3.3.2.2 Tornados

I. Background

According to the National Severe Storms Laboratory (NSSL) of the National Oceanic and Atmospheric Administration (NOAA) a tornado is "a narrow, violently rotating column of air that extends from the base of a thunderstorm to the ground. Because wind is invisible, it is hard to see a tornado unless it forms a condensation funnel made up of water droplets, dust and debris. Tornados are the most violent of all atmospheric storms."

Attributes: About 1,200 tornados hit the United States annually. Historical data pertaining to tornados only date back to 1950 and methodology for spotting and reporting tornados has greatly evolved over the last few decades.

Tornado season in the U.S. usually refers to the time of year when tornados are most likely to occur. For the southern plains, it occurs during May and into early June. On the Gulf Coast, it is earlier in the spring. In the northern plains and upper Midwest, tornado season is in June or July. However, a tornado can occur at any time during the year, and can happen at any time of day or night. Most tornados occur between 4 and 9 p.m.

The most destructive and deadly tornados are spawned from supercells with a well-defined radar circulation called a mesocyclone. Supercells can also produce damaging hail, severe non-tornadic winds, frequent lightning and flash floods.

Analysis of damage caused by the storm, is a common and practical method for determining the strength of a tornado. From the extent of damage, an estimated wind speed can be determined. The "Enhanced Fujita Scale" was implemented by the National Weather Service in 2007 to rate tornados in a consistent and accurate manner. The EF-Scale accounts for more variables than the original Fujita Scale (F-Scale) when determining wind speed rating to a tornado by incorporating 28 damage indicators such as building type, structures and trees. For each damage indicator, there are 8 degrees of damage ranging from the beginning of visible damage to complete destruction of the damage indicator. The original F-scale did not take degrees of damage into account. The historic F-Scale database will not change. A tornado rated F5 years ago is still an F5, but wind speed may have been slightly less than previously estimated.

A comparison between the Fujita Scale and the Enhanced Fujita Scale is shown below. The Enhanced Fujita Scale is a set of wind estimates (not measurements) based on damage evaluations. According to the National Oceanic and Atmospheric Administration the Enhance Fujita Scale "uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to 28 indicators." These 28 indicators are based on the structure type, ranging from manufactured housing to institutional buildings, and from trees to light poles. It is important to note that a 3 second gust is not the same speed of wind observed in standard surface wind. Measurements are taken by weather stations located in open exposures and using a directly measured, "one minute mile" speed.

Table 3.3.2.2.1 - Fujita/Enhanced Fujita Scale						
FUJITA SCALE			DERIVED EF SCALE		**OPERATIONAL EF SCALE**	
F Number	Fastest ¼ mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)	**EF Number**	**3 Second Gust (mph)**
0	40-72	45-78	0	65-85	**0**	**65-85**
1	73-112	79-117	1	86-109	**1**	**86-110**
2	113-157	118-161	2	110-137	**2**	**111-135**
3	158-207	162-209	3	138-167	**3**	**136-165**
4	208-260	210-261	4	168-199	**4**	**166-200**
5	261-318	262-317	5	200-234	**5**	**Over 200**
Source: NOAA						

Tornado - Feburary 29, 2012, Near LaRue County High School in Hodgenville
Photo Tara Wooden

Tornado Facts and Effects

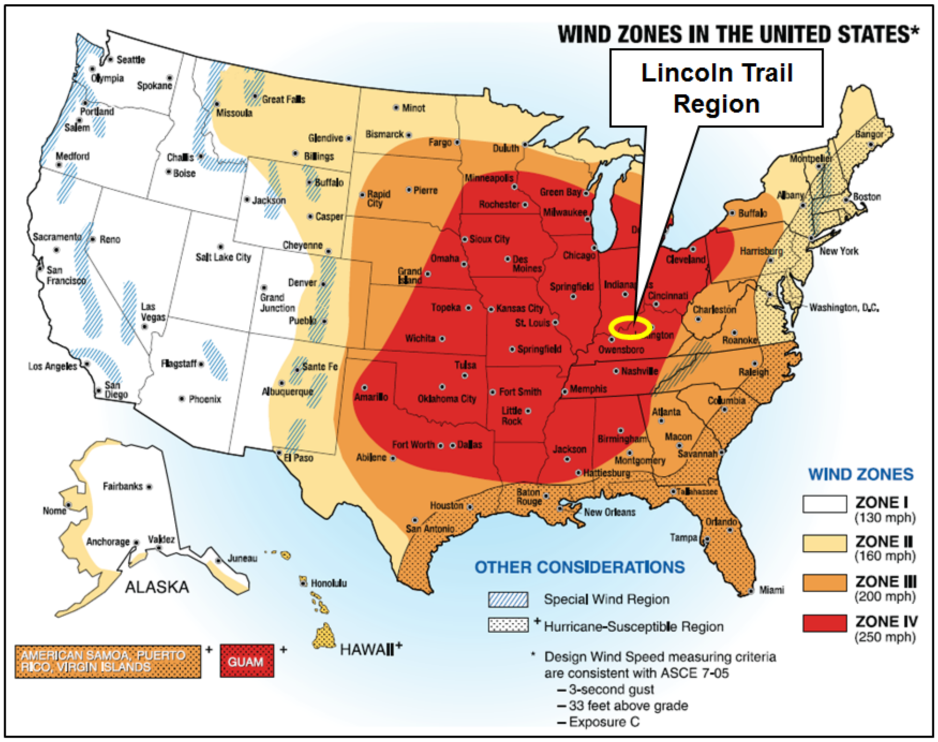
- Tornadoes can last from several seconds to more than an hour.
- A tornado is considered “significant” if it is rated EF2 or greater on the Enhanced Scale or at least F2 on the old F-Scale.

- Hurricanes and tropical storms can spawn tornados.
- Tornados are forecast when the development of temperature and wind flow patterns in the atmosphere can cause enough moisture, instability, life, and wind shear for the formation of tornadic thunderstorms. These are the four main factors for the formation of tornados.
- Tornado damage occurs as the result of exposure to extreme winds or the impact of flying debris. Another hazard exists when hazardous materials are released by tornados such as natural gas, medical waste, gasoline, and other dangerous chemicals or sewage. Winds can topple trees and power lines resulting in long-term power outages.
- Wind associated with tornados can loft debris several miles into the air and carry it for long distances. Small items and paper can be carried over 100 miles away.
- Tornados vary in size with the widest ground width measured at about 4.3 miles. Wind speed also varies. The greatest ground-level speeds have never been measured, but on May 3, 1999, 302 mph winds were recorded near Bridge Creek, OK.
- April is the month with the greatest number of tornado outbreaks. In April, 2011, the NOAA Storm Prediction Center data shows 817 tornados occurred.
- The tornados with the greatest death toll occurred on March 18, 1925 when 695 people were killed when tornados raced across Missouri, Illinois and Indiana producing F5 damage. On April 3, 1974, the main day of a two-day "Super Outbreak," tornados killed 310 people. During that outbreak, seven F5 tornados occurred in one day. The Dixie outbreak of April 27, 2011 killed about 316 people.
- Approximately 1300 tornados occur in the United States each year. On average, 60 people are killed annually as a result of tornados, most from flying or falling debris. Since records have been kept, the greatest number of deaths from tornados occurred in 2011 when 550 people died in 15 states.
- Funnel clouds have rotation, but do not touch the ground. Only a true tornado has ground contact.
- The size or shape of a tornado does not have anything to do with its strength.

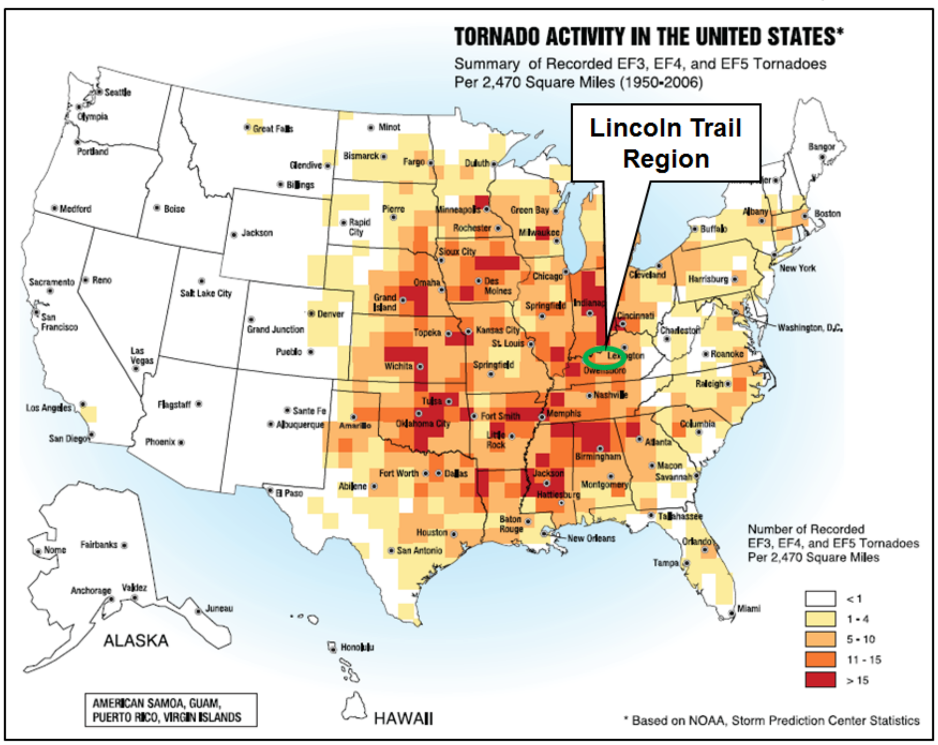
II. Profile

Kentucky is located in Wind Zone IV; the most severe wind zone in the United States. The states most vulnerable to tornado activity are located within this wind zone.

The risk associated with tornados in Kentucky is illustrated in Chart 3.3.2.2.1. Of the 908 tornados reported throughout the State between 1950 and 2014, each of the counties within the Lincoln Trail Region experienced at least 9. Kentucky averages 14 tornados



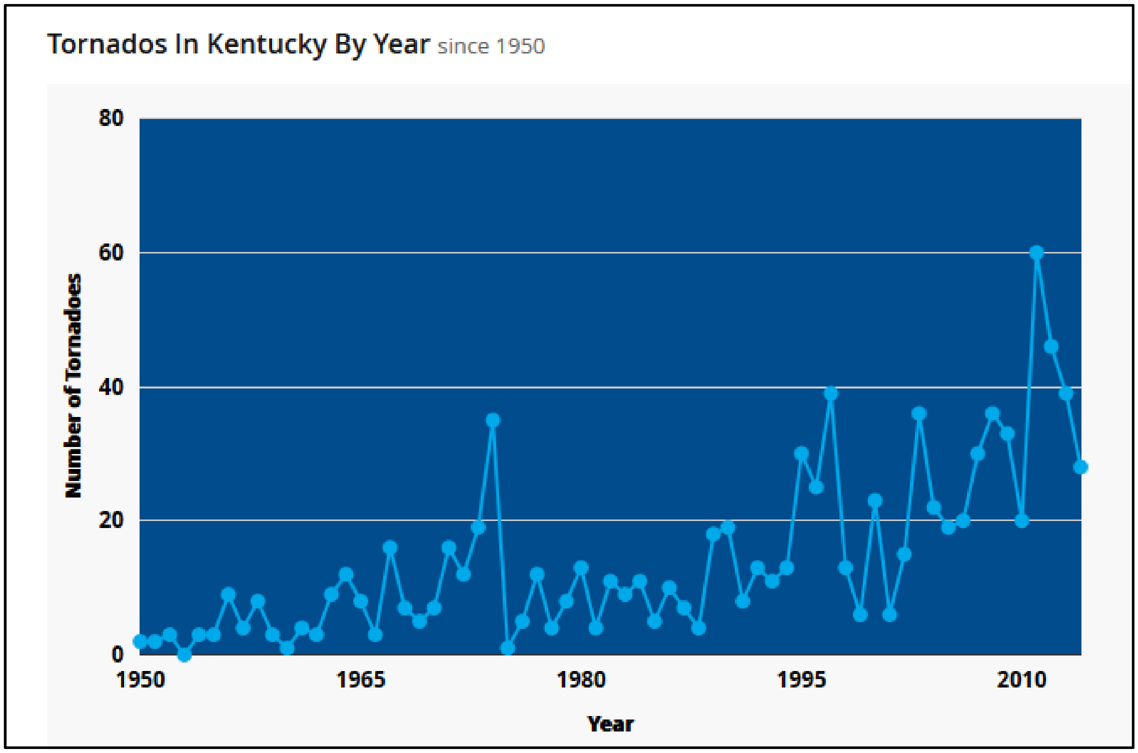
Source: FEMA, *Taking Shelter from the Storm*, 3rd Edition, Fig 1-4.



Source: FEMA, *Taking Shelter from the Storm*, 3rd Edition, Fig 1-2.

annually. Of the 220 people killed in Kentucky due to tornados, 81 were killed in the Lincoln Trail Region. Tornado data has only been collected since 1950 and the history of tornado events in the Lincoln Trail Region dates from 1950 through 2013. Clearly, the Lincoln Trail Region is at risk for tornado activity.

Chart 3.3.2.2.1



Source: www.homefacts.com/tornadoes/Kentucky

Table 3.3.2.2.2 – Tornado Activity

Tornado Activity in Kentucky and the 8-County Lincoln Trail Region Between 1950 and 2014							
Jurisdiction	Dates Yr.,Month,Day	Tornados	Fatalities	Injuries	Highest Injuries	Longest Path	Widest Path
Kentucky	1950/11/20 – 2014/10/07	908	220 People	3,601 People	364 People	84.99 Miles	3,000 Yards
Breckinridge County	1974/04/03 – 2012/03/02	14	32 People	289 People	270 People	32.3 Miles	440 Yards
Grayson Co.	1959/01/21 – 2012/02/29	12	3 People	26 People	16 People	58 Miles	880 Yards
Hardin Co.	1964/01/24 – 2012/02/29	22	3 People	95 People	81 People	37.9 Miles	440 Yards

LaRue Co.	1952/03/22 – 2013/06/26	9	0 People	19 People	18 People	6.65 Miles	1200 Yards
Marion Co.	1952/03/22 – 2013/06/26	9	0 People	19 People	18 People	6.65 Miles	1200 Yards
Meade Co.	1974/04/03 – 2013/01/30	10	32 People	299 People	270 People	32.3 Miles	440 Yards
Nelson Co.	1969/05/08 – 2008/02/05	9	3 People	85 People	81 People	37.9 Miles	1500 Yards
Washington County	1954/08/02 – 2012/03/02	9	11 People	5 People	4 People	46.6 Miles	800 Yards
Source: Storm Prediction Center, Historical Tornado Data File (NOAA)							

III. Anaylsis

To analyze tornados as a hazard threat to the Lincoln Trail Region historical data was researched. The sources of this information include the National Weather Service, National Climatic Data Center, Kentucky Climatic Data Center, ESRI, FEMA, Kentucky Emergency Management Area III, and LTADD GIS.

The following map and tables illustrate a number of the documented tornadic events that have occurred in the Lincoln Trail Region. Note that the general paths are consistent with tornados in this region of the United States. They do affect a widespread region and are not affected in general by geography.

The level of impact is evidenced through the number of lives lost or individual injuries reported, as well as the estimated property and crop damage based on information reported to the National Climate Data Center. This information was subsequently rolled into the data from the National Centers for Environmental Information (NCEI). Data for the original plan was only available through 2003. The 2010 update provided data thru 30 June 2009. This update shows only individual events for the period 1 July 2009 through 30 June 2015. The summary tables show data for the entire periods covered by the various sources. Note that there are many variations in recording the locations of the events over time. In the past, this was typically done at a county level. More recently, nearest place names have been used. Because of this, the records in the summation tables regarding the individual incorporated areas should not be considered all encompassing.

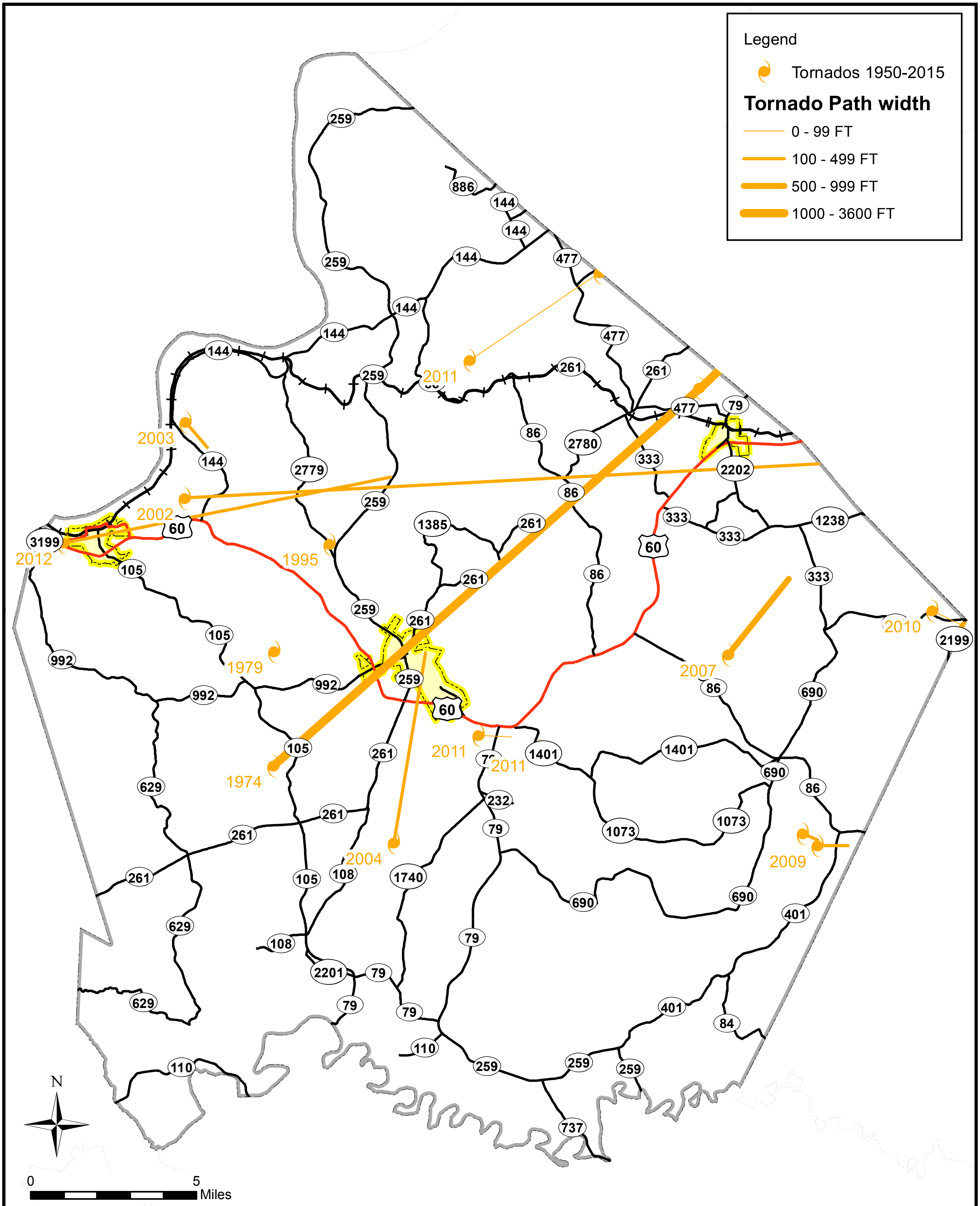
Throughout the following tables, April 3, 1974 will stand out and is probably the most significant day to remember in our region, if not the state, as it pertains to natural hazards and the devastating effects they can have on us all. In what is labeled the worst tornado outbreak in U.S. history, 148 twisters touched down in 13 states, killing 330 people and injuring 5,484. Between the hours of 3:40pm and midnight 26 of those tornados touched down in Kentucky and affected 39 of our 120 counties, killing 77 people and injuring 1,377. Closer to home, within the Lincoln Trail Region a total of 36 of our residents were killed and 353 were injured. The tornado causing the most destruction hit Meade County and had an intensity rating of F5 on the Fujita scale and a path 550 yards wide.

