated water-surface elevation matched recorded or surveyed elevations. Rating curves were extended through the August 2016 flood peak estimates by using straight line extensions.

Historical USGS stage and discharge data from the Amite River at Denham Springs, La., (07378500) streamgage were used to develop a flood-scenario relationship between the Amite River at Magnolia, La. (07377300), and Comite River near Comite, La. (07378000), streamgages. A linear regression of corresponding annual peak streamflow values from 1964 to 2018 at the two Amite River streamgaging stations has a coefficient of determination (R^2) value of 0.98 and a standard deviation of 4,560 cubic feet per second (ft^3/s) (fig. 3). A comparative stage table at even 1-ft increments can be estimated by using the linear regression equation and stage-discharge ratings at the gages (table 4). A linear regression of corresponding annual peak streamflow

Table 3. Estimated discharges for corresponding stages and water-surface elevations at selected locations, used in the hydraulic model of the Amite and Comite Rivers at Central, Louisiana.

[ft, foot; NAVD 88, North American Vertical Datum of 1988; ft^3/s , cubic foot per second]

07377300 Amite River at Magnolia, La.			07378000 Comite River near Comite, La.		
Stage (ft gage datum)	Target water-surface elevation (ft NAVD 88)	Discharge (ft^3/s)	Stage (ft gage datum)	Target water-surface elevation (ft NAVD 88)	Discharge (ft^3/s)
39.0	37.57	15,000	20.0	41.51	9,210
40.0	38.57	17,200	21.0	42.51	9,920
41.0	39.57	20,000	22.0	43.51	10,600
42.0	40.57	23,000	23.0	44.51	11,400
43.0	41.57	26,400	24.0	45.51	12,600
44.0	42.57	30,100	25.0	46.51	14,200
45.0	43.57	34,600	26.0	47.51	16,900
46.0	44.57	39,800	27.0	48.51	20,000
47.0	45.57	45,400	28.0	49.51	25,000
48.0	46.57	51,900	29.0	50.51	29,500
49.0	47.57	59,000	30.0	51.51	35,000
50.0	48.57	67,200	31.0	52.51	42,000
51.0	49.57	76,000	32.0	53.51	49,000
52.0	50.57	86,000	33.0	54.51	58,000
53.0	51.57	98,000	34.0	55.51	70,000
54.0	52.57	112,000	35.0	56.51	82,000
55.0	53.57	127,000			
56.0	54.57	146,000			
57.0	55.57	167,000			
58.0	56.57	191,000			
59.0	57.57	218,000			

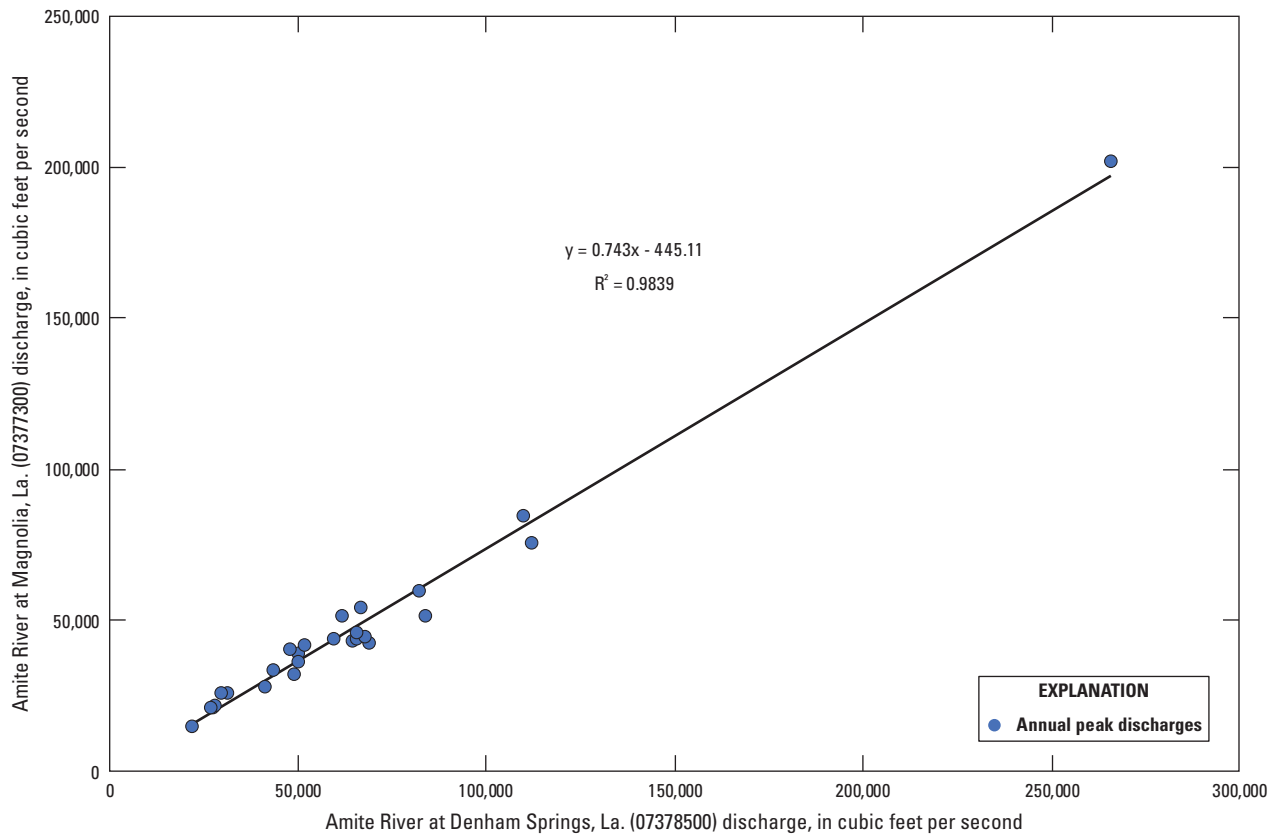


Figure 3. Correlation of corresponding annual peak streamflows, 1964–2018, for Amite River at Magnolia, Louisiana (07377300), and Amite River at Denham Springs, La. (07378500).

values for the same time period, but for the Comite River near Comite, La. (07378000), and Amite River at Denham Springs, La. (07378500), showed poor correlation ($R^2=0.61$) and was indicative of backwater or storage effects (fig. 4). Another comparison was made with the same two streamgages and time period but with corresponding annual peak stage values. From this dataset, upper and lower envelope curves could be assumed for the range of stages that were possible at the Comite River streamgage for a single stage at the Amite River streamgage (fig. 5). A 1-ft “safety factor” was added both above and below the upper and lower envelope curves to account for outliers, and a comparative incremental range-of-stage table was developed for the streamgages (table 5). A corresponding table of 127 possible flooding scenarios (table 6) between the Amite River at Magnolia, La. (07377300), and Comite River near Comite, La. (07378000), streamgages was then created by combining the results of tables 4 and 5.

Hydraulic Model Development

The Amite and Comite River reaches within the study area are characterized by low slopes, wide floodplains, variable backwater effects, and intermingling flows during extreme events. A 2D hydraulic model is better suited for analyzing these types of complex hydraulic characteristics,

particularly where flow directions vary across a floodplain. For this study, individual 2D hydraulic models were developed for the Amite and Comite River reaches by using HEC-RAS version 5.0.3 (USACE, 2018). Individual 2D models of each river reach were chosen over a 2D model of the entire study area for the following reasons:

1. Modeling the entire study area would require trial-and-error adjustments of the flood hydrograph timing to account for backwater along the Comite River reach for all 127 possible flooding scenarios shown in table 6.
2. Model run times were extremely long (5 to 6 hours) for larger floodflows and would require multiple trial-and-error calibration runs for each of the 127 possible flooding scenarios.
3. GIS clean-up of 127 flood inundation maps would be very time consuming.

