Appendix H. Economics and Life Sim

Draft Kansas River Reservoirs Flood and Sediment Study

October 2023

U.S. Army Corps of Engineers
Kansas City District

1.0 Kansas River Watershed

The entire Kansas River Watershed includes the watersheds of the Republican and Smoky Hill Rivers, and those two rivers together are typically referred to as the Upper Kansas River Basin. The Kansas River basin drains nearly the entire northern half of the state of Kansas, part of southern Nebraska and eastern Colorado. It is the world's longest prairie river. The entire Kansas River watershed drains approximately 60,114 square miles across the three states. The Lower Kansas River begins at the confluence of the Smoky Hill and Republican Rivers.

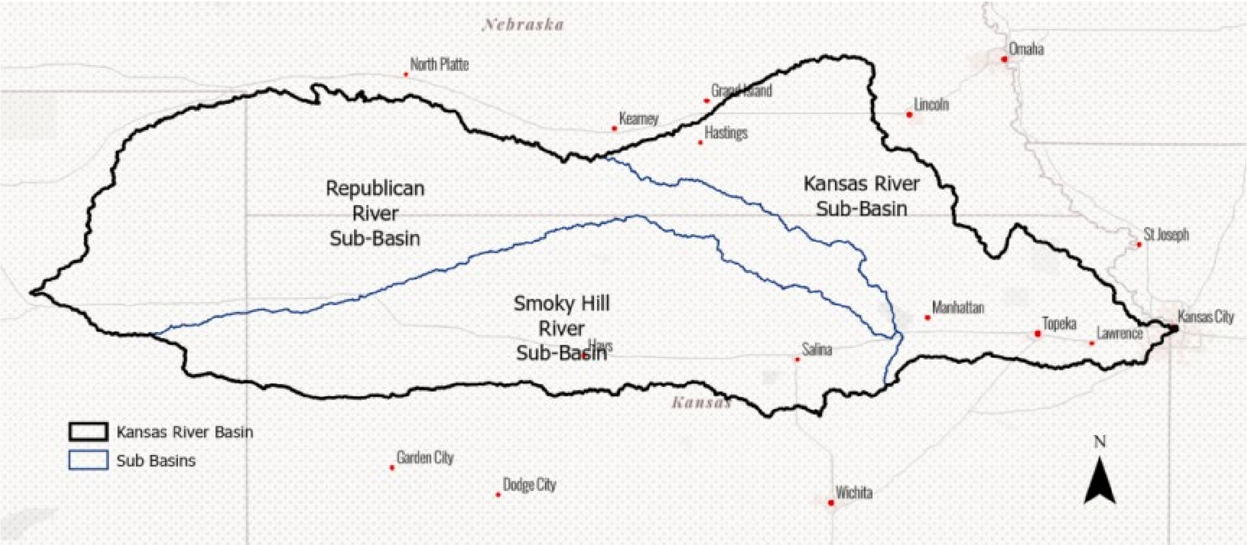


Figure 1-1: Overview of Kansas River Basin including sub basins

1.1 Population

The following table presents approximate population counts, structure values and content values for different structure types for each of the three sub-basins as well as for the entire watershed. These numbers are from USACE's National Structure Inventory (NSI) version 2. Dollar values were updated to FY20 when originally extracted from the NSI. The criteria for the selection of the structures were the hydrologic unit code outlines for each of the basins. Therefore, the data is for the entire basin and not limited to a modeling extent or study area.

Table 1: Population and Structure Values

Basin	Structure Type	Nighttime Population	Daytime Population	Structure Value ($FY20)	Content Value ($FY20)
Smoky Hill River	Residential	188,000	87,000	$ 13,447,011,000	$ 11,952,920,000
	Commercial/Industrial	3,000	54,000	$ 8,679,630,000	$ 9,693,310,000
	Education/Government/Religious	500	42,000	$ 1,471,366,000	$ 1,618,680,000
	Agriculture	100	2,000	$ 188,380,000	$ 188,380,000
	Total	191,600	185,000	$ 23,786,387,000	$ 23,453,290,000
Republican River	Residential	144,000	69,000	$ 23,172,320,000	$ 9,658,630,000
	Commercial/Industrial	1,000	28,000	$ 3,839,180,000	$ 4,309,360,000
	Education/Government/Religious	300	33,000	$679,200,000	$ 741,240,000
	Agriculture	100	2,000	$ 177,210,000	$ 177,210,000
	Total	145,400	131,000	$ 27,867,910,000	$ 14,886,440,000
Kansas River	Residential	975,000	415,000	$ 75,613,020,000	$ 64,999,110,000
	Commercial/Industrial	17,000	326,000	$ 44,186,860,000	$ 46,948,580,000
	Education/Government/Religious	3,000	237,000	$ 15,963,970,000	$ 14,886,440,000
	Agriculture	400	8,000	$ 674,740,000	$ 674,470,000
	Total	995,400	987,000	$ 136,438,320,000	$ 127,508,600,000
Entire Kansas River Watershed	Residential	1,307,000	571,000	$ 112,232,351,000	$ 86,610,660,000
	Commercial/Industrial	21,000	408,000	$ 56,705,670,000	$ 60,951,250,000
	Education/Government/Religious	3,800	312,000	$ 18,114,536,000	$ 17,246,360,000
	Agriculture	600	12,000	$ 1,040,060,000	$ 1,040,060,000
	Total	1,322,400	1,303,000	$ 188,092,617,000	$ 165,848,330,000

2.0 Flood Risk Management

What is flood risk? Flood risk is a combination of the likelihood of a natural or man-made flood hazard happening and the consequences or impact if it occurs. Flood risk is dependent on a source of flooding (such as a river), a route for the flood water to take, and damages caused by the flood (such as damage to homes and businesses). Managing flood risk starts with understanding the chance that certain hazards could occur and then identifying the corresponding magnitude of the potential outcome. If any flood risk management (FRM) structures exist, such as a dam or levee, the performance of those structures also needs to be considered when determining flood risk. Although FRM structures provide some level of protection, they do not eliminate flood risks. Flooding can still occur in surrounding communities and watersheds "even with flood risk management measures (structural and non-structural) in place."

Flood risk can be increased by extreme rainfall events in the Kansas or Missouri River Basins. High water on the Missouri River (i.e., the flood of 2019) can cause water to be held in the reservoirs in the Kansas River Basin reducing their ability to hold water from any new rain events in the basin. Changes in flood risk can also be associated with changes in operations related to changes in storage allocations or a variation in releases from reservoirs for navigation on the Missouri River. An example of the change in storage allocations would be a water supply reallocation that authorizes a reservoir pool raise (a permanent increase in the normal lake elevation) to provide more water storage. This permanent increase in the normal pool elevation reduces the flood storage capacity of the reservoir.

To help ensure FRM structures perform as designed, it is vitally important that the structures are well maintained. This includes all the dams and levees in the Kansas River watershed. The majority of the basin's FRM infrastructure is aging and will need additional investment through operation, maintenance, repair, replacement and rehabilitation (OMRR&R) in order to ensure structures continue to function as designed and continue to provide flood risk reduction measures.

2.1.1 FRM Infrastructure

The flood risk management infrastructure in the Kansas River Watershed consists of reservoirs and levees.

The Kansas River Watershed includes seven USACE reservoirs and six U.S. Bureau of Reclamation (BOR) reservoirs. USACE reservoirs in the Kansas River watershed include Clinton, Kanopolis, Milford, Perry, Tuttle Creek, Harlan County and Wilson. BOR reservoirs include Cedar Bluff, Lovewell, Kirwin, Webster, Waconda (Glen Elder) and Keith Sebelius (Norton) Lakes. While BOR reservoirs were constructed primarily to provide water for irrigation, USACE does control the flood pool in the lakes and uses these flood pools (if necessary) to help control flows in the Kansas River Watershed for the management of flood risk.

Table 2: Flood Risk Management Infrastructure – USACE Dams

Dam	Year Entered Service	Years in Service	Original Cost of Construction	Cost of Construction in Current $ (FY23)	FY19 Flood Damage Repair Costs ($FY19)
Clinton	1977	47	$ 55,759,000	$ 318,517,712	$ 62,000
Harlan County	1952	72	$ 47,686,155	$ 348,037,402	$ 900,000
Kanopolis	1947	77	$ 12,239,902	$ 490,516,877	$ 754,000
Milford	1965	59	$ 45,634,843	$ 603,876,750	$ 52,000
Perry	1967	57	$ 47,054,000	$ 622,656,171	$ 112,000
Tuttle Creek	1960	64	$ 80,995,633	$ 1,103,435,906	$ 2,285,000
Wilson	1964	60	$ 18,970,000	$ 242,946,893	$ 31,000

There are two classifications of levees – federal and non-federal levees. A federal levee, more appropriately a "federally constructed levee," is a levee that was constructed by the federal government resulting from specific congressional authorization such as the 1936 Flood Control Act or other federal law. Once these levees are constructed, they are turned over to the local sponsor to maintain. A non-federal levee is constructed by organizations other than the federal government and is not associated with any specific congressional authorization.

Both federal and non-federal levees can be enrolled in the Public Law 84-99 rehabilitation program. This program provides for the inspection (during the Preparedness phase) and rehabilitation of enrolled flood risk management projects damaged or destroyed by floods and coastal storms. All projects must meet certain standards to be eligible for rehabilitation assistance through the program. Public Law 84-99 is also where USACE gets its basic authority to provide for emergency activities in support of State and Local governments prior to, during, and after a flood event. The federal and non-federal levees in the Kansas River Basin are shown below in Table 3 and Table 4, respectively.