Table 3.3.2.2.3 - County Specific Data – Tornados, *Source: NCEI*

BRECKINRIDGE

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
HARDINSBURG	10/9/2009	0	0	$0	$0	EF0
BIG SPG	5/21/2010	0	0	$25,000	$0	EF1
MYSTIC	4/19/2011	0	0	$0	$0	EF0
HARNED	6/19/2011	0	0	$50,000	$0	EF2
LOCUST HILL	6/19/2011	0	0	$5,000	$0	EF0
CLOVERPORT	3/2/2012	0	0	$150,000	$0	EF2

Local Story - June 19, 2011: "The National Weather Service confirms two tornadoes touched down in Breckinridge County Sunday. An EF-0 and EF-2 twister hit the town of Harned. There were no reported injuries, but strong wind ripped the roof off a house and blew it into the back yard. A twister also flattened a barn. On another farm, winds lifted a barn off its foundation and moved it several feet. One of the tornadoes ripped away chunks of an outer wall on Breckinridge County High School." *Source: WLEX TV 18, Lexington KY, 6/21/2011.*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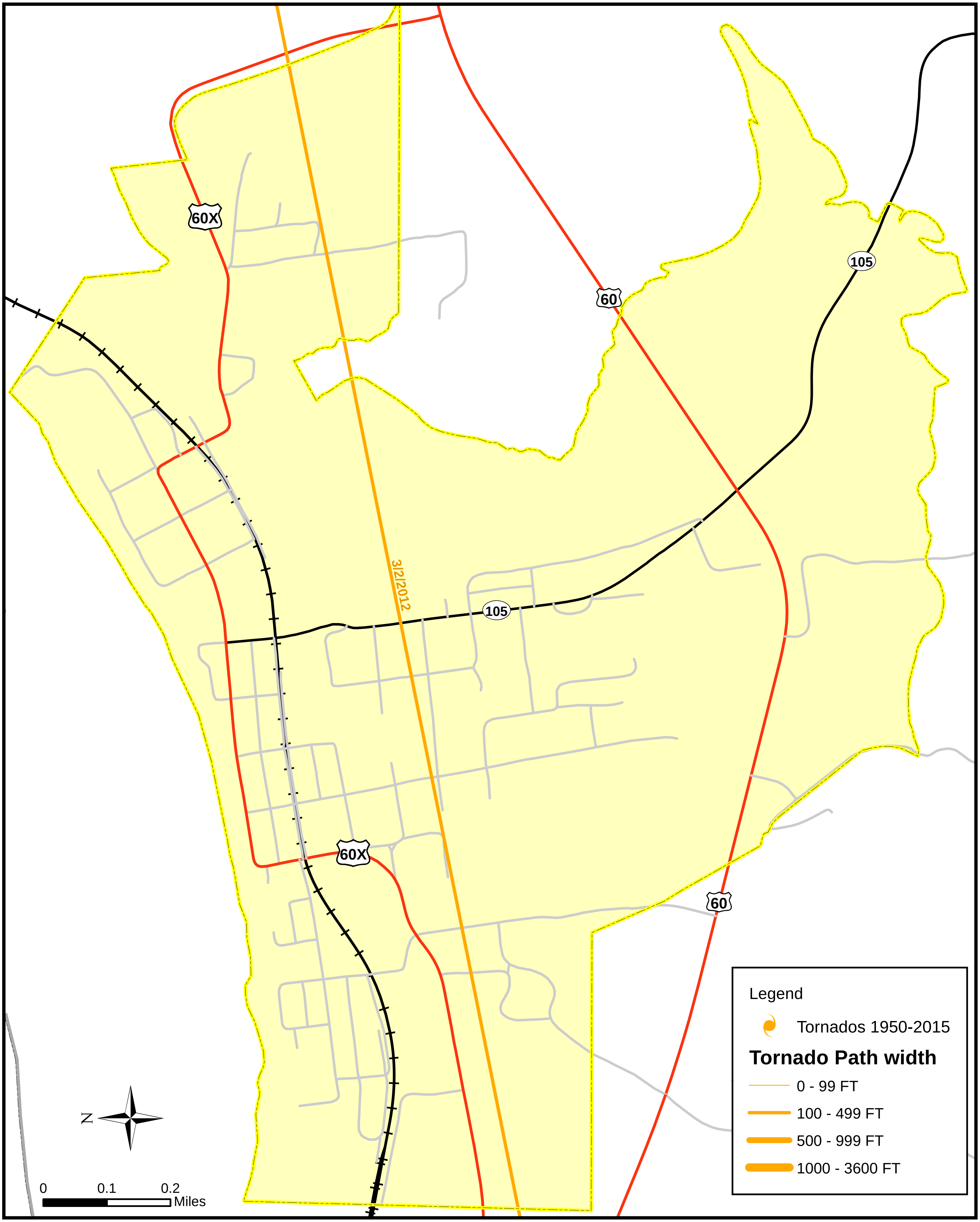
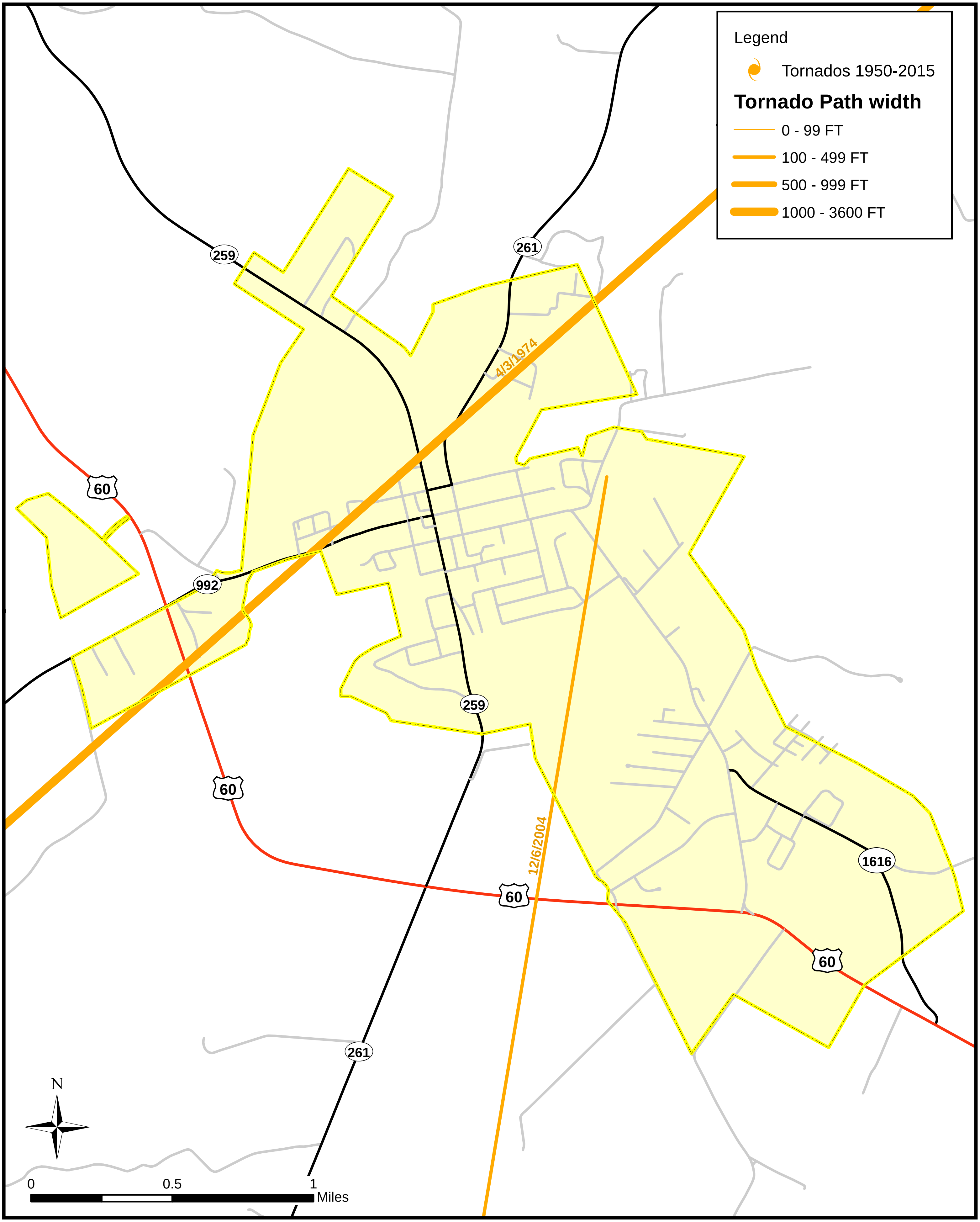
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
2011
2003
2002
2012
1995
1979
1974
2011
2011
2004
2007
2010
2009
N
0
5
Miles


60X
60
105
105
3/2/2012
60X
60
N
0
0.1
0.2
Miles
Legend
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT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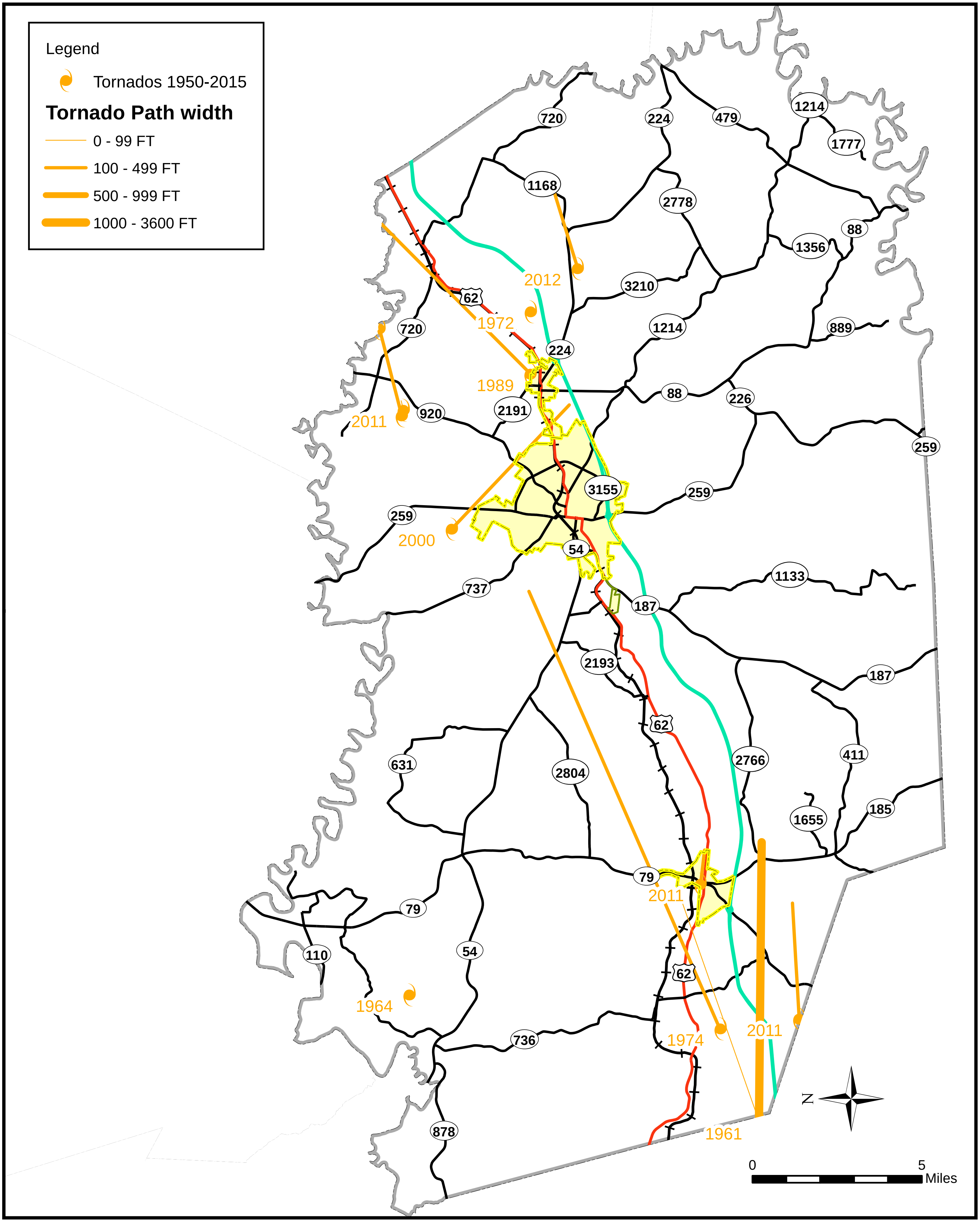
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
4/3/1974
12/6/2004
259
261
60
992
1616
N
0
0.5
1
Miles

GRAYSON

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
NEAFUS	4/4/2011	0	0	$0	$0	EF1
CANEYVILLE	4/4/2011	0	0	$0	$0	EF1
TAR HILL	4/26/2011	0	0	$0	$0	EF2
TAR HILL	4/26/2011	0	0	$0	$0	EF0
WEST CLIFTY	2/29/2012	0	1	$50,000	$0	EF2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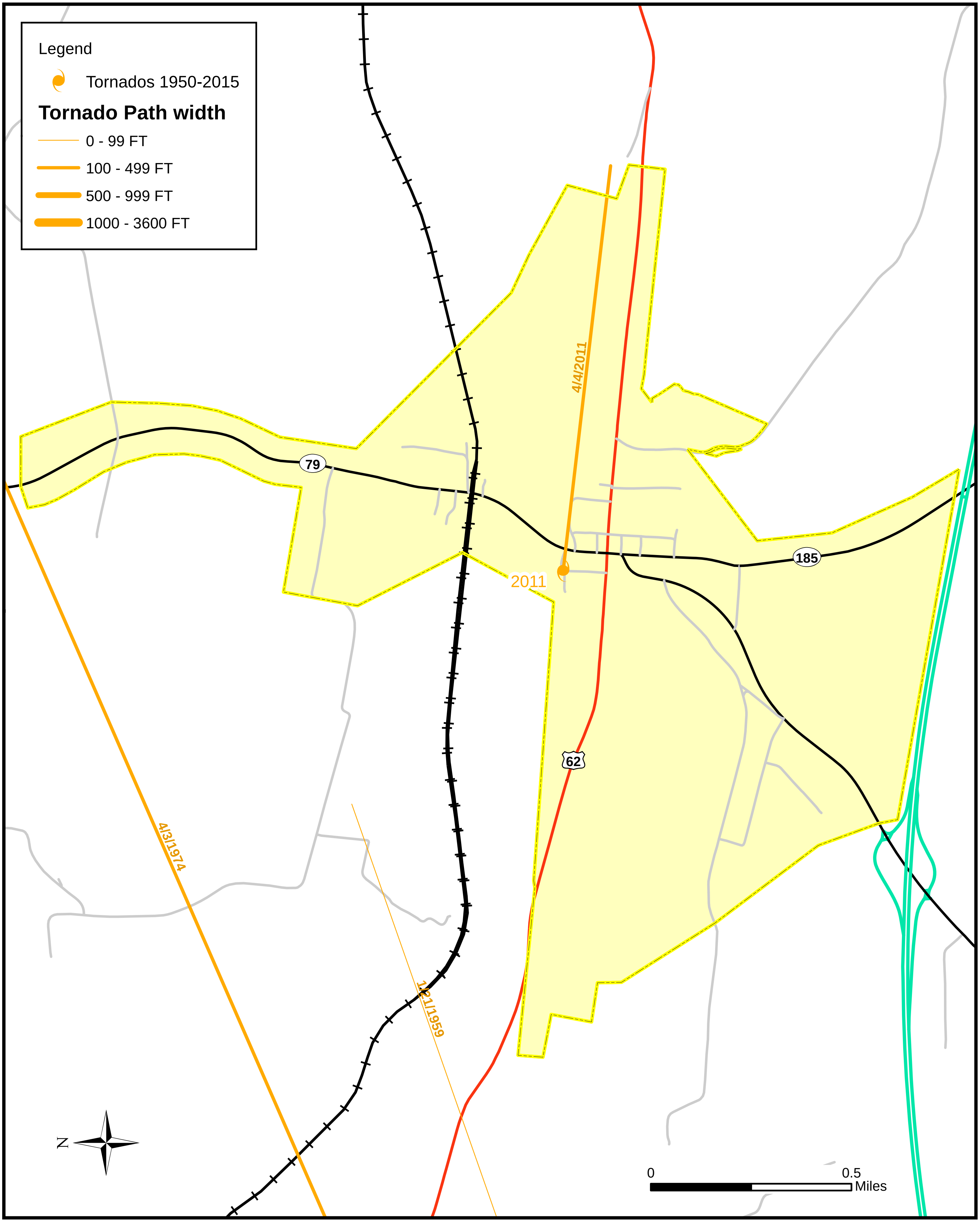
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
720
224
479
1214
1777
1168
2778
88
1356
2012
3210
62
1972
720
224
1214
889
1989
88
226
2011
920
2191
259
3155
259
259
2000
54
1133
737
187
2193
187
62
2766
411
631
2804
1655
185
79
2011
79
110
54
62
1964
736
1974
2011
878
1961
N
0
5
Miles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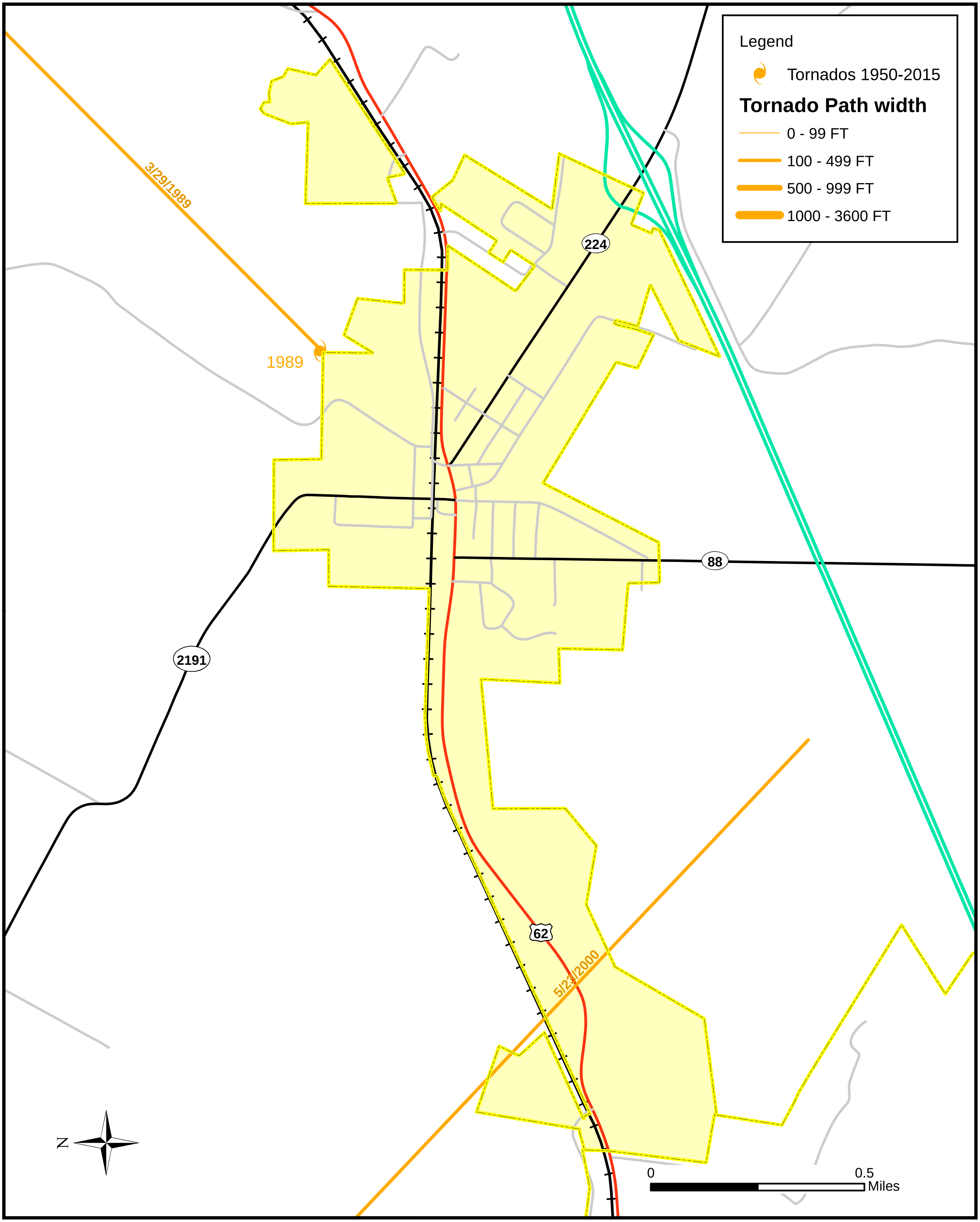
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
79
185
62
4/4/2011
2011
4/3/1974
1/21/1959
N
0
0.5
Miles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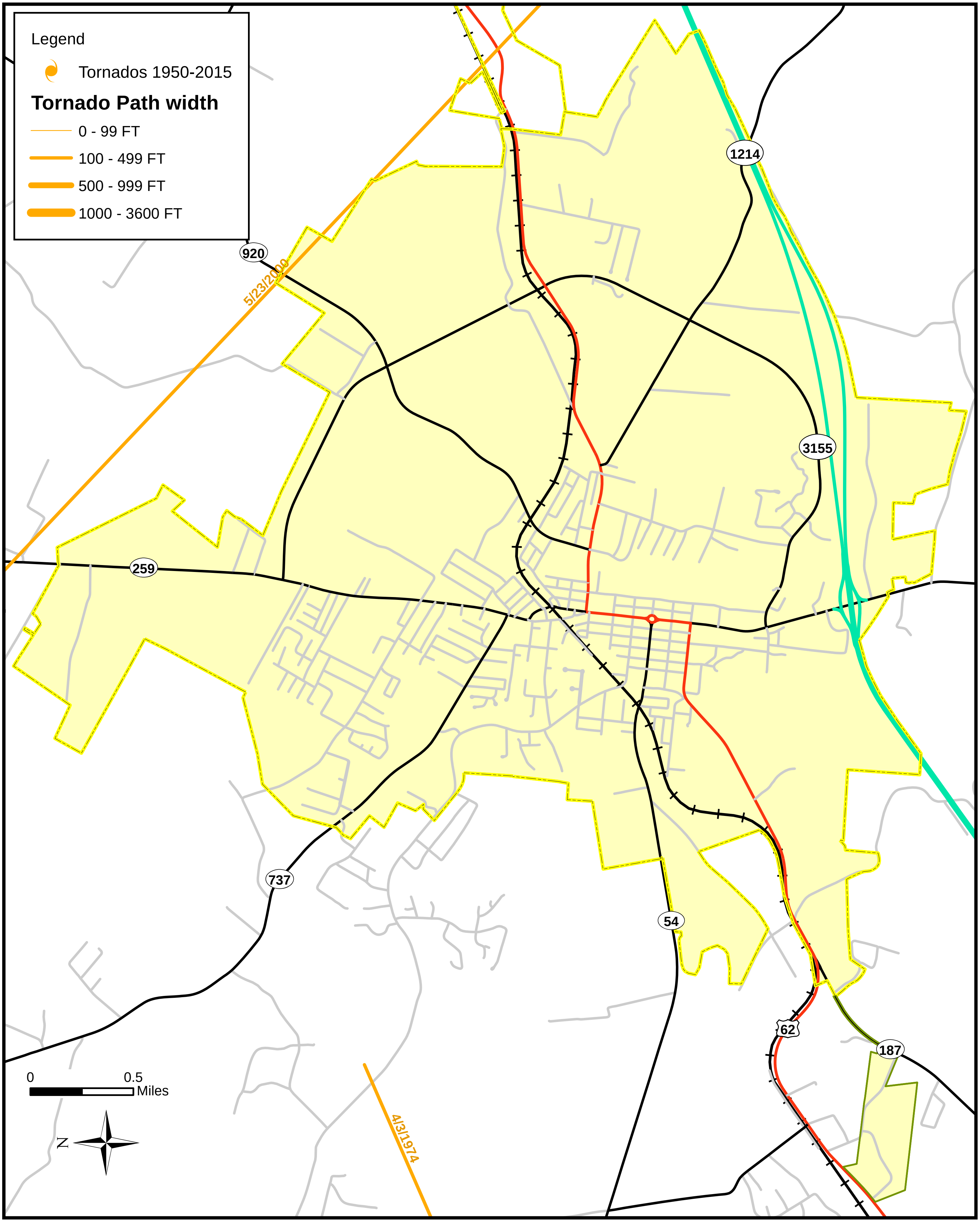
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
3/29/1989
1989
224
88
2191
62
5/23/2000
N
0
0.5
Miles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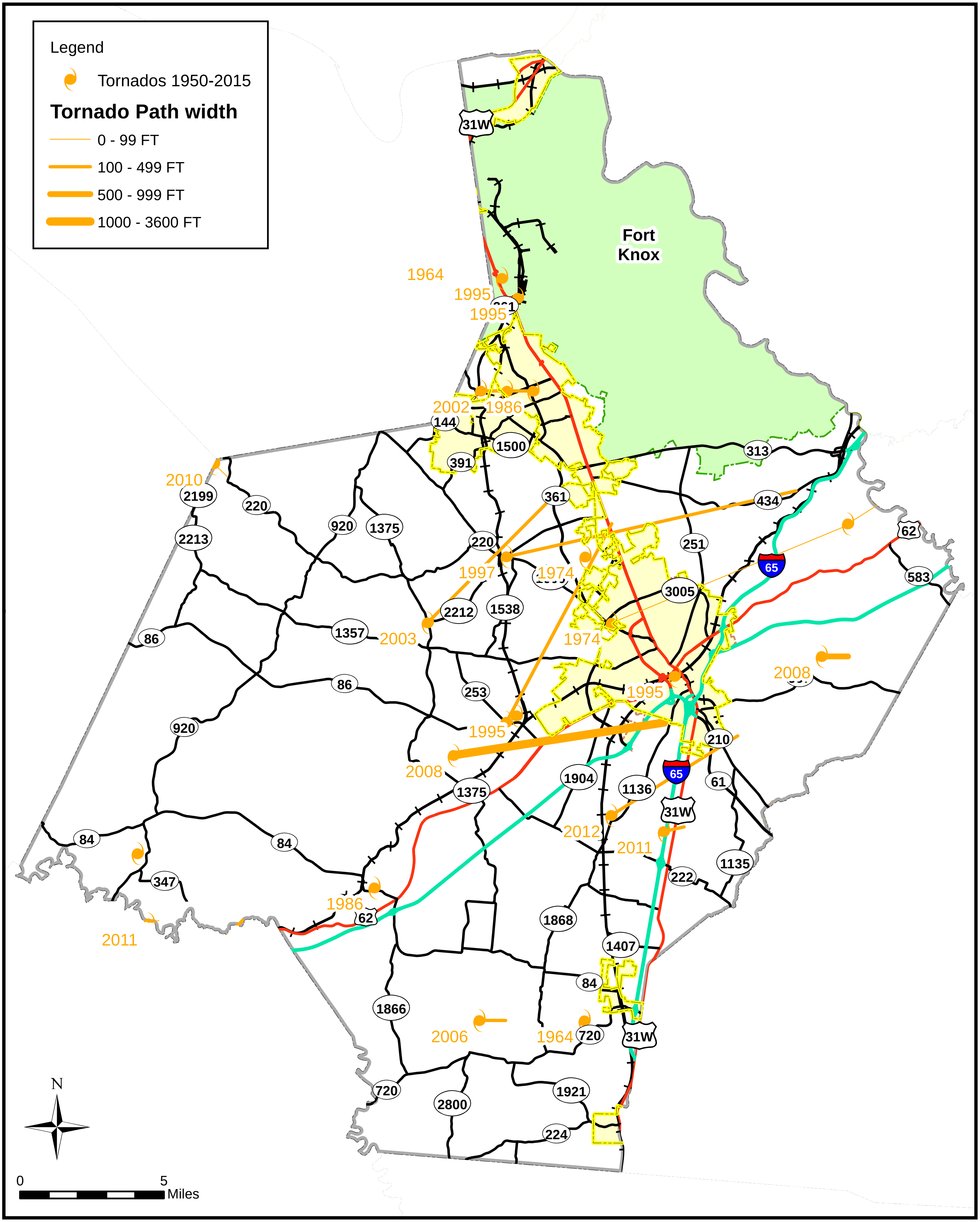
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
920
5/23/2000
1214
3155
259
737
54
62
187
4/3/1974
0
0.5
Miles
N

