



Prepared in Cooperation with Camp Atterbury Joint Maneuver Training Center, Edinburgh, Indiana

Flood-Inundation Maps for the Driftwood River and Sugar Creek near Edinburgh, Indiana

By Kathleen K. Fowler, Moon H. Kim, and Chad D. Menke

Scientific Investigations Map **XXXX**

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Geological Survey Streamgage 03363000

1. Gage height of 9.0 and an elevation of 645.6 feet [link](#)
2. Gage height of 10.0 and an elevation of 646.6 feet [link](#)
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Conversion Factors

Inch/Pound to SI

Length		
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square foot (ft ²)	0.09290	square meter (m ²)
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)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Elevation, as used in this report, refers to distance above the vertical datum.

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Abstract

Digital flood-inundation maps for an 11.2-mile reach of the Driftwood River and a 5.2-mile reach of Sugar Creek, both near Edinburgh, Indiana, were created by the U.S. Geological Survey (USGS) in cooperation with the Camp Atterbury Joint Maneuver Training Center, Edinburgh, Indiana. The inundation maps, which can be accessed through the USGS Flood Inundation Mapping Science Web site at http://water.usgs.gov/osw/flood_inundation/, depict estimates of the areal extent and depth of flooding corresponding to selected water levels (stages) at the USGS streamgage 03363000 Driftwood River near Edinburgh, Ind. Current conditions at the USGS streamgage in Indiana may be obtained on the Internet at <http://waterdata.usgs.gov/in/nwis/current/?type=flow>. In addition, the information has been provided to the National Weather Service (NWS) for incorporation into their Advanced Hydrologic Prediction Service (AHPS) flood warning system at <http://water.weather.gov/ahps/>. The NWS forecasts flood hydrographs at many places that are often collocated at USGS streamgages. That forecasted peak-stage information, also available on the Internet, may be used in conjunction with the maps developed in this study to show predicted areas of flood inundation.

For this study, flood profiles were computed for the stream reaches by means of a one-dimensional step-backwater model. The model was calibrated using the most current stage-discharge relations at the USGS streamgage 03363000 Driftwood River near Edinburgh, Ind. The hydraulic model was then used to determine elevations throughout the study reaches for nine water-surface profiles for stages at 1-ft intervals referenced to the streamgage datum and ranging from bankfull to nearly the highest recorded water level at the USGS streamgage 03363000 Driftwood River near Edinburgh, Ind. The simulated water-surface profiles were then combined with a geospatial digital elevation model (derived from Light Detection and Ranging (LiDAR) data) in order to delineate the area flooded at each water level.

The availability of these maps along with real-time information available online regarding current stage from USGS streamgages and forecasted stream stages from the NWS 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 post flood recovery efforts.

Introduction

The Camp Atterbury Joint Training and Maneuvers Center, hereafter known as Camp Atterbury, is the home base for members of the Army National Guard and Army Reserves, Marine Corps, and other units that train and mobilize at Camp Atterbury. Camp Atterbury also serves as a training site for both individuals and units from all branches of service for both Reserve and Active Duty training and other special training events. In recent years Camp Atterbury has mobilized over 50,000 and demobilized over 30,000 soldiers, sailors, and airmen for duty in the United States and overseas. The facility has live fire ranges along with more than 33,000 acres of maneuver training area and dozens of artillery and mortar firing points (<http://www.campatterbury.in.ng.mil/AboutUs/tabid/691/Default.aspx>, accessed Oct. 21, 2011).

Camp Atterbury has a varying population depending on military activities at any particular time. The area has undergone flooding numerous times; most notably in 2008. The majority of flood damages have occurred along the Driftwood River, Sugar Creek, and a tributary to the Driftwood River, Nineveh Creek. Flood plains along the study reach are moderately developed and contain a mix of military, residential, agricultural, and forested areas. The town closest to Camp Atterbury is Edinburgh, Indiana, with a population of approximately 4,480 people in the 2010 census (U.S. Census Bureau, 2010).

