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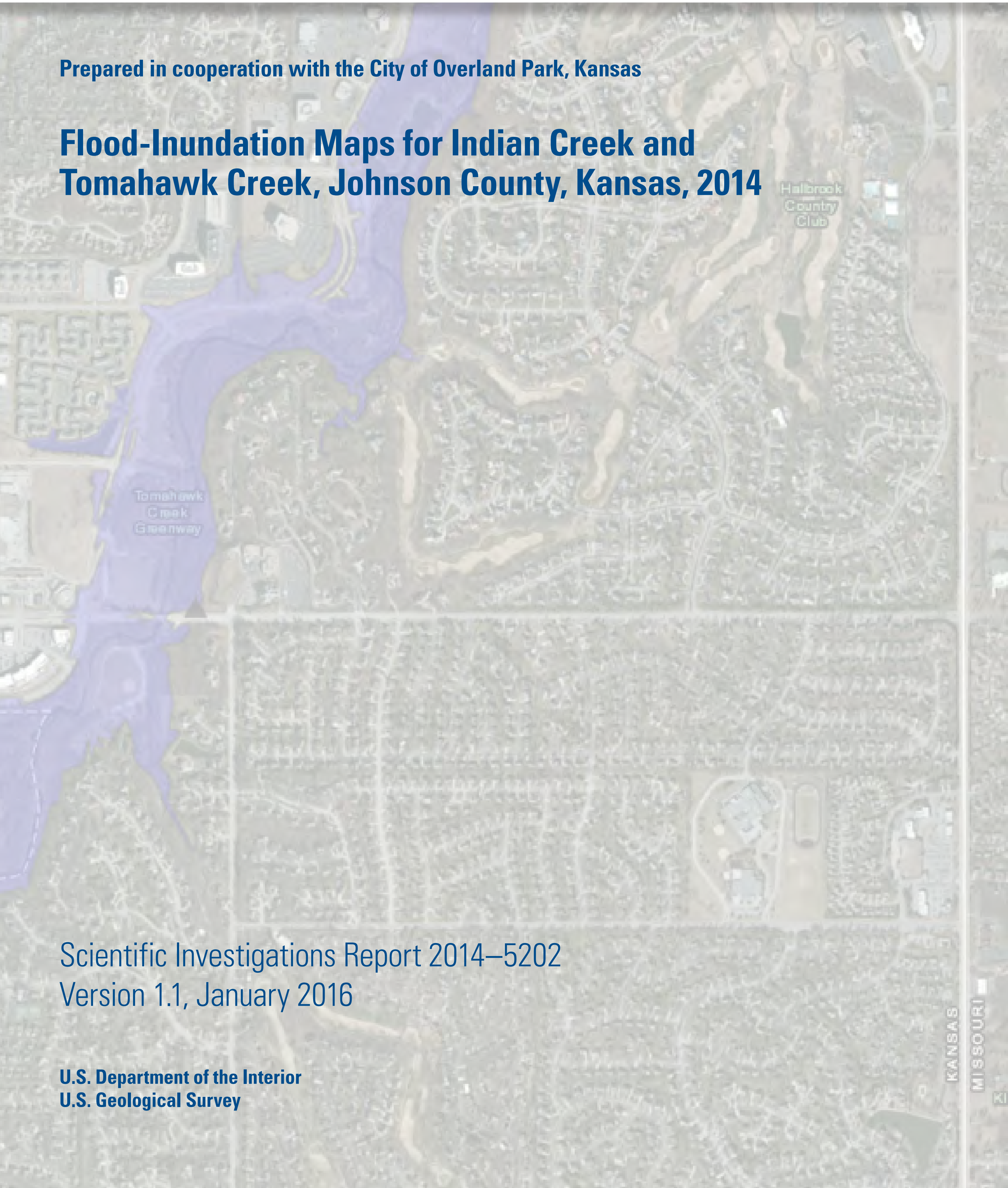
Flood-Inundation Maps for Indian Creek and Tomahawk Creek, Johnson County, Kansas, 2014

Scientific Investigations Report 2014–5202
Version 1.1, January 2016

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



Cover background illustration: figure 3 from this report.

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Contents

Figures

Tables

Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
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)

Datums

Vertical coordinate information is referenced to (1) stage, or the height above an arbitrary datum established at a streamgage; and (2) elevation, or 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).

Supplemental Information

Slope is given in feet per mile (ft/mi).

Flood-Inundation Maps for Indian Creek and Tomahawk Creek, Johnson County, Kansas, 2014

By Arin J. Peters and Seth E. Studley

Abstract

Digital flood-inundation maps for a 6.4-mile upper reach of Indian Creek from College Boulevard to the confluence with Tomahawk Creek, a 3.9-mile reach of Tomahawk Creek from 127th Street to the confluence with Indian Creek, and a 1.9-mile lower reach of Indian Creek from the confluence with Tomahawk Creek to just beyond the Kansas/Missouri border at State Line Road in Johnson County, Kansas, were created by the U.S. Geological Survey in cooperation with the city of Overland Park, Kansas. The flood-inundation maps, which can be accessed through the U.S. Geological Survey 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 U.S. Geological Survey streamgages on Indian Creek at Overland Park, Kansas; Indian Creek at State Line Road, Leawood, Kansas; and Tomahawk Creek near Overland Park, Kansas. Near real time stages at these streamgages may be obtained on the Web from the U.S. Geological Survey National Water Information System at http://waterdata.usgs.gov/nwis or the National Weather Service Advanced Hydrologic Prediction Service at http://water.weather.gov/ahps/, which also forecasts flood hydrographs at these sites.