HARDIN

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
NORTH FOUR CORNERS	5/21/2010	0	0	$10,000	$0	EF0
SOLWAY	4/26/2011	0	0	$0	$0	EF0
GLENDALE JCT	4/26/2011	0	0	$0	$0	EF1
GLENDALE	2/29/2012	0	0	$200,000	$0	EF2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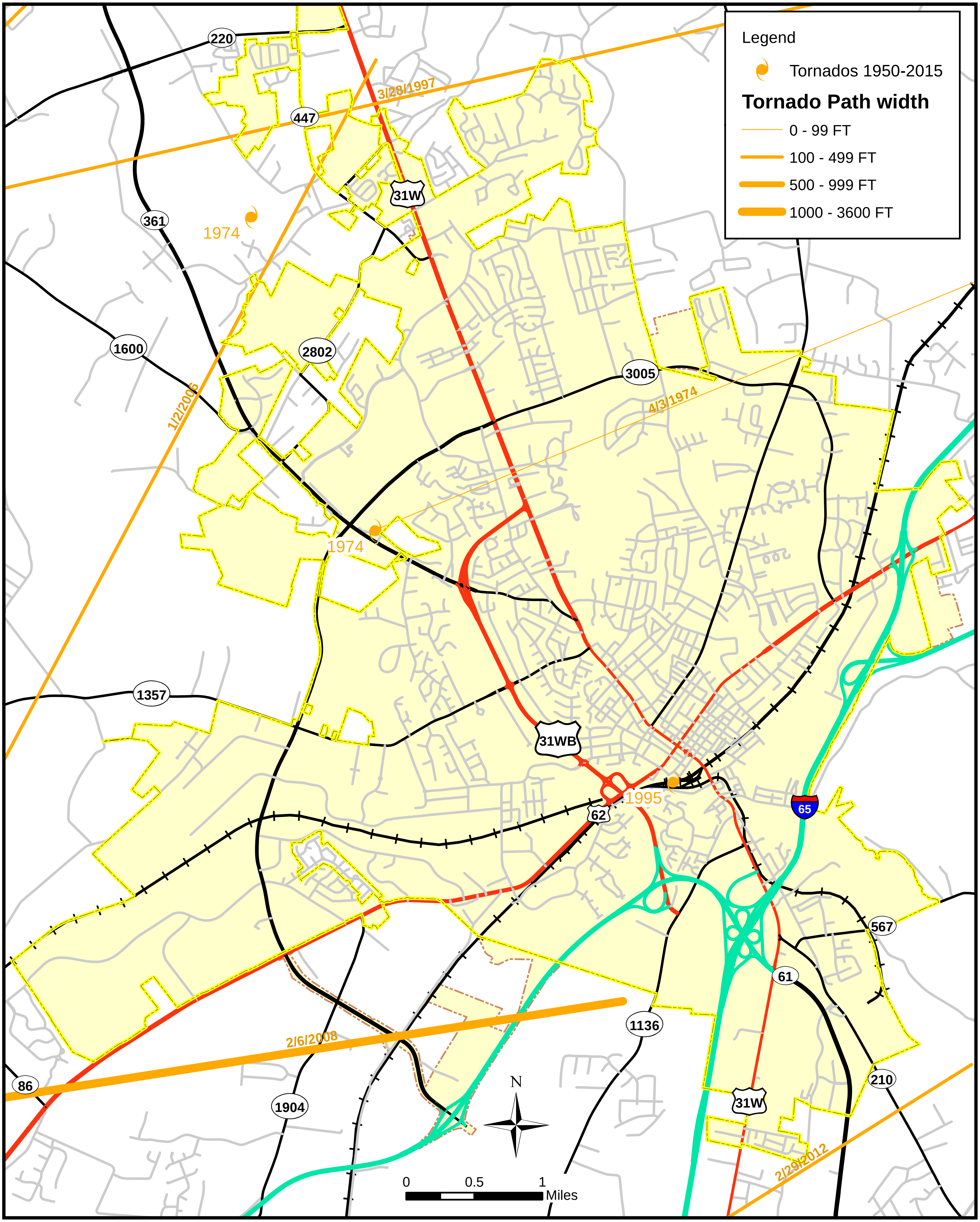
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
Fort Knox
1964
1995
1995
2002
1986
2010
1997
1974
2003
1974
2008
1995
1995
2008
2012
2011
1986
2011
2006
1964
31W
144
1500
391
361
313
434
2199
220
920
1375
2213
220
251
62
65
583
1538
2212
3005
86
1357
86
253
920
210
65
1904
1136
61
1375
31W
84
84
347
222
1135
62
1868
1407
84
1866
720
31W
720
2800
1921
224
N
0
5
Miles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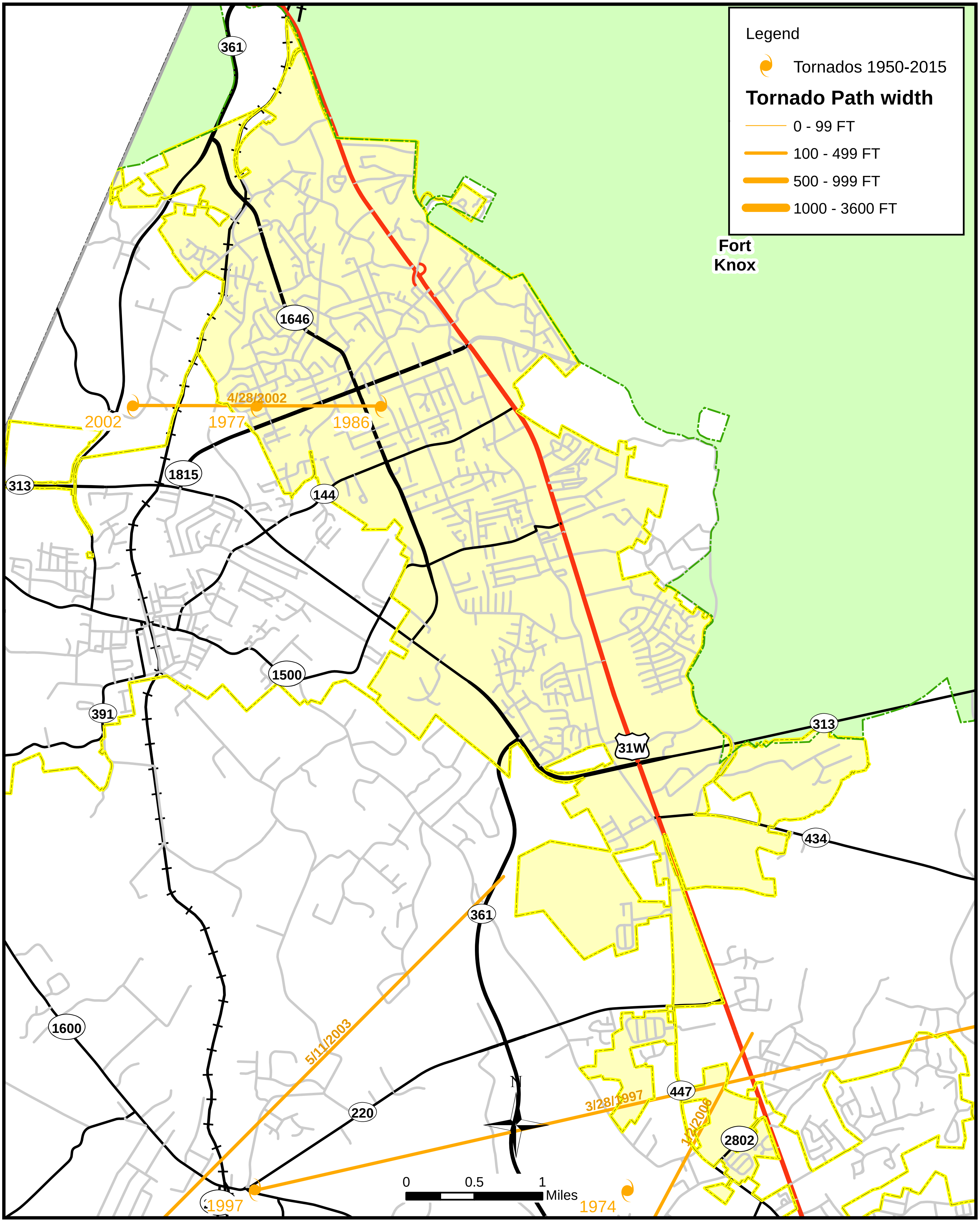
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
3/28/1997
1974
1974
4/3/1974
1/2/2006
1995
2/6/2008
2/29/2012
220
447
31W
361
1600
2802
3005
1357
31WB
62
65
567
61
1136
210
86
1904
31W
N
0
0.5
1
Miles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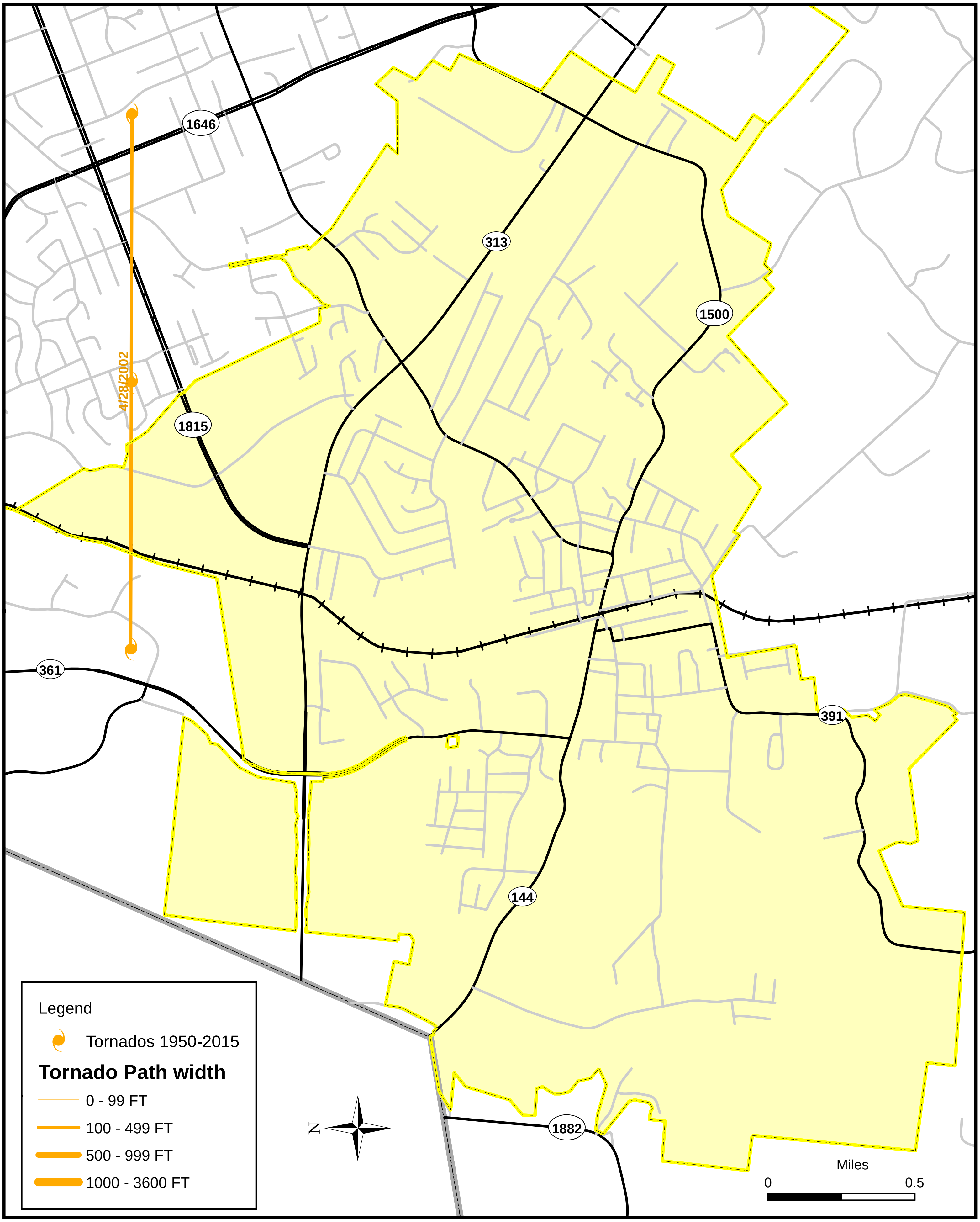
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
Fort Knox
361
1646
1815
313
144
1500
391
31W
434
1600
220
447
2802
4/28/2002
2002
1977
1986
5/11/2003
3/28/1997
1/2/2006
1997
1974
0
0.5
1
Miles
N

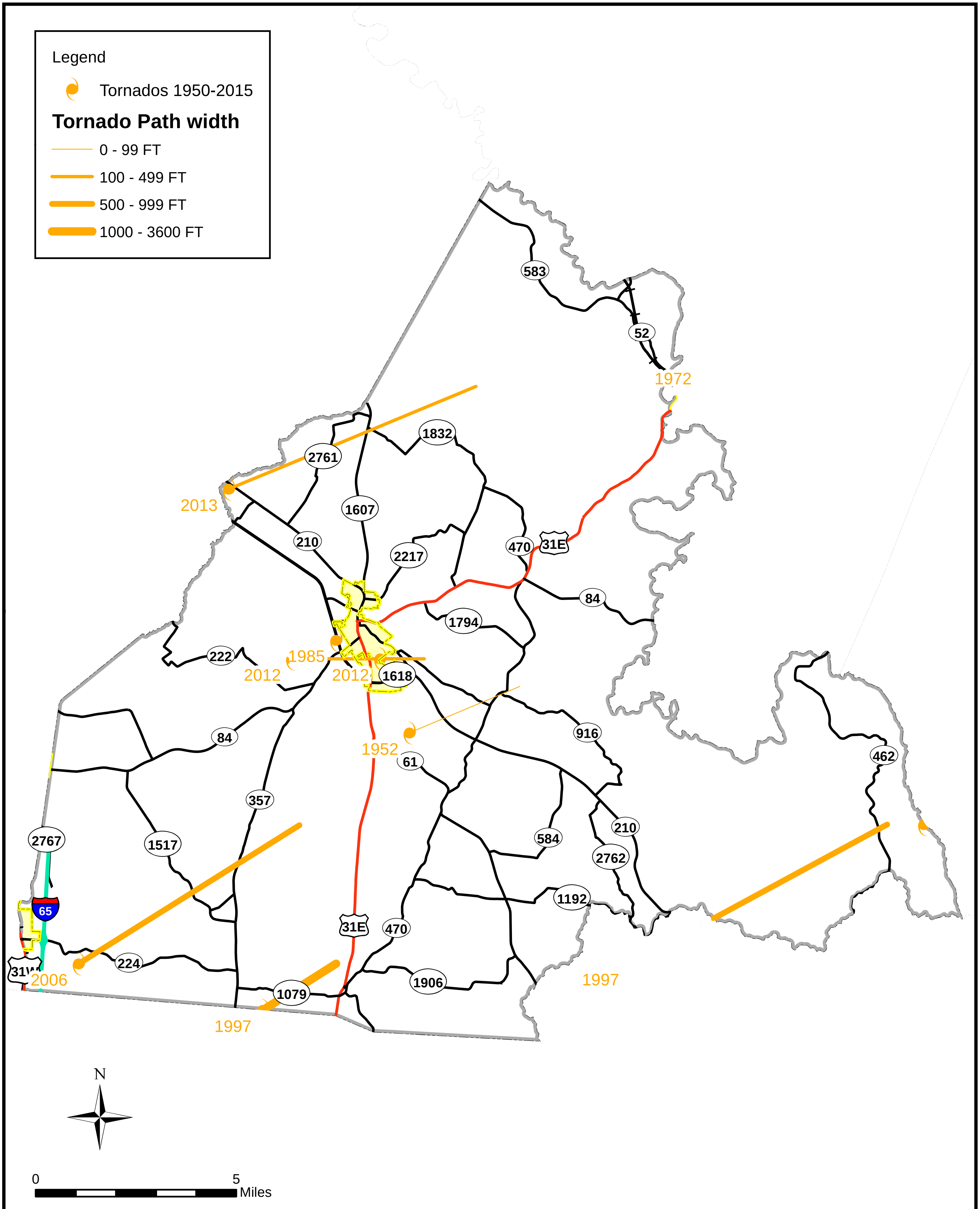

1646
313
1500
1815
4/28/2002
361
391
144
1882
Legend
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
N
Miles
0
0.5

LARUE

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
HODGENVILLE	2/29/2012	0	0	$200,000	$0	EF2
HODGENVILLE	2/29/2012	0	0	$20,000	$0	EF2
TONIEVILLE	6/26/2013	0	0	$500,000	$0	EF2


Tornado Damage in LaRue County, Feb 29, 2012. *Source: Nolin RECC, "Kentucky Living" magazine, April 2012.*

Cleanup work in LaRue County, Feb 29, 2012. *Source: Nolin RECC, "Kentucky Living" magazine, April 2012.*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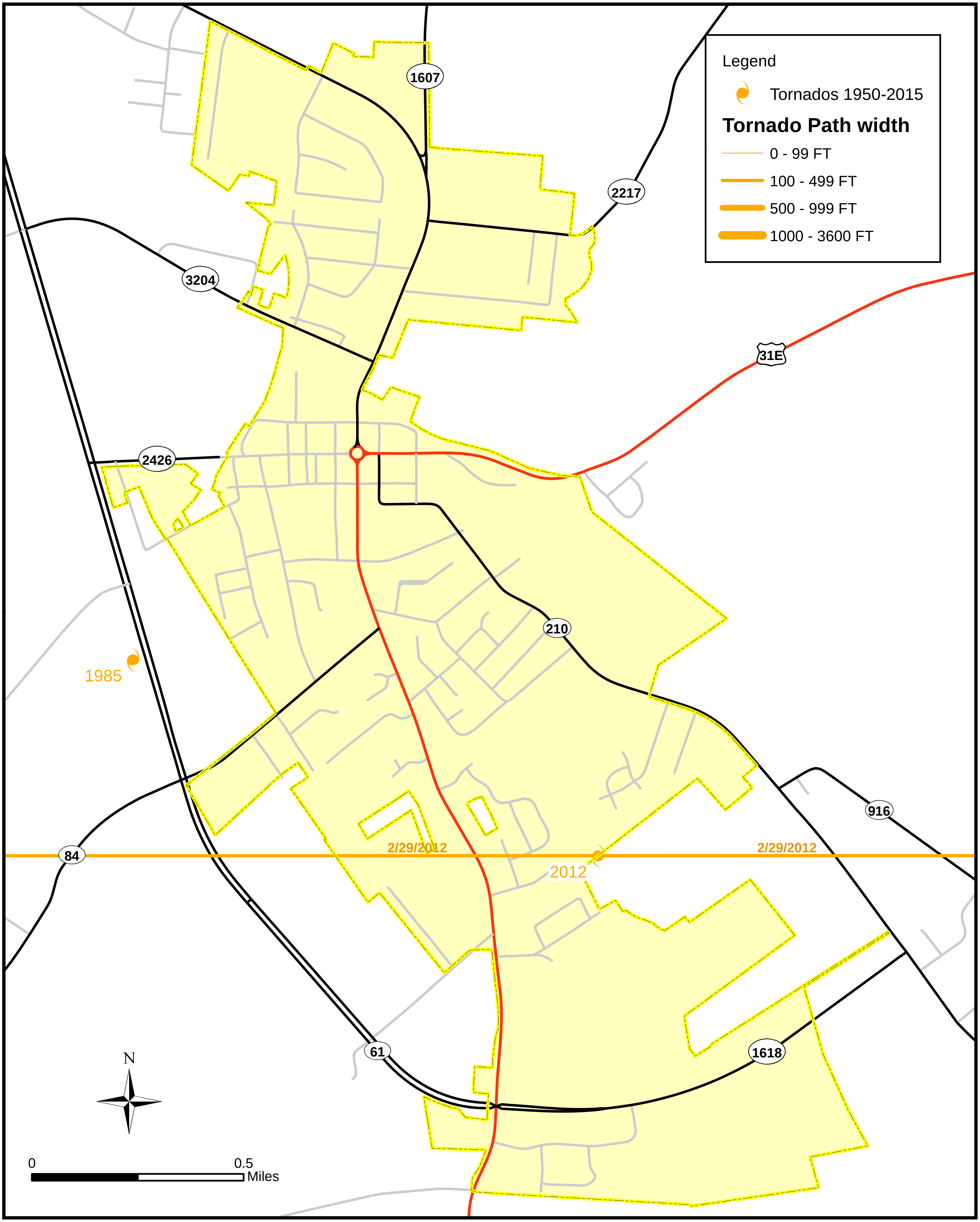
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
583
52
1972
1832
2761
2013
1607
210
2217
470
31E
84
1794
222
1985
2012
2012
1618
84
916
1952
61
462
357
2767
1517
210
584
2762
1192
65
31E
470
224
31W
2006
1906
1079
1997
1997
N
0
5
Miles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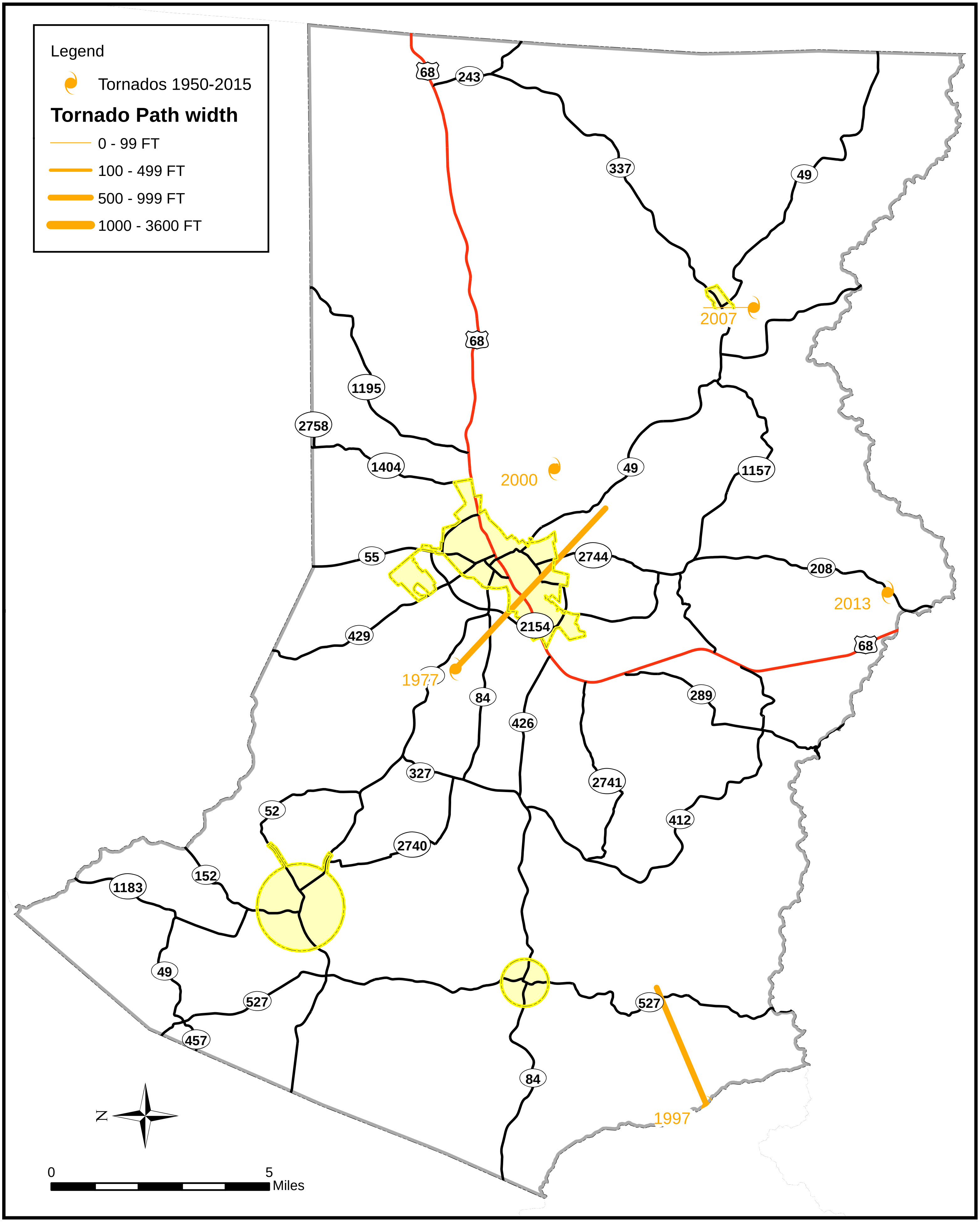
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
1607
2217
3204
31E
2426
210
1985
84
2/29/2012
2/29/2012
2012
916
61
1618
N
0
0.5
Miles