Flow computations for the individual 2D models occur within an area defined by a computational mesh that is directly connected to external boundary conditions and overlays a digital elevation model (DEM) layer. For this study, a computational mesh of 200-ft \times 200-ft grid cells was created. Barriers to flow, such as roadways or high ground, were delineated as break lines within the mesh. A finer grid of 10-ft \times 10-ft cells align along these break lines and then gradually transition back to the original mesh dimensions.

8 Flood-Inundation Maps for the Amite and Comite Rivers From State Hwy. 64 To U.S. Hwy. 190 at Central, Louisiana

Table 4. Regression estimated stage correlations between Amite River at Magnolia, Louisiana (07377300), and Amite River at Denham Springs, La. (07378500).

[ft, foot; ft³/s, cubic foot per second]

07378500		07377300			07377300	
Stage (ft gage datum)	Discharge (ft ³ /s)	Regression calculated discharge (ft ³ /s)	Rounded discharge (ft ³ /s)	Stage (ft gage datum)	Adjusted stage (ft gage datum)	Discharge (ft ³ /s)
28.0	20,400	14,712	14,700	38.83	39.0	15,000
29.0	25,000	18,130	18,100	40.31	40.0	17,200
30.0	29,800	21,696	21,700	41.56	41.0	20,000
30.0	29,800	21,696	21,700	41.56	42.0	23,000
31.0	35,000	25,560	25,600	42.76	43.0	26,400
32.0	40,400	29,572	29,600	43.86	44.0	30,100
33.0	46,100	33,807	33,800	44.82	45.0	34,600
¹ 34.0	52,000	38,191	38,200	45.70	46.0	39,800
35.0	58,200	42,797	42,800	46.54	46.0	39,800
36.0	64,600	47,553	47,600	47.34	47.0	45,400
37.0	71,200	52,456	52,500	48.08	48.0	51,900
¹ 38.0	78,100	57,583	57,600	48.81	49.0	59,000
39.0	85,100	62,784	62,800	49.47	49.0	59,000
40.0	92,400	68,208	68,200	50.12	50.0	67,200
41.0	102,000	75,341	75,300	50.92	51.0	76,000
42.0	113,000	83,514	83,500	51.76	52.0	86,000
43.0	130,000	96,145	96,100	52.85	53.0	98,000
44.0	154,000	113,977	114,000	54.15	54.0	112,000
44.6	170,900	126,534	126,000	54.94	55.0	127,000
45.0	187,000	138,496	138,000	55.60	56.0	146,000
45.7	228,500	169,330	169,000	57.09	57.0	169,000
46.0	250,000	185,305	185,000	57.77	58.0	191,000
46.4	294,600	218,443	218,000	59.00	59.0	218,000

¹Not used. The next higher stage produced similar results and was considered more conservative.

Water-surface profiles are simulated with a 2D unsteady flow equations solver by using an Implicit Finite Volume algorithm to solve user-specified Saint-Venant or Diffusion Wave equations (Brunner, 2016b). The Diffusion Wave equations, which were chosen for this study, allow the software to run faster and have greater stability properties. The Finite Volume algorithm also provides improved stability and robustness over traditional finite difference and finite element techniques. The algorithm can also handle subcritical, supercritical, and mixed flow regimes.

Topographic and Bathymetric Data

All topographic data used in this study were referenced vertically to NAVD 88 and horizontally to the North American Datum of 1983. The base terrain elevation data used by the

HEC-RAS models were obtained from the Louisiana State University Department of Geography and Anthropology (2018). Elevation data were retrieved as a DEM derived from light detection and ranging (lidar) data collected and processed in 2001 during Phase 1 of the Louisiana Statewide LiDAR Project (Cunningham and others, 2004). The original lidar data have horizontal resolution of 16.40 ft and vertical accuracy of 0.75 ft at a 95-percent confidence level. Green band lidar was not used in the data collection effort, so no elevation data below the water surface were collected. Supplementary channel elevation data were collected by USGS field crews to define the channel bottom at select locations in the study reach. Cross-sectional depths were measured at the upstream and downstream side of nine bridge crossings by tapedowns from the handrails at 10-ft increments to define the channel elevation between the top of banks. USGS surveying standards

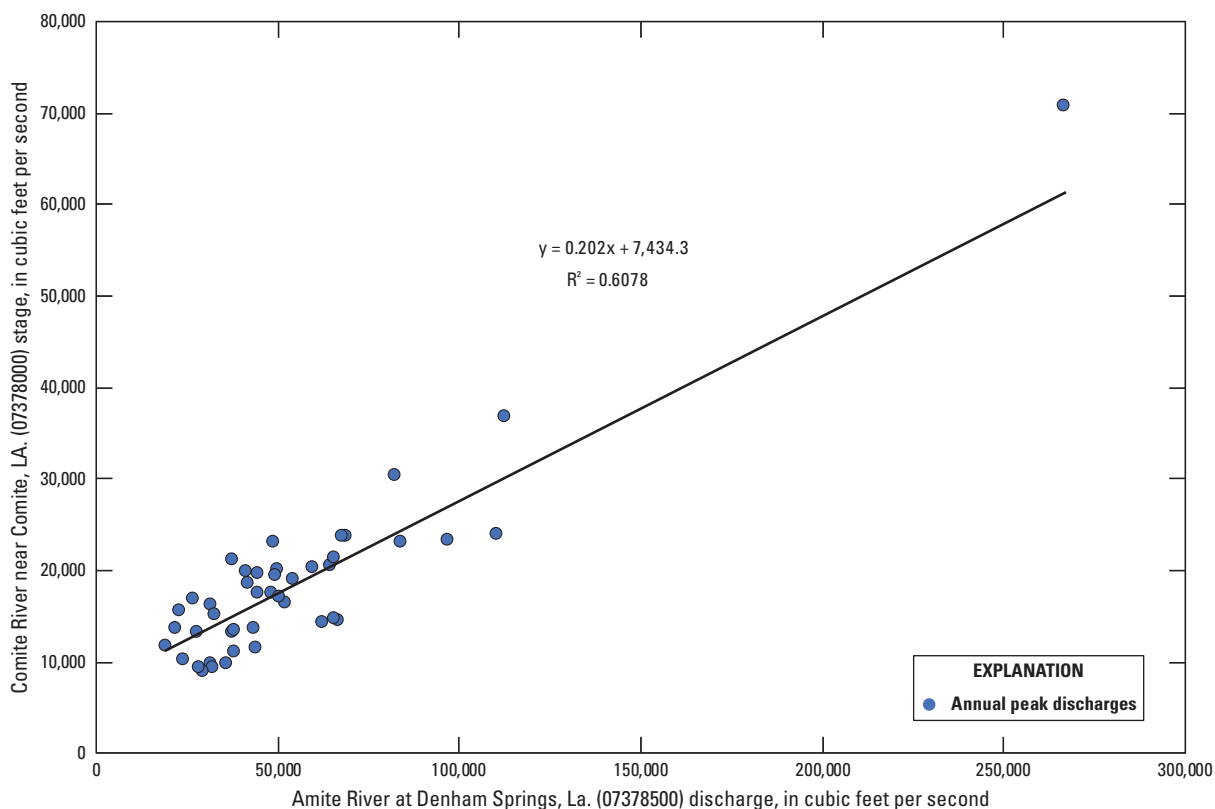


Figure 4. Correlation of corresponding annual peak streamflows, 1964–2018, for Comite River near Comite, Louisiana (07378000), and Amite River at Denham Springs, La. (07378500).