Flood profiles were computed for the stream reaches by means of a one-dimensional step-backwater model. The model was calibrated for each reach by using the most current stage-discharge relations at the streamgages. The hydraulic models were then used to determine 15 water-surface profiles for Indian Creek at Overland Park, Kansas; 17 water-surface profiles for Indian Creek at State Line Road, Leawood, Kansas; and 14 water-surface profiles for Tomahawk Creek near Overland Park, Kansas, for flood stages at 1-foot intervals referenced to the streamgage datum and ranging from bankfull to the next interval above the 0.2-percent annual exceedance probability flood level (500-year recurrence interval). The simulated water-surface profiles were then combined in a geographic information system with a digital elevation model derived from light detection and ranging data (having a 0.429-foot vertical and 0.228-foot horizontal accuracy) to delineate the area flooded at each water level.

The availability of these maps, along with Web information regarding current stage from the U.S. Geological Survey streamgages and forecasted high-flow stages from the National Weather Service, will provide emergency management personnel and residents with information that is critical for flood response activities such as evacuations, road closures, and postflood recovery efforts.

Introduction

The adjacent communities of Overland Park and Leawood, Kansas (fig. 1), together form a large urban community with a total estimated population of 205,239 (U.S. Bureau of Census, 2014). Overland Park (fig. 1) has had moderate flooding events numerous times, most notably in 1984, 1990, and 1998 (U.S. Geological Survey, 2014a).

Overland Park officials relied on several information sources, all of which are available on the Web, to make decisions on how to best alert the public and mitigate flood damages. One source is the Federal Emergency Management Agency (FEMA) flood insurance study (FIS) for Johnson County, Kansas (fig. 1), and incorporated areas dated August 3, 2009 (Federal Emergency Management Agency, 2009). A second source of information is U.S. Geological Survey (USGS) streamgages on Indian Creek at Overland Park, Kansas (06893300); Indian Creek at State Line Road, Leawood, Kansas (06893390); and Tomahawk Creek near Overland Park, Kansas (06893350; fig. 1), from which current or historical water levels (stage) can be obtained (U.S. Geological Survey, 2014a). A third source is the National Weather Service (NWS) forecast of peak stage at the USGS Tomahawk Creek near Overland Park streamgage through the Advanced Hydrologic Prediction Service (AHPS) site (National Weather Service, 2014).

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 the water-surface elevation is not constant along the entire stream reach. Knowledge of water

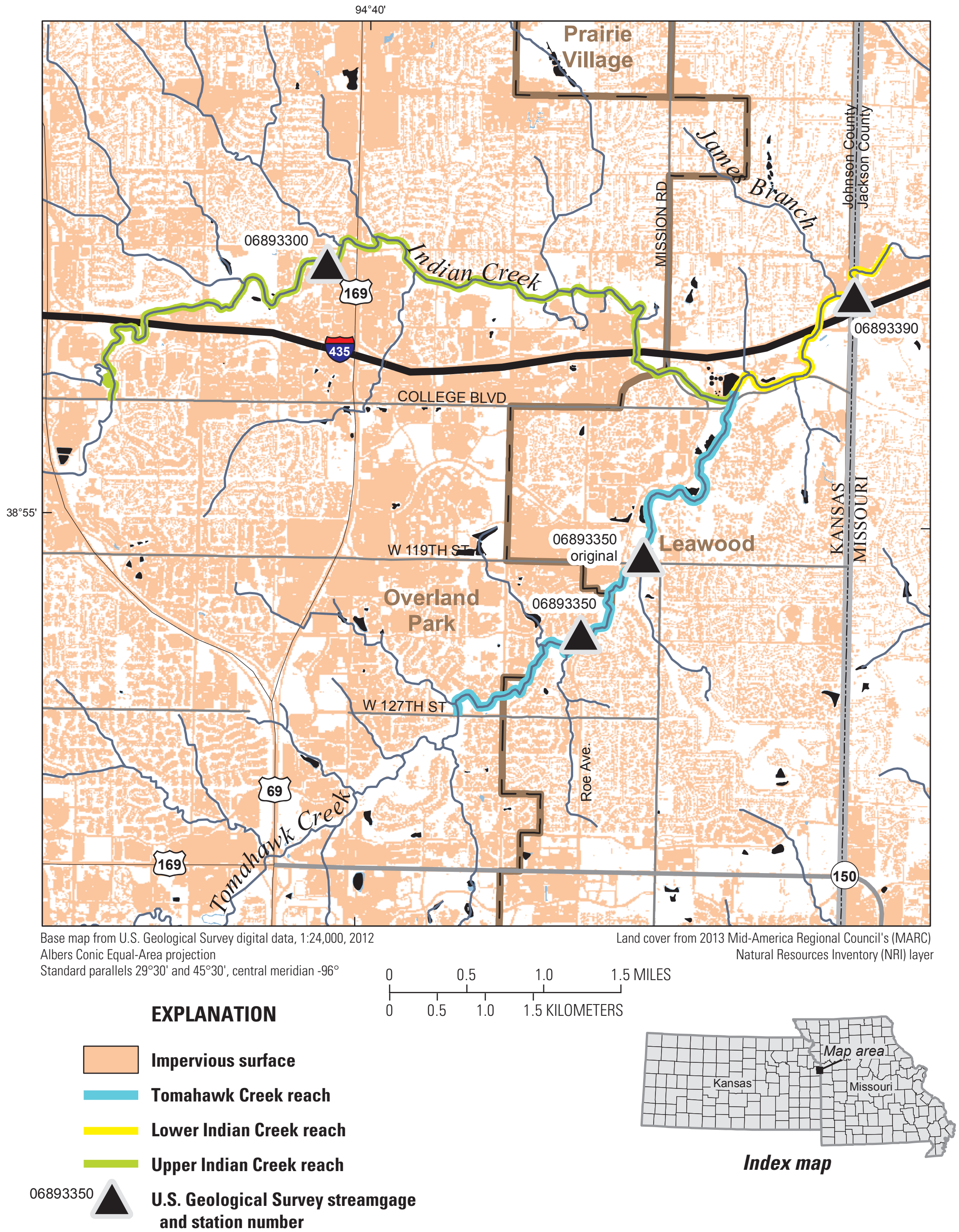

Figure 1. Location of study reaches for Indian and Tomahawk Creeks in Johnson County, Kansas, and location of U.S. Geological Survey streamgages.