Prior to this study, Camp Atterbury officials have relied on several information sources to make decisions on how to best alert the public and military personnel and to mitigate flood damages. One source is the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for both Bartholomew and Johnson Counties dated September 15, 1981, and August 2, 2007 respectively (Federal Emergency Management Agency, 1981, 2007). A second source of information is the USGS streamgage 03362500 Sugar Creek near Edinburgh, Ind., from which current or historical water levels (stage) can be obtained at <http://waterdata.usgs.gov/in/nwis/current/?type=flow>. A third source is the National Weather Service's forecast of peak stage at the USGS streamgages through the AHPS site at <http://water.weather.gov/ahps2/index.php?wfo=ind>. Although USGS current stage and NWS information is useful for residents in the immediate vicinity of a streamgage, it is of limited use to residents farther upstream or downstream because the water-surface elevation is not constant along the entire stream channel. Also, FEMA and State emergency management mitigation teams or property owners typically lack information related to how deep the water is at locations other than near USGS streamgages or NWS flood-forecast points.

Purpose and Scope

The purpose of this report is to describe the development of a series of estimated flood-inundation maps for the Driftwood River and Sugar Creek near Camp Atterbury, Edinburgh, Indiana, and to make these maps available to emergency workers and the public on the USGS Flood Inundation Mapping Science Web site available at http://water.usgs.gov/osw/flood_inundation/. The purpose is to (1) provide users with a library of flood inundation maps that correspond to a range of flood elevations on three rivers that come together near Camp Atterbury, and (2) provide links between NWS forecasted peak stage at streamgages during times of flood and the corresponding flood inundation map that shows what that forecast stage will look like on the ground.

The scope of the study was limited to approximately 11.2 miles of the Driftwood River, 5.2 miles of Sugar Creek, and 1.1 mile of the Big Blue River for a total of 17.5 miles. The upstream extent of the Driftwood River begins at the confluence of Sugar Creek and the Big Blue River and ends at a location about 0.6 miles downstream of W. Lowell Road. The upstream extent of Sugar Creek begins at a location about 0.5 mile upstream of the U.S. Government Railroad Bridge and ends at its confluence with Big Blue and Driftwood River. The short reach of the Big Blue River begins at the U.S. Highway 31 bridge down to the confluence with Sugar Creek and was included for modeling and mapping continuity (fig. 1).

Figure 1. Location of study reach for the Driftwood River and Sugar Creek, and location of USGS streamgage and National Weather Service forecast sites.

Table 1. USGS Streamgage information for sites near Edinburgh, Indiana.

Techniques that varied significantly from previously documented methods due to local hydrologic conditions or available data are described in detail in this report. Maps were produced for inundation levels referenced to the water-surface elevations (stage) at the USGS streamgage 03363000 Driftwood River near Edinburgh, Ind., and range from approximately bankfull to near the maximum recorded water level at the gage site.

Study Area Description

The Driftwood River, and those portions of Sugar Creek and Big Blue River that are included in this study, are in south central Indiana near the northern tip of the Scottsburg Lowland physiographic division. The USGS streamgage 03363000 Driftwood River near Edinburgh, Ind., hereafter referred to as the Driftwood River gage, is in Bartholomew County and the USGS streamgage 03362500 on Sugar Creek near Edinburgh, Ind., hereafter referred to as the Sugar Creek gage, is in Johnson County. The drainage area of the Driftwood River ranges from 1,058 mi² at the upstream extent to 1,137 mi² at the downstream extent of the study reach and is one of the shortest rivers in Indiana. The Driftwood River is formed by the confluence of the Big Blue River and Sugar Creek. The Driftwood River originates in the southernmost part of Johnson County, and the stream flows generally southward before flowing into the East Fork White River in Columbus, Ind. There are two major tributaries to the Driftwood River that join the main stem as it flows along the boundary of Camp Atterbury, Nineveh Creek and Muddy Branch Creek. The basin terrain is generally broad terraced valleys and low till-covered hills. The Driftwood River reach is approximately 11.2 mi long, has an average top-of-bank channel width of about 220 ft and an average channel slope of 2.5 ft/mi. The Driftwood River winds through farmlands with wooded areas along both banks. The upper reach is mostly natural while the lower reach shows some development. The main channel within the study reach has three major road crossings: Hendricks Ford Road, Tannehill Road and West Lowell Road.