MARION

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
PHILLIPSBURG	1/30/2013	0	2	$25,000	$0	EF0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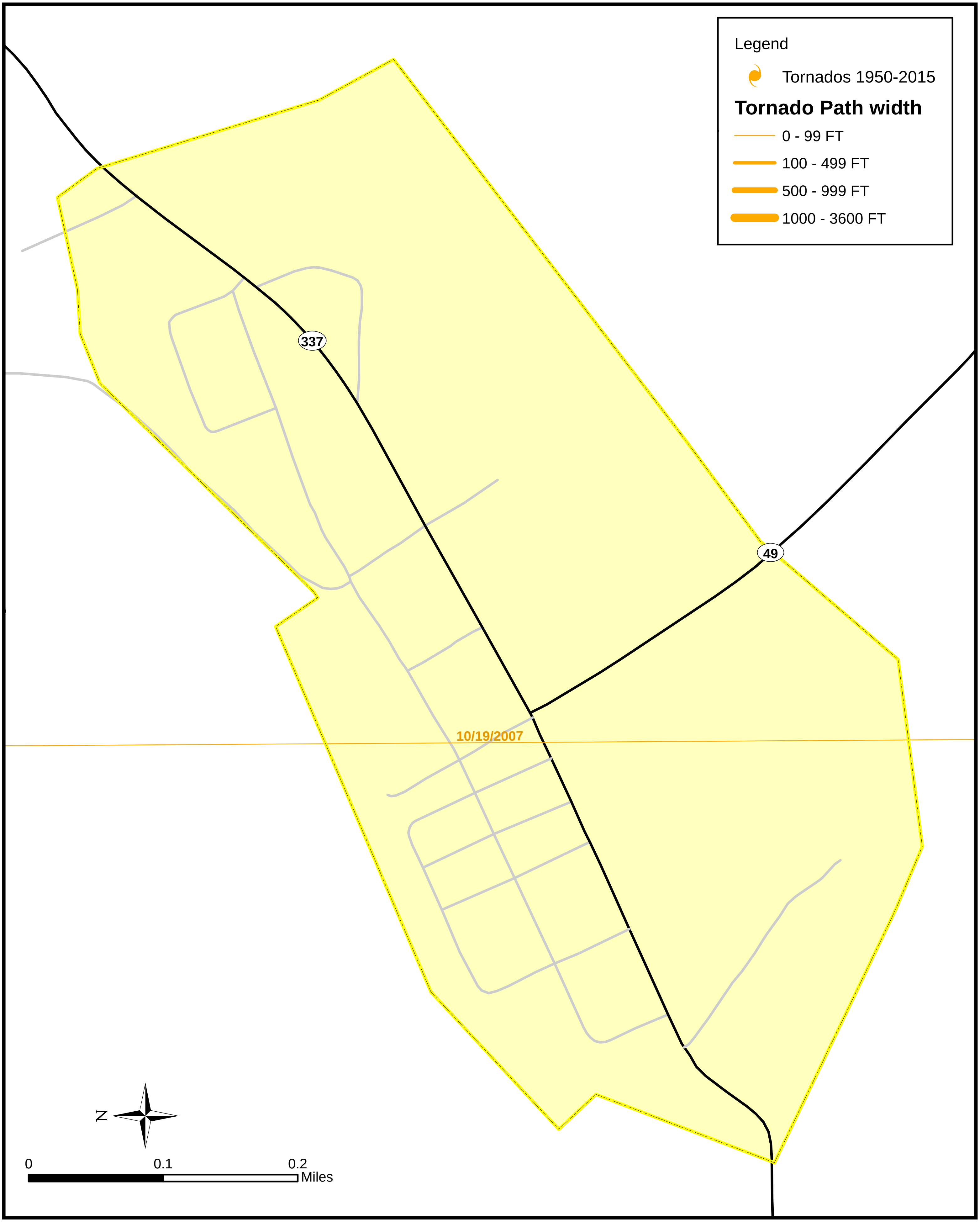
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
68
243
337
49
2007
68
1195
2758
1404
2000
49
1157
55
2744
208
2013
429
2154
68
1977
84
289
426
327
2741
52
412
2740
152
1183
49
527
527
457
84
1997
N
0
5
Miles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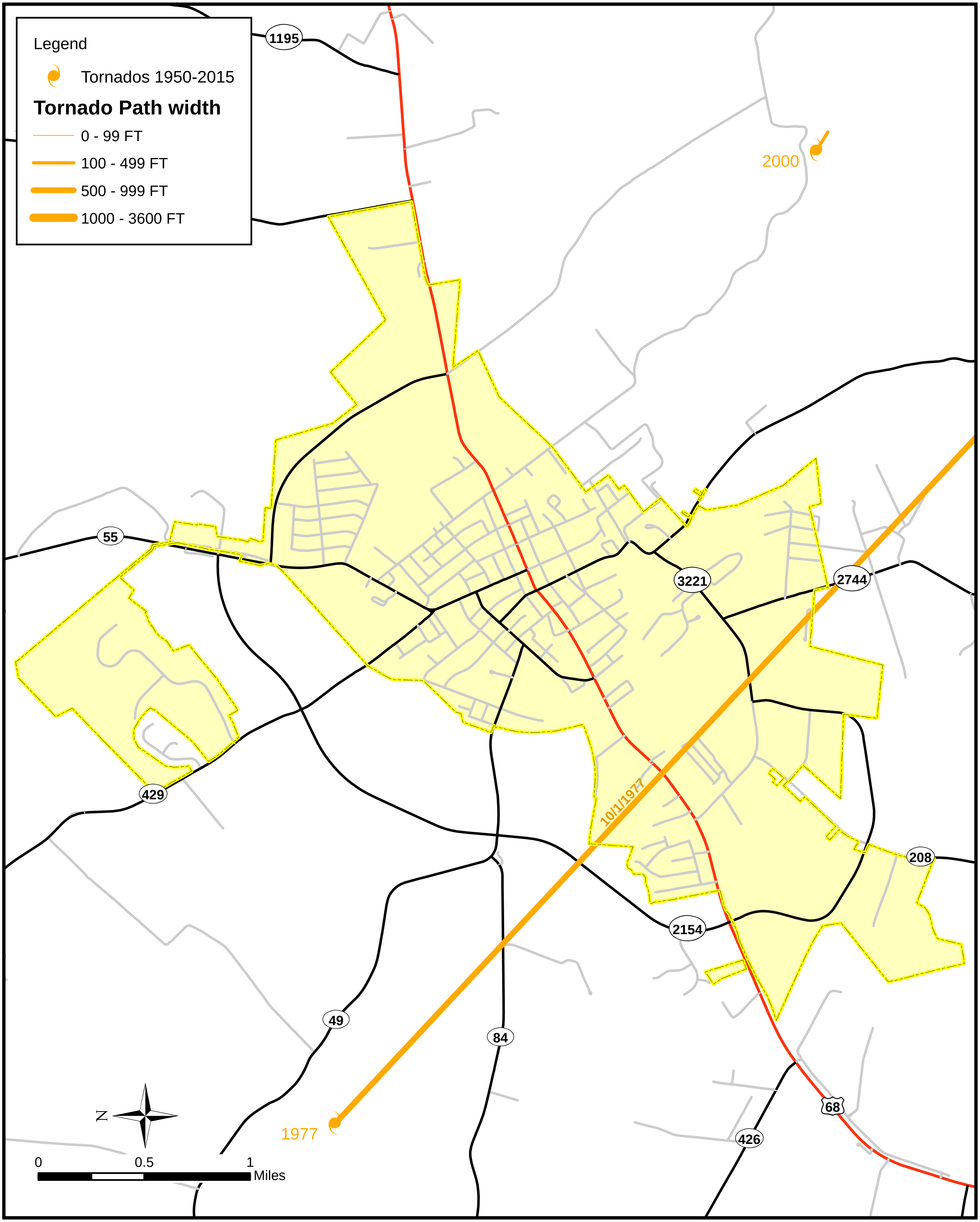
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
337
49
10/19/2007
N
0
0.1
0.2
Miles


Legend
Tornados 1950-2015
Tornado Path width
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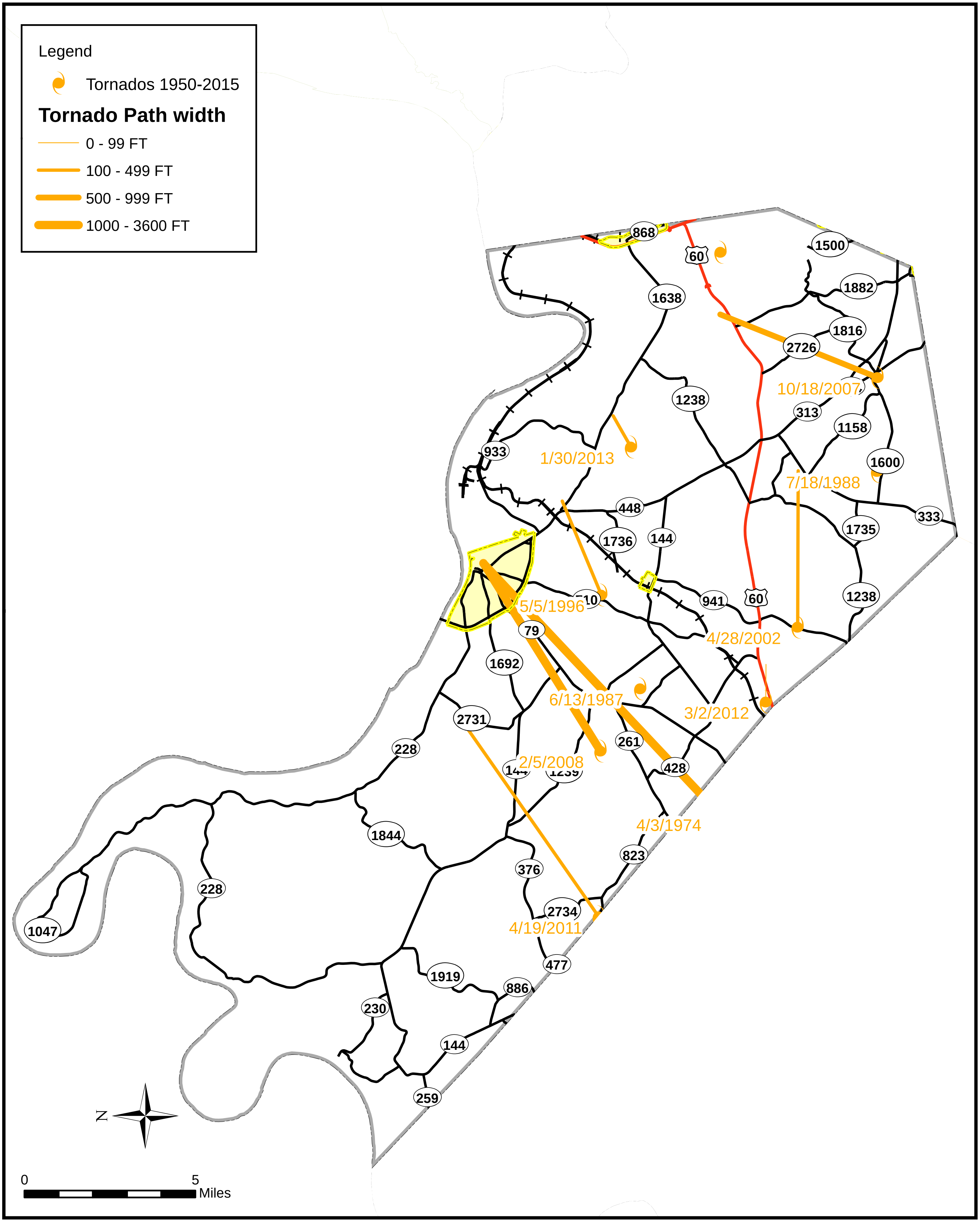
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
1195
2000
55
3221
2744
429
10/1/1977
208
2154
49
84
68
426
1977
N
0
0.5
1
Miles

MEADE

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE	F SCALE
PAYNEVILLE	4/19/2011	0	0	$0	$0	EF0
GUSTON	3/2/2012	0	0	$2,000	$0	EF0
BUCK GROVE	1/30/2013	0	0	$50,000	$0	EF0

NELSON – No new events recorded 1 July 2009-30 June 2015.