level at a streamgage is difficult to translate into depth and areal extent of flooding at points distant from the streamgage. To address these informational gaps, the USGS, in cooperation with the city of Overland Park, Kansas, produced a library of flood-inundation maps that are referenced to the stages recorded at USGS streamgages on Indian and Tomahawk Creeks. By referring to the appropriate map, 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 plans for notification or evacuation of residents in potential danger for some distance upstream and downstream from the streamgage. In addition, the capability to visualize the potential extent of flooding has been determined to 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 the development of a series of estimated flood-inundation maps for Indian and Tomahawk Creeks at Leawood and Overland Park, Kansas (fig. 1), and identify where on the Web the maps can be located and ancillary data (geographic information system [GIS] flood polygons and depth grids) can be downloaded.

The scope of the study was limited to a 6.4-mile (mi) upper reach of Indian Creek from College Boulevard to the confluence with Tomahawk Creek, a 3.9-mi reach of Tomahawk Creek from 127th Street to the confluence with Indian Creek, and a 1.9-mi lower reach of Indian Creek from the confluence with Tomahawk Creek to just beyond the Kansas/Missouri border at State Line Road in Johnson County, Kansas (fig. 1).

The maps were produced for flood levels referenced to the stage recorded at three USGS streamgages. Indian Creek at Overland Park, Kansas (06893300), is within the upper reach of Indian Creek (fig. 1). Tomahawk Creek near Overland Park, Kansas (06893350), is in the upper one-half of the Tomahawk Creek reach (fig. 1). Indian Creek at State Line Road, Leawood, Kansas (06893390), is at the end of the lower reach of Indian Creek (fig. 1).

The maps cover a range in stage from 8 to 22 feet (ft; streamgage datum) at Indian Creek at Overland Park, 10 to 23 ft at Tomahawk Creek near Overland Park, and 17 to 33 ft at Indian Creek at State Line Road, Leawood. The lower stage at each site represents approximately bankfull, and the upper stage (figs. 2–4) exceeds the stage that corresponds to the estimated 0.2-percent annual exceedance probability flood (500-year recurrence interval flood).

Methods used are generally cited from previously published reports. If techniques differed substantially from previously documented methods because of local hydrologic conditions or availability of data, they are described in detail in this report. Maps were produced for water levels referenced to the stages at each of the streamgages that range from approximately bankfull to the stage corresponding to the 0.2-percent annual exceedance probability flow.

Study Area Description

Indian Creek and Tomahawk Creek are located in northeast Kansas in the Osage Cuestas region (Omernik, 1987). The drainage areas of the study locations range from 20.5 square miles (mi^2) at the Tomahawk Creek near Overland Park, Kansas, streamgage to 64.2 mi^2 at the downstream extent of the study reach (table 1). The headwaters originate in Johnson County, Kansas, and the streams flow generally northeast (fig. 1). No primary tributaries to Indian Creek join the main stem as it flows through Overland Park until Tomahawk Creek joins it near the Kansas/Missouri border (fig. 1). The study