Table 3: Flood Risk Management Infrastructure – Federal Levees (National Levee Database Portfolio)

System Name	County	Length – Miles	Overtopping ACE	Leveed Area – Sq Mile	Leveed Area - Acres	Population At Risk	Structures at Risk	Property Value Protected & Price Level
Auburndale Unit (S. Topeka)	Shawnee	1.11	.002	0.55	350.73	2,000	634	$ 125,460,000 FY12
Armourdale	Wyandotte	6.65	.005	3.08	1971.72	6700	1468	$ 1,887,250,000 FY17
North Topeka – Soldier Creek RB2	Shawnee	18.48	.005	9.47	6063.51	7,000	3291	$ 1,653,370,000 FY15
Lawrence	Douglas, Jefferson, Leavenworth	16.21	.005	13.38	8563.51	2,000	1,236	$ 336,3000,000 FY12
Argentine	Wyandotte	5.52	.002	3.09	1976.16	11,000	723	$ 3,506,500,000 FY17
South Topeka Oakland	Shawnee	12.36	.005	5.37	3439.07	12,275	3,253	$ 1,048,000,000 FY13
Stonehouse Creek Drainage District #1	Jefferson	0.89		0.31	199.92	100	36	$ 21,470,000 FY14
Manhattan	Pottawatomie, Riley	5.39	.005	2.35	1501.92	1,000	1,734	$ 1,319,040,000 FY17
Water Works (South Topeka)	Shawnee	0.71	.002	0.06	40.48	8,100	9	$ 64,980,000 FY12
CID – Central Industrial District	Jackson, Wyandotte	4.9	.0005	1.48	949.99	7,000	287	$ 966,800,000 FY17
Soldier Creek LB4	Shawnee	0.62	.005	0.03	16.28	7	3	$ 60,000 FY14
Soldier Creek LB5	Shawnee	1.23	.005	0.09	56.07	300	137	$ 20,340,000 FY15

System Name	County	Length – Miles	Overtopping ACE	Leveed Area – Sq Mile	Leveed Area - Acres	Population At Risk	Structures at Risk	Property Value Protected & Price Level
Solder Creek LB2	Shawnee	1.45	.005	0.22	141.44	8	4	$ 170,000 FY14
Soldier Creek LB3	Shawnee	1.82	.005	0.23	148.79	0	0	$ 375,000 FY14
Soldier Creek LB1	Shawnee	0.85	.005	0.07	45.13	0	0	$ 0 FY14
Soldier Creek RB1	Shawnee	2.87	.005	0.54	342.51	0	2	$ 10,000 FY14
Soldier Creek LB6	Shawnee	1.41		0.47	302.54	0	2	$ 1,200,000 FY14
Turkey Creek LB Levee and Restored Channel	Wyandotte	0.5		0.05	31.77	200	24	$ 44,680,000 FY21
Turkey Creek RB Levee and Walled Channel	Jackson, Wyandotte	0.54		0.3	194	1,000	113	$ 326,660,000 FY21

Table 4: Flood Risk Management Infrastructure – Non-Federal Levees (National Levee Database Portfolio)

System Name	County	Length – Miles	Overtopping ACE	Leveed Area – Sq Mile	Leveed Area - Acres	Population At Risk	Structures at Risk	Property Value Protected ($FY21)
Bourtonais Creek Levee	Pottawatomie, Shawnee	1.13		0.95	607.75	20	4	$ 2,050,000
Johnson Kansas River 1	Douglas, Johnson	0.82		0.27	174.04	0	0	0
Johnson Kansas River 2	Johnson	3.14		1.17	749.81	10	5	$ 1,120,000
Kansas River Levee – St. George 5	Pottawatomie	0.58		0.05	29.61	0	2	$ 50,000
Kansas River Levee – St. George 1	Pottawatomie	7.75		2.45	1570.65	10	5	$ 630,000
Belvue Levee 1	Pottawatomie	0.62		0.1	61.76	30	6	$ 1,100,000
Kansas River Wabaunsee 1	Wabaunsee	3.29		2.73	1746.49	40	11	$ 4,380,000
Kansas River Wabaunsee 2	Wabaunsee	0.91		0.45	285.2	0	0	0

System Name	County	Length – Miles	Overtopping ACE	Leveed Area – Sq Mile	Leveed Area - Acres	Population At Risk	Structures at Risk	Property Value Protected ($FY21)
Kansas River Wabaunsee 3	Wabaunsee	0.42		0.11	69.14	0	0	0
Silver Lake Ditch Levee	Shawnee	1.82		0.23	150.18	0	0	0
Silver Lake Ditch Levee B	Shawnee	2.37		0.12	76.21	0	0	0
Silver Lake Ditch Levee C	Shawnee	1.93		0.45	289.16	0	0	0
Silver Lake Ditch Levee D	Shawnee	0.48		0.15	93.67	0	0	0
Silver Lake Ditch Levee E	Shawnee	0.77		0.12	76.98	10	1	$ 140,000
Silver Lake Ditch Levee F	Shawnee	0.7		0.14	88.03	0	0	0
College Creek St. Mary's Left	Pottawatomie	0.79	.01	0.54	345	1,000	13	$ 24,140,000
Deep Creek Levee	Riley, Wabaunsee	4.24		1.34	854.41	10	4	$ 1,260,000
Kansas River – St. George 2	Pottawatomie	1.08		0.23	146.89	10	2	$ 411,000
Silver Lake Ditch Levee South	Shawnee	5.29		1.65	1056.77	10	5	$ 1,610,000
College Creek – St. Mary's Right	Pottawatomie	0.81	.01	0.34	220.25	400	127	$ 50,960,000
Kansas River Levee -St George 3	Pottawatomie	1.36		0.11	70.46	0	0	0
Kaw River Drainage	Shawnee	8.25	.01	8.54	5464.88	200	100	$ 31,390,000
Tri-County Drainage District 1, Section 1	Pottawatomie, Shawnee, Wabaunsee	5.21	.02	1.68	1076.76	0	0	0
Tri-County Drainage District 1, Section 2	Shawnee, Wabaunsee	6.08	.01	6.36	4068.37	50	27	$ 5,340,000
Tri-County Drainage	Shawnee	6.16	.02	8.52	5450.71	100	60	$ 11,080,000

System Name	County	Length – Miles	Overtopping ACE	Leveed Area – Sq Mile	Leveed Area - Acres	Population At Risk	Structures at Risk	Property Value Protected ($FY21)
District 1, Section 3								
Fall Leaf Drainage District	Leavenworth	1.06	.05	1.1	704.69	10	10	$ 210,000
Douglas County Drainage District	Douglas	4.08	.02	2.24	1436.11	20	24	$ 4,870,000
LAT-0001	Atchison	0.73		0.14	87.6	0	0	0
LAT-0002	Atchison	1.02		0.21	137.09	0	0	0
LAT-0003-C	Atchison	1.44		0.42	266.54	0	0	0
LAT-0006-C	Atchison	0.56		0.23	145.77	0	0	0
LAT-0007-C	Atchison	0.25		0.18	114.55	0	0	0
LAT-0008	Atchison	0.12		0.06	38.95	10	1	$ 280,000
LAT-0009	Atchison	0.65		0.09	56.78	0	0	0
LAT-0028	Atchison	0.37		0.13	80.08	0	0	0
LGE-0020	Geary	0.35		0.29	184.63	0	0	0
LGE-0042	Geary	0.28		0.18	116.04	0	0	0
LJA-0004	Jackson	0.71		0.25	158.98	0	0	0
LJA-0013	Jackson	0.28		0.12	74.1	0	1	0
LJF-0006	Jefferson	0.65		0.1	62.24	0	0	0
LJF-0018	Jefferson	1.11		1.06	675.56	10	6	$ 3,230,000
LJF-0228	Johnson	1.88		0.97	618.57	20	12	$ 4,940,000
LWB-0023	Wabaunsee	0.39		0.07	46.99	0	0	0
LWB-0017	Wabaunsee	1.47		0.3	193.88	20	2	$ 1,260,000
LWB-0006	Pottawatomie	0.63		0.11	69.65	0	0	0
LDG-0017	Douglas	0.62		0.1	63.4	0	0	0
LLV-0055	Leavenworth	0.3		0.02	10.74	10	2	$ 4,410,000
LLV-0049	Leavenworth	0.45		0.12	74.93	10	2	$ 270,000
LLV-0001, LLV0103	Leavenworth	1.12		0.47	300.3	0	0	0
LLV-0125, LJO-0002, LLV-0003	Leavenworth	0.8		0.2	130.99	10	2	$ 580,000
LLV-0005	Leavenworth	0.38		0.02	14.7	0	0	0
LLV-0014	Leavenworth	0.49		0.07	42.69	0	0	0
LPT-014	Pottawatomie	0.91		0.18	112.3	0	0	0
LRL-0041-FF	Riley	0.48		0.05	31.7	100	30	$ 57,100,000
LSN-0034, LSN0035	Shawnee	0.44		0.14	88.3	0	0	0
LSN-0043	Shawnee	0.36		0.14	88.3	0	0	0
LSN-0059-C	Shawnee	0.73		0.18	113.6	0	0	0

2.1.2 Flood Damages Prevented

House Report No. 98-217, which is a part of Congressional documents for the Energy and Water Development Appropriation Bill of 1984, directs USACE to issue an annual report to Congress on floods, flood damage, hurricanes, and other natural disasters requiring Corps intervention. Every year USACE Districts calculate flood damages prevented for each project, categorized by USACE and USACEcontrolled reservoir projects, levees, and emergency operations. The flood damages prevented are an estimate of the monetary value of damages that floods would have caused in the absence of these projects and their flood risk reduction capabilities. To compute damages prevented, stages are collected for each regulated stream reach that exceeded flood stage at least once during a particular year. Stages are estimated for the same stream reaches as if the USACE project did not exist. The difference between the two stages is the reduction in stage attributable to a project. The resulting estimated stage reductions are associated with estimated economic damages. These economic damages are then used as the damages prevented estimates. It should be noted that each damages prevented estimate is based on stream stages during the given year. If there are no events that raise the stage of a stream above flood stage during a given year, there will be no damages prevented estimates for the project on that stream for that year. Damages prevented have been calculated for each project since the project's inception. Each fiscal year, damages prevented that are calculated for projects are added the previous damages prevented for that project to have the cumulative damages prevented. The damages prevented that are presented in Nominal Dollars are the total damages prevented for a project for each year added up using the value in each year's dollars such as damages prevented from 2020 expressed in 2020 dollars are added to 2021 damages prevented expressed in 2021 dollars and so on. Damages Prevented in Current Dollars for a project are the total damages prevented at a project for each individual year since the project's inception escalated to the current fiscal year price level and then all those escalated yearly damages are summed providing the total damages prevented for the project in current fiscal year dollars. The cumulative total of flood damages prevented in the Kansas River Watershed through fiscal year (FY) 2022 is summarized by project in the following table.