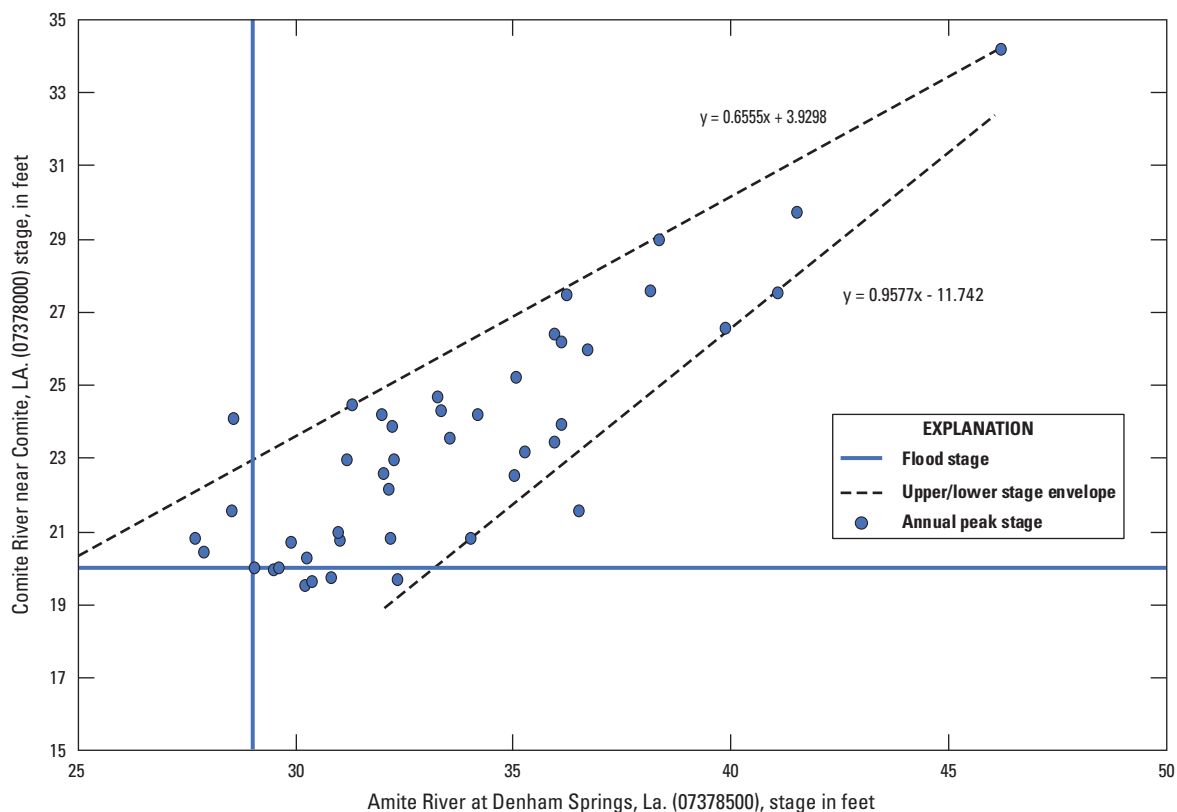


Figure 5. Correlation of corresponding annual peak stages, 1964–2018, for Comite River near Comite, Louisiana, (07378000) and Amite River at Denham Springs, La. (07378500).

Table 5. Range-of-stage correlation for Comite River near Comite, Louisiana (07378000), and Amite River at Denham Springs, La. (07378500).

[ft, foot]

07378500	07378000
Stage (ft gage datum)	Range in stage (ft gage datum)
28.0	20.0 to 24.0
29.0	20.0 to 24.0
30.0	20.0 to 25.0
31.0	20.0 to 25.0
32.0	20.0 to 26.0
33.0	20.0 to 27.0
35.0	21.0 to 28.0
36.0	22.0 to 29.0
37.0	23.0 to 29.0
39.0	25.0 to 31.0
40.0	26.0 to 31.0
41.0	27.0 to 32.0
42.0	28.0 to 33.0
43.0	28.0 to 33.0
44.0	29.0 to 34.0
44.6	30.0 to 34.0
45.0	30.0 to 34.0
45.7	31.0 to 35.0
46.0	31.0 to 35.0
46.4	32.0 to 35.0

Table 6. Range-of-stage correlation for Amite River at Magnolia, Louisiana (07377300), and Comite River near Comite, La. (07378000).

[ft, foot]

07378500	07377300	07378000
Stage (ft gage datum)	Stage (ft gage datum)	Range in stage (ft gage datum)
28.0	39.0	20.0 to 24.0
29.0	40.0	20.0 to 24.0
30.0	41.0	20.0 to 25.0
30.0	42.0	20.0 to 25.0
31.0	43.0	20.0 to 25.0
32.0	44.0	20.0 to 26.0
33.0	45.0	20.0 to 27.0
35.0	46.0	21.0 to 28.0
36.0	47.0	22.0 to 29.0
37.0	48.0	23.0 to 29.0
39.0	49.0	25.0 to 31.0
40.0	50.0	26.0 to 31.0
41.0	51.0	27.0 to 32.0
42.0	52.0	28.0 to 33.0
43.0	53.0	28.0 to 33.0
44.0	54.0	29.0 to 34.0
44.6	55.0	30.0 to 34.0
45.0	56.0	30.0 to 34.0
45.7	57.0	31.0 to 35.0
46.0	58.0	31.0 to 35.0
46.4	59.0	32.0 to 35.0

and protocols (Rydland and Densmore, 2012) were followed by using a differential Global Positioning System (GPS) device with real-time network technology (RTN) to establish horizontal locations and the elevation of the water surface and bridge handrails at each surveyed cross section. A “channel-only” DEM was created by interpolating channel shape and channel-bottom elevations between cross sections by using the HEC-RAS Mapper and by following a series of steps outlined in the HEC-RAS 2D Modeling User’s Manual (Brunner, 2016a). An improved terrain model could then be created within the HEC-RAS Mapper by combining the original lidar DEM with the “channel-only” DEM (Brunner, 2016a).

Hydraulic Structures

Ten hydraulic structures, consisting of nine road crossings (Magnolia Bridge Road, U.S. Highway 190, State Highway 64, Dyer Road, Comite Drive, Hooper Road, Joor Road, Greenwell Springs Road, and Central Thruway), and a railroad crossing (Illinois Central Railroad) can affect

water-surface elevations during floods along the stream. A primary limitation of the HEC-RAS 2D model is the lack of capability to incorporate bridge hydraulic routines into its flow computations. As a result, no hydraulic structures are defined, and flows were modeled with a simple narrowing of the channel or constriction at the crossings. Roadways approaching these structures tend to be lower in elevation than the bridge structure because of the wide floodplains and low slopes associated with the Amite and Comite Rivers. It is assumed that during extreme events, when floodflows are affected by the bridges, water will have already broken over the roadways and effects to the water surface elevation will be localized near the bridge. Break lines were delineated along all major roadways within the computational mesh by creating a refined grid cell size of 10 ft × 10 ft along the roadway centerlines. This refined grid better defines the elevation change in the DEM and diverts or blocks flow paths when the roadway elevation is higher than the upstream water surface and eliminates “leakage” across the road. The grid cell size transitions gradually back to the original 200-ft × 200-ft mesh dimensions as distance is gained away from the break lines.

Energy-Loss Factors

The Amite and Comite Rivers are wide, low-gradient channels made up of sand and silt bed material and have steep banks. Floodplains vary in their composition and include dense bottom land forests, open agricultural areas, and medium and high-density urbanization. All of these characteristics are factors that contribute to the frictional resistance on flow.