WASHINGTON – No new events recorded 1 July 2009-30 June 2015.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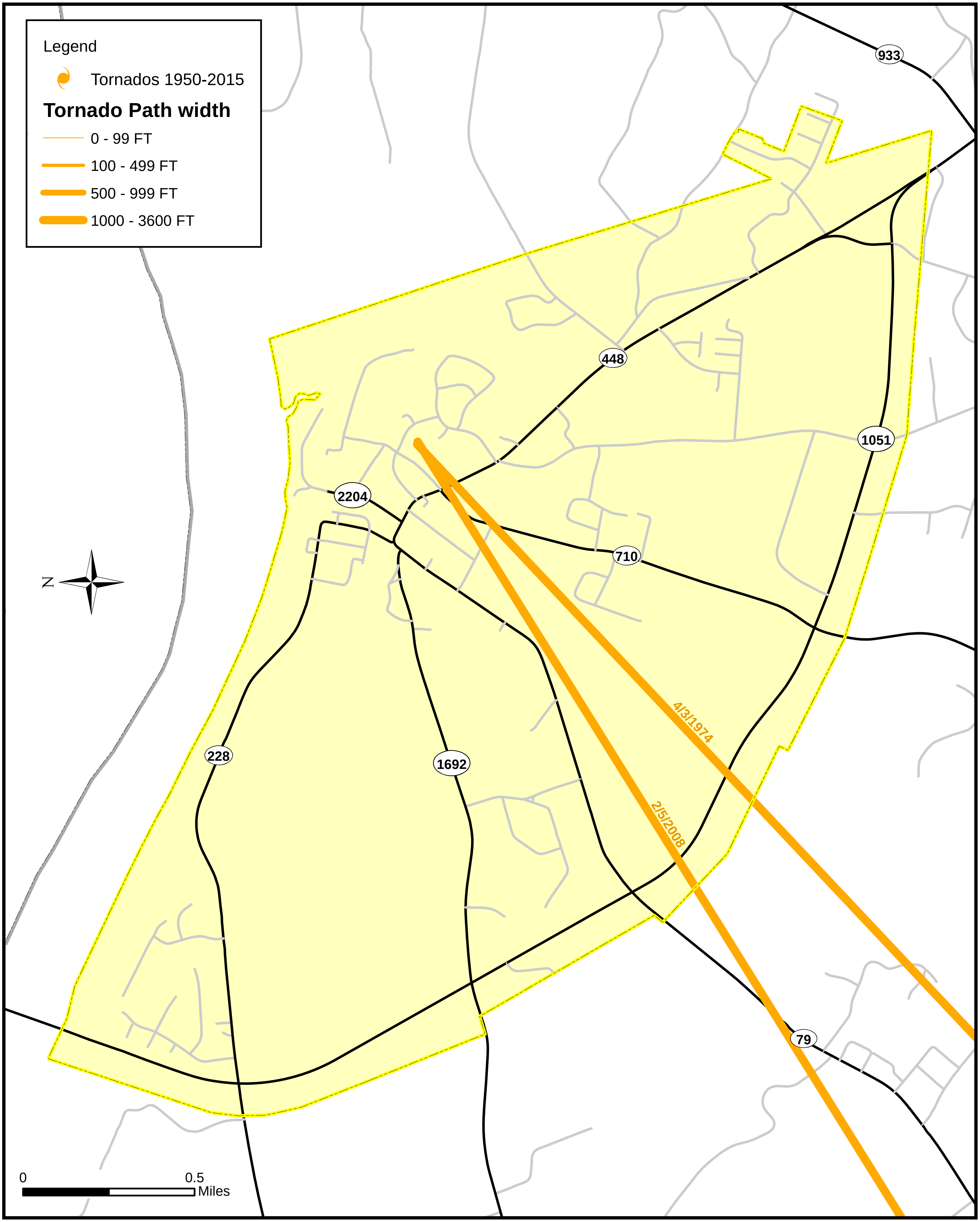
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
10/18/2007
1/30/2013
7/18/1988
5/5/1996
4/28/2002
6/13/1987
3/2/2012
2/5/2008
4/3/1974
4/19/2011
0
5
Miles
N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Tornados 1950-2015
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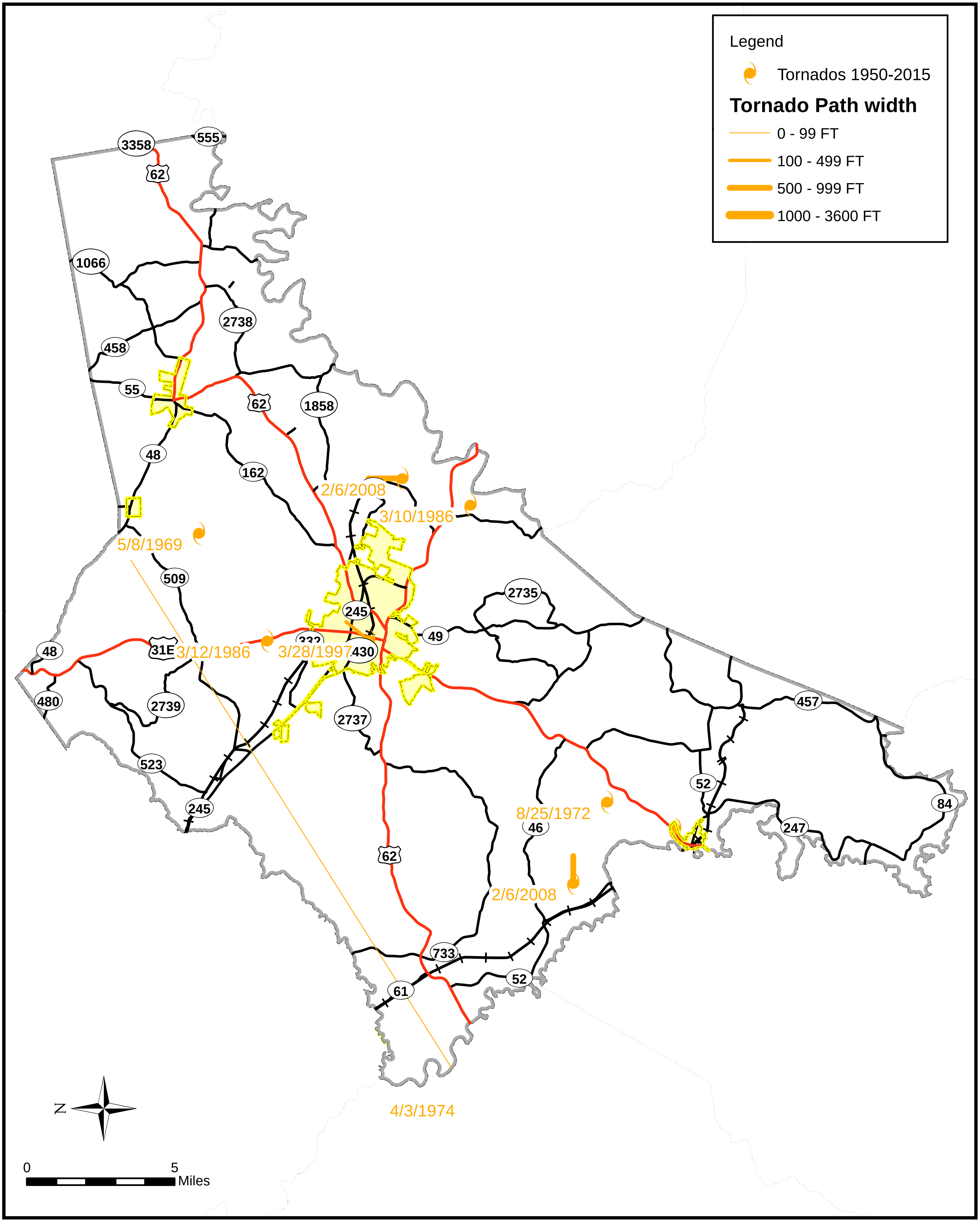
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
N
933
448
1051
2204
710
228
1692
79
4/3/1974
2/5/2008
0
0.5
Miles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100 - 499 FT
500 - 999 FT
1000 - 3600 FT
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555
62
1066
2738
458
55
62
1858
48
162
2/6/2008
3/10/1986
5/8/1969
509
2735
245
49
48
31E
3/12/1986
3/28/1997
332
430
480
2739
2737
457
523
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46
247
62
2/6/2008
733
61
52
4/3/1974
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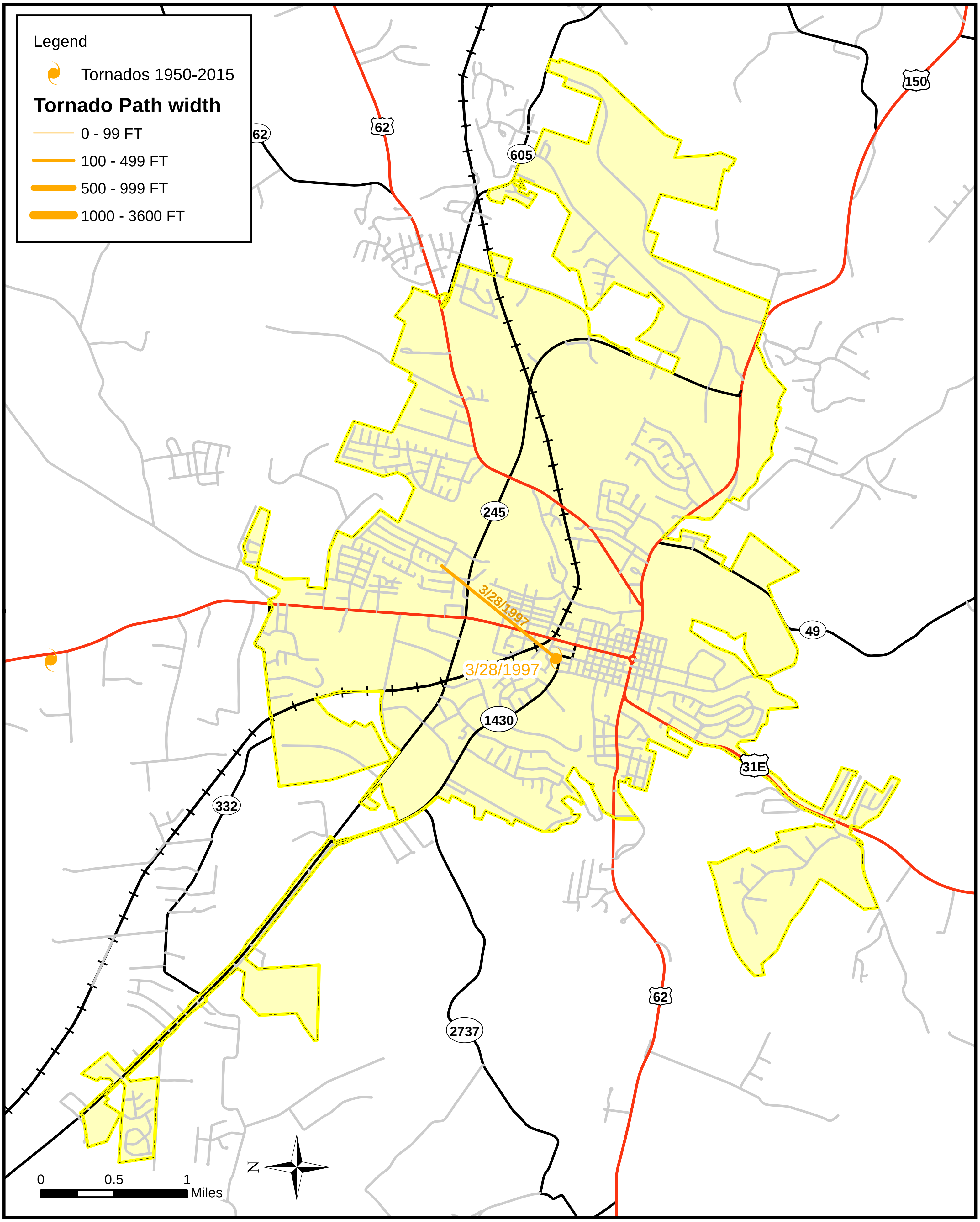
Miles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1000 - 3600 FT
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62
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150
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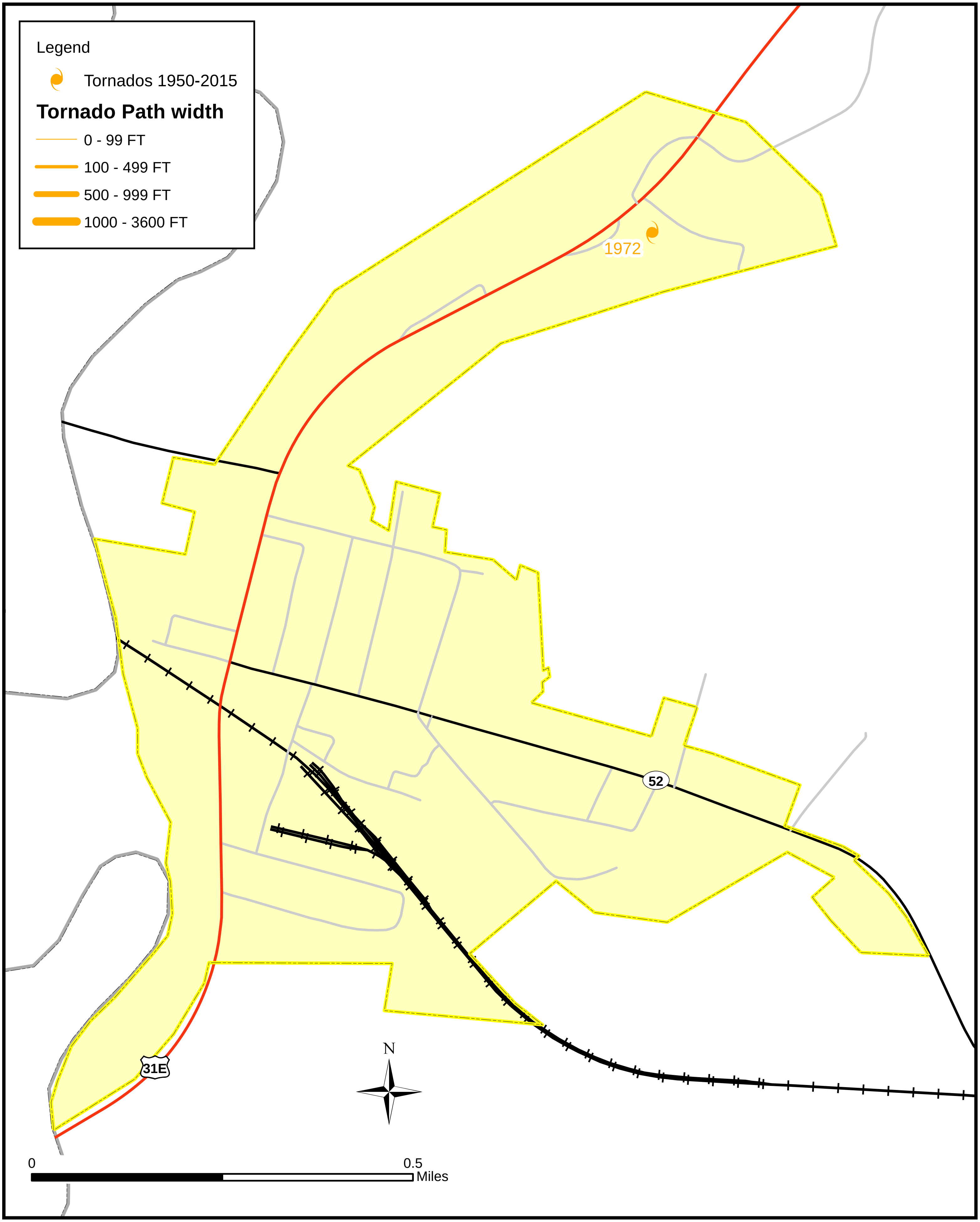
3/28/1997
3/28/1997
49
1430
31E
332
62
2737
N
0
0.5
1
Miles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1000 - 3600 FT
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52
31E
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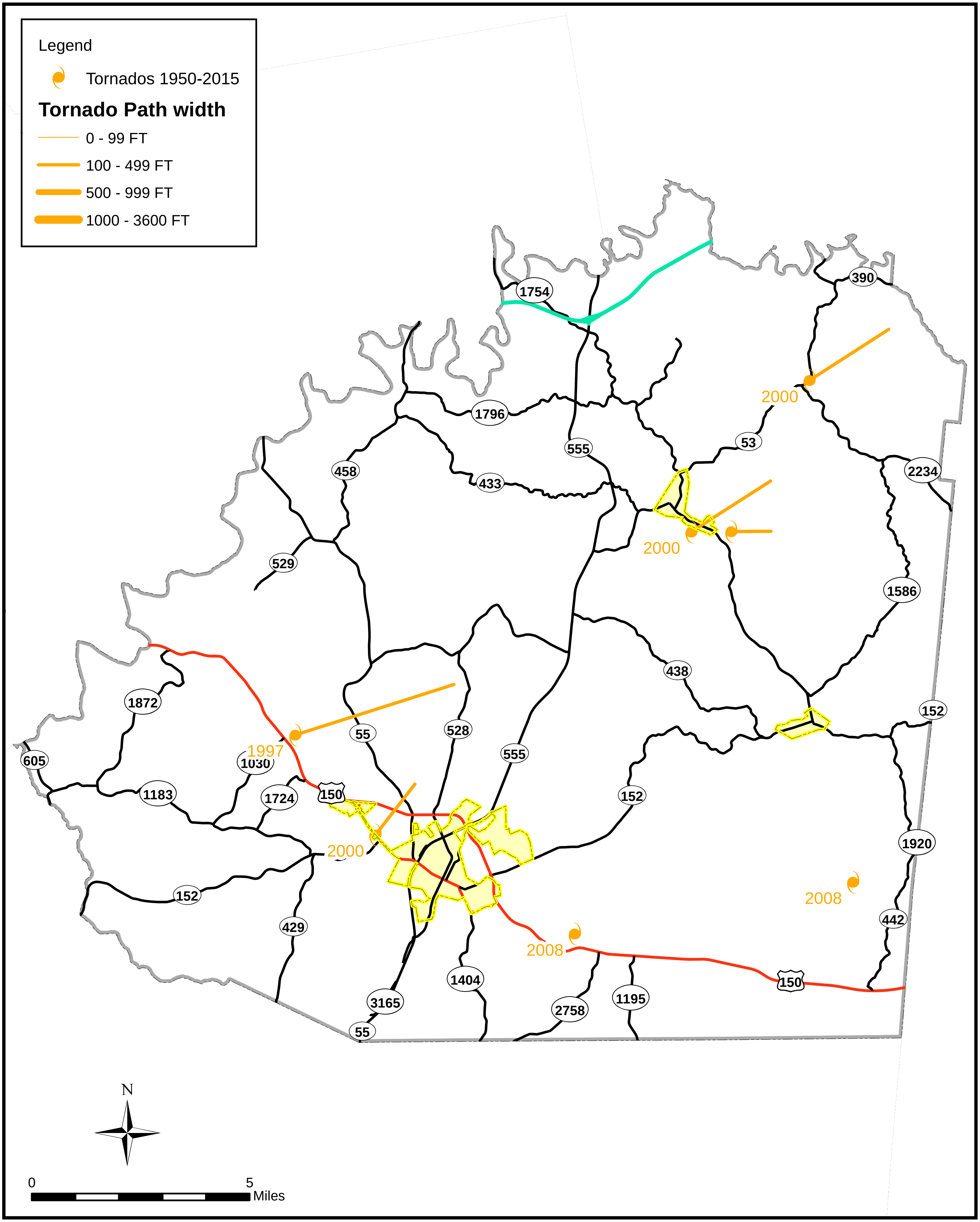
0
0.5
Miles


Legend
Tornados 1950-2015
Tornado Path width
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100 - 499 FT
500 - 999 FT
1000 - 3600 FT
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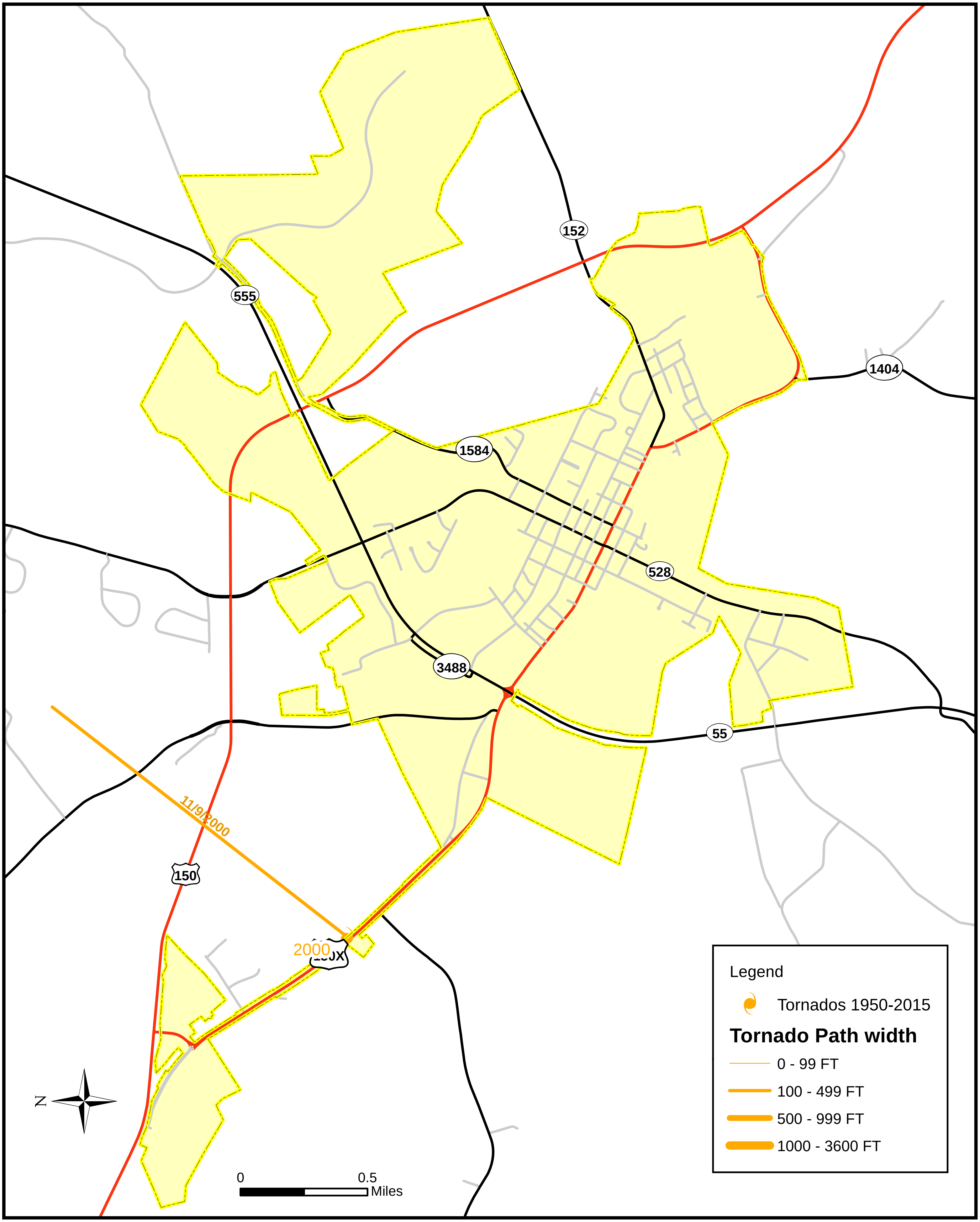
390
1796
555
53
2000
458
433
2234
2000
529
1586
438
152
1872
55
528
1997
605
1030
555
1183
1724
150
152
2000
1920
152
2008
429
442
2008
1404
150
3165
1195
2758
55
N
0
5
Miles


152
555
1404
1584
528
3488
55
150
11/9/2000
2000
N
0
0.5
Miles
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500 - 999 FT
1000 - 3600 FT

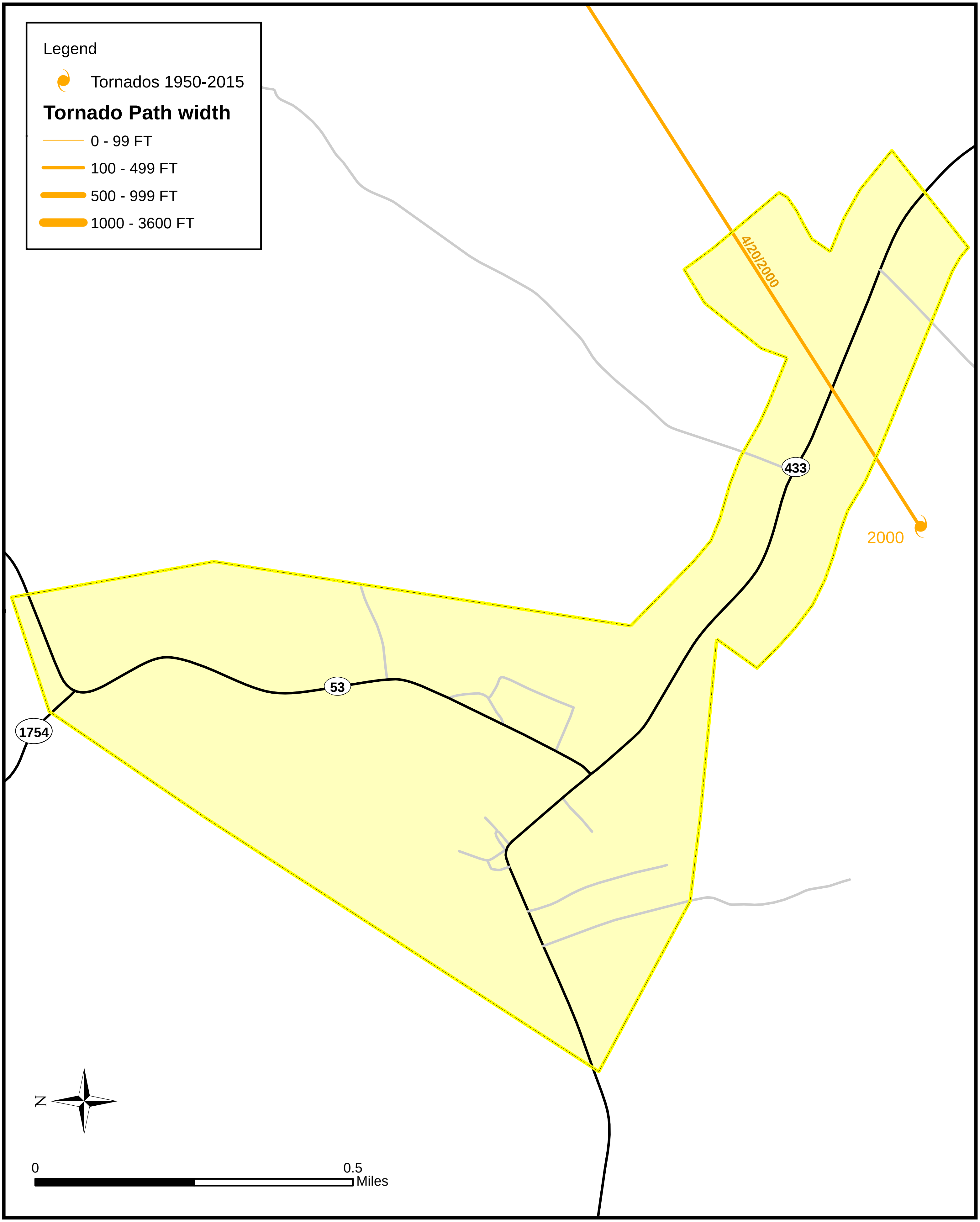
Legend
Tornados 1950-2015
Tornado Path width
0 - 99 FT
100 - 499 FT
500 - 999 FT
1000 - 3600 FT
4/20/2000
2000
433
53
1754
N
0
0.5
Miles

Table 3.3.2.2.4 - Summary of Tornado Data, Costs

TORNADOS	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDGE	$5,185,260	16	54.5	1.09	20.00	$95,142	$324,079	0.02	0.07	0.37	1.25
Cloverport	$900,000	2	54.5	1.00	7.00	$16,514	$450,000	0.02	0.50	0.13	3.50
Hardinsburg	$100,000	2	54.5	0.00	0.00	$1,835	$50,000	0.00	0.00	0.00	0.00
Irvington	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
GRAYSON	$56,483,213	15	55.5	3.00	23.09	$1,017,716	$3,765,548	0.05	0.20	0.42	1.54
Caneyville	$0	1	55.5	0.00	0.00	$0	na	0.00	na	0.00	na
Clarkson	$0	0	55.5	0.00	0.00	$0	na	0.00	na	0.00	na
Leitchfield	$50,000,000	1	55.5	0.00	16.00	$900,901	$50,000,000	0.00	0.00	0.29	16.00
HARDIN	$16,118,723	24	54.5	2.00	73.09	$295,756	$671,613	0.04	0.08	1.34	3.05
Elizabethtown	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
Radcliff	$650,000	2	54.5	0.00	0.00	$11,927	$325,000	0.00	0.00	0.00	0.00
Sonora	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
Upton	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
Vine Grove	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
West Point	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
LARUE	$5,110,111	11	62.5	0.00	19.12	$81,762	$464,556	0.00	0.00	0.31	1.74
Hodgenville	$220,000	2	62.5	0.00	0.00	$3,520	na	0.00	na	0.00	na
MARION	$735,833	11	54.5	0.00	4.15	$13,502	$66,894	0.00	0.00	0.08	0.38
Bradfordsville	$100,000	1	54.5	0.00	0.00	$1,835	$100,000	0.00	0.00	0.00	0.00
Lebanon	$100,000	1	54.5	0.00	0.00	$1,835	$100,000	0.00	0.00	0.00	0.00
Loretto	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
Raywick	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
MEADE	$6,142,325	12	54.5	31.00	267.09	$112,703	$511,860	0.57	2.58	4.90	22.26
Brandenburg	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
Ekron	$500,000	1	54.5	0.00	10.00	$9,174	$500,000	0.00	0.00	0.18	10.00
Muldraugh	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
NELSON	$2,033,978	13	54.5	1.00	28.15	$37,321	$156,460	0.02	0.08	0.52	2.17
Bardstown	$50,000	1	54.5	0.00	0.00	$917	$50,000	0.00	0.00	0.00	0.00
Bloomfield	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
Fairfield	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
New Haven	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
WASHINGTON	$1,840,007	11	54.5	0.00	5.15	$33,762	$167,273	0.00	0.00	0.09	0.47
Mackville	$0	0	54.5	0.00	0.00	$0	na	0.00	na	0.00	na
Springfield	$15,000	1	54.5	0.00	0.00	$275	$15,000	0.00	0.00	0.00	0.00
Willisburg	$70,000	2	54.5	0.00	4.00	$1,284	$35,000	0.00	0.00	0.07	2.00
LTADD	$93,649,450	113	56	38.09	439.84	$1,683,586	$828,756	0.68	0.34	7.91	3.89

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30 2015.