Table 5: FY22 Cumulative Damages Prevented for USACE Projects in the Kansas River Watershed

Cumulative Damages Prevented	Nominal $	Current $
USACE Reservoirs in Kansas River Watershed		
Clinton	$ 1,738,021,100	$ 2,784,923,800
Harlan County	$ 396,673,400	$ 702,860,200
Kanopolis	$ 2,492,160,600	$ 4,205,418,700
Milford	$ 2,269,697,000	$ 3,901,414,900
Perry	$ 7,071,106,200	$ 12,407,800,900
Tuttle Creek	$ 8,513,655,100	$ 15,127,459,000
Wilson	$ 1,851,772,800	$ 3,285,568,800
Total, USACE Reservoirs	**$ 24,333,086,200**	**$ 42,415,446,300**
Bureau of Reclamation Lakes		
Bonny (CO - Republican R.)	$ 2,870,900	$ 23,243,000
Cedar Bluff (KS - Smoky Hill R.)	$ 188,314,500	$ 403,633,600
Enders (NE - Republican R.)	$ 3,618,500	$ 14,627,100
Harry Strunk / Medicine Creek (NE - Republican R.)	$ 26,992,500	$ 40,059,700
Hugh Butler / Red Willow (NE - Republican R.)	$ 13,489,900	$ 19,501,900
Keith Sebelius / Norton (KS - Republican R.)	$ 11,597,600	$ 26,028,200
Kirwin (KS - Solomon R.)	$ 196,204,500	$ 316,536,400
Lovewell (KS - Republican R.)	$ 237,501,400	$ 419,265,300
Swanson / Trenton (NE - Republican R.)	$ 51,551,600	$ 92,234,200
Waconda / Glen Elder (KS - Solomon R.)	$ 1,711,702,700	$ 3,062,608,400
Webster (KS - Solomon R.)	$ 164,776,200	$ 302,837,900
Total, BOR Reservoirs	**$ 2,608,620,300**	**$ 4,720,575,700**
Federal Levees		
Lawrence (KS - Kansas R.)	$ 12,127,000	$ 40,047,300
Manhattan (KS - Kansas R.)	$ 15,622,000	$ 44,215,700
Topeka/Auburndale (KS - Kansas R.)	$ 2,070,900	$ 5,158,400

Cumulative Damages Prevented	Nominal $	Current $
Topeka/North (KS - Kansas R.)	$ 219,582,500	$ 601,447,600
Topeka/Oakland (KS - Kansas R.)	$ 35,550,000	$ 99,596,200
Topeka/South (KS - Kansas R.)	$ 52,216,000	$ 228,979,300
Total, Federal Levees	**$ 337,168,400**	**$ 1,019,444,500**
Total Damages Prevented	**$ 27,278,874,900**	**$48,155,466,500**

3.0 Study Area for Modeling

The area for the modeling is the Lower Kansas River in eastern Kansas. The river is 148 miles in length and drains a basin of 60,114 square miles. For modeling purposes in HEC-LifeSim, the study area begins just east of Chapman, Kansas and follows the Kansas River to the confluence with the Missouri River at Kansas City, Kansas/Kansas City, Missouri.

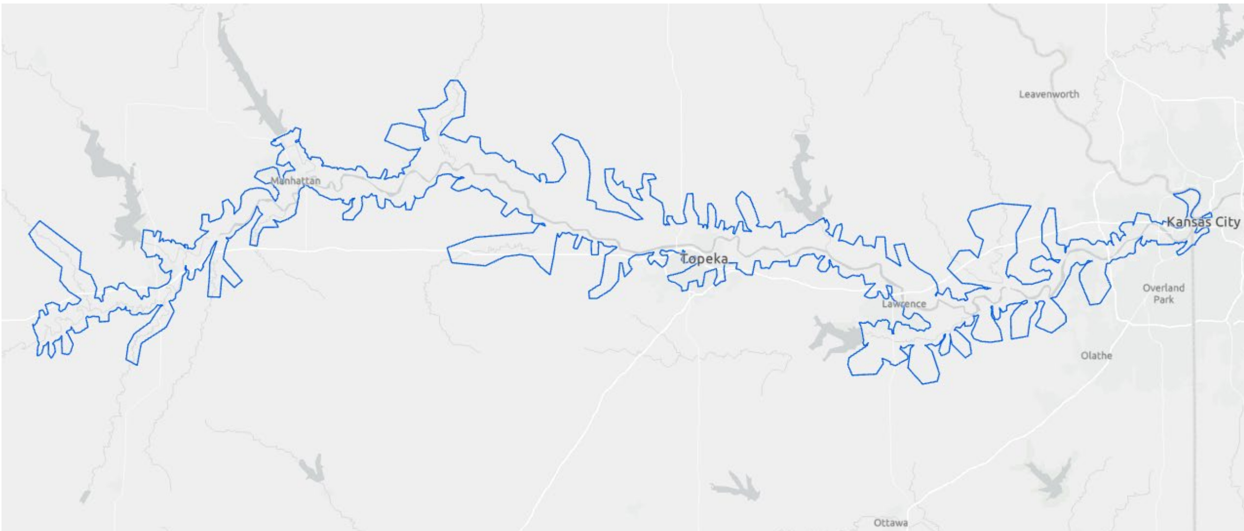


Figure 3-1: Modeling Study Area

This study area was then broken down into reaches to facilitate reporting of the model's results. The reaches generally contain a single city along the river and are named after that city. Rather than make the reaches that contain cities overly large, the rural areas between cities are created as separate reaches and are named for the cities they fall between. The model reaches are listed below.

Start of River	Between Eudora and De Soto
Junction City	De Soto
Fort Riley	Between De Soto and Bonner Springs
Manhattan	Bonner Springs
Between Manhattan and Wamego	Shawnee
Wamego	Edwardsville
Between Wamego and Topeka	Muncie*
Topeka	Argentine Leveed Area*
Between Topeka and Lawrence	Armourdale Leveed Area*
Lawrence	CID (Central Industrial District) Leveed Area*
Eudora	Fairfax Leveed Area*

* These five areas are neighborhoods of Kansas City, Kansas with Muncie being the only one of the five that is not located behind a levee.

3.1 Population

The population of the cities from along the river are provided in Table 6 below.

Table 6: Population Details for Cities Along Kansas River

City	Population	Median Age	Population Aged 65 or Older
Junction City	22,932	28.5	9.9%
Manhattan	54,100	25	8.9%
Wamego	4,841	35.1	*
Topeka	126,587	37.8	18.1%
Lawrence	94,934	31.3	11.6%
Eudora	6,408	37.6	8.1%
De Soto	6,118	34.9	9.8%
Bonner Springs	7,837	40	15.8%
Edwardsville	4,717	37.4	*
Kansas City, Kansas	156,607	34.7	12.3%

*Statistic not available for places with populations less than 5,000
Population Source: 2020 Decennial Census, US Census Bureau
Other Data Source: 2021 American Community Survey 5-year estimate, US Census Bureau

3.2 Economies

This section provides some economic data for cities along the Kansas River. Table 7 below shows the median income, college education, and employment rate for cities along the river. Following the table, anything notable about the city and the top three industries and top three occupations are listed.

Table 7: Economies of Cities Along Kansas River

City	Median Household Income (FY20)	Bachelor's Degree or Higher	Employment Rate
Junction City	$52,159	22.4%	59.1%
Manhattan	$50,957	52.8%	65.2%
Wamego	$54,491	40.7	74.2%
Topeka	$49,647	30.1%	58.1%
Lawrence	$55,598	54.3%	62.6%
Eudora	$87,392	34.9%	71.2%
De Soto	$60,568	36.9%	66.5%
Bonner Springs	$68,250	21.6%	63.75%
Edwardsville	$74,063	30.5%	66.7%
Kansas City, Kansas	$46,424	21.3%	60.1%

Interstate 70 typically follows along the Kansas River but generally not in the flood plain except in areas within Kansas City, Lawrence – where it crosses directly over the Kansas River, Topeka, Fort Riley, and Junction City.

Junction City: County seat of Geary County. Located near Fort Riley Army post, southeast of Milford Lake. Top 3 occupations are Office and Administrative Support (10.5%), Education Instruction and Library Occupations (8.49%), and Sales (7.46). Top 3 employment industries are Health Care and Social Assistance (12.4%), Public Administration (12.4%) and Educational Services (12.2%).

Manhattan: Home of Kansas State University. Located southeast of Tuttle Creek Lake. Top 3 occupations are Education, Instruction and Library (13.4%), Office and Administrative Support (12%), and Food Preparation and Serving (9.5%). Top 3 employment industries are Educational Services (28.7%), Retail (11.9%), and Health Care and Social Assistance (10.9%).

Wamego: Is a small farm town located on the river. Top 3 occupations are Office and Administrative Support (11.7%), Sales (11.6%), and Production (11.3%). Top 3 employment industries are Retail (15.4%), Educational Services (14.7%), and Health Care and Social Assistance (11.9%).

Topeka: Is the state capital of Kansas. Home of Washburn University. Top 3 occupations are Office and Administrative Support (12.7%), Sales (8.72%), and Management (7.34%). Top 3 employment industries are Health Care and Social Assistance (16.8%), Manufacturing (11.3%), and Retail Trade (10.3%).

Lawrence – County seat of Douglas County and home of The University of Kansas. Located northwest of Clinton Lake and southwest of Perry Lake. Top 3 occupations are Education Instruction and Library (11.3%), Office and Administrative Support (10.8%), and Management (9.54%). Top 3 employment industries are Educational Services (18.7), Health Care and Social Assistance (11.8%), and Retail (11.7%).