Hydraulic analyses require the estimation of energy losses that result from frictional resistance exerted by a channel on flow. These energy losses are quantified by the Manning's roughness coefficient (" n " value). Initial (precalibration) n values were selected based on field observations and high-resolution aerial photographs (Arcement and Schneider, 1989).

As part of the calibration process, the initial n values were varied by flow and adjusted until the differences between simulated and observed water-surface elevations at the streamgages and high watermarks were minimized. The final n values for the main channel of the Amite and Comite Rivers ranged from 0.026 to 0.055 and 0.030 to 0.058, respectively. Floodplain area n values modeled in this analysis ranged from 0.07 to 0.20.

Hydraulic Model Calibration

The HEC-RAS 2D flow models for the Amite and Comite River reaches were calibrated to water-surface profiles for the March and August 2016 floods, to surveyed high-water marks from the August 2016 flood, and to the current stage-discharge relations at the Amite River at Magnolia, La. (07377300), and Comite River near Comite, La. (07378000), streamgages.

Upstream boundary conditions of the 2D flow area for both river reaches were unit value hydrographs with 30-minute time-step intervals. The hydrographs were held steady once they reached the target discharge to simulate a steady-state condition. The downstream boundary condition of the 2D flow area was the current stage-discharge rating at the Amite River at Denham Springs, La. (07378500), streamgage. Flow data consisted of boundary conditions and peak flows that produced average water-surface elevations at the corresponding streamgage that matched target water-surface elevations (see "Hydrologic Data" for more on the peak flows used in the model). Lesser tributaries entering the Comite and Amite River reaches were considered to be small enough to assume that inflows would have already peaked prior to the main-stem flood peak arrival and that the tributary would be in backwater. Therefore, the streamgage-derived discharges were not adjusted for tributary inflows. During extreme flooding conditions, some of these tributaries can become conduits to convey Amite and Comite River floodplain flow. Model calibrations were accomplished by adjusting Manning's n values until the results of the hydraulic computations closely agreed with the observed water-surface elevations for given flows. Absolute differences between observed and modeled

water-surface elevations for the March and August 2016 floods along the Amite River reach were equal to or less than 0.13 ft and 0.07 ft, respectively (table 7). Absolute differences between observed and modeled water-surface elevations for the March and August 2016 floods along the Comite River reach were equal to or less than 0.34 ft and 0.20 ft, respectively (table 7). Absolute differences between surveyed and modeled high-water mark elevations for the August 2016 flood (fig. 6) were equal to or less than 1.4 ft (table 8). Absolute differences between observed and modeled water-surface elevations for the 21 simulated flows at the Amite River at Magnolia, La. (07377300), streamgage were equal to or less than 0.16 ft (table 9). Absolute differences between observed and modeled water-surface elevations for the 16 simulated flows at the Comite River near Comite, La. (07378000), streamgage were equal to or less than 0.18 ft (table 9). The results demonstrated that the models are capable of simulating accurate water levels over a wide range of flows in the basin.

Development of Water-Surface Profiles

The calibrated 2D hydraulic models were used to generate water-surface profiles at 1-ft increments for 21 river stages between 39 and 59 ft at the Amite River at Magnolia, La. (07377300), streamgage and 16 river stages between 20 and 35 ft at the Comite River near Comite, La. (07378000), streamgage. Discharges corresponding to the target stages were obtained from the current (2018) stage-discharge relations shown in table 3. Tributaries along the Amite and Comite River reaches were considered to be in backwater, and modeled discharges were not adjusted.

Incremental flood profiles for flow values along the Comite River reach model were calculated as if there was no flow on the Amite River above the confluence. Roughness coefficients were adjusted until the average simulated water surface at the Comite River near Comite, La. (07378000), streamgage matched the targeted stage within 0.2 ft (table 7). The model produced accurate water-surface profiles above the Comite River gage but can underestimate profile elevations as distance increases downstream from the streamgage because of the absence of control from the Amite River.

A second 2D model was created containing floodflows for both river reaches. Incremental flood profiles for the Amite River reach were calculated by using the correlated flow values determined from the regression analysis results summarized in table 4. Tributary flow from the Comite River was included in this model as the difference in flow values between the two Amite River streamgages. Roughness coefficients were adjusted until the simulated water surface at the Amite River at Magnolia, La. (07377300), streamgage matched the targeted stage within 0.2 ft (table 7). Comite River channel roughness coefficients were adjusted until the average simulated water surface at the Comite River near Comite, La. (07378000), streamgage approximately matched the lowest stage of the corresponding Comite River stage range. This is the corresponding lower envelope stage (table 6).

Table 7. Calibration of model to water-surface elevations at U.S. Geological Survey streamgages along the Amite and Comite Rivers, Louisiana, for the floods of March 2016 and August 2016.

[ft³/s, cubic foot per second; ft, foot; NAVD 88, North American Vertical Datum of 1988; --, no calibration value; **, gage overtopped, four high-water marks collected with a 1.3-ft range, omitted for this study]

Station name	Station number	March 2016 flood					August 2016 flood				
		Discharge (ft ³ /s)	Stage (ft gage datum)	Water surface elevation (ft NAVD 88)	Model water-surface elevation (ft NAVD 88)	Elevation difference (ft)	Discharge (ft ³ /s)	Stage (ft gage datum)	Water surface elevation (ft NAVD 88)	Model water-surface elevation (ft NAVD 88)	Elevation difference (ft)
Amite River at Magnolia, La.	07377300	46,000	47.1	45.67	45.54	-0.13	202,000	58.56	57.13	57.08	-0.05
Amite River at Denham Springs, La.	07378500	65,200	36.09	34.74	34.82	0.08	266,000	46.2	44.85	44.78	-0.07
Comite River near Zachary, La.	07377750	--	--	--	81.95	--	--	31.99	90.57	90.59	0.02
Comite River near Baker, La.	07377754	--	18.78	66.99	66.94	-0.05	--	26.91	75.12	75.06	-0.06
Comite River at Comite Drive near Baton Rouge, La.	07377760	--	22.18	58.61	58.64	0.03	--	29.36	65.79	65.87	0.08
Comite River at Hooper Road near Baton Rouge, La.	07377870	--	24.13	52.62	52.55	-0.07	--	31.96	60.45	60.25	-0.20
Comite River near Comite, La.	07378000	17,400	26.18	47.69	47.68	0.01	71,000	34.22	55.73	55.78	0.05
Comite River at Greenwell Springs Road near Baton Rouge, La.	07378050	--	43.65	42.7	42.36	-0.34	--	**	**	51.53	--