Table 3.3.2.2.5 - Summary of Tornado Data, Events

TORNADOS	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	16	54.5	7	10	15	3.41	29.36%	0.7	0.5	0.3
Cloverport	2	54.5	1	2	2	27.25	3.67%	0.1	0.1	0.04
Hardinsburg	2	54.5	1	2	2	27.25	3.67%	0.1	0.1	0.04
Irvington	0	54.5	0	0	0	0.00	0.00%	0	0	0
GRAYSON	15	55.5	5	6	10	3.70	27.03%	0.5	0.3	0.2
Caneyville	1	55.5	1	1	1	55.50	1.80%	0.1	0.05	0.02
Clarkson	0	55.5	0	0	0	0.00	0.00%	0	0	0
Leitchfield	1	55.5	0	1	1	55.50	1.80%	0	0.05	0.02
HARDIN	24	54.5	8	11	21	2.27	44.04%	0.8	0.55	0.42
Elizabethtown	0	54.5	0	0	0	0.00	0.00%	0	0	0
Radcliff	2	54.5	0	1	2	27.25	3.67%	0	0.05	0.04
Sonora	0	54.5	0	0	0	0.00	0.00%	0	0	0
Upton	0	54.5	0	0	0	0.00	0.00%	0	0	0
Vine Grove	0	54.5	0	0	0	0.00	0.00%	0	0	0
West Point	0	54.5	0	0	0	0.00	0.00%	0	0	0
LARUE	11	62.5	4	6	9	5.68	17.60%	0.4	0.3	0.18
Hodgenville	2	62.5	0	0	0	31.25	3.20%	0	0	0
MARION	11	54.5	2	4	8	4.95	20.18%	0.2	0.2	0.16
Bradfordsville	1	54.5	1	1	1	54.50	1.83%	0.1	0.05	0.02
Lebanon	1	54.5	0	1	1	54.50	1.83%	0	0.05	0.02
Loretto	0	54.5	0	0	0	0.00	0.00%	0	0	0
Raywick	0	54.5	0	0	0	0.00	0.00%	0	0	0
MEADE	12	54.5	5	7	10	4.54	22.02%	0.5	0.35	0.2
Brandenburg	0	54.5	0	0	0	0.00	0.00%	0	0	0
Ekron	1	54.5	0	1	1	54.50	1.83%	0	0.05	0.02
Muldraugh	0	54.5	0	0	0	0.00	0.00%	0	0	0
NELSON	13	54.5	2	3	13	4.19	23.85%	0.2	0.15	0.26
Bardstown	1	54.5	0	1	1	54.50	1.83%	0	0.05	0.02
Bloomfield	0	54.5	0	0	0	0.00	0.00%	0	0	0
Fairfield	0	54.5	0	0	0	0.00	0.00%	0	0	0
New Haven	0	54.5	0	0	0	0.00	0.00%	0	0	0
WASHINGTON	11	54.5	5	7	11	4.95	20.18%	0.5	0.35	0.22
Mackville	0	54.5	0	0	0	0.00	0.00%	0	0	0
Springfield	1	54.5	0	1	1	54.50	1.83%	0	0.05	0.02
Willisburg	2	54.5	1	2	2	27.25	3.67%	0.1	0.1	0.04
LTADD	113	56	38	54	97	0.49	203.15%	3.8	2.7	1.94

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

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Compilation of SHELDUS, NCDC & NCEI. 1967- June 30 2015.

3.3.2.3 <u>Severe Thunderstorms</u>

I. Background

Definition: Thunderstorm. The National Oceanic and Atmospheric Administration (NOAA) defines a thunderstorm as "a rain shower during which you hear thunder. Since thunder comes from lightning, all thunderstorms have lightning."

Severe Thunderstorm: NOAA classifies a thunderstorm as severe " when it contains one or more of the following: hail one inch or greater, winds gusting in excess of 50 knots (57.5 mph), or a tornado."

Cause and Types of Thunderstorms

Three basic ingredients are necessary for a thunderstorm to form: moisture, rising unstable air (air that keeps rising when given a nudge), and a lifting mechanism to provide the "nudge." Lifts can form from fronts, sea breezes or mountains. Upward moving air is an updraft. Cooler air tends to sink and produces downdraft winds. Downdraft winds can result in one of four different storms; single cell, multicell cluster, multicell line, or supercell.

When sun heats the surface of the earth, it warms the air above the ground. If this warm air is forced to rise as a result of "bumping" into cooler or damper air, it will continue to rise for as long as it weighs less and remains warmer than the air around it. As the air rises, it transfers heat from the earth's surface to the upper levels of the atmosphere; a process know as convection. The water vapor in the air begins to cool, releases heat, condenses and forms a cloud. This cloud gradually grows upward into areas where the temperature is below freezing. These Cumulonimbus clouds are also known as "thunderhead" clouds and produce lightning.

As a storm rises up into freezing air, ice particles can form and grow by condensing vapor and collecting smaller liquid drops that haven't yet frozen (a state called "supercooled"). When two ice particles collide, they usually bounce off of each other, but one particle can rip off a little bit of ice from another and grab some electric charge. When lots of these collisions build up big areas of electric charges, it causes a bolt of lightning and creates sound waves that are heard as thunder.

Thunderstorms can occur year-round and at all hours, and happen in every US state. However, they are most likely to occur in the spring and summer months and during the afternoon and evening hours. It is estimated that approximately 1,800 thunderstorms occur across our planet every day. About 100,000 thunderstorms occur in the U.S. each year.

A typical thunderstorm is 15 miles in diameter and lasts an average of 30 minutes. All thunderstorms produce lightning and are dangerous. Lightning kills between 75 to 100 people annually. Lightning can also cause fires. In addition, thunderstorms can cause flash floods that kill more people each year than hurricanes, tornadoes or lightning. Severe thunderstorms can produce hail up to the size of softballs that damages cars and property, and kills livestock caught out in the open. Strong, straight-line winds associated with thunderstorms knock down trees, power lines and mobile homes. Severe thunderstorms can spawn tornadoes with winds up to 300 mph that can destroy well-built man-made structures.

Shelf Cloud

A shelf cloud is a low, horizontal wedge-shaped cloud associated with a thunderstorm gust front or, occasionally, with a cold front. Shelf clouds can be attached to the front side of lines of storms or even a single storm. Usually, there isn't any persistent rotation on a vertical axis within shelf clouds or within individual cloud fragments that extend down from the shelf cloud. Shelf clouds often resemble snow plows, big waves or tsunamis and can look very threatening.

Meade County Thunderstorm, 10/27/2009, *Source: Meade County Emergency Management Office.*

Single Cell or Pulse Storm

A pulse storm is short-lived and usually lasts 30 to 60 minutes. Pulse storms are common in summer and are usually not severe. Pulse storms may produce heavy rain, thunder, lightning, and possible hail and gusty winds. Brief severe weather is possible during a pulse storm in the form of a microburst. These storms are moderately dangerous to the public and moderately to highly dangerous to aviation.

Multicell Cluster

A multicell cluster is a group of severe or non-severe cells in various stages of development. The most common of thunderstorms, mature thunderstorms are located near the center of the cluster, while dissipating thunderstorms exist on their downwind side. Each cluster may only last 20 minutes, but the storm itself may persist for hours. Multicell cluster storms are stronger than single cell storms, but much weaker than a supercell storm. A multicell cluster is capable of producing moderate-sized hail, flash flooding, and weak tornados.

Multicell Line

A multicell line, also known as squall line, is an elongated line of severe thunderstorms that can form along and/or ahead of a cold front. It has the potential to produce heavy precipitation, hail, frequent lightning, strong straight-line winds, and possibly tornados and waterspouts. Severe weather in the form of strong straight-line winds can be expected in areas of the squall line where the line itself is in the shape of a bow echo and within that portion of the line that bows out the most. Tornados can be found along waves within the line echo wave pattern, or LEWP, where mesoscale low-pressure areas are present.

Supercells

Supercell storms are large, usually severe storms that form in an environment where wind speed or wind direction varies with height (an area of "wind shear"), and they have separate downdrafts and updrafts with a strong, rotating updraft ("mesocyclone"). A supercell storm can be 15 miles wide. Research shows that at least 90% of supercell storms cause severe weather. Sometimes these storms produce F3 or higher tornados, extremely large hail (4 inches in diameter), straight-line winds in excess of 80 mph and flash floods. Supercell storms are the most powerful type of thunderstorm and a danger to the public and aviation.

Visible Warning Signs of Thunderstorms

- Dark, towering, threatening clouds
- Distant lightning and thunder

General Facts

- The National Weather Service estimates that there approximately 1,800 thunderstorms daily, on our planet
- There are about 100,000 thunderstorms annually in the U.S. and about 10% of those are severe
- All thunderstorms are dangerous and produce lightning
- Lightning can reach a temperature of 53,540 degrees Fahrenheit; the surface of sun reaches 10,340 degrees Fahrenheit

Dangers Associated with Thunderstorms

- Cloud to ground lightning
- Hail
- Tornados and Waterspouts
- Flash Floods
- Downbursts (Downburst winds are generally very powerful and are often mistaken for wind speeds produced by tornados. These winds are capable of destroying

unstable or weakly constructed infrastructures, damaging agricultural crops, displacing automobiles, and crashing aircraft engaged in takeoff or landing.

Damaging Winds

According to the National Severe Storms Laboratory, severe and damaging winds can be produced by any type of thunderstorm, even one that is dying. There are several types of damaging wind as outlined below:

Straight-line wind is the term used to define any wind associated with a thunderstorm that is not a result of rotation and tornadic winds.

A **downdraft** is a small-scale column of air that rapidly sinks toward the ground.

A **downburst** is the result of a strong downdraft with horizontal dimensions larger than 2.5 miles that results in an outward burst of damaging wind on or near the ground. A downburst may begin as a microburst and spread out over a larger area. It can produce damage similar to a strong tornado.

A **microburst** is a small concentrated downburst that produces an outward burst of damaging wind at the surface. They are usually small and last only 5 to 10 minutes, with wind speeds up to 168 mph.

The leading edge of rain-cooled air that clashes with warmer thunderstorm inflow is called a **gust front.** Gust fronts are characterized by a wind shift, temperature drop, and gusty winds out ahead of a thunderstorm. At times, these winds push up air above them and form a shelf cloud or detached roll cloud.

A **derecho** is a widespread, long-lived wind storm associated with a band of rapidly moving showers or thunderstorms. It consists of numerous microbursts, downbursts, and clusters of downbursts. A derecho includes winds of at least 58 mph or greater and a swath of damage that extends more than 240 miles, by definition.

A wall of dust that is pushed out along the ground from a thunderstorm downdraft at high speeds is called a **haboob**.

Table 3.3.2.3.1 - International Tornado Intensity Scale (TORRO)	
Tornado Intensity	Description of Tornado and Windspeeds
T0	Light Tornado 17 – 24 m s-1 (39 – 54 mi h-1)
T1	Mild Tornado 25 – 32 m s-1 (55 – 72 mi h-1)
T2	Moderate Tornado 33 – 41 m s-2 (73 – 92 mi h-1)
T3	Strong Tornado 42 – 51 m s-1 (93 – 114 mi h-1)
T4	Severe Tornado 52 – 61 m s-1 (115 – 136 mi h-1)
T5	Intense Tornado 62 – 72 m s-1 (127 – 160 mi h-1)
T6	Moderately-Devastating Tornado 73 – 83 m s-1 (161 – 186 mi h-1)
T7	Strongly-Devastating Tornado 84 – 95 m s-1 (187 – 212 mi h-1)
T8	Severely-Devastating Tornado 96 – 107 m s-1 (213 – 240 mi h-1)
T9	Intensely-Devastating Tornado 108 – 120 mi s-1 (241 – 269 mi h-1)
T10	Super Tornado 121 – 134 m s-1 (270 – 299 mi h-1)
Source: The Tornado and Storm Research Organization	

II. Anaylsis

To analyze severe thunderstorms as a threat to the Lincoln Trail Region, the generalized threat of thunderstorms was identified by reviewing historical data on wind and hail events.

The following tables outline the mean number of days precipitation and thunderstorms occur in an average year and the history of thunderstorms that have been recorded in a given county/jurisdiction within the Lincoln Trail region since 1960. The level of impact is evidenced through the number of lives lost or individual injuries recorded, as well as the estimated cost of property and crop damage based on information reported to the National Climate Data Center which was subsequently rolled into the National Centers for Environmental Information (NCEI). For the original plan, data was only available through 2003. The 2010 update provided data thru 30 June 2009. This update shows only individual events for the period 1 July 2009 through 30 June 2015. The summary tables show data for the entire period as reported by various sources. Note that there are many variations in recording the locations of the events over time. In the past this was typically done at a county level. More recently they have used nearest place names. Because of this, the records in the summation tables that pertain to individual incorporated areas, should not be considered all encompassing.

Table 3.3.2.3.2 - County Specific Data – Severe Thunderstorms, *Source: NCEI*

BRECKINRIDGE

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
CLOVERPORT	8/4/2009	0	0	$0	$0
HARNED	8/4/2009	0	0	$0	$0
BIG SPG	5/21/2010	0	0	$5,000	$0
CLOVERPORT	6/15/2010	0	0	$0	$0
CLOVERPORT	7/19/2010	0	0	$0	$0
HARDINSBURG ARPT	7/19/2010	0	0	$0	$0
HIGH PLAINS	8/12/2010	0	0	$0	$0
ROFF	8/14/2010	0	0	$0	$0
FALLS OF ROUGH	2/28/2011	0	0	$0	$0
HARDINSBURG ARPT	4/19/2011	0	0	$0	$0
HARDINSBURG ARPT	4/19/2011	0	0	$0	$0
WEBSTER	4/19/2011	0	0	$0	$0
HARDINSBURG	5/25/2011	0	0	$0	$0
MC QUADY	6/27/2011	0	0	$0	$0
CLOVERPORT	1/17/2012	0	0	$0	$0
HARDINSBURG ARPT	1/17/2012	0	0	$2,000	$0
HARNED	1/17/2012	0	0	$8,000	$0
MC QUADY	1/17/2012	0	0	$2,000	$0
ROFF	1/17/2012	0	0	$0	$0
CLOVERPORT	1/23/2012	0	0	$0	$0
CLOVERPORT	7/1/2012	0	0	$0	$0
BIG SPG	7/18/2012	0	0	$0	$0
CUSTER	7/18/2012	0	0	$0	$0
FALLS OF ROUGH	1/30/2013	0	0	$0	$0
CLOVERPORT	6/26/2013	0	0	$5,000	$0
MC DANIELS	6/26/2013	0	0	$0	$0
MC QUADY	6/26/2013	0	0	$2,000	$0
STEPHENSPORT	6/26/2013	0	0	$0	$0
GARFIELD	7/10/2013	0	0	$0	$0
HARDINSBURG ARPT	12/21/2013	0	0	$0	$0
MC DANIELS	12/21/2013	0	0	$0	$0
IRVINGTON	7/26/2014	0	0	$0	$0
IRVINGTON	7/26/2014	0	0	$30,000	$0

GRAYSON

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
LEITCHFIELD	5/15/2010	0	0	$5,000	$0
CLARKSON	6/2/2010	0	0	$0	$0
ROYAL	10/26/2010	0	0	$0	$0
SADLER	10/26/2010	0	0	$0	$0
LEITCHFIELD	4/19/2011	0	0	$0	$0
LEITCHFIELD	4/19/2011	0	0	$0	$0
CANEYVILLE	4/26/2011	0	0	$0	$0
LEITCHFIELD	4/26/2011	0	0	$0	$0
CLARKSON	5/12/2011	0	0	$0	$0
CLARKSON	5/22/2011	0	0	$0	$0
LEITCHFIELD	1/23/2012	0	0	$0	$0
CANEYVILLE	3/2/2012	0	0	$0	$0
CANEYVILLE	3/2/2012	0	0	$0	$0
LEITCHFIELD	5/5/2012	0	0	$10,000	$0
SHREWSBURY	7/19/2012	0	0	$0	$0
CANEYVILLE	1/30/2013	0	0	$10,000	$0
SKAGGSTOWN	6/23/2014	0	0	$0	$0
SHREWSBURY	5/30/2015	0	0	$0	$0

HARDIN

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
ELIZABETH TOWN	8/4/2009	0	0	$0	$0
STEPHENSBURG	8/4/2009	0	0	$3,000	$0
ELIZABETH TOWN	10/9/2009	0	0	$0	$0
RINEYVILLE	10/9/2009	0	0	$0	$0
SONORA	10/9/2009	0	0	$0	$0
FRANKLIN XRDS	4/7/2010	0	0	$0	$0
FLINT HILL	6/2/2010	0	0	$0	$0
RINEYVILLE	8/12/2010	0	0	$0	$0
ELIZABETH TOWN	10/26/2010	0	0	$0	$0
RADCLIFF	4/4/2011	0	0	$0	$0
ST JOHN	4/4/2011	0	0	$0	$0
ELIZABETH TOWN	4/19/2011	0	0	$0	$0
GLENDALE	4/26/2011	0	0	$0	$0
ELIZABETH TOWN	6/27/2011	0	0	$0	$0
ROGERSVILLE	1/23/2012	0	0	$0	$0
(FTK)GODMAN AAF FT K	3/2/2012	0	0	$0	$0
ELIZABETH TOWN	3/2/2012	0	0	$0	$0
GAITHERS	3/2/2012	0	0	$0	$0
SONORA	3/2/2012	0	0	$0	$0
ROGERSVILLE	3/15/2012	0	0	$0	$0
ROGERSVILLE	7/8/2012	0	0	$0	$0
FRANKLIN XRDS	7/19/2012	0	0	$0	$0
VINE GROVE JCT	7/19/2012	0	0	$0	$0
ROGERSVILLE	7/26/2012	0	0	$0	$0
ELIZABETH TOWN	7/27/2012	0	0	$0	$0
VINE GROVE	7/27/2012	0	0	$10,000	$0
RADCLIFF	9/7/2012	0	0	$0	$0
(FTK)GODMAN AAF FT K	1/30/2013	0	0	$0	$0
(FTK)GODMAN AAF FT K	6/17/2013	0	0	$0	$0
CECILIA	6/26/2013	0	0	$2,000	$0
ELIZABETH TOWN	6/26/2013	0	0	$2,000	$0
ROGERSVILLE	6/26/2013	0	0	$0	$0
CREST	7/10/2013	0	0	$0	$0
TUNNEL HILL	9/11/2013	0	0	$0	$0
ELIZABETH TOWN	12/21/2013	0	0	$0	$0
FRANKLIN XRDS	12/21/2013	0	0	$0	$0

HOWE VLY	12/21/2013	0	0	$1,000	$0
ROGERSVILLE	12/21/2013	0	0	$0	$0
VINE GROVE	12/21/2013	0	0	$0	$0
RED HILL	5/22/2014	0	0	$150,000	$0
ELIZABETH TOWN	7/26/2014	0	0	$0	$0
ROGERSVILLE	7/26/2014	0	0	$0	$0
WEST PT	7/26/2014	0	0	$0	$0
VINE GROVE	8/23/2014	0	0	$0	$0
CECILIA	10/6/2014	0	0	$0	$0
HARDIN CO.	4/7/2015	0	0	$0	$0
HARDIN CO.	4/7/2015	0	0	$0	$0

LARUE

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
LARUE (ZONE)	10/31/2013	0	0	$10,000	$0
LYONS	10/9/2009	0	0	$0	$0
BARREN RUN	4/24/2010	0	0	$0	$0
HODGENVILLE	4/24/2010	0	0	$0	$0
LEAFDALE	4/24/2010	0	0	$0	$0
TONIEVILLE	4/24/2010	0	0	$0	$0
BUFFALO	7/10/2010	0	0	$0	$0
BARREN RUN	10/26/2010	0	0	$0	$0
MAGNOLIA	2/24/2011	0	0	$0	$0
MAGNOLIA	2/24/2011	0	0	$0	$0
MAGNOLIA	2/28/2011	0	0	$0	$0
MAGNOLIA	4/4/2011	0	0	$0	$0
JERICHO	4/20/2011	0	0	$0	$0
MAGNOLIA	4/20/2011	0	0	$0	$0
WHITE CITY	1/17/2012	0	0	$0	$0
HODGENVILLE	7/19/2012	0	0	$0	$0
BUFFALO	7/26/2012	0	0	$0	$0
HODGENVILLE	7/26/2012	0	0	$0	$0
HODGENVILLE	7/27/2012	0	0	$10,000	$0
MAXINE	5/13/2014	0	0	$30,000	$0
HODGENVILLE	5/22/2014	0	0	$100,000	$0
LEAFDALE	5/22/2014	0	0	$0	$0
MAGNOLIA	7/26/2014	0	0	$0	$0
BUFFALO	7/27/2014	0	0	$0	$0
LEAFDALE	10/6/2014	0	0	$0	$0

MARION

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
MARION (ZONE)	12/9/2009	0	0	$0	$0
LORETTO	10/9/2009	0	0	$0	$0
LEBANON	4/24/2010	0	0	$0	$0
LEBANON	8/14/2010	0	0	$0	$0
LEBANON	10/26/2010	0	0	$0	$0
LEBANON	4/26/2011	0	0	$0	$0
LEBANON	8/18/2011	0	0	$0	$0
ST MARY	9/4/2011	0	0	$0	$0
PENICKS	1/23/2012	0	0	$0	$0
BRADFORDSVILLE	7/1/2012	0	0	$0	$0
NEW MARKET	7/26/2012	0	0	$0	$0
GRAVEL SWITCH	6/26/2013	0	0	$1,000	$0
LEBANON	7/10/2013	0	0	$0	$0
RAYWICK	7/10/2013	0	0	$0	$0
LORETTO	7/13/2013	0	0	$0	$0

MEADE

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
BATTLETOWN	10/26/2010	0	0	$0	$0
BRANDENBURG	10/26/2010	0	0	$0	$0
EKRON	3/23/2011	0	0	$0	$0
BRANDENBURG	4/19/2011	0	0	$0	$0
MULDRAUGH	4/23/2011	0	0	$0	$0
BATTLETOWN	6/19/2011	0	0	$0	$0
FLAHERTY	6/19/2011	0	0	$0	$0
BRANDENBURG	6/22/2011	0	0	$0	$0
BRANDENBURG	2/29/2012	0	0	$0	$0
MIDWAY	2/29/2012	0	0	$0	$0
BRANDENBURG	3/2/2012	0	0	$0	$0
MIDWAY	3/15/2012	0	0	$0	$0
DOE VLY ESTATES	5/29/2012	0	0	$0	$0
SIROCCO	5/29/2012	0	0	$25,000	$0
BATTLETOWN	5/31/2012	0	0	$0	$0
BRANDENBURG	7/8/2012	0	0	$0	$0
BRANDENBURG	7/19/2012	0	0	$0	$0
BRANDENBURG	7/27/2012	0	0	$0	$0
FLAHERTY	7/27/2012	0	0	$10,000	$0
EKRON	9/7/2012	0	0	$0	$0
EKRON	9/7/2012	0	0	$0	$0
BATTLETOWN	1/30/2013	0	0	$0	$0
BRANDENBURG	7/10/2013	0	0	$0	$0
BRANDENBURG	7/10/2013	0	0	$0	$0
BRANDENBURG	7/26/2014	0	0	$0	$0
MEADE CO.	4/7/2015	0	0	$100,000	$0
MEADE CO.	4/7/2015	0	0	$0	$0