Bonner Springs – Edge of the Kansas City metropolitan area. Top 3 occupations are Office and Administrative Support (13.8%), Production (7.85%), and Management (7.59%). Top 3 employment industries are Health Care and Social Assistance (13.1%), Manufacturing (13%), and Educational Services (9.28%).

Eudora – Near the confluence of the Wakarusa Rive and the Kansas River. Top 3 occupations are Office and Administrative Support (14.9%), Management (11.7%), and Sales (9.73%). Top 3 employment industries are Health Care and Social Assistance (17%), Retail (14.7%), and Educational Services as well as Manufacturing (both are 12.2%).

De Soto – Located in Johnson and Leavenworth counties along the Kansas River. Top 3 occupations are Management (17.5%), Food Preparation and Serving (14.6%), and Office and Administrative Support (9.85%). Top 3 employment industries are Accommodation and Food Services (17.4%), Educational Services (12%), and Manufacturing (11%).

Bonner Springs – Reputed to be first commercial center and permanent settlement in Kansas. Top 3 occupations are Office and Administrative Support (13.8%), Production (7.85%), and Management (7.59%). Top 3 employment industries are Health Care and Social Assistance (13.1%), Manufacturing (13%), and Educational Services (9.28%).

Edwardsville – Close to I435 and I70 interchange and the Kansas Speedway racetrack. Top 3 occupations are Office and Administrative Support (12.7%), Management (8.03%), and Installation, Maintenance and Repair (7.37%). Top 3 employment industries are Health Care and Social Assistance (10.8%), Retail Trade (10.6%), and Finance and Insurance (9.34%).

Kansas City, Kansas – County seat of Wyandotte County and home of the unified government for the county and several cities. Located at the confluence of the Kansas River and the Missouri River. Top 3 occupations are Office and Administrative Support (11.2%), Production (10.2%), and Construction and Extraction (9.3%). Top 3 employment industries are Manufacturing (13.4%), Health Care and Social Assistance (11.4%), and Construction (10.8%).

4.0 Modeling

The life loss and direct damage estimation software, LifeSim was used for the modeling. LifeSim is an agent-based system for estimating life loss with the fundamental intent to simulate population redistribution during an evacuation. Life loss and economic damages are then determined by the hazard (e.g., flooding). LifeSim is designed to simulate the entire warning and evacuation process for estimating potential life loss and direct economic damages resulting from catastrophic floods. There were three hydraulic events analyzed in the modeling, the 10% AEP, the 1% AEP, and the 0.2% AEP events.

4.1 Agent Based Modeling

LifeSim uses an agent-based approach to track individuals throughout the warning and evacuation process. During an evacuation, agents are interacting with the roads, other vehicles, and the incoming hazard. After the warning and evacuation process has been simulated, LifeSim calculates lethality for those people that are exposed and direct damages due to the hazard. By tracking individual people and their movements, LifeSim can help identify where people are most at risk of losing their lives, whether it is on roads or in structures. We can now pinpoint the locations of greatest potential life loss, which is useful when developing alternative project formulations.

4.2 Uncertainty

LifeSim applies both natural variability and knowledge uncertainty through monte carlo analysis. Multiple parameters can be entered with uncertainty including those that influence the warning and evacuation timeline. Each iteration in a simulation represents a scenario that could occur given the data uncertainties in the model. The results of the analysis provide a distribution of estimated consequences from a given hazard. The Kansas River model was set to use 1,000 iterations for each event.

4.3 Life Loss Methodology

To determine the percentage of population at risk (PAR) within a structure that is warned and mobilized over time, several parameters are used within LifeSim to estimate the probable values of warning and mobilization percentages at each time step. These include when hazards are identified and warnings will be issued (hazard identification and delays), how long they will take to become effective (warning diffusion), and the rate at which PAR will mobilize in response (mobilization). The figure below is an example breach warning and response timeline.

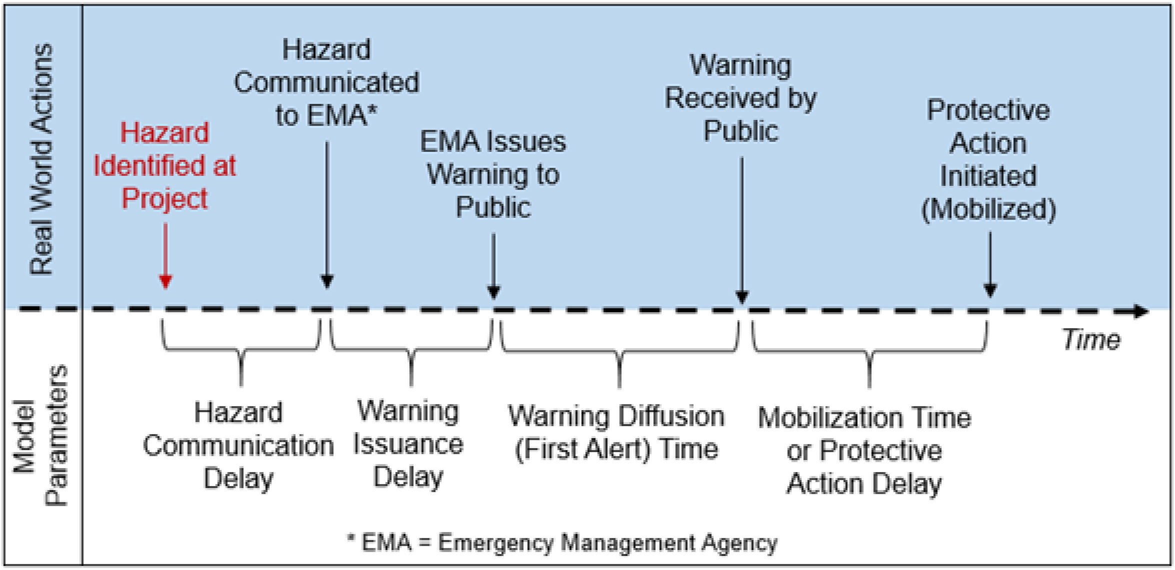


Figure 4-1: Warning and Response Timeline

4.4 Population at Risk

Population at risk (PAR) is defined as the number of people that would be subject to inundation during a flood hazard event.

Table 8: 10% AEP Population At Risk

Reach	Structures Inundated	Max Structure Depth (ft)	PAR Nighttime	PAR Daytime
Start of Modeled Area	0	0	0	0
Junction City	0	0	0	0
Fort Riley	0	0	0	0
Manhattan	0	0	0	0
Between Manhattan & Wamego	0	0	0	0
Wamego	0	0	0	0
Between Wamego & Topeka	0	0	0	0
Topeka	0	0	0	0
Between Topeka & Lawrence	6	2.06	6	0
Lawrence	2	5.55	0	0
Eudora	0	0	0	0
Between Eudora & De Soto	0	0	0	0
De Soto	0	0	0	0
Between De Soto & Bonner Springs	0	0	0	0
Bonner Springs	0	0	0	0
Shawnee	0	0	0	0
Edwardsville	0	0	0	0
Muncie	0	0	0	0
Argentine	0	0	0	0
Armourdale	0	0	0	0
CID	0	0	0	0
Fairfax	0	0	0	0
Total Reaches	8	5.5	6	0

Table 9: 1% AEP Population At Risk

Reach	Structures Inundated	Max Structure Depth (ft)	PAR Nighttime	PAR Daytime
Start of Modeled Area	3	3.42	3	0
Junction City	58	7.34	99	245
Fort Riley	364	10.77	672	322
Manhattan	21	4.69	37	19
Between Manhattan & Wamego	15	3.89	28	20
Wamego	5	3.00	10	7
Between Wamego & Topeka	41	6.80	93	132
Topeka	10	9.48	8	63
Between Topeka & Lawrence	284	12.33	582	266
Lawrence	148	14.52	762	403
Eudora	12	2.74	32	10
Between Eudora & De Soto	6	5.99	12	3
De Soto	14	6.80	32	56
Between De Soto & Bonner Springs	1	3.36	2	0
Bonner Springs	31	4.32	90	31
Shawnee	37	7.05	138	379
Edwardsville	79	8.46	342	2,486
Muncie	296	11.29	292	388
Argentine	0	0	0	0
Armourdale	0	0	0	0
CID	0	0	0	0
Fairfax	0	0	0	0
Total Reaches	1,426	14.52	3,234	4,830

Table 10: 0.2% AEP Population At Risk

Reach	Structures Inundated	Max Structure Depth (ft)	PAR Nighttime	PAR Daytime
Start of Modeled Area	353	10.20	868	460
Junction City	255	17.41	642	1,211
Fort Riley	1,047	19.48	3,356	2,024
Manhattan	1,516	15.70	4,596	5,804
Between Manhattan & Wamego	64	9.53	122	84
Wamego	20	9.21	39	20
Between Wamego & Topeka	537	16.56	1,018	726
Topeka	2,423	19.24	10,536	8,117
Between Topeka & Lawrence	945	18.36	2,129	3,300
Lawrence	1,134	19.53	2,843	3,176
Eudora	34	7.59	95	50
Between Eudora & De Soto	24	12.39	42	15
De Soto	47	12.71	86	83
Between De Soto & Bonner Springs	13	9.20	14	49
Bonner Springs	153	12.69	436	155
Shawnee	87	15.74	180	627
Edwardsville	907	17.97	3,767	5,308
Muncie	345	20.89	420	1,585
Argentine	7	6.02	28	14
Armourdale	0	0	0	0
CID	0	0	0	0
Fairfax	0	0	0	0
Total Reaches	9,911	20.89	31,217	32,808

4.5 Life Loss Model Inputs and Parameters

4.5.1 Structure Inventory

The structure inventory was developed using the USACE National Structure Inventory (NSI) version 2 as the base dataset. The NSI is developed from estimated information regarding the locations, building types, population, values, and other relevant information for all residential, commercial, industrial, agricultural, public, and private structures across the nation. Data sources for this information include national level parcel data, Census data, building footprints, and other sources for employment and school information. The value of structures, contents, and vehicles were indexed to 2022 price levels. Additional calibration on the structure point placement was accomplished using aerial imagery and inundation maps for both high and low flow scenarios.