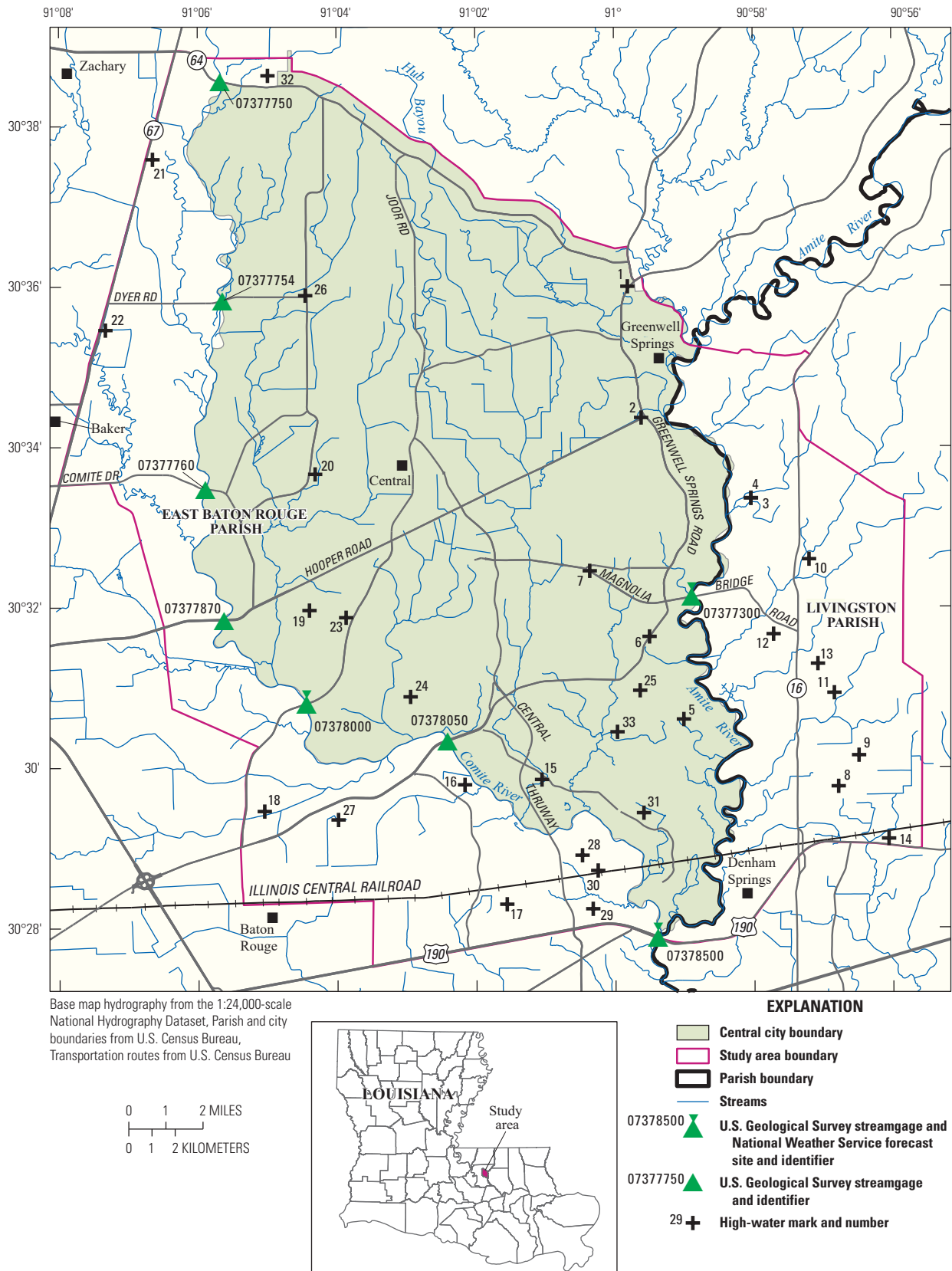


Figure 6. Location of study reach for the Amite and Comite Rivers at Central, Louisiana, and location of U.S. Geological Survey streamgages, National Weather Service forecast sites, and high-water mark locations observed following the August 2016 flood.

14 Flood-Inundation Maps for the Amite and Comite Rivers From State Hwy. 64 To U.S. Hwy. 190 at Central, Louisiana

Table 8. Calibration of model to water-surface elevations at select high-water mark locations within the study reach along the Amite and Comite Rivers, Louisiana, for the flood of August 2016.

[HWM, high-water mark; ft, foot; NAVD 88, North American Vertical Datum of 1988]

HWM location (see fig. 6)	HWM ID number	Latitude	Longitude	HWM type	HWM quality	HWM elevation (ft NAVD 88)	Model water-surface elevation (ft NAVD 88)	Elevation difference (ft NAVD 88)
1	15367	30.600	-90.997	Seed line	Good: +/- 0.10 ft	69.6	69.3	-0.3
2	15381	30.573	-90.994	Seed line	Good: +/- 0.10 ft	65.3	65.4	0.1
3	15516	30.556	-90.967	Mud	Good: +/- 0.10 ft	60	60.7	0.7
4	15518	30.556	-90.967	Mud	Good: +/- 0.10 ft	60	60.8	0.8
5	15557	30.510	-90.984	Seed line	Good: +/- 0.10 ft	52.2	52.8	0.6
6	15565	30.527	-90.992	Seed line	Good: +/- 0.10 ft	55.1	55.4	0.3
7	15568	30.541	-91.006	Seed line	Excellent: +/- 0.05 ft	57.2	57.9	0.7
8	15220	30.496	-90.946	Seed line	Excellent: +/- 0.05 ft	48	48.2	0.2
9	15272	30.503	-90.941	Seed line	Excellent: +/- 0.05 ft	51.9	51.3	-0.6
10	15278	30.544	-90.953	Seed line	Excellent: +/- 0.05 ft	56.8	57.2	0.4
11	15419	30.516	-90.947	Seed line	Excellent: +/- 0.05 ft	52.2	51.4	-0.8
12	15451	30.528	-90.962	Seed line	Excellent: +/- 0.05 ft	56.6	55.7	-0.9
13	15457	30.522	-90.951	Seed line	Good: +/- 0.10 ft	52.8	52.4	-0.4
14	15465	30.485	-90.934	Seed line	Excellent: +/- 0.05 ft	46.1	46	-0.1
15	15241	30.498	-91.018	Seed line	Excellent: +/- 0.05 ft	49.6	49.8	0.2
16	15289	30.497	-91.036	Seed line	Excellent: +/- 0.05 ft	50.9	50.8	-0.1
17	15299	30.472	-91.026	Seed line	Good: +/- 0.10 ft	47.4	47.6	0.2
18	15300	30.491	-91.084	Seed line	Excellent: +/- 0.05 ft	53.9	54.1	0.2
19	15305	30.533	-91.073	Seed line	Excellent: +/- 0.05 ft	61.3	61.2	-0.1
20	15319	30.561	-91.072	Seed line	Excellent: +/- 0.05 ft	63.9	65.3	1.4
21	15393	30.627	-91.111	Seed line	Excellent: +/- 0.05 ft	83.9	84.3	0.4
22	15397	30.591	-91.122	Seed line	Good: +/- 0.10 ft	73.6	73.8	0.2
23	15404	30.532	-91.065	Seed line	Good: +/- 0.10 ft	59.2	57.8	-1.4
24	15409	30.515	-91.049	Stain line	Excellent: +/- 0.05 ft	54.4	54	-0.4
25	15430	30.516	-90.994	Debris	Good: +/- 0.10 ft	51.3	51.4	0.1
26	15460	30.598	-91.074	Seed line	Excellent: +/- 0.05 ft	76.1	75.8	-0.3
27	15503	30.489	-91.066	Stain line	Good: +/- 0.10 ft	52.6	53.6	1
28	15547	30.482	-91.008	Seed line	Excellent: +/- 0.05 ft	47.1	47	-0.1
29	15211	30.471	-91.005	Seed line	Excellent: +/- 0.05 ft	46.1	46.2	0.1
30	15226	30.479	-91.004	Seed line	Excellent: +/- 0.05 ft	46.8	46.6	-0.2
31	15260	30.491	-90.993	Seed line	Excellent: +/- 0.05 ft	46.8	47.2	0.4
32	15327	30.644	-91.083	Seed line	Fair: +/- 0.20 ft	91.6	91.1	-0.5
33	15555	30.508	-90.999	Seed line	Good: +/- 0.10 ft	49.7	49.5	-0.2

Table 9. Calibration of model to target water-surface elevations at U.S. Geological Survey streamgages at Amite River at Magnolia, Louisiana (07377300), and Comite River near Comite, La. (07378000).