The drainage area of the Sugar Creek study reach ranges from 468 mi² at the upstream extent to 474 mi² at the downstream extent. Sugar Creek originates in Henry County and the river flows generally southward before joining the Big Blue River to form the Driftwood River. This part of the study reach is about 5.2 mi. in length and is entirely in Johnson County. In the study area, Sugar Creek has an average top-of-bank channel width of about 160 ft and an average channel slope of 3.5 ft/mi. Near the Camp Atterbury property, Sugar Creek flows through mostly forested lowlands and undeveloped gently rolling terrain. The channel has two major road crossings, County Road 650 South and Hospital Road, and a US Government railroad crossing.

Previous Studies

A Flood Insurance Study (FIS) for Bartholomew County (Federal Emergency Management Agency, 1981) was completed by the Louisville District of the U.S. Army Corps of Engineers for the Federal Insurance Administration in August, 1979. That study provided information on the 0.2, 1.0, 2.0, and 10 percent annual exceedance probability water-surface profiles and associated flood plain maps for the Driftwood River, East Fork White River, Flatrock River, and numerous creeks and tributaries. A revised FIS was completed for Johnson County in 2007 (Federal Emergency Management Agency, 2007). That study provided information on the 0.2, 1.0, 2.0, and 10 percent annual exceedance probability water-surface profiles and associated flood plain maps for Sugar Creek, Big Blue River, and numerous creeks, ditches, and swales in Johnson County.

Methods

Development of the inundation maps was accomplished by first constructing water-surface profiles for the study reach. Constructing water-surface profiles included: (1) re-establishment of the streamgage on the Driftwood River and examination of current and historical data from streamgages on

the Driftwood River and Sugar Creek (table 1); (2) collection of hydrologic and steady flow data; (3) collection of topographic, geometric (for structures/bridges), and bathymetric data throughout the study reach; (4) determination of energy-loss factors (roughness coefficients) in the stream channel and flood plain; (5) model calibration and evaluation and (6) computation of water-surface profiles using the U.S. Army Corps of Engineer's HEC-RAS computer program (U.S. Army Corps of Engineers, 2010).

Flood inundation maps were then produced from the results of the modeled water-surface profiles. Production of estimated flood-inundation maps corresponding to targeted water-surface elevations at the gages (gage heights) were done using the U.S. Army Corps of Engineer's HEC-GeoRas computer program (U.S. Army Corps of Engineers, 2009) and a Geographic Information System (GIS). An interface tool that links to USGS real-time streamgage information and (or) NWS forecasted peak gage height to facilitate the online display of user-selected flood-inundation maps was developed.

Constructing Water-Surface Profiles

The water-surface profiles used to produce the nine flood-inundation maps in this study were computed using HEC-RAS, version 4.1.0 (U.S. Army Corps of Engineers, 2010). HEC-RAS is a one-dimensional step-backwater model for simulation of water-surface profiles with steady-state (gradually varied) or unsteady-state flow computation options. The HEC-RAS analysis for this study was done using the steady-state flow computation option.