4.5.2 Emergency Preparedness

Because of uncertainty associated with emergency operations and response during a flood event, it was necessary to account for a wide range of possible warning and evacuation outcomes. A series of preset curves are included in LifeSim. These curves were developed using the research from Mileti and Sorensen (2014). For this study, the "Preparedness Unknown" curves were chosen for the warning parameters (Warning Issuance Delay and Warning Diffusion). The Emergency Preparedness parameters are described in the sections below.

4.5.3 Relative Hazard Identification

The Hazard Identification time is the time at which a hazard is identified (flooding) relative to when it occurs (the actual flooding initiation time). In some forms of modeling such as dam breach, two different warning scenarios are simulated with different ranges of hazard identification time: minimal warning and ample warning. Since the modeling for the Kansas River Basin was flooding related to rainfall, a single warning scenario was used. The hydraulic data has a hydrologic timeframe of five months covering several large rainfall events. The warning time was set to 72 hours before which in effect is assuming that everyone received a warning.

4.5.4 Hazard Communication Delay

The Hazard Communication Delay is the time that it would take from when the hazard, flooding in this case, is identified to when the emergency planning zone (EPZ) representatives would be notified. For example, if flooding occurs when no one is observing the trouble areas then the emergency managers could be notified after the hazard is identified. The hazard communication delay was set as a uniform distribution between 0.1 hours and 0.5 hours in this analysis.

4.5.5 Warning Issuance Delay

The Warning Issuance Delay is the time it takes from when the emergency managers receive the notification of the imminent hazard to when they issue the first evacuation order to the public. The preset "Preparedness Unknown" warning issuance delay curve was used in this analysis. Although the range of possible warning issuance delay possibilities is between 0 minutes and 300 minutes, the most likely outcome is warning issuance 30 minutes after officials are notified of the flood hazard.

4.5.6 Warning Diffusion

The preset "Preparedness Unknown" warning diffusion curves were used in this analysis. The curves utilize a uniform distribution, and the warning diffusion curves are sampled during each Monte Carlo iteration in LifeSim. The upper bound of the curve reaches 100% diffusion after 100 minutes, and the lower bound reaches 100% diffusion after 360 minutes.

4.5.7 Protective Action Initiation

Protective Action Initiation (PAI) is the rate at which PAR acts after receiving an evacuation order (warning). Unlike the warning diffusion curves, the PAI “Preparedness Unknown” curve includes a perception element as well. The perception element describes a PAR as being aware of their flood risk (Perception = Likely to Impact) or generally unaware that they are at risk of being flooded (Perception = Unlikely to Impact). The “Preparedness Unknown, Perception Unknown” curve was used in this analysis for downstream areas.

Time (Minutes)	Minimum % Mobilized	Maximum % Mobilized
0	0	0
10	0.07	14.79
20	0.14	47.27
30	0.31	76.309998
40	0.54	92.269997
50	0.85	98.169998
60	1.21	99.68
70	1.64	99.949997
80	2.12	99.949997
90	2.66	99.949997
100	3.26	99.949997
110	3.9	99.949997
120	4.59	99.949997
180	9.48	99.949997
240	14.99	99.949997
300	20.32	99.949997
360	24.870001	99.949997
420	28.379999	99.949997
480	30.83	99.949997
1440	73.07	99.949997
4320	82.949997	99.949997

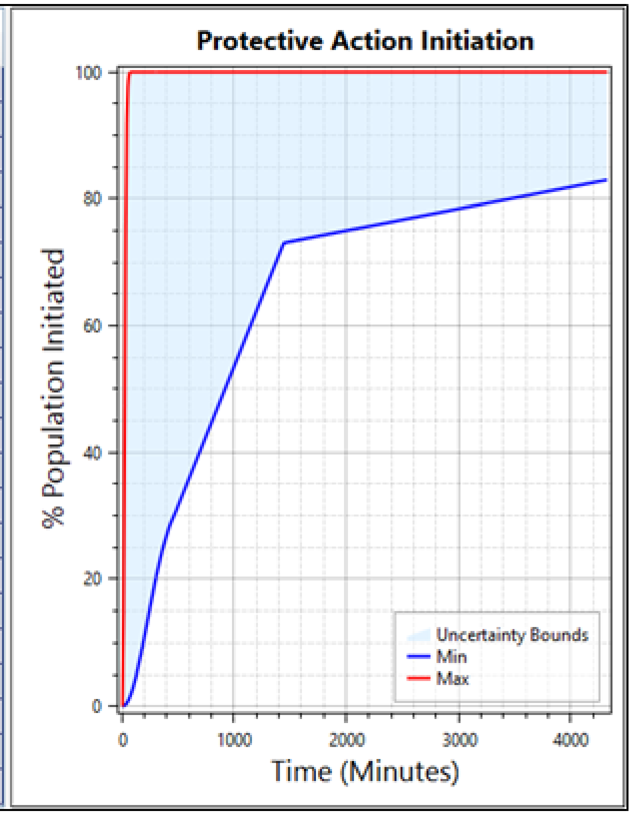


Figure 4-2: PAI Curve: Preparedness Unknown, Perception Unknown

4.6 Direct Life Loss

LifeSim, using monte carlo analysis, will estimate direct life loss for any alternative that it simulates. The hydraulic data file for each of the three return period events contain several flood events within a hydraulic timeframe of five months. Due to limitations of the modeling software, these multiple events over a long hydrologic timeframe reduce the fidelity of life loss numbers generated by LifeSim.

Table 11 Life Loss for 10% AEP Flood

Reach	Nighttime Life Loss
Start of Modeled Area	0
Junction City	0
Fort Riley	0
Manhattan	0
Between Manhattan & Wamego	0
Wamego	0
Between Wamego & Topeka	0
Topeka	0

Reach	Nighttime Life Loss
Between Topeka & Lawrence	0
Lawrence	0
Eudora	0
Between Eudora & De Soto	0
De Soto	0
Between De Soto & Bonner Springs	0
Bonner Springs	0
Shawnee	0
Edwardsville	0
Muncie	0
Argentine	0
Armourdale	0
CID	0
Fairfax	0
Total Reaches	0

Table 12 Life Loss for 1% AEP Flood

Reach	Nighttime Life Loss
Start of Modeled Area	0
Junction City	0
Fort Riley	0
Manhattan	0
Between Manhattan & Wamego	0
Wamego	0
Between Wamego & Topeka	0
Topeka	0
Between Topeka & Lawrence	0
Lawrence	0
Eudora	0
Between Eudora & De Soto	0
De Soto	0
Between De Soto & Bonner Springs	0
Bonner Springs	0
Shawnee	0
Edwardsville	0
Muncie	5
Argentine	0
Armourdale	0
CID	0
Fairfax	0
Total Reaches	5

Table 13 Life Loss for 0.2% AEP Flood

Reach	Nighttime Life Loss
Start of Modeled Area	0
Junction City	2
Fort Riley	41
Manhattan	0
Between Manhattan & Wamego	0
Wamego	0
Between Wamego & Topeka	0
Topeka	7
Between Topeka & Lawrence	1
Lawrence	0
Eudora	0
Between Eudora & De Soto	0
De Soto	0

Reach	Nighttime Life Loss
Between De Soto & Bonner Springs	0
Bonner Springs	4
Shawnee	0
Edwardsville	24
Muncie	14
Argentine	0
Armourdale	0
CID	0
Fairfax	0
Total Reaches	93

The spatial distribution of direct mean life loss for the 1% AEP flood at night and minimal warning scenario is shown in the following figure. The highest impacts are in the Muncie neighborhood of Kansas City, Kansas.

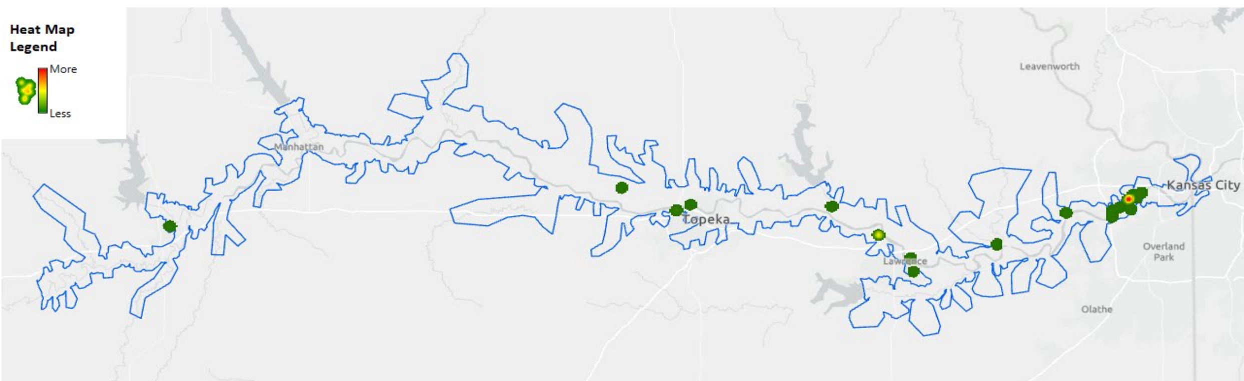


Figure 4-3: Direct Mean Life Loss Heat Map for 1% AEP Flood at Night

The spatial distribution of direct mean life loss for the 0.2% EAP flood at night and minimal warning scenario is shown in the following figure. Edwardsville, Topeka and Fort Riley are the areas of highest impacts.