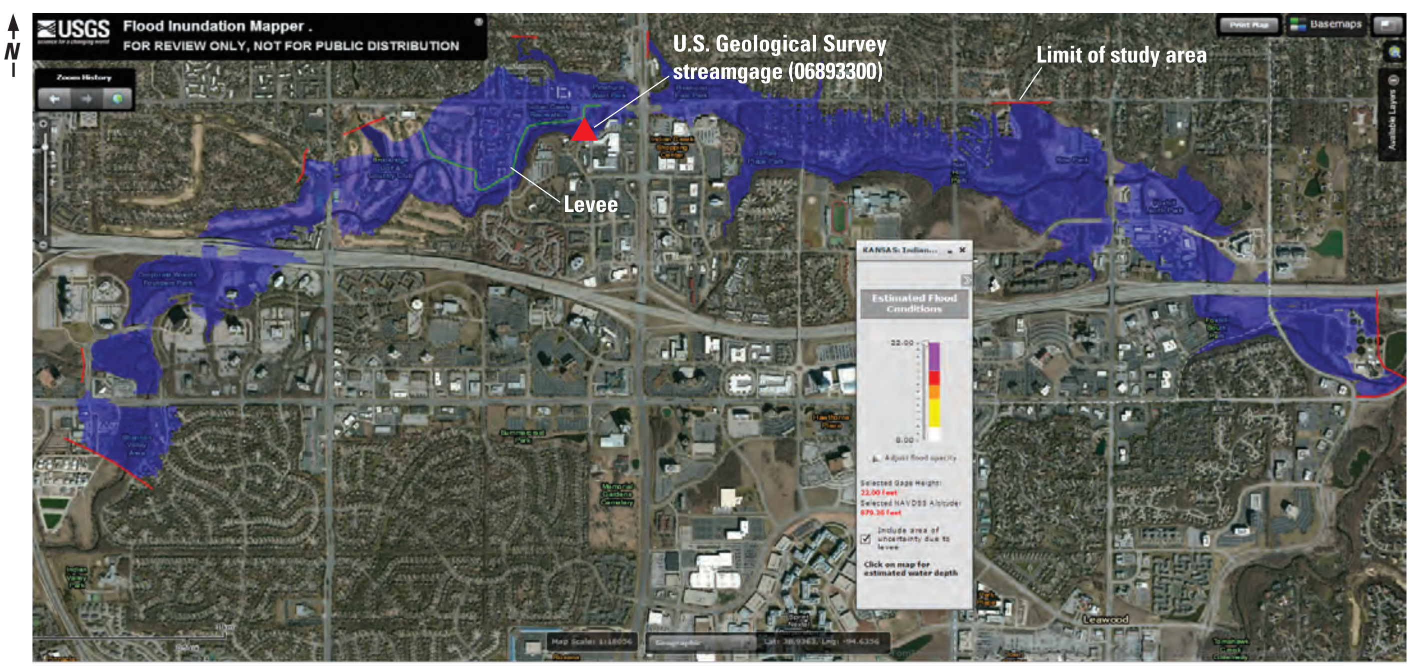

Figure 2. Flood-inundation map for the upper reach of Indian Creek corresponding to a stage of 22.00 feet at the U.S. Geological Survey streamgage (06893300). Basemap is a screenshot of the online interactive Flood Inundation Mapper web site at: http://wimcloud.usgs.gov/apps/FIM/FloodInundationMapper.html. The color bar in the stage selector references National Weather Service flood categories (white, no flooding; yellow, action stage; orange, flood stage; red, moderate flood stage; purple, major flood stage).

Figure 3. Flood-inundation map for Tomahawk Creek corresponding to a stage of 23.00 feet at the U.S. Geological Survey streamgage (06893350). Basemap is a screenshot of the online interactive Flood Inundation Mapper web site at: http://wimcloud.usgs.gov/apps/FIM/FloodInundationMapper.html.

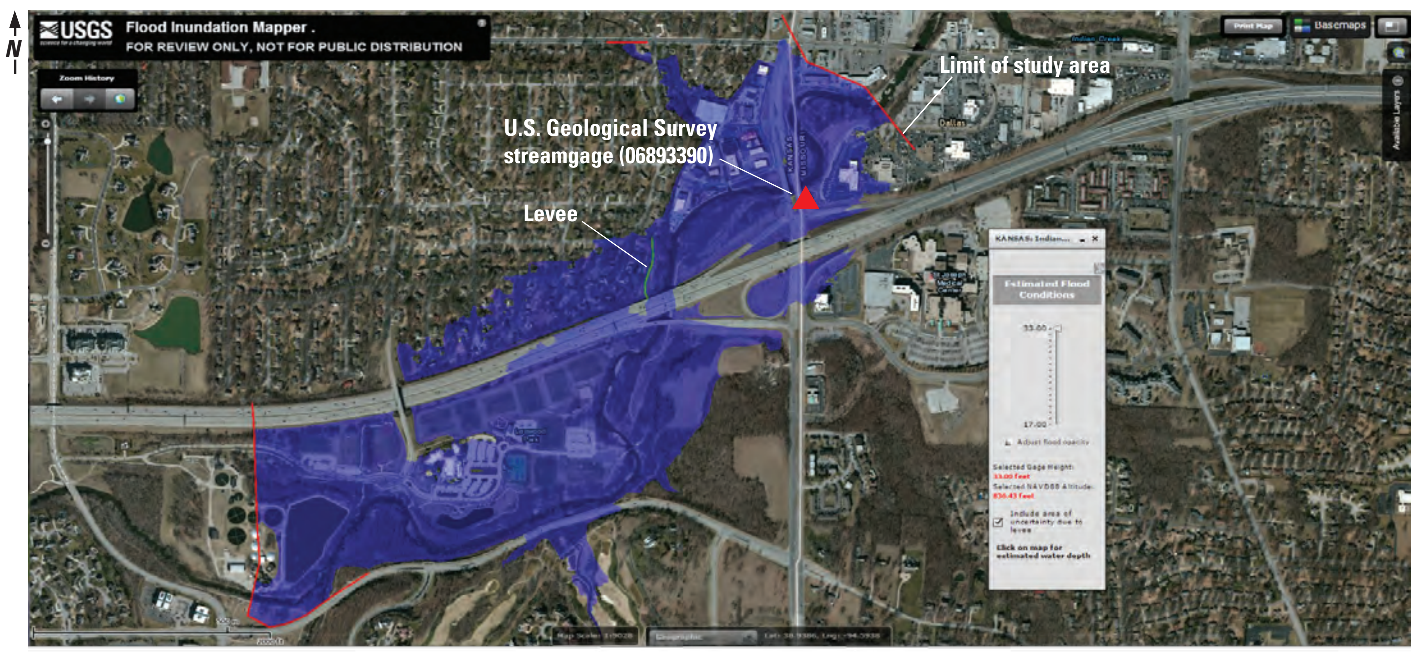

Figure 4. Flood-inundation map for the lower reach of Indian Creek corresponding to a stage of 33.00 feet at the U.S. Geological Survey streamgage (06893390). Basemap is a screenshot of the online interactive Flood Inundation Mapper web site at: http://wimcloud.usgs.gov/apps/FIM/FloodInundationMapper.html.

reaches are approximately 6.4 mi long for the upper reach of Indian Creek, 3.9 mi long for Tomahawk Creek, and 1.9 mi long for the lower reach of Indian Creek from Tomahawk Creek to just beyond the Kansas/Missouri border (fig. 1) and have an average top-of-bank channel width of 70–85 ft and an average channel slope of 11 feet per mile (described in the "Topographic and Bathymetric Data" section). All of the land contiguous to the study reaches is classified as urban or developed (Fry and others, 2011). The main channels within the study reaches have 23 primary road crossings and 10 other structures (foot bridges and cart paths) that lie within the channel or the adjacent flood plain.