[ft, foot; ft³/s, cubic foot per second; NAVD 88, North American Vertical Datum of 1988]

07377300 Amite River at Magnolia, La.					07378000 Comite River near Comite, La.				
Stage (ft gage datum)	Discharge (ft ³ /s)	Target water-surface elevation (ft NAVD 88)	Model water-surface elevation (ft NAVD 88)	Elevation difference (ft)	Stage (ft gage datum)	Discharge (ft ³ /s)	Target water-surface elevation (ft NAVD 88)	Model water-surface elevation (ft NAVD 88)	Elevation difference (ft)
39.0	15,000	37.57	37.63	0.06	20.0	9,210	41.51	41.6	0.09
40.0	17,200	38.57	38.7	0.13	21.0	9,920	42.51	42.59	0.08
41.0	20,000	39.57	39.72	0.15	22.0	10,600	43.51	43.4	-0.11
42.0	23,000	40.57	40.71	0.14	23.0	11,400	44.51	44.4	-0.11
43.0	26,400	41.57	41.44	-0.13	24.0	12,600	45.51	45.69	0.18
44.0	30,100	42.57	42.47	-0.10	25.0	14,200	46.51	46.53	0.02
45.0	34,600	43.57	43.49	-0.08	26.0	16,900	47.51	47.46	-0.05
46.0	39,800	44.57	44.5	-0.07	27.0	20,000	48.51	48.63	0.12
47.0	45,400	45.57	45.45	-0.12	28.0	25,000	49.51	49.62	0.11
48.0	51,900	46.57	46.45	-0.12	29.0	29,500	50.51	50.63	0.12
49.0	59,000	47.57	47.46	-0.11	30.0	35,000	51.51	51.63	0.12
50.0	67,200	48.57	48.45	-0.12	31.0	42,000	52.51	52.65	0.14
51.0	76,000	49.57	49.48	-0.09	32.0	49,000	53.51	53.66	0.15
52.0	86,000	50.57	50.52	-0.05	33.0	58,000	54.51	54.58	0.07
53.0	98,000	51.57	51.67	0.10	34.0	70,000	55.51	55.49	-0.02
54.0	112,000	52.57	52.72	0.15	35.0	82,000	56.51	56.37	-0.14
55.0	127,000	53.57	53.7	0.13					
56.0	146,000	54.57	54.71	0.14					
57.0	167,000	55.57	55.73	0.16					
58.0	191,000	56.57	56.7	0.13					
59.0	218,000	57.57	57.5	-0.07					

Comparing the resulting Comite River reach profiles from the two individual 2D models determines the estimated point of backwater control along the Comite River stream reach for that particular flood scenario. Further discussion related to determining this location is provided in the following section.

Development of Flood-Inundation Maps

The HEC-RAS Mapper module was used to create GIS shapefiles of estimated inundation extent polygons and associated depth grids for each water-surface profile generated by the 2D models. Shapefiles were created for 1-ft incremental profiles ranging from 39 to 59 ft at the Amite River at Magnolia, La. (07377300), streamgage and from 20 ft to 35 ft at the Comite River near Comite, La. (07378000), streamgage. The shapefiles were exported from HEC-RAS and then edited by using the ArcMap application of ArcGIS to remove erroneous areas of inundation (Esri, 2018). Any inundated areas that were detached from the main channel were examined to identify subsurface connections with the main

river, such as through culverts under roadways. Where such connections existed, the mapped inundated areas were retained in their respective flood maps; otherwise, the erroneously delineated parts of the flood extent were deleted.

A total of 127 possible flooding scenarios were shown to exist between the Amite and Comite River reaches within the study area (table 6). Flood-inundation maps depicting the estimated areal extent and flood depths were created by combining each scenario's shapefiles at their point of overlap on the Comite River reach by using ArcMap. For each flooding scenario, the point of overlap was determined by subtracting the Amite River model depth grid file from the corresponding Comite River model depth grid file to produce a grid file of depth-differences. This file was contoured at 0.5-ft intervals to determine where the line of zero-difference was located along the Comite River reach (fig. 7). The areal extent polygon shapefiles of the flood scenario were clipped and merged along this line and the depth grid shapefiles were clipped and mosaiced along this line as well to produce seamless flood-inundation maps.

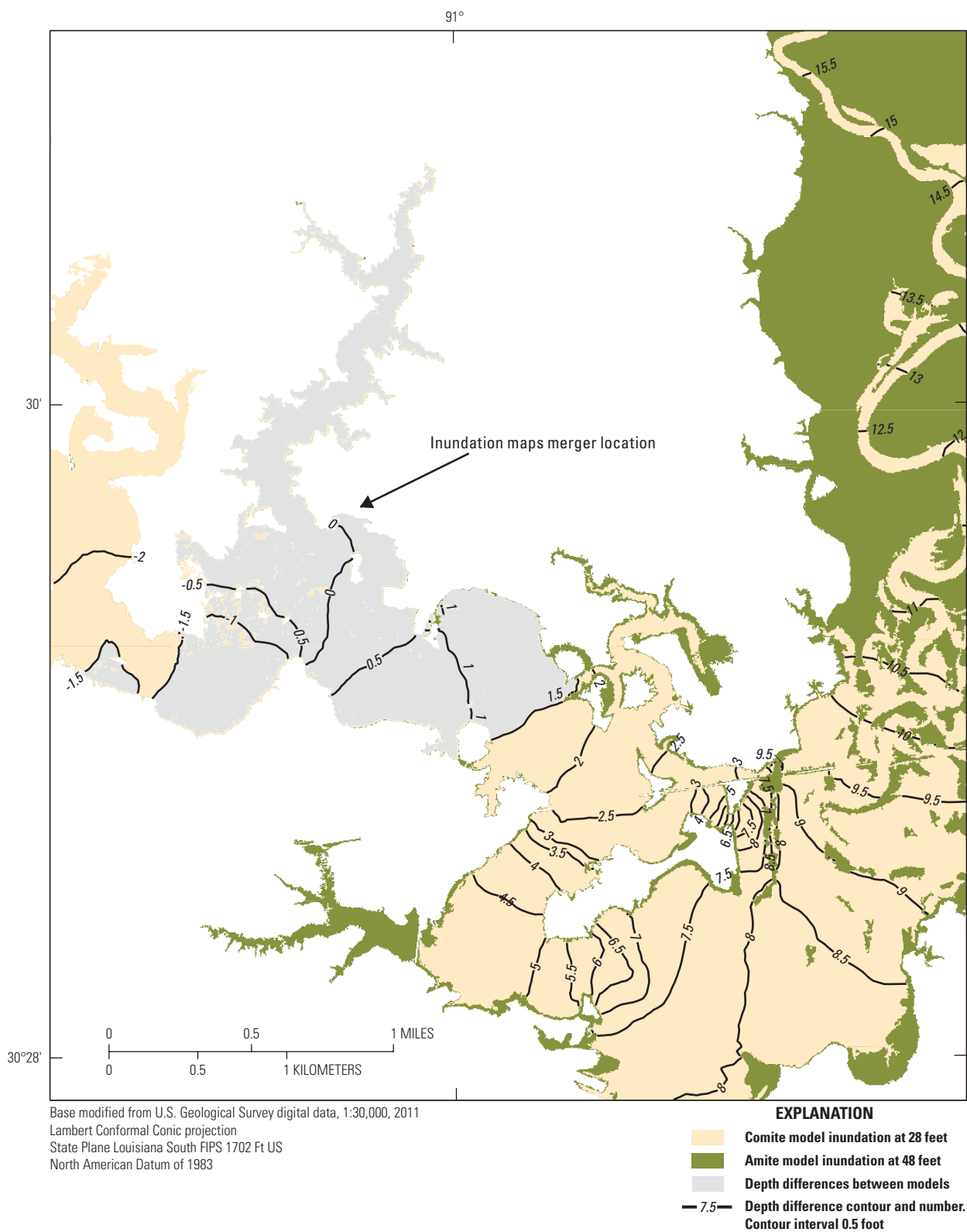


Figure 7. Merger location for a flood scenario of 48 ft at the Amite River at Magnolia, Louisiana (07377300), and 28 ft at the Comite River near Comite, La. (07378000).