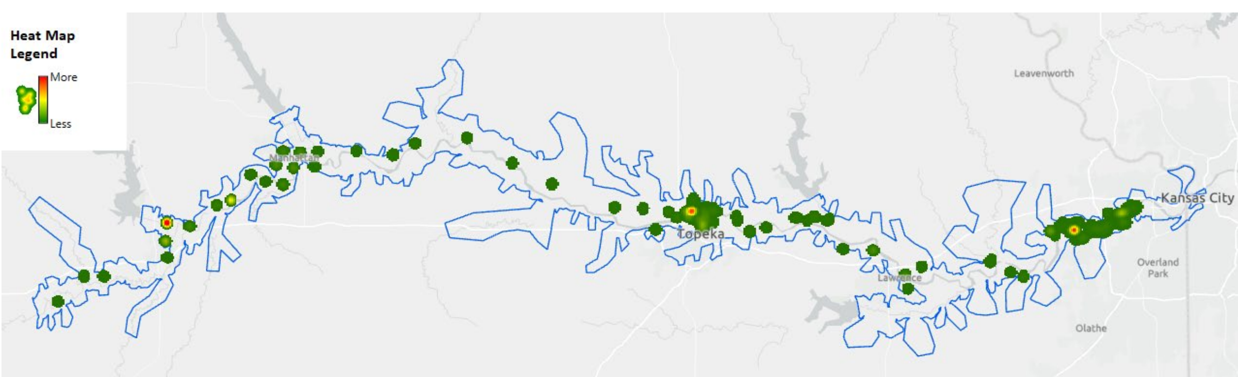


Figure 4-4: Direct Mean Life Loss Heat Map for 0.2% AEP Flood at Night

4.7 Levees

There are several federal levees along the Kansas River within the study area. The levees listed in the following table were included in the Hydraulic and Hydrologic modeling. In the modeling, they were overtopped but none were breached.

Table 14: Modeled Federal Levees Along Kansas River

County	Levee	Protected Population	Protected Buildings	Miles	Max Height	Year Constructed
Riley	Manhattan Unit	10,859	1,734	5.39	28	1963
Shawnee	N. Topeka – Solder Creek	6,687	3,291	18.48	20	1967
	S. Topeka – Oakland Unit	12,275	3,253	12.36	25	1939
	S. Topeka – Auburndale Unit	1,824	634	1.11	26	1962
Douglas	Lawrence Unit	2,215	1,236	16.21	22	1978
Wyandotte	Argentine Unit	10,700	723	5.52	20*	1951
	Armourdale Unit	6,700	1,468	6.28	15*	1951
	CID – Commercial Industrial District	15,858	341	4.9	26*	1950
	Fairfax – Jersey Creek	9,487	200	6.04	24	1953

Levee Data Source: USACE National Levee Database
*Argentine, Armourdale, and CID levees are currently being raised.

4.8 Economic Losses

Direct Economic Losses are property damages. These damages include structure, content, and vehicle damage. They were estimated in LifeSim using standard depth-percent damage curves specific to each structure occupancy type and structure stability curves which evaluate damage caused by combined depth and velocity of the flood waters.

Table 15: 10% AEP Economic Damages

Reach	Total Damages
Start of Modeled Area	$-
Junction City	$-
Fort Riley	$-
Manhattan	$-
Between Manhattan & Wamego	$-
Wamego	$-
Between Wamego & Topeka	$-
Topeka	$-
Between Topeka & Lawrence	$111,381
Lawrence	$391,064
Eudora	$-
Between Eudora & De Soto	$-
De Soto	$-
Between De Soto & Bonner Springs	$-
Bonner Springs	$-
Shawnee	$-

Reach	Total Damages
Edwardsville	$-
Muncie	$-
Argentine	$-
Armourdale	$-
CID	$-
Fairfax	$-
Total Reaches	$502,445

Table 16: 1% AEP Economic Damages

Reach	Total Damages
Start of Modeled Area	$21,999
Junction City	$3,757,469
Fort Riley	$11,583,022
Manhattan	$2,375,427
Between Manhattan & Wamego	$1,081,736
Wamego	$348,467
Between Wamego & Topeka	$3,811,488
Topeka	$3,189,013
Between Topeka & Lawrence	$16,357,495
Lawrence	$18,190,481
Eudora	$625,566
Between Eudora & De Soto	$467,769
De Soto	$3,310,963
Between De Soto & Bonner Springs	$99,949
Bonner Springs	$222,070
Shawnee	$5,397,154
Edwardsville	$125,753,926
Muncie	$103,512,222
Argentine	$-
Armourdale	$-
CID	$-
Fairfax	$-
Total Reaches	$300,106,216

Table 17: 0.2% AEP Economic Damages

Reach	Total Damages
Start of Modeled Area	$359,10,729
Junction City	$172,873,980
Fort Riley	$291,247,122
Manhattan	$572,964,927
Between Manhattan & Wamego	$7,247,535
Wamego	$1,025,411
Between Wamego & Topeka	$46,018,129
Topeka	$908,485,556
Between Topeka & Lawrence	$113,301,238
Lawrence	$189,735,313
Eudora	$3,167,693
Between Eudora & De Soto	$1,872,484
De Soto	$13,579,460
Between De Soto & Bonner Springs	$4,733,248
Bonner Springs	$21,037,344
Shawnee	$59,618,628
Edwardsville	$558,876,073
Muncie	$275,236,751

Reach	Total Damages
Argentine	$350,898
Armourdale	$-
CID	$-
Fairfax	$-
Total Reaches	$3,241,371,790

4.9 Agriculture

Kansas is a state with a considerable amount of agriculture. In the study area for the model, there are approximately 216,500 acres of land devoted to agriculture. The primary crops in this area of the state are corn, soybeans, oats and alfalfa. The following 2 tables show crop damages for the 1% AEP and the 0.2% AEP events using crop budgets of FY16.

Table 18: 1% AEP Crop Damages

Category	Damages (FY16)
Corn	$ 6,257,350
Soybeans	$ 3,586,001
Alfalfa	$ 88,223
Oats	$ 5,706
Barley	$ 67
Sunflowers	$ 26
Total	$ 9,937,374

Table 19: 0.2% AEP Crop Damages

Category	Damages (FY16)
Corn	$ 16,679,862
Soybeans	$ 9,159,241
Alfalfa	$ 203,519
Oats	$ 16,555
Barley	$ 289
Sunflowers	$ 26
Total	$ 25,503,022

4.10 Inundation Mapping

The following six figures show the extent and depth of inundation in areas along the Kansas River for the 0.2% AEP flood.