Two levee protected areas exist along Indian Creek—one in the upper Indian Creek reach (fig. 2) and another in the lower Indian Creek reach (fig. 4). These two levees are not included in the U.S. Army Corps of Engineers (USACE) National Levee Database, and the overall effectiveness of these levees is unknown. As-built plans for these levees were provided by representatives of the cities of Overland Park and Leawood, Kansas (Joe Johnson, City of Leawood Public Works Department, written commun., 2014; Lorraine Basalo, City of Overland Park Public Works Department, written commun., 2014). The levee in the upper Indian Creek reach was simulated as a levee in the hydrologic model developed for this study, whereas the levee in the lower Indian Creek reach was not. The levees and the uncertain protection they provide are shown as such on the flood-inundation maps at the request of representatives from the cities of Overland Park and Leawood, Kansas (Joe Johnson, City of Leawood Public Works Department, written commun., 2014; Lorraine Basalo, City of Overland Park Public Works Department, written commun., 2014).

Previous Studies

The current FIS for Indian Creek in Johnson County, Kansas (Federal Emergency Management Agency, 2009), was completed by Phelps Engineering, Inc. in 2006. The current FIS for Tomahawk Creek in Johnson County, Kansas (Federal Emergency Management Agency, 2009), was completed by Phelps Engineering, Inc. in 1998. Those studies provided information on the 1.0- and 0.2-percent annual exceedance probability water-surface profiles and associated flood plain (table 2). Estimates of the peak discharges for the 10-, 2.0-, 1.0-, and 0.2-percent annual exceedance probability flood along Indian Creek and Tomahawk Creek, as listed in table 2, are described by Federal Emergency Management Agency (2009).

Creation of Flood-Inundation-Map Library

The USGS has standardized the procedures for creating flood-inundation maps for flood-prone communities (U.S. Geological Survey, 2014b) so that the process followed and products produced are similar regardless of which USGS office is responsible for the work.

Tasks specific to development of the maps for this report were (1) relocation of one streamgage on Tomahawk Creek in 2014 (fig. 1); (2) collection of topographic data and geometric data (for structures/bridges) throughout the study reach; (3) determination of energy-loss factors (roughness coefficients) in the stream channel and flood plain, and compilation of steady-flow data; (4) computation of water-surface profiles using the USACE Hydrologic Engineering Center's River Analysis System (HEC–RAS) hydraulic model (U.S. Army Corps of Engineers, 2010); (5) production of estimated

Table 1. Information for U.S. Geological Survey streamgages along Indian Creek and Tomahawk Creek in Johnson County, Kansas.

[mi^2, square mile; ft, foot; ft^3/s, cubic foot per second]

Station name	Station number (fig.1)	Drainage area (mi^2)	Latitude	Longitude	Period of peak-flow record	Maximum recorded stage (ft) and date	Maximum discharge (ft^3/s) and date
Indian Creek at Overland Park, Kansas	06893300	26.6	38°56′26″	94°40′16″	Mar. 7, 1963 to date of publishing	17.78, June 9, 1984	12,800, June 9, 1984
Tomahawk Creek near Overland Park, Kansas	06893350	20.5	38°54′23″	94°38′24″	1970–1982 and 2011 to date of publishing	19.17, August 13, 1982	8,250, August 13, 1982
Indian Creek at State Line Road, Leawood, Kansas	06893390	64.2	38°56′18″	94°36′28″	Mar. 22, 2003 to date of publishing	25.5, June 14, 2010	18,700, June 14, 2010

Table 2. Peak discharges for selected annual exceedance probabilities on Indian and Tomahawk Creeks in Johnson County, Kansas.

[mi^2, square mile; ft^3/s, cubic foot per second; sta. no., station number; Data from Federal Emergency Management Agency, 2009]

Location on Indian and Tomahawk Creeks (fig.1)	Drain-age area (mi^2)	Estimated discharges (ft^3/s) for indicated annual exceedance probabilities (in percent)			
		10	2	1	0.2
Indian Creek at Overland Park, Kansas. (sta. no. 06893300)	26.6	9,175	14,662	17,303	23,350
Tomahawk Creek near Overland Park, Kansas. (sta. no. 06893350)	20.5	8,380	11,895	13,425	17,145
Indian Creek at State Line Road, Leawood, Kansas. (sta. no. 06893390)	64.2	18,206	26,518	30,753	41,210

flood-inundation maps at incremental stream stages using the USACE HEC–GeoRas computer program (U.S. Army Corps of Engineers, 2009) and a GIS; and (6) development of a Web interface that links to USGS real-time streamgage information and NWS forecasted peak stage to facilitate the display of user-selected flood-inundation maps on the Web.

Computation of Water-Surface Profiles

The water-surface profiles used to produce the 46 flood-inundation maps (15 for the upper reach of Indian Creek, 14 for the Tomahawk Creek reach, and 17 for the lower reach of Indian Creek; fig. 1) in this study were computed using HEC–RAS version 4.1 (U.S. Army Corps of Engineers, 2010). The HEC–RAS is a one-dimensional step-backwater model for simulation of water-surface profiles with gradually varied, steady-state (or unsteady-state) flow computation options.