The flood-inundation maps can be overlaid on georeferenced, aerial photographs of the study area for determining affected structures at different flooding scenarios. Bridge surfaces are displayed as inundated regardless of the actual water-surface elevation in relation to the lowest structural chord of the bridge or the bridge deck. The flood map corresponding to the highest simulated water-surface profile scenario, a stage of 59 ft at the Amite River at Magnolia, La. (07377300), streamgage and a stage of 35 ft at the Comite River near Comite, La. (07378000), is presented in figure 8.

Flood-Inundation Map Viewer

The FIM Program website (USGS, 2018b) has been established to make USGS-derived flood-inundation data available to the public. An interactive viewer presents map libraries over user-selected base maps and provides detailed information on flood extents and depths for modeled stream reaches. The estimated flood-inundation maps are presented in the interactive viewer so that preparations for flooding and decisions for emergency response can be performed for the mapped area. Depending on the flood magnitude, roadways are shown as shaded (inundated and likely impassable) or not shaded (dry and passable) to facilitate emergency planning and use. Bridges are shaded—that is, shown as inundated—regardless of the flood magnitude. A shaded building should not be interpreted to mean that the structure is completely submerged, but rather that bare earth surfaces near the building are inundated. In these instances, the water depth (as indicated in the mapping application by clicking with the cursor over an inundated area) near the building would be an estimate of the water level inside the structure, unless flood proofing measures had been implemented. The interactive flood inundation map library for the Amite and Comite Rivers at the city of Central, La., is located at https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-fim-program?qt-science_center_objects=0#qt-science_center_objects. The map libraries are downloadable in formats that may be used in other software packages and are available to the public in an accessible, machine-readable format from Heal and Storm (2019).

Disclaimer for Flood-Inundation Maps

The flood-inundation maps should not be used for navigation, regulatory, permitting, or other legal purposes. The USGS provides these maps “as-is” for a quick reference, emergency planning tool but assumes no legal liability or responsibility resulting from the use of this information.

Uncertainties and Limitations Regarding Use of Flood-Inundation Maps

Although the flood-inundation maps represent the boundaries of inundated areas with a distinct line, some uncertainty is associated with these maps. The flood boundaries shown were estimated on the basis of water stages

and streamflows at selected USGS streamgages. Water-surface elevations along the stream reaches were estimated by steady-state hydraulic modeling, assuming unobstructed flow, and used streamflows and hydrologic conditions anticipated at the USGS streamgages. The scenario-based modeling approach produces many potential flooding scenario estimates that have not previously occurred or been measured. Backwater affects along the Comite River can vary and may not be fully represented by this modeling approach. The hydraulic model reflects the land-cover characteristics and any bridge, dam, levee, or other hydraulic structures existing as of May 2018. Unique meteorological factors (timing and distribution of precipitation) may cause actual streamflows along the modeled reach to vary from those assumed during a flood, which may lead to deviations in the water-surface elevations and inundation boundaries shown. Additional areas may be flooded by unanticipated conditions such as changes in the streambed elevation or roughness, backwater into major tributaries along a main stem river, or backwater from localized debris. The accuracy of the floodwater extent portrayed on these maps will vary with the accuracy of the DEM used to simulate the land surface.

If this series of flood-inundation maps will be used in conjunction with NWS river forecasts, the user should be aware of additional uncertainties that may be inherent or factored into NWS forecast procedures. The NWS uses forecast models to estimate the quantity and timing of water flowing through selected stream reaches in the United States. These forecast models (1) estimate the amount of runoff generated by precipitation and snowmelt, (2) simulate the movement of floodwater as it proceeds downstream, and (3) predict the flow and stage (and water-surface elevation) for the stream at a given location (AHPS forecast point) throughout the forecast period (every 6 hours and 3 to 5 days out in many locations). For more information on AHPS forecasts, please see: https://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf.

Summary

A library of digital flood-inundation maps was developed by the U.S. Geological Survey (USGS) in cooperation with the city of Central, Louisiana, for a 14.5-mile (mi) reach of the Amite River and a 20.2-mi reach of the Comite River that extend approximately from State Highway 64 to U.S. Highway 190. The flood-inundation maps were developed by using 2D modeling options in the U.S. Army Corps of Engineers’ Hydrologic Engineering Center-River Analysis System (HEC–RAS, version 5.0.3) software to compute water-surface profiles and delineate estimated inundation extents for selected stream stages referenced to the Amite River at Magnolia, La. (07377300), and Comite River near Comite, La. (07378000), streamgages. Flood-inundation layers were created at 1.0-foot (ft) increments ranging from 39 to 59 ft, gage datum, at the Amite River streamgage and from 20 to 35 ft, gage datum, at the Comite River streamgage. These