Hydrologic and Steady Flow Data

The study area hydrologic network consists of two streamgages (fig. 1; table 1). One of the gages, Sugar Creek, already existed; the other gage at Driftwood River had been discontinued in 1991 and was re-activated in 2011 with a continuous recorder and recording tipping-bucket rain gage. Water

level (stage) is measured continuously at both of the sites. All water-surface elevations are referenced to North American Vertical Datum of 1988 (NAVD 88). The gages are equipped with satellite radio transmitters that allow data to be transmitted routinely on the Internet within an hour of collection. Data can be accessed at <http://waterdata.usgs.gov/in/nwis/current/?type=flow> by clicking on the appropriate station number.

Steady-flow data consisted of flow regime, boundary conditions (either known water-surface elevation associated with a previous study, normal depth, or streamgage rating curve value), and peak discharge information.

Topographic/Bathymetric Data

Channel cross sections were developed from USGS field surveys that were carried out in May of 2011. These cross sections provide detailed channel elevation data below the water surface and were collected using hydroacoustic instrumentation to measure depth and Differential Global Positioning System (DGPS) instrumentation to determine horizontal position. Light Detection and Ranging (LiDAR) data were used to provide digital elevation data for the portions of the cross sections that were above the water surface at the time of the surveys. Two sets of LiDAR data were merged for this study. The LiDAR data for Camp Atterbury and Sugar Creek were originated by Indianapolis Mapping and Geographic Infrastructure System in 2010. The LiDAR data for the Driftwood River were originated from Aero-Metric, Inc., Sheboygan, Wisconsin, in 2010.

Various manmade drainage structures (bridges and roadway embankments) in and along the stream affect or have the potential to affect water-surface elevations during floods along the stream. To properly account for these features in the model, structural dimensions for six bridges were measured and surveyed in the field concurrently with the stream channel surveys. A detailed description of the

methods used to acquire and process the topographic and bathymetric data can be found in Bales and others (2007).

Energy Loss Factors

Field observations and high-resolution aerial photographs were used to select initial (pre-calibration) Manning's roughness coefficients (" n " values) for energy (friction) loss calculations. The initial values were adjusted as part of the calibration process. The n -values for the main channel of the Driftwood River range from 0.035 to 0.044, and n -values for overbanks range from 0.045 to 0.12. For the main channel of Sugar Creek, n -values range from 0.031 to 0.035 and n -values for the overbanks range from 0.08 to 0.10. The n -value for the main channel of the Big Blue River was 0.038, and n -values for overbanks range from 0.08 to 0.09.

Model Calibration and Performance

The hydraulic model was calibrated to the gage height-discharge relations at the USGS streamgage 03363000 Driftwood River near Edinburgh, Ind., and verified by comparing the gage height values at the USGS streamgage 03362500 Sugar Creek near Edinburgh, Ind., based on estimated streamflow. Model calibration was accomplished by adjusting Manning's n -values and loss coefficients until the results of the hydraulic computations closely agreed with the known gage height values. Differences between measured and simulated gage heights for models calibrated to gage heights were less than 0.16 ft for the Driftwood River gage (table 2). The differences between estimated and simulated values of gage heights for the Sugar Creek gage were less than 0.25 ft (table 3). The results demonstrate that the model is capable of simulating accurate water levels over a wide range of flows in the basin. However, due to the relatively large distance from the Driftwood River gage to the downstream extent of the study (10.3 miles), the accuracy of the maps may decrease toward the

downstream end. Details on techniques used in model development and calibration can be found in Bales and others (2007).

Table 2. Comparison of hydraulic-model output and stage elevations at USGS streamgage 03363000 Driftwood River near Edinburgh, Indiana.

Table 3. Comparison of hydraulic-model output and stage elevations at USGS streamgage 03362500 Sugar Creek near Edinburgh, Indiana.

Development of Water-Surface Profiles

Profiles were developed for a total of nine gage heights at 1-ft intervals between 9.0 ft and 17.0 ft as referenced to the USGS streamgage 03363000 Driftwood River near Edinburgh, Ind., corresponding to elevations of between 645.6 and 653.6 ft NAVD88.