NELSON

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
BARDSTOWN	8/4/2010	0	0	$0	$0
BLOOMFIELD	9/7/2010	0	0	$0	$0
COXS CREEK	9/7/2010	0	0	$10,000	$0
FAIRFIELD	9/7/2010	0	0	$0	$0
BLOOMFIELD	10/26/2010	0	0	$0	$0
BALLTOWN	4/9/2011	0	0	$0	$0
BARDSTOWN	4/20/2011	0	0	$0	$0
BARDSTOWN	4/26/2011	0	0	$0	$0
HIGHGROVE	7/19/2011	0	0	$3,000	$0
BARDSTOWN	8/13/2011	0	0	$0	$0
HIGHGROVE	1/17/2012	0	0	$0	$0
BALLTOWN	3/2/2012	0	0	$0	$0
BOURBON SPGS	5/4/2012	0	0	$0	$0
BOSTON	7/18/2012	0	0	$40,000	$0
GREENBRIER	7/18/2012	0	0	$0	$0
BARDSTOWN ARPT	7/19/2012	0	0	$0	$0
BOTLAND	7/19/2012	0	0	$0	$0
CHAPLIN	7/19/2012	0	0	$0	$0
CHAPLIN	7/26/2012	0	0	$0	$0
CHAPLIN	7/1/2013	0	0	$0	$0
CRAVENS	7/10/2013	0	0	$0	$0
WOODLAWN	8/12/2013	0	0	$0	$0
BARDSTOWN	12/21/2013	0	0	$0	$0
BARDSTOWN	4/27/2014	0	0	$0	$0
BARDSTOWN	7/26/2014	0	0	$0	$0

WASHINGTON

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
SPRINGFIELD	4/24/2010	0	0	$0	$0
ST CATHERINE	4/20/2011	0	0	$0	$0
MAUD	5/23/2011	0	0	$0	$0
SPRINGFIELD	6/19/2011	0	0	$0	$0
WILLISBURG	8/8/2011	0	0	$0	$0
WILLISBURG	7/1/2012	0	0	$0	$0
WASHINGTON CO.	4/7/2015	0	0	$0	$0
WASHINGTON CO.	4/7/2015	0	0	$0	$0

Table 3.3.2.3.3 **- Summary of Thunderstorm/Winds Data, Costs**

THUNDERSTORMS WINDS	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDGE	$1,211,803	206	54.5	0.25	2.21	$22,235	$5,883	0.00	0.00	0.04	0.01
Cloverport	$5,000	10	54.5	0	0	$92	$500	0.00	0.00	0.00	0.00
Hardinsburg	$105,000	24	54.5	0	0	$1,927	$4,375	0.00	0.00	0.00	0.00
Irvington	$55,000	5	54.5	0	0	$1,009	$11,000	0.00	0.00	0.00	0.00
GRAYSON	$1,215,287	196	56.5	0.25	6.62	$21,510	$6,200	0.00	0.00	0.12	0.03
Caneyville	$0	20	56.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Clarkson	$0	6	56.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Leitchfield	$202,000	27	56.5	0	0	$3,575	$7,481	0.00	0.00	0.00	0.00
HARDIN	$64,735,949	300	58.5	4.45	133.17	$1,106,597	$215,786	0.08	0.01	2.28	0.44
Elizabethtown	$80,000	35	58.5	0	0	$1,368	$2,286	0.00	0.00	0.00	0.00
Radcliff	$5,050,000	13	58.5	0	46	$86,325	$388,462	0.00	0.00	0.79	3.54
Sonora	$1,000	8	58.5	0	0	$17	$125	0.00	0.00	0.00	0.00
Upton	$0	1	58.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Vine Grove	$50,020,000	10	58.5	0	0	$855,043	$5,002,000	0.00	0.00	0.00	0.00
West Point	$0	4	58.5	0	0	$0	$0	0.00	0.00	0.00	0.00
LARUE	$1,509,787	193	54.5	1.32	11.6	$27,703	$7,823	0.02	0.01	0.21	0.06
Hodgenville	$150,000	20	54.5	0	0	$2,752	$7,500	0.00	0.00	0.00	0.00
MARION	$1,247,735	180	54.5	0.24	1.63	$22,894	$6,932	0.00	0.00	0.03	0.01
Bradfordsville	$0	1	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Lebanon	$175,000	25	54.5	0	0	$3,211	$7,000	0.00	0.00	0.00	0.00
Loretto	$10,000	4	54.5	0	0	$183	$2,500	0.00	0.00	0.00	0.00
Raywick	$0	2	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
MEADE	$1,679,733	208	55.5	3.45	46.26	$30,265	$8,076	0.06	0.02	0.83	0.22
Brandenburg	$57,000	22	55.5	0	0	$1,027	$2,591	0.00	0.00	0.00	0.00
Ekron	$0	4	55.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Muldraugh	$10,000	4	55.5	0	0	$180	$2,500	0.00	0.00	0.00	0.00
NELSON	$1,404,130	228	54.5	0.3	12.58	$25,764	$6,158	0.01	0.00	0.23	0.06
Bardstown	$55,000	41	54.5	0	0	$1,009	$1,341	0.00	0.00	0.00	0.00
Bloomfield	$0	3	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Fairfield	$0	1	54.5	0	0	$0	$0	0.00	0.00	0.00	0.00
New Haven	$50,000	3	54.5	0	0	$917	$16,667	0.00	0.00	0.00	0.00
WASHINGTON	$1,453,572	168	54.5	0.22	3.58	$26,671	$8,652	0.00	0.00	0.07	0.02
Mackville	$175,000	4	54.5	0	0	$3,211	$43,750	0.00	0.00	0.00	0.00
Springfield	$70,000	16	54.5	0	0	$1,284	$4,375	0.00	0.00	0.00	0.00
Willisburg	$1,000	7	54.5	0	0	$18	$143	0.00	0.00	0.00	0.00
LTADD	$74,457,996	1679	58.5	10.48	217.65	$1,272,786	$44,347	0.18	0.01	3.72	0.13

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30 2015.

Table 3.3.2.3.4 **- Summary of Thunderstorm/Winds Data, Events**

THUNDERSTORMS WINDS	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	206	54.5	53	95	195	0.26	377.98%	5.3	4.75	3.9
Cloverport	10	54.5	8	10	10	5.45	18.35%	0.8	0.5	0.2
Hardinsburg	24	54.5	9	21	24	2.27	44.04%	0.9	1.05	0.48
Irvington	5	54.5	3	4	5	10.90	9.17%	0.3	0.2	0.1
GRAYSON	196	56.5	41	78	185	0.29	346.90%	4.1	3.9	3.7
Caneyville	20	56.5	12	20	20	2.83	35.40%	1.2	1	0.4
Clarkson	6	56.5	4	6	6	9.42	10.62%	0.4	0.3	0.12
Leitchfield	27	56.5	12	26	27	2.09	47.79%	1.2	1.3	0.54
HARDIN	300	58.5	70	139	285	0.20	512.82%	7	6.95	5.7
Elizabethtown	35	58.5	18	35	35	1.67	59.83%	1.8	1.75	0.7
Radcliff	13	58.5	3	12	13	4.50	22.22%	0.3	0.6	0.26
Sonora	8	58.5	4	8	8	7.31	13.68%	0.4	0.4	0.16
Upton	1	58.5	0	1	1	58.50	1.71%	0	0.05	0.02
Vine Grove	10	58.5	4	9	10	5.85	17.09%	0.4	0.45	0.2
West Point	4	58.5	3	4	4	14.63	6.84%	0.3	0.2	0.08
LARUE	193	54.5	36	64	176	0.28	354.13%	3.6	3.2	3.52
Hodgenville	20	54.5	9	20	20	2.73	36.70%	0.9	1	0.4
MARION	180	54.5	22	55	62	0.30	330.28%	2.2	2.75	1.24
Bradfordsville	1	54.5	1	1	1	54.50	1.83%	0.1	0.05	0.02
Lebanon	25	54.5	10	24	25	2.18	45.87%	1	1.2	0.5
Loretto	4	54.5	4	4	4	13.63	7.34%	0.4	0.2	0.08
Raywick	2	54.5	1	2	2	27.25	3.67%	0.1	0.1	0.04
MEADE	208	55.5	46	84	196	0.27	374.77%	4.6	4.2	3.92
Brandenburg	22	55.5	13	22	22	2.52	39.64%	1.3	1.1	0.44
Ekron	4	55.5	4	4	4	13.88	7.21%	0.4	0.2	0.08
Muldraugh	4	55.5	2	4	4	13.88	7.21%	0.2	0.2	0.08
NELSON	228	54.5	45	51	210	0.24	418.35%	4.5	2.55	4.2
Bardstown	41	54.5	18	40	41	1.33	75.23%	1.8	2	0.82
Bloomfield	3	54.5	3	3	3	18.17	5.50%	0.3	0.15	0.06
Fairfield	1	54.5	1	1	1	54.50	1.83%	0.1	0.05	0.02
New Haven	3	54.5	0	2	3	18.17	5.50%	0	0.1	0.06
WASHINGTON	168	54.5	18	45	150	0.32	308.26%	1.8	2.25	3
Mackville	4	54.5	2	4	4	13.63	7.34%	0.2	0.2	0.08
Springfield	16	54.5	5	15	15	3.41	29.36%	0.5	0.75	0.3
Willisburg	7	54.5	3	7	7	7.79	12.84%	0.3	0.35	0.14
LTADD	1679	58.5	331	611	1459	0.03	2870.09%	33.1	30.55	29.18

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

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Compilation of SHELDUS, NCDC & NCEI. 1967- June 30 2015.

3.3.2.4 <u>Severe Winter Storms</u>

I. Background

Definitions:

Winter Storm: According to the National Severe Storms Laboratory (NSSL), a winter storm is an event in which the main types of precipitation are snow, sleet or freezing rain. A winter storm is a combination of heavy snow, blowing snow and/or dangerous wind chills. A winter storm can be a life-threatening event. A **severe winter storm** consists of one or more of the following elements; blinding wind-driven snow, extreme cold, icy roads, avalanches and downed trees and power lines. All winter storms can be dangerous and result in injuries, loss of life and property damage. The effects of a winter storm can impact a region for extended periods of time. Most deaths from winter storms are not a direct result of the storm itself, but rather a result of traffic accidents on icy roads, heart attacks while shoveling snow and hypothermia from prolonged exposure to cold.

Winter storms form just like any other storm at other times of the year. The right combination of ingredients is necessary for a winter storm to develop. The three basic components of a winter storm are cold air, lift and moisture. Below freezing temperatures in the clouds and near the ground are essential to make snow and/or ice. Lift is necessary to raise moist air to form clouds and cause precipitation. Lift occurs when warm air collides with cold air and is forced to rise over the cold dome. The boundary between a warm and cold air mass is called a front. Moisture must be present to form clouds and result in precipitation. Air moving across a lake or large body of water such as an ocean, is an excellent source of moisture.

Blizzard: A blizzard is a dangerous winter storm composed of a combination of blowing snow and wind that results in very low visibility. Heavy snowfalls and severe cold often accompany blizzards, but are not required elements. At times, strong wind picks up ground snow and creates a ground blizzard. Blizzards contain winds over 35 mph and reduce visibility to ¼ miles or less for at least three hours.

Ice Storm: An ice storm results in the accumulation of at least .25” of ice on exposed surfaces. Ice storms create hazardous driving and walking conditions. Power outages and property damage can occur when tree branches and power lines snap under the weight of the accumulated ice.

Snow: Snowflakes are collections of ice crystals that cling to each other as they fall to the ground. Wintertime clouds will produce snow as long as the top layer of the storm is cold enough to create snowflakes. Precipitation will continue to fall as snow when the temperature remains at or below 0 degrees Celsius. The following is a summary of snow events:

- Snow Flurries: Light snow falling for a short duration and resulting in no accumulation or a light dusting

- Snow Shower: Snow falling at differing intensities for brief periods of time with some accumulation possible
- Snow Squall: A brief, intense snow shower, accompanied by strong and gusty winds with possible significant accumulation, defines a snow squall. This event usually occurs in the Great Lakes Region.
- Blowing Snow: Wind driven snow that reduces visibility and causes significant drifting. Blowing snow may occur when snow is falling and/or loose ground snow is picked up by the wind.

Sleet: Sleet occurs when snowflakes partially melt when falling through a shallow layer of warm air resulting in slushy drops that refreeze as they fall through a deep layer of freezing air above the surface and reach the ground as frozen rain drops that bounce on impact.

Freezing Rain/Ice Storm: Freezing rain occurs when snowflakes fall through a warmer layer of air and melt completely. When this rain falls through another thin layer of freezing air just above the surface of the ground, it doesn't have time to refreeze before hitting the ground. Because the rain is "supercooled," it instantly freezes upon contact with anything that is at or below 0 degrees C, and creates a glaze of ice on the ground, trees, power lines, or other objects. A significant accumulation of freezing rain lasting several hours or more is called an ice storm.


2009 Ice Storm, Vine Grove. *Source: LTADD Archive*.

Facts

- Winter storms come in different sizes and are created by different combinations of atmospheric conditions and local geography, but can occur anywhere in the United States.
- Winter storms usually occur between the end of October and the end of March in the U.S.
- Winter storms can last for days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures.

- The aftermath of a winter storm can impact a community or region for a day, weeks, or even months.

Effects

Snow and Ice Accumulation
Snow and ice accumulation on roads and surfaces can result in several adverse effects. Roads and sidewalks become dangerous and, at times, impassable resulting in vehicular accidents, falls, road closures, and delayed response time from emergency agencies. Snow and ice accumulation on trees, poles, power lines and roofs can result in falling debris that causes property damage and human injuries. People attempting to shovel snow can suffer injuries from their efforts as well. 70% of all weather related injuries are the result of vehicle accidents. Black ice on roadways is another dangerous hazard, as is thawing and refreezing of snow and ice on surfaces.

Power Outages
Snow and ice events can result in area and regional power outages. Power outages can have a significant social and economic impact on an area and may last for an extended period of time. Fires and dangerous situations arise from the improper use of kerosene lamps and heaters, candles and space heaters.

2009 Ice Storm, Nelson County. *Source: LTADD Archive*.

2009 Ice Storm, Vine Grove. *Source: LTADD Archive*.

Extreme Cold
Cold air outbreaks can send temperatures plummeting to single digits or lower and it is far more dangerous to be outside for prolonged periods of time. Some of the major threats are:

- Wind Chill: Wind chill is a measure of what the temperature outside *feels* like when wind speed is factored in. As wind speed increases, more heat can be removed from a body by the wind.

- Frostbite: Frostbite results from prolonged exposure to very cold air. Injury is caused by body tissue becoming frozen. Extremities such as fingers and toes are the most susceptible to frostbite.
- Hypothermia: Hypothermia is similar to frostbite and occurs when the body is exposed to prolonged cold. Hypothermia occurs when the body temperature drops below 95 degrees Fahrenheit.

Flooding

Depending on the amount of accumulation on the ground, flooding can result when ice and snow begin to melt as temperatures begin to rise.

Snow runoff flooding at White Mills (Hardin County) *Source: News-Enterprise, Neal Cardin Photo.*

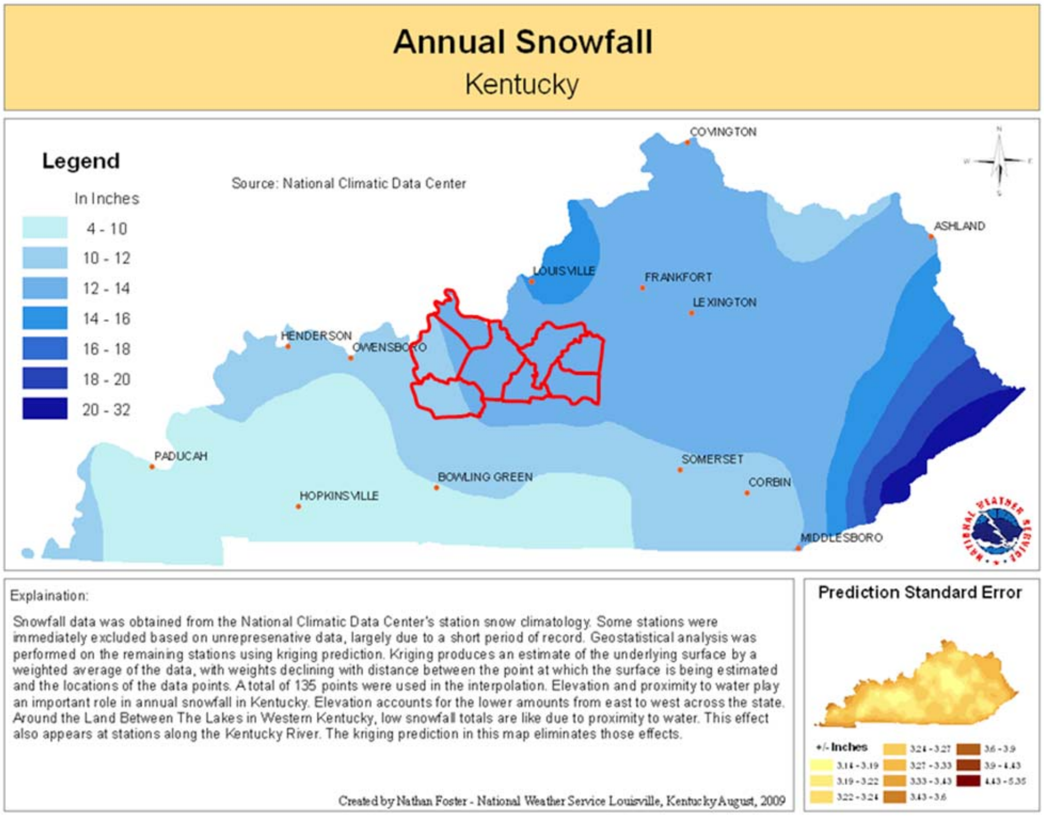
II. Profile

The Kentucky Mesonet data presented below shows minimum temperatures in the Lincoln Trail Region over the last 3 to 4 years. Cold temperatures and the severe weather conditions that often accompany them, make the region susceptible to severe winter storms.

Table 3.3.2.4.1

Minimum Temperature Table for Lincoln Trail Region from 2010 to 2015 ***Source: Kentucky Mesonet***							
Mesonet Station	2010	2011	2012	2013	2014	2015 Jan. – March 3	Average Station 5 Year Average 2010 – 2014
Breckinridge Co. (MQDY)	1.9	-1.5	12.1	7.9	-4.5	-10.2	5.7
Grayson Co. (BLRK)	0.9	-3.0	11.3	9.3	-3.4	-15.1	15.1
Hardin Co. (CCLA)	-0.4	-2.4	10.8	8.8	-3.8	-18.0	2.6
LaRue Co. (HDGV)	NA	18.0 Sept. – Dec.	13.4	8.3	-3.8	-12.1	NA
Marion Co. (LRTO)	NA	17.1 May – Dec.	14.8	8.4	-4.6	-16.2	NA
Meade Co. (BRND)	NA	13.4 March – Dec.	7.7	5.4	-4.0	-21.8	NA
Average	0.8	-2.3 Full Year Sites Only	11.68	8.02	-4.02	-15.57 Jan. – March 3	-0.232 Annual 8-County Regional 5 Year Average 2010 – 2014

Kentucky's geographic location makes it vulnerable to extreme winter weather. The State's close proximity to the Gulf of Mexico, provides the moisture source for precipitation, while the region is far enough north to be influenced by polar air masses. Low-pressure systems can bring heavy snow to Kentucky that normally track eastward across the southern United States before tracking toward the northeast.



The Lincoln Trail Region is outlined in red above. Breckinridge and Grayson County fall predominately in the 10-12 inch range. Hardin, LaRue, Marion, Meade, Nelson and Washington Counties fall entirely in the 12-14 inch range.

III. Analysis

The analysis for determining the threat of winter storms as a local hazard, involved identifying the conditions that produce winter storms, along with the types of severe winter weather that occur. Data was also tracked concerning the number of events that occur in the Region over time. Sources used to gather information include the National Weather Service, Kentucky Mesonet, the National Climatic Data Center, and Kentucky and County Emergency Management.

The Winter Storm of 2009 began on January 28, 2009 and left the Region devastated. Icy rain turned into solid ice that left the entire eight-county area without power, water and phone service. Roads were closed and power lines and poles snapped. Many were without power for weeks and the cleanup effort ran well into the late summer months. The State declared a disaster and FEMA issued disaster declaration #1818. Mitigation money from this disaster enabled many local jurisdictions to purchase emergency backup generators, bury power lines, and replace or repair damaged bridges. The chart below illustrates the impact the local Counties reported as a result of the 2009 Ice Storm.

Table 3.3.2.4.2 – 2009 Winter Storm Impact

County	Days Without Power	Injuries Reported	Deaths Reported	Local Economic Impact*
Breckinridge	Up to 3 weeks	3	0	$1.2-1.5 million
Grayson	Up to 3 weeks	0	0	$2.2 million
Hardin	Up to 2 weeks	0	1	$1.2 million
LaRue	Up to 2 weeks	0	0	$600,000
Marion	Up to 1 week	2	0	$245,000
Meade	Up to 2 weeks	24	0	$1.2 million
Nelson	Up to 3 weeks	0	0	$260,000
Washington	Up to 3 weeks	1	0	$375,000
Totals		30	1	$7,280,000
** Reported by local government; Does not include private utility losses, or individuals' losses of property or wages*				

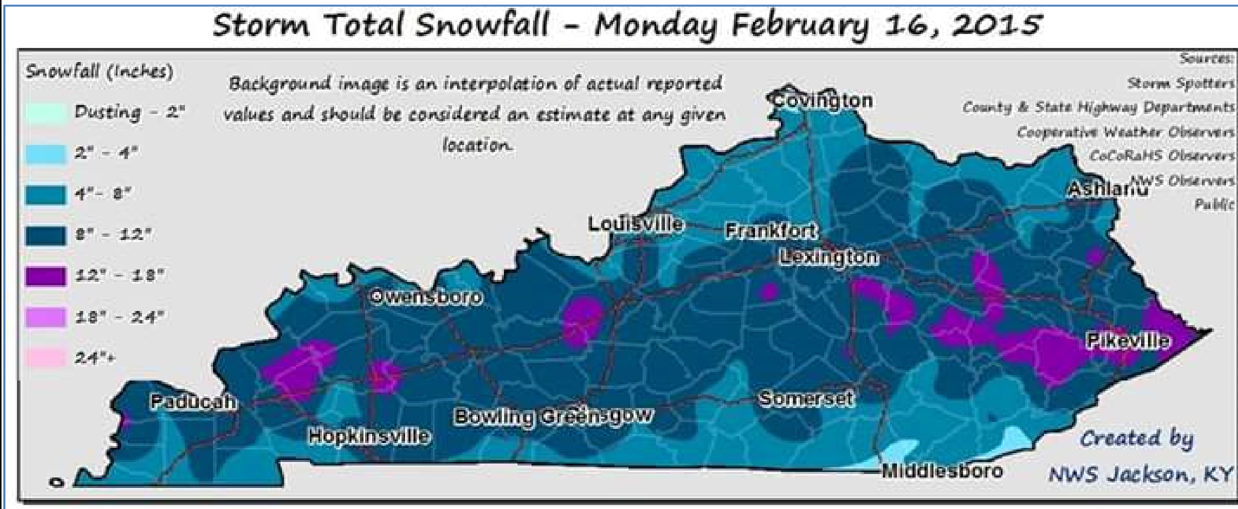
2015 Overturned snowplow in Meade County. *Source: Meade County Emergency Management.*

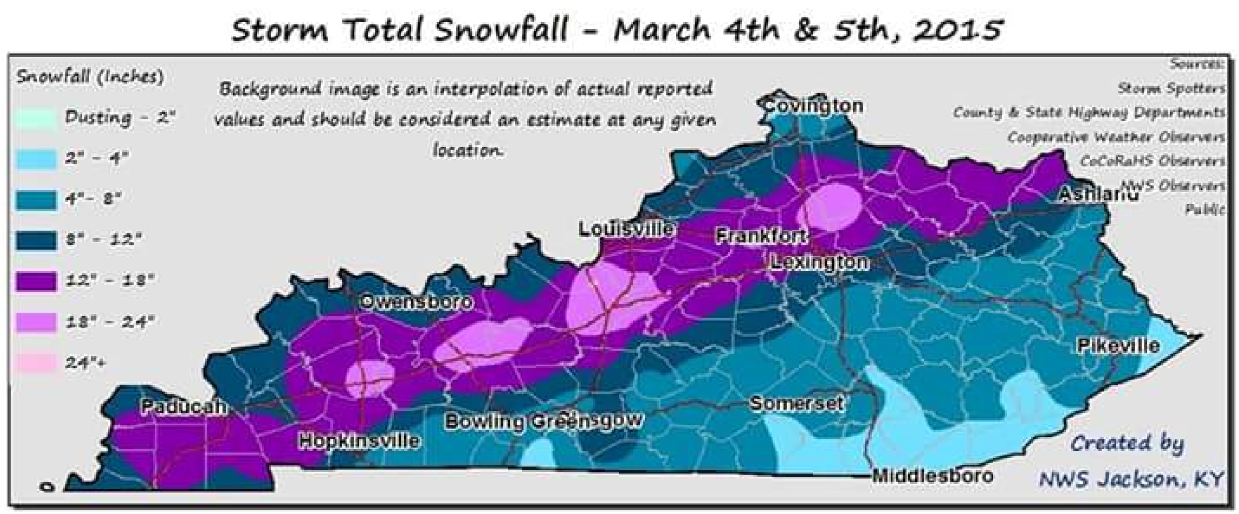
The winter of 2015 was another devastating one for this region. On February 21, Kentucky Mesonet data shows that between 18 and 19 inches of snow fell in the Hardin County area. Beginning on March 4, 2015 almost 30" of snow fell throughout the region and shut down I65 through Hardin County for over 14 hours. Thousands of cars, trucks and people were stranded on the interstate.