Table 20: 0.2% AEP Flood Inundation at Junction City, KS and Fort Riley, KS

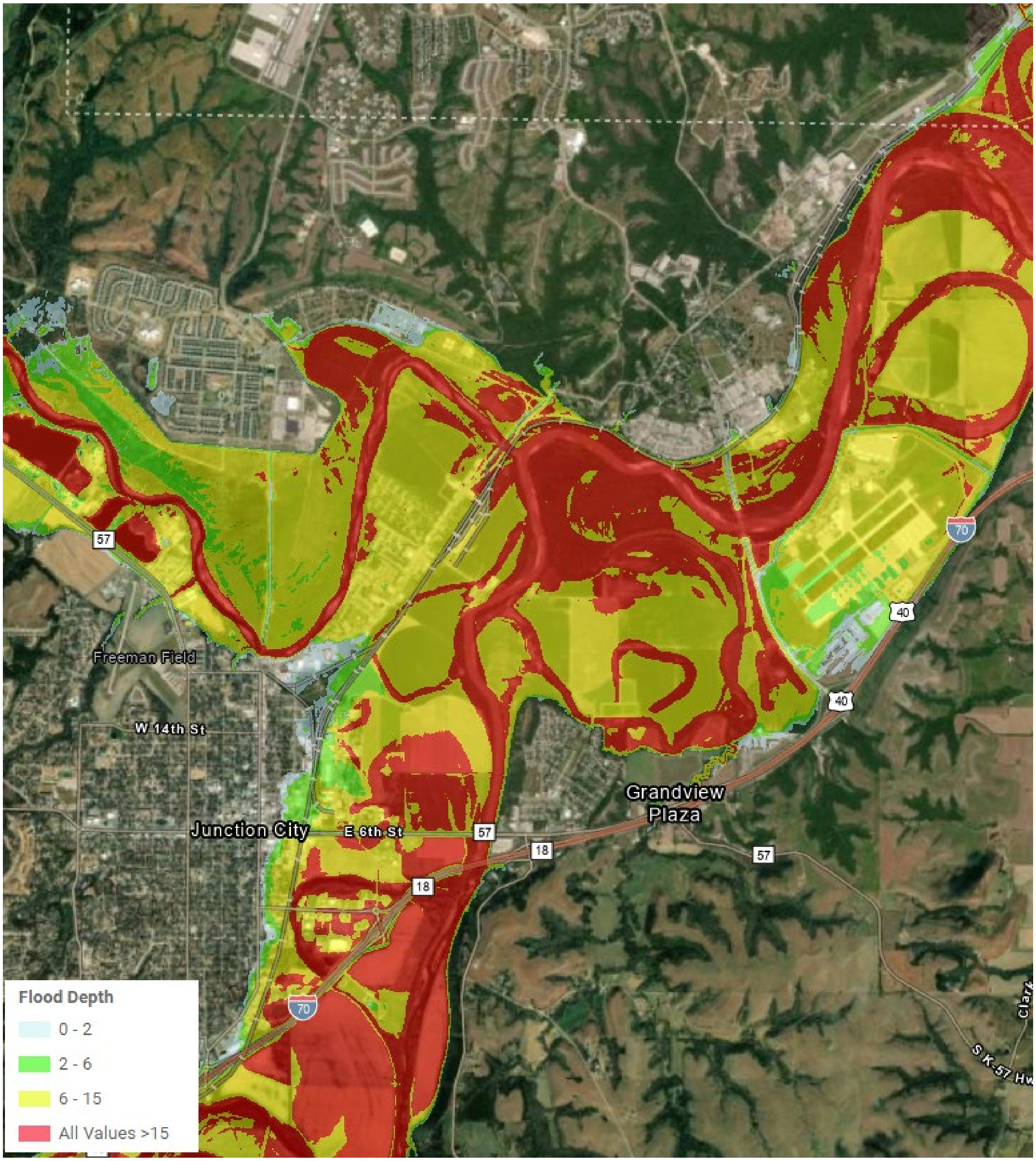


Table 21: 0.2% AEP Flood Inundation at Manhattan, KS

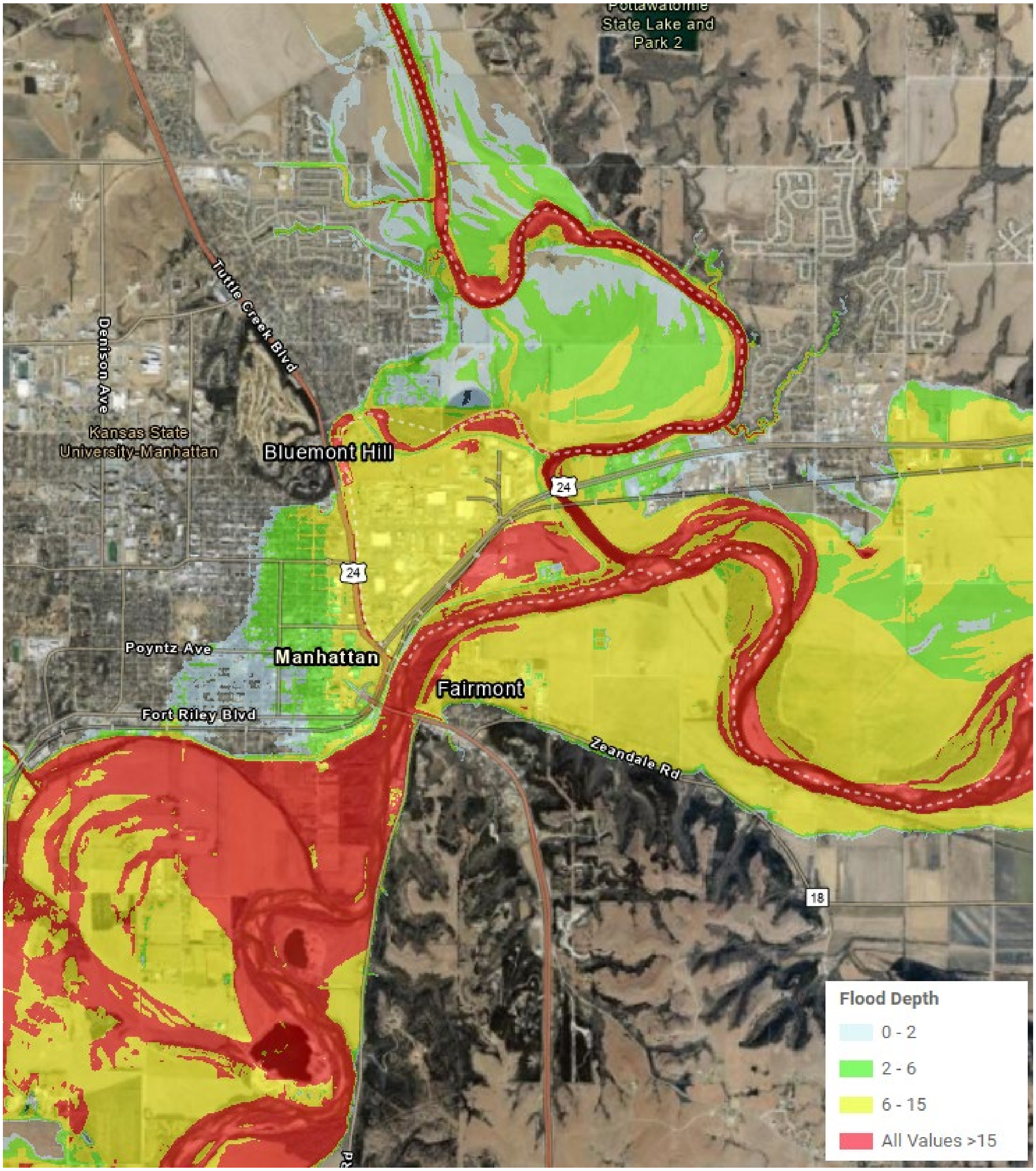


Table 22: 0.2% AEP Flood Inundation at Topeka, KS

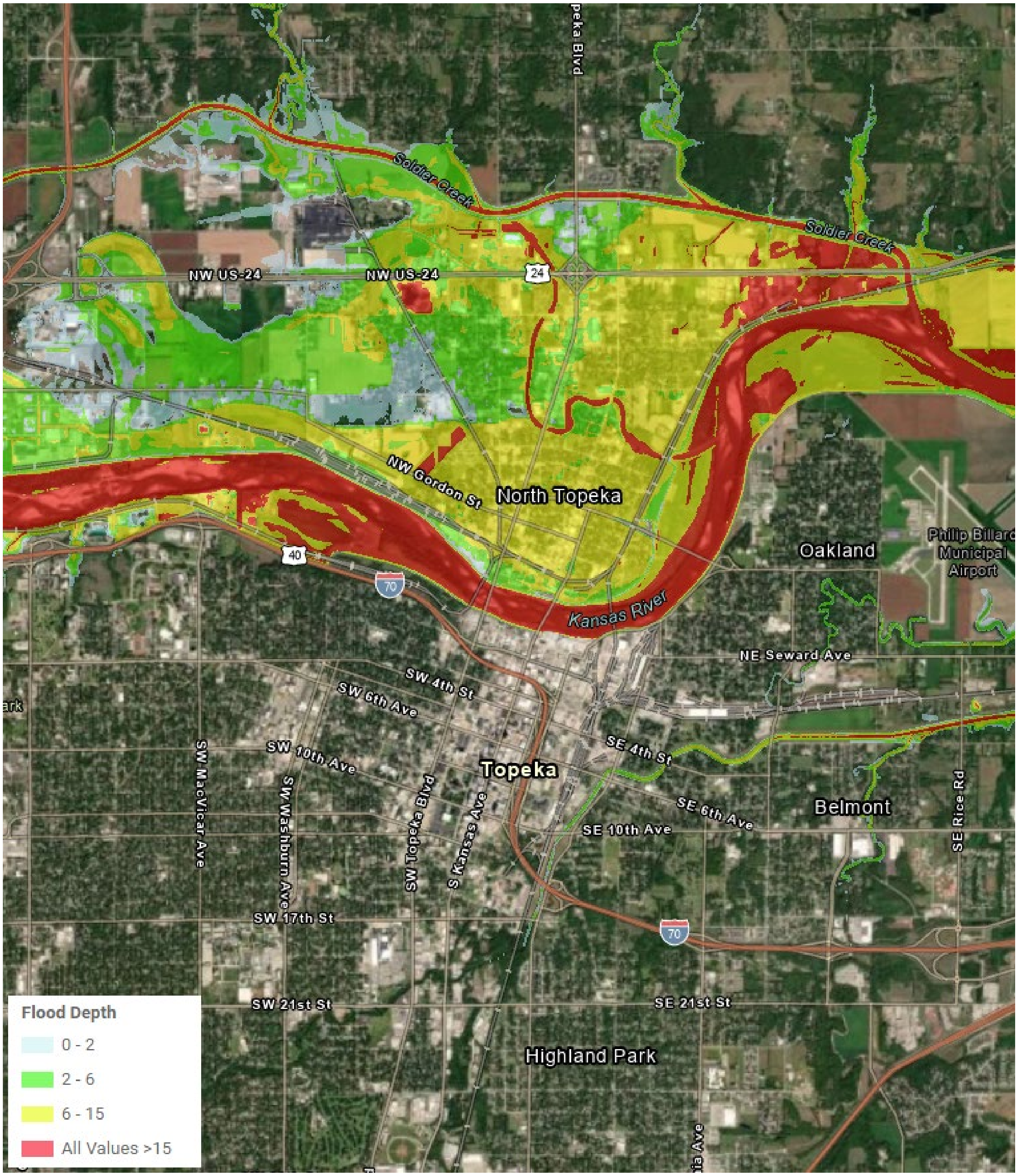


Table 23: 0.2% AEP Flood Inundation at Lawrence, KS

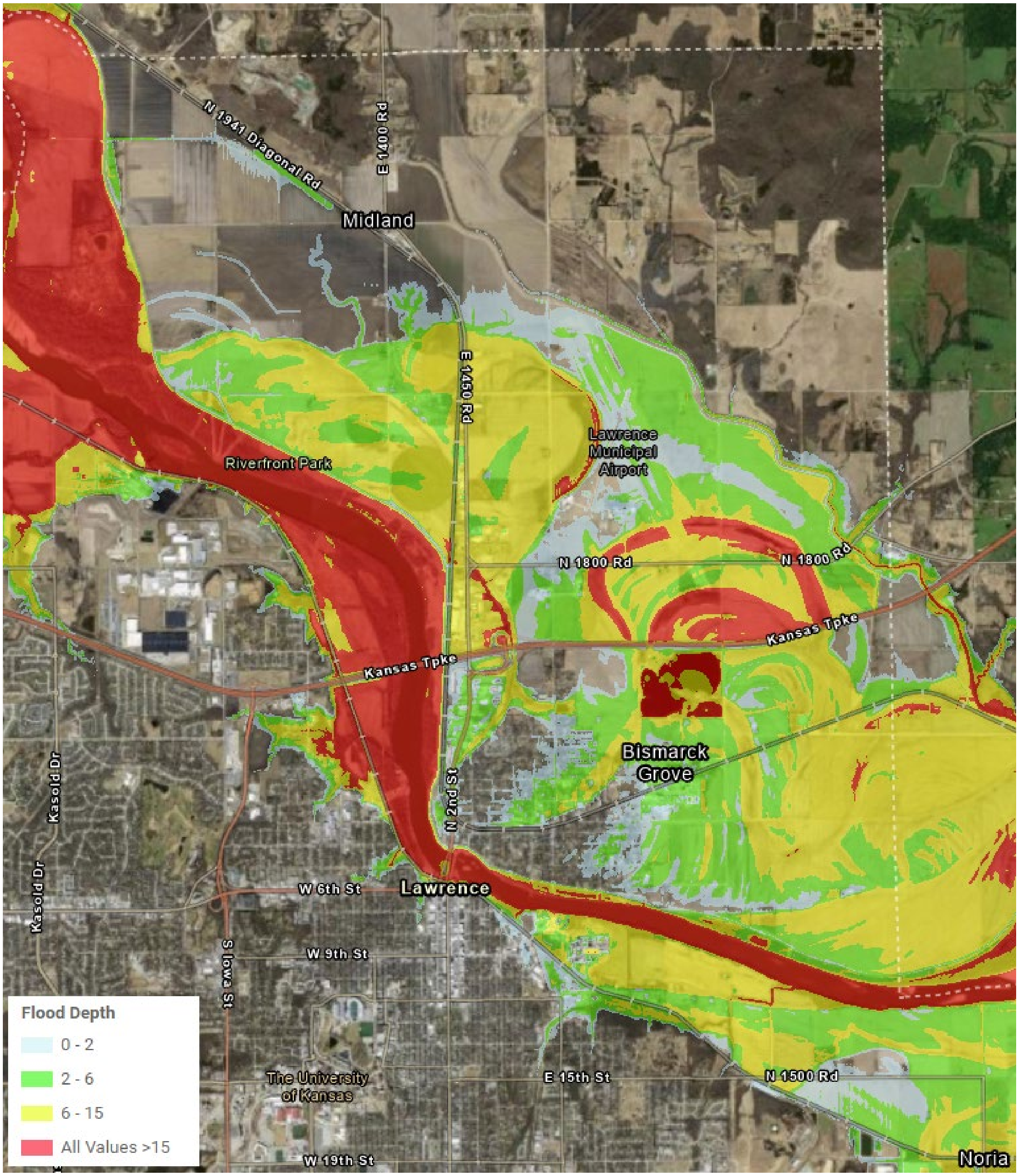


Table 24: 0.2% AEP Flood Inundation at Edwardsville, KS

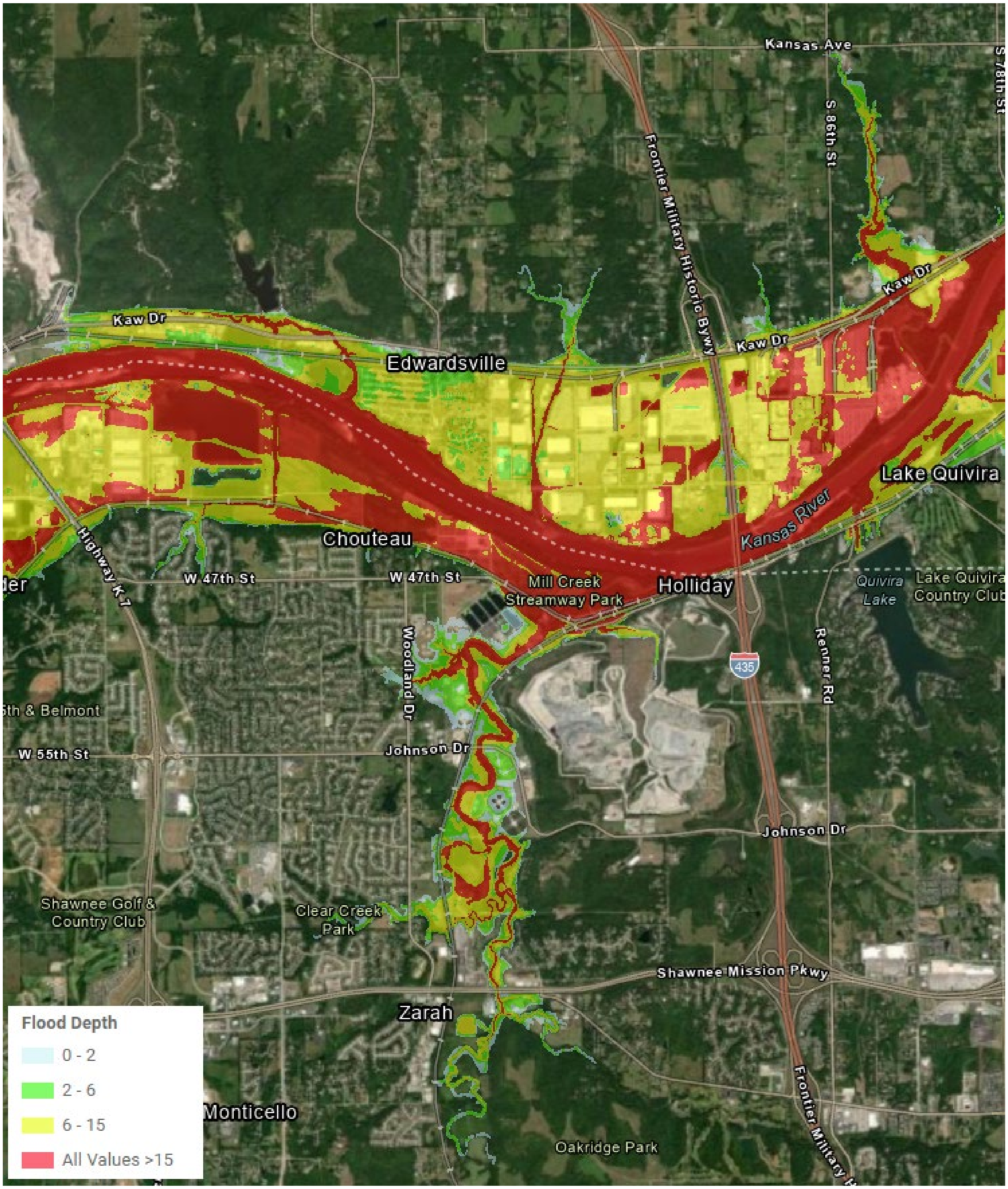
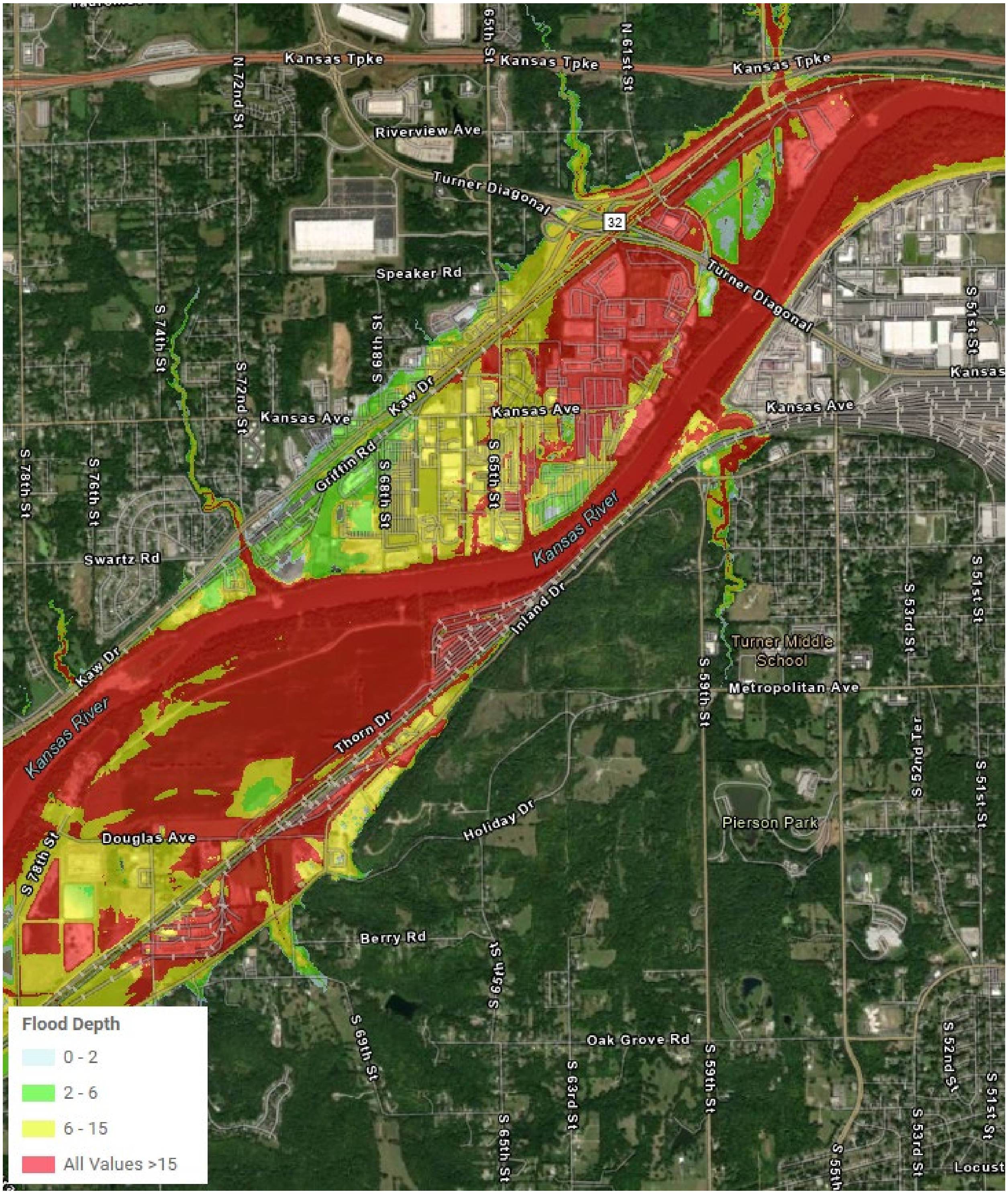


Table 25: 0.2% AEP Flood Inundation at Muncie, KS (Neighborhood in Kansas City, KS)



4.11 Future Conditions

H&H states that the 100-year future without project (FWOP) and existing conditions (EC) peak flows vary by less than 2% at every mainstem Kansas River gage. This margin is well within the bounds of the assumed HEC-RAS model accuracy for producing depth grids and inundation boundaries. As such, they did not produce any hydraulic data for the future conditions and therefore there was no HEC-LifeSim modeling for future conditions. More details on the H&H future conditions decision is available in Section 7 of the Hydrology and Hydraulics appendix.