Models on the Driftwood River were calibrated to produce the selected profile elevations at the USGS streamgage 03363000 (table 4) and the estimated profile elevations at the Sugar Creek gage (table 5). Discharges at the mouth of Nineveh Creek and Muddy Branch Creek flowing in at various locations on the reach and at the downstream extent of the study reach on the Driftwood River were determined by calculating cubic feet per second per square mile (CFSM) that corresponded to the measured discharges at the Driftwood River gage. Discharges at the Pisgah Lake tributary and at the upstream extent of Sugar Creek were also determined using CFSM. The CFSM is defined as the average number of cubic feet of water per second flowing from each square mile of area drained by a stream, assuming that the runoff is distributed uniformly in time and area.

Discharges on Sugar Creek and Big Blue River at the confluence with the Driftwood River were determined by calculating the relative percentage of drainage area to the combined drainage area of the Driftwood River at the gage. The drainage area for Sugar Creek is approximately 45 percent of the

drainage area at the Driftwood River gage. The drainage area for Big Blue River is approximately 55 percent of the drainage area at the Driftwood River gage. It is important to note that the percentages of the two contributing basins is an estimate based on drainage areas, the actual discharge contributions depend on precipitation amounts in each basin. If a large amount of precipitation falls in only one of the contributing basins, the percentage of flow to the Driftwood River increases from that basin.

Conversely, if little or no precipitation occurs in one of the basins there is little contribution to Driftwood River and the percentage decreases. Drainage areas were calculated using a Web-based GIS application called Streamstats which can be accessed at

<http://water.usgs.gov/osw/streamstats/indiana.html>. Profile verification at the Sugar Creek gage used elevations that corresponded to 45 percent of the discharges at the Driftwood River gage. For example, the 9 ft profile at the Driftwood River gage has a discharge of 5020 ft³/s. Forty-five percent of 5,020 ft³/s is 2,259 ft³/s. Using the current stage-discharge rating for the Sugar Creek gage, a discharge of 2,259 cfs corresponds to a stage of 7.62 or an elevation of 653.45 ft. This comparison method was used for each of the nine profiles. The modeled elevations at the Driftwood River gage were all within 0.2 ft of the elevations corresponding to the estimated discharges at the gage. The modeled elevations at the Sugar Creek gage were all within 0.3 ft of the elevations corresponding to the estimated discharges at the gage.

Table 4. Discharge in cubic feet per second (ft³/s) for corresponding gage height estimates at selected locations for the Driftwood River near Edinburgh, Indiana, for simulated water-surface profiles.

Table 5. Discharge in cubic feet per second (ft³/s) for corresponding gage height estimates at selected locations for Sugar Creek near Edinburgh, Indiana, for simulated water-surface profiles.

Inundation Mapping

Flood-inundation maps were created for two stream reaches near USGS streamgages, one of which, the Driftwood River gage, has been designated as a NWS flood-forecast point (as of 2012). The maps were created in a geographic information system by combining the water-surface profiles and digital elevation model data. The digital elevation model (DEM) data were derived from merged LiDAR data sets with horizontal accuracy ranging from 1.0 to 3.2 ft and a vertical accuracy ranging from 0.18 to 0.37 ft. The initial resolution of the DEM with 2.5-ft cell size was later modified to 10-ft cell size in order to reduce the GIS processing time. Estimated flood-inundation boundaries for each simulated profile were developed with HEC–GeoRAS software (U.S. Army Corps of Engineers, 2009). HEC–GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS by using a graphical user interface (Whitehead and Ostheimer, 2009). The interface allows the preparation of geometric data for import into HEC–RAS and processes simulation results exported from HEC–RAS (U.S. Army Corps of Engineers, 2010). The HEC–GeoRAS results at the cross sections were adjusted to ensure a hydraulically reasonable transition of the boundary between modeled cross sections relative to the contour data for the land surface (Whitehead and Ostheimer, 2009). The maps show estimated flood-inundated areas overlaid on high-resolution, georeferenced aerial photographs of the study area for each of the water-surface profiles that were generated by the hydraulic model.