Hydrologic Data

The study reaches include three streamgages (fig. 1). Stage is measured every 15 minutes, transmitted hourly by a satellite radio in the streamgage, and made available on the Web through the USGS National Water Information System (NWIS; U.S. Geological Survey, 2014c). 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 857.26 ft for 06893300, 803.43 ft for 06893390, and 850.44 ft for 06893350 (fig. 1). Continuous records of streamflow are computed from a stage-discharge relation, which has been developed for the streamgage, and are available through the USGS NWIS Web site (U.S. Geological Survey, 2014a). The data from these three sites were used to calibrate the models. The model for Tomahawk Creek was calibrated at the 119th Street location (06893350 original, fig. 1), early in the project when the gage was located there. Then the flood-inundation maps were developed for the Roe Avenue location (06893350, fig. 1) when the gage was relocated there in August of 2014, using a simulated stage-discharge relation resulting from the calibration with the stage-discharge relation developed at the original streamgage location on 119th Street, about 0.75 mi downstream.

The rated discharges used in the model simulations (tables 3–5) were extracted from the current stage-discharge relation at each streamgage and correspond to the target rated stages. No primary tributaries join Indian and Tomahawk Creeks within the study reaches (fig. 1); therefore, the streamgage-derived discharges were not adjusted for tributary inflows but were held constant throughout the study reach for a given profile.

Topographic and Bathymetric Data

All topographic data used in this study are referenced vertically to the NAVD 88 and horizontally to the North American Datum of 1983 (NAD 83). Cross-section elevation data and average unwetted channel slope were obtained from a digital elevation model (DEM) that was derived from light detection and ranging (lidar) data collected during December 2011 by M.J. Harden Associates. Postprocessing of these data was completed by M.J. Harden Associates in April 2012. The original lidar data have a horizontal accuracy of 0.228 ft and vertical accuracy of 0.429 ft at a 95-percent confidence level for the open terrain land-cover category (root mean squared error of 0.410 ft).

Hydraulic Structures

Various structures including bridges, culverts, roadway embankments, levees, and dams have the potential to affect water-surface elevations during floods along the stream. Bridge-geometry data were obtained from field surveys completed by the USGS.

Two levee-protected areas exist along Indian Creek including one in the upper Indian Creek reach (fig. 2) and another in the lower Indian Creek reach (fig. 4). These levees provide an uncertain level of flood protection to a certain water-surface elevation but not for the entire range of flows simulated in each of the two respective reaches. These two levees are not included in the USACE National Levee Database; therefore, the landward side of both levees is shown as areas of uncertainty up to the elevations of the top of the levees. The levee in the upper Indian Creek reach provides an uncertain level of flood protection to a stage of 18 ft at the Indian Creek at Overland Park streamgage (06893300). The

Table 3. Calibration of model to target rated stages, and observed and simulated water-surface elevations for the streamgage at Indian Creek at Overland Park, Kansas (station number 06893300, fig. 1), with corresponding discharges based on the most current stage-discharge relation (rating number 48).

[ft^3/s, cubic foot per second; NAVD 88, North American Vertical Datum of 1988; ft, foot; flood-inundation maps available online at http://dx.doi.org/10.3133/sir20145202]

Model calibration results					
Rated discharge (ft^3/s)	Observed elevation (NAVD 88)	Simulated elevation (NAVD 88)	Rated stage (ft)	Simulated stage (ft)	Difference from rating (ft)
616	865.26	865.62	8	8.36	0.36
1,140	866.26	866.37	9	9.11	0.11
1,820	867.26	867.51	10	10.25	0.25
2,670	868.26	868.64	11	11.38	0.38
3,690	869.26	869.71	12	12.45	0.45
4,880	870.26	870.63	13	13.37	0.37
6,240	871.26	871.52	14	14.26	0.26
7,780	872.26	872.49	15	15.23	0.23
9,500	873.26	873.44	16	16.18	0.18
11,400	874.26	874.47	17	17.21	0.21
13,500	875.26	875.34	18	18.08	0.08
15,700	876.26	876.26	19	19.00	0.00
18,200	877.26	877.26	20	20.00	0.00
20,800	878.26	878.21	21	20.95	-0.05
23,600	879.26	879.22	22	21.96	-0.04

Table 4. Calibration of model to target rated stages, and observed and simulated water-surface elevations for the streamgage at Indian Creek at State Line Road, Leawood, Kansas (station number 06893390, fig. 1), with corresponding discharges based on the most current stage-discharge relation (rating number 4).

[ft^3/s, cubic foot per second; NAVD 88, North American Vertical Datum of 1988 ; ft, foot; flood-inundation maps available online at http://dx.doi.org/10.3133/sir20145202]

Model calibration results					
Rated discharge (ft^3/s)	Observed elevation (NAVD 88)	Simulated elevation (NAVD 88)	Rated stage (ft)	Simulated stage (ft)	Difference from rating (ft)
3,300	820.43	820.88	17	17.45	0.45
4,120	821.43	821.71	18	18.28	0.28
5,060	822.43	822.56	19	19.13	0.13
6,120	823.43	823.44	20	20.01	0.01
7,430	824.43	824.37	21	20.94	-0.06
9,120	825.43	825.33	22	21.90	-0.10
11,000	826.43	826.30	23	22.87	-0.13
13,200	827.43	827.33	24	23.90	-0.10
15,500	828.43	828.32	25	24.89	-0.11
18,100	829.43	829.36	26	25.93	-0.07
20,900	830.43	830.37	27	26.94	-0.06
23,900	831.43	831.34	28	27.91	-0.09
27,200	832.43	832.32	29	28.89	-0.11
30,800	833.43	833.37	30	29.94	-0.06
34,600	834.43	834.34	31	30.91	-0.09
38,700	835.43	835.45	32	32.02	0.02
43,000	836.43	836.43	33	33.00	0

Table 5. Calibration of model to target rated stages, and observed and simulated water-surface elevations for the streamgage at Tomahawk Creek near Overland Park, Kansas (station number 06893350, original location at 119th Street, fig. 1), with corresponding discharges from the simulated stage-discharge relation based on the current stage-discharge relation (rating number 3) derived at the original location.