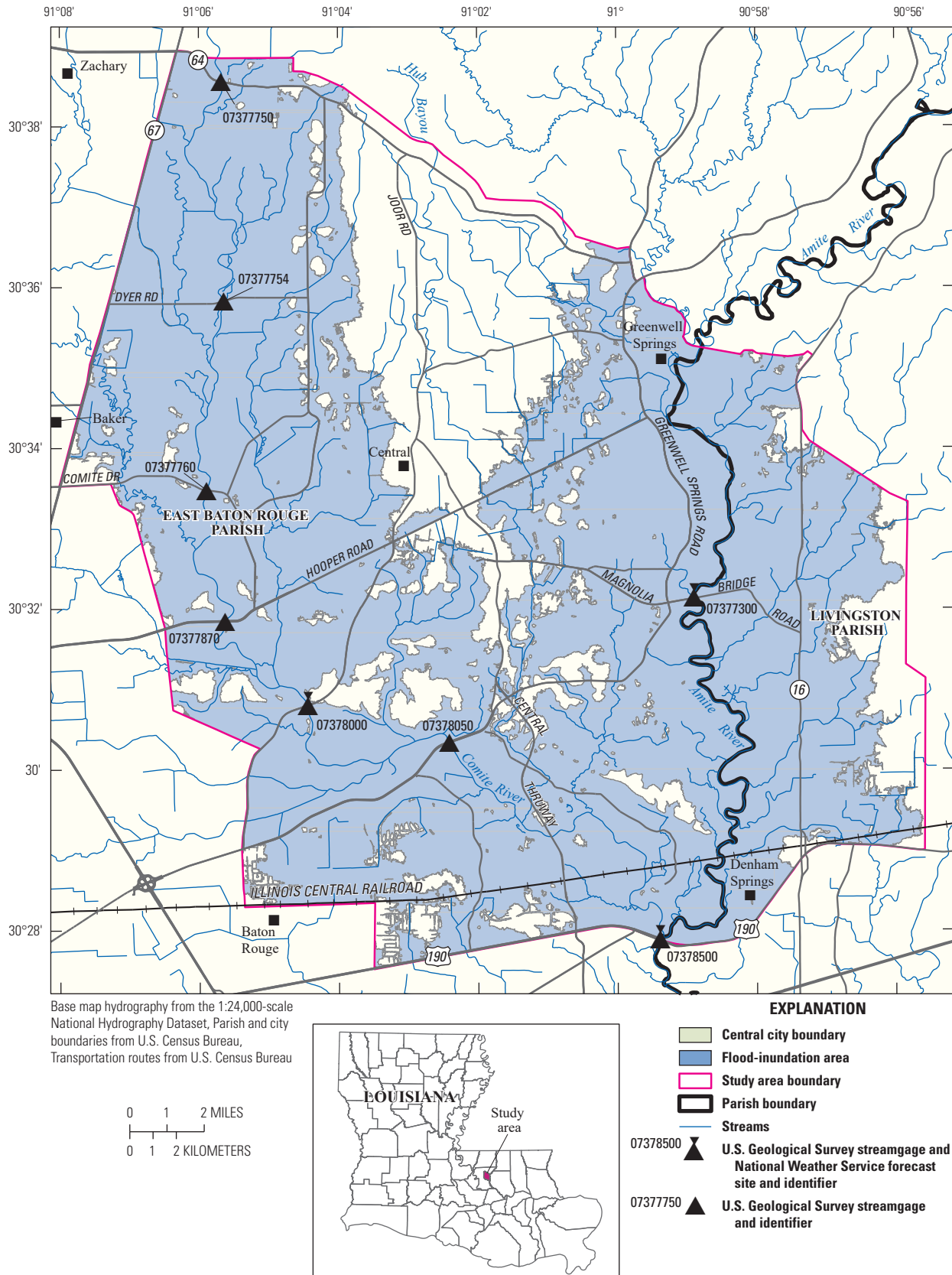


Figure 8. Flood-inundation map for the Amite and Comite Rivers at Central, La., corresponding to stages of 59.0 ft and 35.0 ft at the U.S. Geological Survey streamgages Amite River at Magnolia, La. (07377300), and Comite River near Comite, La. (07378000), respectively.

layers were seamlessly combined by using ArcGIS to define estimated inundation extents and flood depths for 127 different flood scenarios that are possible between the two river reaches based on historical stage and flow data. The maps are downloadable in formats that may be used in other software packages and are available to the public. The flood-inundation maps are also presented on the interactive USGS Flood Inundation Mapping Program website along with USGS real-time streamgage data and National Weather Service flood forecast information to assist the public and local officials during a flood emergency.

References Cited

- Aquaveo, 2018, Surface-Water Modeling System, Version 13.0: Aquaveo website accessed April 2019, at <https://www.aquaveo.com/software/sms-surface-water-modeling-system-introduction>
- Arcement, G.J., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and floodplains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.
- Brunner, G.W., 2016a, U.S. Army Corps of Engineers Hydrologic Engineering Center-River Analysis System (HEC-RAS)—2D modeling user's manual (Version 5.0): Davis, Calif., U.S. Army Corps of Engineers report CPD-68A, 171 p.
- Brunner, G.W., 2016b, U.S. Army Corps of Engineers Hydrologic Engineering Center-River Analysis System (HEC-RAS)—Hydraulic reference manual (Version 5.0): Davis, Calif., U.S. Army Corps of Engineers report CPD-69, 547 p.
- Cunningham, R., Gisclair, D., and Craig, J., 2004, The Louisiana statewide LiDAR project: Accessed October 2018, at http://atlas.lsu.edu/central/la_lidar_project.pdf.
- Di Liberto, T., 2016, August 2016 extreme rain and floods along the Gulf Coast: Accessed August 2018, at <https://www.climate.gov/news-features/event-tracker/august-2016-extreme-rain-and-floods-along-gulf-coast>
- Esri, 2018, ArcGIS: Accessed August 2018, at <https://www.esri.com/en-us/arcgis/about-arcgis/overview>.
- Federal Emergency Management Agency [FEMA], 2012, Flood insurance study, East Baton Rouge Parish, Louisiana, and incorporated areas: Washington D.C., Federal Emergency Management Agency report 41 p., 108 pl.
- Froehlich, D.C., 1989, HW031.D - Finite Element Surface-Water Modeling System—Two-dimensional flow in a horizontal plane - user's manual: Federal Highway Administration Report FHWA-RD-88-177, 285 p.
- Gulf Engineers and Consultants, Inc., 2015, Amite River Basin Floodplain Management Plan for the Amite River Basin Drainage and Water Conservation District: Baton Rouge, La., G.E.C., Inc., 77 p.
- Heal, E.N., and Storm, J.B., 2019, Flood inundation maps for the Amite and Comite Rivers from State Highway 64 to U.S. Highway 190—City of Central, Louisiana: U.S. Geological Survey data release, <https://doi.org/10.5066/P9PQKSYF>.
- Louisiana State University Department of Geography and Anthropology, 2018, Atlas—The Louisiana statewide GIS: Baton Rouge, La., accessed August 2018, at <http://atlas.lsu.edu>.
- National Oceanic and Atmospheric Administration [NOAA], 2016, U.S. billion-dollar weather and climate disasters: National Centers for Environmental Information website accessed August 2018, at <https://www.ncdc.noaa.gov/billions/events/US/1980-2018>.
- National Weather Service [NWS], 2018a, Advanced hydrologic prediction service: National Weather Service web page accessed August 2018, at <https://water.weather.gov/ahps2/hydrograph.php?wfo=lix&gage=den11>.
- National Weather Service [NWS], 2018b, Advanced hydrologic prediction service: National Weather Service web page accessed August 2018, at <https://water.weather.gov/ahps/>.
- National Weather Service [NWS], 2018c, National Weather Service glossary: National Weather Service web page accessed August 2018, at <http://w1.weather.gov/glossary/index.php?word=action+stage>.
- Rantz, S.E., and others, 1982, Measurement and computation of streamflow—Volume 2. Computation of Discharge: U.S. Geological Survey Water-Supply Paper 2175, 631 p.
- Renken, R.A., 1998, Groundwater Atlas of the United States—Arkansas, Louisiana, and Mississippi: U.S. Geological Survey Hydrologic Atlas 730–F.
- Rydland, P.H., Jr., and Densmore, B.K., 2012, Methods of practice and guidelines for using survey-grade global navigation satellite systems (GNSS) to establish vertical datum in the United States Geological Survey: U.S. Geological Survey Techniques and Methods, book 11, chap. D1, 102 p. with appendixes.
- U.S. Army Corps of Engineers [USACE], 2012, Amite River Basin and tributaries, Louisiana, Comite River Diversion Project Review Plan: U.S. Army Corps of Engineers New Orleans District report, accessed August 2018, at <http://www.mvn.usace.army.mil/Portals/56/docs/PD/PeerReview/Comiteapprovedplan.pdf>

U.S. Army Corps of Engineers, [USACE] 2018, HEC-RAS River Analysis System, Version 5.0.3: U.S. Army Corps of Engineers Hydrologic Engineering Center website accessed August 2018, at <https://www.hec.usace.army.mil/software/hec-ras/downloads.aspx>.

U.S. Census Bureau, 2010, 2010 Census QuickFacts, Central, LA: U.S. Census Bureau web page accessed August 2018, at <https://www.census.gov/quickfacts/fact/table/centralcitylouisiana,eastbatonrougeparishlouisiana,la/PST045217>.

U.S. Geological Survey [USGS], 2018a, National Water Information System—Web interface: U.S. Geological Survey National Water Information System database accessed August 2018, at <http://dx.doi.org/10.5066/F7P55KJN>.

U.S. Geological Survey [USGS], 2018b, USGS flood inundation mapping science: U.S. Geological Survey web page, accessed August 2018, at https://water.usgs.gov/osw/flood_inundation.

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