Driftwood River and Sugar Creek, Indiana, Flood-Inundation Maps on the Internet

A USGS Flood Inundation Mapping Science World Wide Web portal has been established by the USGS at http://water.usgs.gov/osw/flood_inundation/ to provide flood inundation information to the public. The maps and data from this study showing the extent of inundated areas can be downloaded in three electronic file formats from that portal: (1) GIS shapefile format (2) keyhole markup language

zipped (kml) file format, and (3) Portable Document (PDF) Format. Users can print out formatted maps quickly or create a customized map using available GIS data layers. In addition, downloadable GIS raster files and kml map files showing the depth of flooded areas are available at the web portal. The estimated inundation areas are shaded to give a general indication of depth of water at any point. All pdf and kml maps show aerial photography beneath the flood layers. The estimated flood-inundation maps are displayed in sufficient detail to note the extent of flooding with respect to individual structures so that preparations for flooding and decisions for emergency response can be performed efficiently. Each stream reach displayed on the Web portal contains links to USGS graphs of the current gage height and streamflow at USGS streamgage 03363000 Driftwood River near Edinburgh, Ind.—to which the inundation maps are referenced. A link also is provided to the NWS Advanced Hydrologic Prediction Service (AHPS) site (<http://water.weather.gov/ahps/>) so that the user can obtain applicable information on forecasted peak gage heights.

Disclaimer for Flood-Inundation Maps

Inundated areas shown 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.

Uncertainty Associated with 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 based on water stages (water-surface elevations) and streamflows at selected USGS streamgages. Water-surface elevations along the stream reaches were estimated by steady-state hydraulic modeling, assuming unobstructed flow, and using discharges and hydrologic conditions anticipated at the USGS

streamgage(s). The hydraulic model reflects the land-cover characteristics and any bridge, dam, levee, or other hydraulic structures existing as of December 2011. Unique meteorological factors (timing and distribution of precipitation) may cause actual discharges along the modeled reach to vary from assumed during a flood and lead to deviations in the water-surface elevations and inundation boundaries shown. Additional areas may be flooded due to 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 or ice jams. The accuracy of the floodwater extent portrayed on these maps will vary with the accuracy of the digital elevation model used to simulate the land surface. Additional uncertainties and limitations pertinent to this study are described in the document accompanying this set of flood inundation map plates.

If this series of flood-inundation maps will be used in conjunction with National Weather Service (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 or snowmelt, (2) simulate the movement of floodwater as it proceeds downstream, and (3) predict the flow and stage (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:

http://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf

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Summary

A series of estimated flood-inundation maps were developed in cooperation with Camp Atterbury Joint Maneuver Training Center for the Driftwood River and Sugar Creek near Edinburgh, Indiana. In addition to maps showing areas of inundation, downloadable GIS raster files and kml map files showing the depth of flooded areas were produced. The estimated inundation areas are shaded to give a general indication of depth of water at any point.

These maps, available at a USGS Web portal, in conjunction with the real-time stage data from the USGS streamgage 03363000 Driftwood River near Edinburgh, Ind., and National Weather Service flood-stage forecasts, can help to guide the general public in taking individual safety precautions and can provide Camp Atterbury officials with a tool to efficiently manage emergency flood operations and flood mitigation efforts.

The maps were developed using the U.S. Army Corps of Engineers' HEC-RAS and HEC-GeoRAS programs to compute water-surface profiles and to delineate estimated flood-inundation areas for selected stream stages. The maps show estimated flood-inundation areas overlaid on high-resolution, georeferenced, aerial photographs of the study area. Maps reflect profiles developed for nine gage heights between 9 and 17 ft (645.6 and 653.6 ft NAVD88) at USGS streamgage 03363000 Driftwood River near Edinburgh, Ind.

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