[ft^3/s, cubic foot per second; NAVD 88, North American Vertical Datum of 1988; ft, foot; flood-inundation maps available online at http://dx.doi.org/10.3133/sir20145202]

Model calibration results					
Rated discharge (ft^3/s)	Observed elevation (NAVD 88)	Simulated elevation (NAVD 88)	Rated stage (ft)	Simulated stage (ft)	Difference from rating (ft)
2,490	854.33	854.82	10	10.49	0.49
3,060	855.33	855.64	11	11.31	0.31
3,670	856.33	856.43	12	12.10	0.10
4,360	857.33	857.24	13	12.91	-0.09
5,150	858.33	858.11	14	13.78	-0.22
6,000	859.33	858.99	15	14.66	-0.34
6,990	860.33	859.97	16	15.64	-0.36
8,290	861.33	861.2	17	16.87	-0.13
9,720	862.33	862.64	18	18.31	0.31
11,400	863.33	863.7	19	19.37	0.37
13,600	864.33	864.34	20	20.01	0.01
16,100	865.33	865.26	21	20.93	-0.07
18,900	866.33	866.23	22	21.90	-0.10
22,000	867.33	867.46	23	23.13	0.13

levee in the lower Indian Creek reach provides an uncertain level of flood protection to a stage of 31 ft at the Indian Creek at State Line Road, Leawood, Kansas, streamgage (06893390). Showing these uncertainty areas as they are on the maps was requested by representatives of the cities of Overland Park and Leawood, Kansas (Joe Johnson, City of Leawood Public Works Department, written commun., 2014; Lorraine Basalo, City of Overland Park Public Works Department, written commun., 2014).

Energy-Loss Factors

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 (referred to herein as "*n* value"). Field observations and high-resolution aerial photographs were used to select initial (precalibration) *n* values for energy-loss (friction-loss) calculations.

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 streamgage were minimized. The final *n* values ranged from 0.020 to 0.045 for the main channel and 0.015 to 0.15 for the overbank areas modeled in this analysis.

Hydraulic Model

The HEC–RAS analysis for this study was completed using the steady-state flow computation option. Steady-state flow data consisted of flow regime, boundary conditions, and rated discharges that produced water-surface elevations at the streamgage cross section that matched target rated water-surface elevations. These target water-surface elevations coincided with even 1-ft increments of stage referenced to the local streamgage datum. Subcritical (tranquil) flow regime was assumed for the simulations. Normal-depth boundary conditions were assumed by using a friction slope estimated from the average streambed slope through the reach unless miscellaneous discharge measurements referenced to a known datum were available. The rated discharges that were used in the model were discussed in the "Hydrologic Data" section.

The HEC–RAS model was calibrated to the current stage-discharge relation at each of the three streamgages. Model calibration was accomplished by adjusting *n* values and, in some cases, adding ineffective flow areas until the results of the hydraulic computations closely agreed with the observed water-surface elevations for the rated discharges. Differences between observed and simulated water-surface elevations for the 46 simulated flows at the USGS streamgages were equal to or less than 0.50 ft (tables 3–5). The results demonstrate that the model is capable of simulating accurate water levels over a wide range of flows in the Indian/Tomahawk Creek basins. No high-water marks were available to aid in calibration.

Development of Water-Surface Profiles

The calibrated hydraulic model was used to generate water-surface profiles for three reaches on Indian and Tomahawk Creeks in Johnson County, Kansas, referenced to the most current stage-discharge relation at a streamgage within each reach (fig. 1). A total of 15 profiles were generated at 1-ft intervals between 8 ft and 22 ft as referenced to rating number 48 at Indian Creek at Overland Park, Kansas (06893300; table 3; fig. 1). These stages correspond to elevations from 865.26 ft to 879.26 ft NAVD 88 (table 3). A total of 14 profiles were generated at 1-ft intervals between 10 ft and 23 ft as referenced to rating number 3 at Tomahawk Creek near Overland Park, Kansas (06893350, original location at 119th Street; table 5; fig. 1). These stages correspond to elevations from 854.33 ft to 867.33 ft NAVD 88 (table 5). After the Tomahawk Creek model was calibrated at the 119th Street gage, the gage was relocated 0.75 mi upstream to Roe Avenue, and the flood-inundation maps were referenced to stages at the Roe Avenue location based on a relation developed between the two sites. A total of 17 profiles were generated at 1-ft intervals between 17 ft and 33 ft as referenced to rating number 4 at Indian Creek at State Line Road, Leawood, Kansas (06893390; table 4; fig. 1). These stages correspond to elevations from 820.43 ft to 836.43 ft NAVD 88 (table 4).

Development of Flood-Inundation Maps

Flood-inundation maps were created for three USGS streamgages (figs. 2–4), and the streamgage Indian Creek at Overland Park, Kansas (06893300) has been designated as a NWS flood-forecast point. The maps were created in a GIS by combining the water-surface profiles and DEM data. The DEM data were derived from the same lidar data described previously in the “Topographic and Bathymetric Data” section and, therefore, have an estimated vertical accuracy of 2 ft (plus or minus 1 ft), which is based on rounding the computed vertical accuracy of the lidar data (plus or minus about 0.4 ft) to the nearest foot. Estimated flood-inundation boundaries for each simulated profile were developed with HEC–GeoRAS software (U.S. Army Corps of Engineers, 2009), which 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 is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS by using a graphical user interface (Whitehead and Ostheimer, 2009). Shapefile polygons and depth grids of the inundated areas for each profile were modified, as required, in the ArcMap application of ArcGIS (Esri, 2013) to ensure a hydraulically reasonable transition of the flood boundaries between modeled cross sections.

Any inundated areas that were detached from the main channel were examined to identify subsurface connections, such as through culverts under roadways, with the main streams. 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. The flood-inundation areas are overlaid on high-resolution, georeferenced, aerial photographs of the study area. Bridge surfaces in inundated areas 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. Estimates of water depth can be obtained from the depth-grid data that are included with the presentation of the flood maps on an interactive USGS mapping application described in the “Flood-Inundation Map Delivery” section. The flood maps corresponding to the highest simulated water-surface profiles at each streamgage are presented in figures 2–4.

Flood-Inundation Map Delivery

The flood-inundation maps (figs. 2–4) and current study documentation are available online at the USGS Publications Warehouse (http://dx.doi.org/10.3133/sir20145202). Also, a flood-inundation mapping science Web site has been established at http://water.usgs.gov/osw/flood_inundation/ to provide a portal for USGS flood-inundation study information to the public. That Web site has a link to interactive online map libraries that can be downloaded in several commonly used electronic file formats. At the map library site, each stream reach displayed contains further links to NWISWeb graphs of the current stage and streamflow at USGS streamgages 06893300, 06893350, and 06893390 (fig. 1) to which the inundation maps are referenced. A link also is provided to the NWS AHPS site (http://water.weather.gov/ahps/) so that the user can obtain applicable information on forecasted peak stage if applicable. 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 completed efficiently. 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. A shaded building should not be interpreted to mean that the structure is completely submerged; rather, it means that bare-earth surfaces in the vicinity of the building are inundated. In these instances, the water depth (as indicated in the mapping application by holding 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.

Disclaimer for Flood-Inundation Maps

The flood-inundation maps (figs. 2–4) should not be used for navigation, regulatory, permitting, or other legal purposes. The USGS provides these maps 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 (figs. 2–4) 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 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 streamflows and hydrologic conditions anticipated at the USGS streamgages. 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 streamflows along the modeled reach to differ 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 because of unanticipated conditions such as changes in the streambed elevation or roughness, backwater into primary 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 differ 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 http://water.weather.gov/ahps/pcpn_and_river_forecasting.pdf.

Another rather large area of uncertainty with these flood-inundation maps is that the two levees on Indian Creek provide uncertain levels of flood protection on the landward side of these structures. These levees are not certified by the USACE and, therefore, any protection they may provide is not guaranteed. The levees also do not provide flood protection for the full range of stages simulated in these maps and, when overtopped, flooding will result on the landward side of these structures.

Summary

A series of 46 digital flood-inundation maps were developed by the U.S. Geological Survey, in cooperation with the City of Overland Park, Kansas, for two reaches on Indian Creek from College Boulevard to the Kansas/Missouri State Line and one reach on Tomahawk Creek from 127th Street to its confluence with Indian Creek totaling 12.2 miles. The maps were developed by using the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC–RAS) and HEC–GeoRAS programs to compute water-surface profiles and delineate estimated flood-inundation areas and depths of flooding for selected stream stages. The HEC–RAS hydraulic model was calibrated to the current stage-discharge relation at Indian Creek at Overland Park, Kansas; Indian Creek at State Line Road, Leawood, Kansas; Tomahawk Creek near Overland Park, Kansas; and National Weather Service flood-stage forecasts. For Indian Creek at Overland Park, the model was used to compute 15 water-surface profiles for flood stages at 1-foot (ft) intervals referenced to the streamgage datum and ranged from 8 ft or near bankfull to 22 ft, which exceeds the stage of the maximum recorded peak discharge. For Indian Creek at State Line Road, the model was used to compute 17 water-surface profiles for flood stages at 1-ft intervals referenced to the streamgage datum and ranged from 17 ft or near bankfull to 33 ft, which exceeds the stage of the maximum recorded peak discharge. For Tomahawk Creek near Overland Park, the model was used to compute 14 water-surface profiles for flood stages at 1-ft intervals referenced to the streamgage datum and ranged from 10 ft or near bankfull to 23 ft, which exceeds the stage of the maximum recorded peak discharge. The simulated water-surface profiles were then combined in a geographic information system with a digital elevation model derived from light detection and ranging data to delineate estimated flood-inundation areas as shapefile polygons and depth grids for each profile. These flood-inundation polygons were overlaid on high-resolution, georeferenced, aerial photographs of the study area. The flood-inundation maps are available through a mapping application that can be accessed on the U.S. Geological Survey Flood Inundation Mapping Science Web site (http://water.usgs.gov/osw/flood_inundation).

Interactive use of the flood-inundation maps on this mapping application can provide users with a general indication of depth of water at any point by using the mouse cursor to click within the shaded areas. These maps, in conjunction with real-time stage data from the U.S. Geological Survey streamgages used in this analysis and forecasted flood-stage data from the National Weather Service Advanced Hydrologic Prediction Service, will help to guide the general public in taking individual safety precautions and provide emergency management personnel with a tool to efficiently manage emergency flood operations and postflood recovery efforts.

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