Table 3.3.2.4.3 - 2015 Winter Storm Snow Records

County	February 16, 2015 Snowfall Amount	March 4-5, 2015 Snowfall Amount	Record Place of March 4-5 Snow
Breckinridge	NA	20 inches	1st
Grayson	10 inches	16 inches	
Hardin	13.3 inches	23 inches	1st
LaRue	10 inches	18.3 inches	1st
Marion	11 inches	11 inches	2nd
Meade	8 inches	17 inches	1st
Nelson	13 inches	22 inches	2nd
Washington	12 inches	7.1 inches	

Source: National Weather Service – Louisville, KY





The following tables detail the history of winter storms that have been recorded in a given county/jurisdiction within the Lincoln Trail region since 1993. The level of impact is evidenced through the number of lives lost or individual injuries reported, as well as the estimated cost of property and crop damage. This information is reported to the National Climate DataCenter (NCDC) and subsequently rolled into the data of the National Centers for Environmental Information (NCEI). For the original plan, data was only available through 2003. The 2010 update provided data thru 30 June 2009. This update shows only individual events for the period 1 July 2009 through 30 June 2015. The summary tables show data for the entire periods covered by the various sources. Note that there are many variations in recording the locations of the events over time. In the past this was typically done at a county level. More recently, nearest place names have been used. Because of this, the records in the summation tables regarding the individual incorporated areas should not be considered all encompassing.

When reviewing the tables below, there may appear to be duplication of data across counties. This is due to the nature of a winter storm. One winter storm system most often affects multiple counties and is logged as one event but recorded in each county. Detailed individual county information is not always available; therefore some data may not reflect the true impact at the county or city level.

Table 3.3.2.4.4 - County Specific Data – Winter Storms, *Source: NCEI*

BRECKINRIDGE

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
BRECKINRIDGE	1/29/2010	Heavy Snow	0	0	0	0
BRECKINRIDGE	2/8/2010	Heavy Snow	0	0	0	0
BRECKINRIDGE	2/14/2010	Heavy Snow	0	0	0	0
BRECKINRIDGE	1/25/2011	Heavy Snow	0	0	0	0
BRECKINRIDGE	12/6/2013	Winter Storm	0	0	0	0
BRECKINRIDGE	2/2/2014	Heavy Snow	0	0	0	0
BRECKINRIDGE	2/4/2014	Winter Storm	0	0	0	0
BRECKINRIDGE	3/2/2014	Winter Storm	0	0	0	0
BRECKINRIDGE	2/16/2015	Heavy Snow	0	0	0	0
BRECKINRIDGE	3/4/2015	Heavy Snow	0	0	0	0

GRAYSON

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
GRAYSON	1/29/2010	Heavy Snow	0	0	0	0
GRAYSON	2/8/2010	Heavy Snow	0	0	0	0
GRAYSON	1/26/2011	Heavy Snow	0	0	0	0
GRAYSON	2/7/2011	Heavy Snow	0	0	0	0
GRAYSON	12/6/2013	Winter Storm	0	0	0	0
GRAYSON	2/2/2014	Winter Storm	0	0	0	0
GRAYSON	2/4/2014	Winter Storm	0	0	0	0
GRAYSON	3/2/2014	Winter Storm	0	0	0	0
GRAYSON	1/23/2015	Heavy Snow	0	0	0	0
GRAYSON	2/16/2015	Heavy Snow	0	0	0	0
GRAYSON	3/4/2015	Heavy Snow	0	0	0	0

HARDIN

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
HARDIN	1/29/2010	Heavy Snow	0	0	0	0
HARDIN	2/8/2010	Heavy Snow	0	0	0	0
HARDIN	12/15/2010	Ice Storm	0	0	0	0
HARDIN	1/25/2011	Heavy Snow	0	0	0	0
HARDIN	1/25/2013	Winter Weather	0	0	$100,000	0
HARDIN	12/6/2013	Winter Storm	0	0	0	0
HARDIN	2/2/2014	Heavy Snow	0	0	0	0
HARDIN	2/4/2014	Winter Storm	0	0	0	0
HARDIN	3/2/2014	Winter Storm	0	0	0	0
HARDIN	1/23/2015	Heavy Snow	0	0	0	0
HARDIN	2/16/2015	Heavy Snow	0	0	0	0
HARDIN	3/4/2015	Heavy Snow	0	0	0	0

LARUE

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
LARUE	1/29/2010	Heavy Snow	0	0	0	0
LARUE	12/24/2010	Heavy Snow	0	0	0	0
LARUE	1/20/2011	Heavy Snow	0	0	0	0
LARUE	2/2/2014	Winter Storm	0	0	0	0
LARUE	2/4/2014	Winter Storm	0	0	0	0
LARUE	3/2/2014	Winter Storm	0	0	0	0
LARUE	2/16/2015	Heavy Snow	0	0	0	0
LARUE	3/4/2015	Heavy Snow	0	0	0	0

MARION

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
MARION	1/29/2010	Heavy Snow	0	0	0	0
MARION	3/2/2014	Winter Storm	0	0	0	0
MARION	2/16/2015	Heavy Snow	0	0	0	0
MARION	3/4/2015	Heavy Snow	0	0	0	0

MEADE

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
MEADE	1/29/2010	Heavy Snow	0	0	0	0
MEADE	2/8/2010	Heavy Snow	0	0	0	0
MEADE	2/14/2010	Heavy Snow	0	0	0	0
MEADE	12/15/2010	Ice Storm	0	0	0	0
MEADE	12/6/2013	Winter Storm	0	0	0	0
MEADE	2/2/2014	Heavy Snow	0	0	0	0
MEADE	2/4/2014	Winter Storm	0	0	0	0
MEADE	3/2/2014	Winter Storm	0	0	0	0
MEADE	2/16/2015	Heavy Snow	0	0	0	0
MEADE	3/4/2015	Heavy Snow	0	0	0	0
MEADE	3/4/2015	Heavy Snow	0	0	0	0

NELSON

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
NELSON	1/29/2010	Heavy Snow	0	0	0	0
NELSON	12/15/2010	Ice Storm	0	0	0	0
NELSON	2/7/2011	Heavy Snow	0	0	0	0
NELSON	2/2/2014	Heavy Snow	0	0	0	0
NELSON	2/4/2014	Winter Storm	0	0	0	0
NELSON	3/2/2014	Winter Storm	0	0	0	0
NELSON	1/23/2015	Heavy Snow	0	0	0	0
NELSON	2/16/2015	Heavy Snow	0	0	0	0
NELSON	3/4/2015	Heavy Snow	0	0	0	0

WASHINGTON

LOCATION	DATE	EVENT TYPE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
WASHINGTON	1/29/2010	Heavy Snow	0	0	0	0
WASHINGTON	12/16/2010	Ice Storm	0	0	0	0
WASHINGTON	3/2/2014	Winter Storm	0	0	0	0
WASHINGTON	1/23/2015	Heavy Snow	0	0	0	0
WASHINGTON	2/16/2015	Heavy Snow	0	0	0	0
WASHINGTON	3/4/2015	Heavy Snow	0	0	0	0

Table 3.3.2.4.5 - Summary of Winter Storm Data, Costs

SNOW & ICE	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDGE	$1,411,082	40	54.5	0.31	1.83	$25,891	$35,277	0.01	0.01	0.03	0.05
Cloverport	$0	0									
Hardinsburg	$0	0									
Irvington	$0	0									
GRAYSON	$1,981,398	42	54.5	0.29	3.41	$36,356	$47,176	0.01	0.01	0.06	0.08
Caneyville	$0	0									
Clarkson	$0	0									
Leitchfield	$0	0									
HARDIN	$2,792,155	45	54.5	0.29	3.47	$51,232	$62,048	0.01	0.01	0.06	0.08
Elizabethtown	$0	0									
Radcliff	$0	0									
Sonora	$0	0									
Upton	$0	0									
Vine Grove	$0	0									
West Point	$0	0									
LARUE	$1,050,662	38	54.5	0.29	3.36	$19,278	$27,649	0.01	0.01	0.06	0.09
Hodgenville	$0	0									
MARION	$2,681,555	32	54.5	0.29	3.36	$49,203	$83,799	0.01	0.01	0.06	0.11
Bradfordsville	$0	0									
Lebanon	$0	0									
Loretto	$0	0									
Raywick	$0	0									
MEADE	$1,420,840	40	54.5	0.29	1.81	$26,070	$35,521	0.01	0.01	0.03	0.05
Brandenburg	$0	0									
Ekron	$0	0									
Muldraugh	$0	0									
NELSON	$2,307,155	41	54.5	1.29	3.47	$42,333	$56,272	0.02	0.03	0.06	0.08
Bardstown	$0	0									
Bloomfield	$0	0									
Fairfield	$0	0									
New Haven	$0	0									
WASHINGTON	$2,697,743	42	54.5	0.37	3.48	$49,500	$64,232	0.01	0.01	0.06	0.08
Mackville	$0	0									
Springfield	$0	0									
Willisburg	$0	0									
LTADD	$16,342,589	320	54.5	3.42	24.19	$299,864	$51,071	0.06	0.01	0.44	0.08

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30 2015.

Table 3.3.2.4.6 - Summary of Winter Storm Data, Events

SNOW & ICE	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	40	54.5	14	20	35	1.36	73.39%	1.4	1	0.7
Cloverport	0									
Hardinsburg	0									
Irvington	0									
GRAYSON	42	54.5	15	21	38	1.30	77.06%	1.5	1.05	0.76
Caneyville	0									
Clarkson	0									
Leitchfield	0									
HARDIN	45	54.5	17	23	41	1.21	82.57%	1.7	1.15	0.82
Elizabethtown	0									
Radcliff	0									
Sonora	0									
Upton	0									
Vine Grove	0									
West Point	0									
LARUE	38	54.5	12	17	34	1.43	69.72%	1.2	0.85	0.68
Hodgenville	0									
MARION	32	54.5	7	11	28	1.70	58.72%	0.7	0.55	0.56
Bradfordsville	0									
Lebanon	0									
Loretto	0									
Raywick	0									
MEADE	40	54.5	15	19	36	1.36	73.39%	1.5	0.95	0.72
Brandenburg	0									
Ekron	0									
Muldraugh	0									
NELSON	41	54.5	13	18	37	1.33	75.23%	1.3	0.9	0.74
Bardstown	0									
Bloomfield	0									
Fairfield	0									
New Haven	0									
WASHINGTON	42	54.5	10	14	34	1.30	77.06%	1	0.7	0.68
Mackville	0									
Springfield	0									
Willisburg	0									
LTADD	320	54.5	103	143	283	0.17	587.16%	10.3	7.15	5.66

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

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Compilation of SHELDUS, NCDC & NCEI. 1967- June 30 2015.

3.3.2.5 <u>Lightning</u>

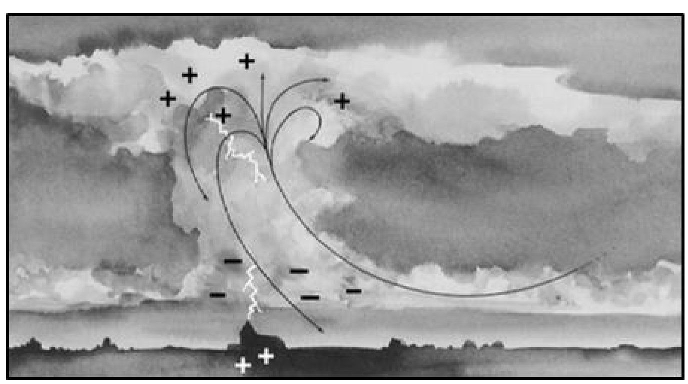
I. Background

Definition: Lightning is a sudden electrostatic discharge during an electrical storm between electrically charged regions of a cloud, between that cloud and another cloud, or between a cloud and the ground. This discharge temporarily equalizes the charged regions in the atmosphere and is called a strike if it hits the ground. Although lightning is always accompanied by thunder, distant lightning may be seen, but be too far away to be heard.

Formation of Lightning

Lightning is usually produced by cumulonimbus clouds, which have bases that are typically 0.6 to 1.25 miles above the ground and tops up to 9.3 miles in height. Lightning originates about 15,000 to 25,000 feet above sea level when raindrops are lifted upward until some of them convert to ice. Cloud to ground lightning begins in this mixed water and ice region. As these particles collide, they create an electric charge and these charges accumulate, filling up the entire cloud. Positive charges or protons form at the top of the cloud while the negative charges or electrons, form at the bottom of the cloud. Because opposites attract, this activity causes a positive charge to build up on the ground beneath the cloud. The electric charge on the ground builds up around anything that sticks up, such as mountains, people or a single tree. The charge coming up from these points eventually connects with a charge coming down from the clouds and creates a lightning strike. As a charge moves downward from a cloud, it does so in 50-yard increments called step leaders. It keeps moving toward the ground in these steps and produces a channel along which the charge is deposited until it encounters something on the ground that is a good connection. Once a conductive channel form bridges the ionized air between the negative

Lightning strike in Brandenburg, 2008. *Source: Meade County Emergency Management.*



Source: National Oceanic and Atmospheric Administration; National Lightning Safety Institute charges in the cloud and the positive charges on ground, a massive electrical discharge follows and neutralization of the positive surface charges occurs first. Then an enormous current of positive charges races up the channel toward the thundercloud. This is the "return stroke" and is the most luminous and noticeable part of the lightning discharge.

Types of Lightning

According to the National Oceanic and Atmospheric Administration (NOAA), there are three primary types of lightning. The type of lightning is determined by what is at the "ends" of a flash channel. Intracloud (IC) occurs within a single thundercloud; cloud-to-cloud (CC) starts and ends between two different "functional" thunderclouds; and cloud to ground (CG) lightning primarily starts in a thundercloud and terminates on the Earth's surface. Occasionally, it may reverse direction, and run from the ground to a cloud. There are variations of each type of lightning such as "positive" versus "negative" CG flashes. Each has distinct characteristics that can be measured.

IC lightning is the most frequently occurring type of lightning. This kind of lightning may be observed at great distances at night and is often referred to as "heat lightning."

CC lightning is sometimes referred to as "Anvil Crawler" due to its characteristic of originating from beneath or within the anvil and scrambling through the upper layers of the thunderstorm usually producing multiple branches of dramatic strokes.

CG lightning can occur with both positive and negative polarity. "Negative" lightning is the most common type of CG lightning and originates in the lower negatively charged portion of a thundercloud. Positive lightning originates in the positively charged anvil of the cumulonimbus and may travel several miles from the anvil of the thunderstorm horizontally before veering towards the ground. A positive lightning strike can occur anywhere within several miles of the thunderstorm anvil. Positive lightning makes up less than 5% of all lightning strikes. Positive lightning bolts are considerably hotter and longer than negative lightning. Ground to Cloud lightning is a type of CG lightning that is artificially triggered when tall, positively charged structures on the ground, such as towers on mountains, have been inductively charged by a negative cloud layer above, and is the origin of the lightning strike.

Lightning Dangers

Cloud to ground lightning can damage or destroy property and inanimate objects, and can kill or injure people and animals. According to NOAA, lightning strikes the United States about 25 million times a year and kills an average of 49 people annually. Almost all lightning occurs in summer, but can strike at any time of the year. The following safety precautions are recommended:

- If you see lightning or hear thunder, seek safe shelter immediately, preferably in a building with plumbing and electricity or a metal-topped vehicle with the windows closed.

- Stay off of corded phones.
- Avoid Plumbing, electrical equipment and cords, bodies of water or standing water.
- Stay away from windows and doors and stay off of porches.
- Do not lie on concrete floors or lean against concrete walls.
- Stay away from trees.
- Stay away from groups of people in the open.
- Rubber soled shoes will not give a person any meaningful protection from lightning.
- A lightning flash is no more than one inch wide.

Vulnerability

Lightning is a hazard that should be taken very seriously. Knowledge about the effects of lightning will help save lives and prevent injuries from lightning. In addition to death and injuries to people and animals alike, lightning causes fires and property damage.

Fatalities and Injuries

In addition to fatalities due to lightning strikes, many injuries occur as well. The chart below illustrates U.S. lightning fatalities between 2006 and May of 2015.

Table 3.3.2.5.1 - U.S. Lightning Fatalities from 2006 to May of 2015			
Year	Male	Female	Total
2006	38	10	48
2007	40	5	45
2008	22	6	28
2009	28	6	34
2010	22	7	29
2011	19	7	26
2012	25	3	28
2013	17	6	23
2014	21	5	26
2015 (Jan.-May)	3	2	5
Source: NOAA and National Weather Service			

Injuries that occur from lightning strikes can range from cardiac arrest to personality changes, and include severe burns, brain damage, memory loss and other long-term effects. It should be noted that deaths and injuries to animals also occurs. The information below compares human fatalities to injury numbers between 1995 and 2013.

Table 3.3.2.5.2

Number of Deaths and Injuries Due to Lightning in the U.S. from 1995 to 2013		
Year	Deaths	Injuries
1995	85	433
2000	51	364

2001	44	371
2002	51	256
2003	44	237
2004	32	280
2005	38	309
2006	48	246
2007	45	138
2008	28	216
2009	34	201
2010	29	182
2011	26	187
2012	28	139
2013	23	14
TOTAL	606	3,573
Source: NOAA		

Fires and Damage

Fires and property damage result from lightning strikes every year. According to the Insurance Information Institute (III), lightning strikes cost homeowners in the United States about $674 million in 2013 alone, down 30.5% from 2012. The Insurance Information Institute estimates the average lightning claim in 2013 at $5,869, down 24% from 2012. The U.S. Department of Commerce and NOAA attributed $23.89 million in property damage as the result of lightning in 2013 and $0.06 million in crop damage, for a total of $23.95 million dollars in damages.

In addition to property damage, lightning starts fires. According to the National Fire Protection Association (NFPA), during the time period from 2007 to 2011, U.S. local fire departments responded to an estimated average of 22,600 fires per year as a result of lightning. Fires started by lightning peak during summer months, are more common in the months of June through August, and usually occur later in the afternoon and early evening. In the years 2008 – 2012, federal and state wildland firefighting agencies reported an average of 9,000 wildland fires started by lightning, to the National Interagency Fire Center. These fires tended to be larger than fires started by human causes. The average fire caused by lightning burned 402 acres, nine times the average area of 45 acres seen in fires caused by human action. Over the ten-year period from 2003 to 2012, forty-two U.S. firefighters were killed as the result of fighting fires caused by lightning strikes.

The table below shows homeowners' insurance claims and payouts for lightning losses between 2009 and 2013.

Table 3.3.2.5.3

Homeowners Insurance Claims and Payouts for Lightning Losses from 2009 to 2013							
	2009	2010	2011	2012	2013	Percent Change 2012-2013	Percent Change 2009-2013
Number Of Claims	185,789	213,278	186,307	151,000	114,740	-24.0%	-38.2%
Insured Losses ($ millions)	$798.1	$1,033.5	$952.5	$969.0	$673.5	-30.5%	-15.6%
Average Cost Per Claim	$4,296	$4,846	$5,112	$6,400	$5,869	-8.3%	36.6%
Source: Insurance Information Institute, State Farm®							

Lightning Facts:

- Lightning is a giant discharge of electricity accompanied by a brilliant flash of light and a loud crack of thunder.
- A spark of lightning can reach over 5 miles in length and raise the air temperature by as much as 50,000 degrees Fahrenheit.
- A lightning strike contains a hundred million electrical volts.
- The immense heat and other energy given off during a lightning stroke has been found to convert elements in compounds that are found in organisms and may have played a part in the evolution of living things.
- The odds of being struck by lightning in the U.S. in any given year is 1 in 700,00 while the odds of being struck in your lifetime is 1 in 3,000.
- Positive lightning is especially dangerous because it can strike away from the rain core, either ahead of or behind the thunderstorm and can strike as far as 5 to 10 miles from the storm.
- Victims of a lightning strike do not retain any charge and are not "electrified." It is safe to help them.
- An umbrella can increase your chance of being struck by lightning.
- Lightning often strikes the same place repeatedly if it is a tall, isolated object.
- Most lightning victims are in open areas or near a tree.
- Lightning can heat its path through the air to a temperature that is five times hotter than the surface of the sun.
- All thunderstorms contain lightning.
- Volcanic material thrust high into the atmosphere can trigger lightning.
- Lightning also occurs in extremely intense forest fires, surface nuclear detonations, heavy snowstorms, and in large hurricanes.

III. Analysis

To analyze lightning as a threat to the Lincoln Trail Region, the generalized threat of lightning was identified by reviewing historical data.

The following tables outline the occurrences of lightning that have been recorded in a given county/jurisdiction within the Lincoln Trail region since 1960. The level of impact is evidenced through the number of lives lost or individual injuries recorded, as well as the estimated cost of property and crop damage based on information reported to the National Climate Data Center which was subsequently rolled into the National Centers for Environmental Information (NCEI). For the original plan, data was only available through 2003. The 2010 update provided data thru 30 June 2009. This update shows only individual events for the period 1 July 2009 through 30 June 2015. The summary tables show data for the entire period as reported by various sources. Note that there are many variations in recording the locations of the events over time. In the past this was typically done at a county level. More recently, nearest place names have been used. Because of this, the records in the summation tables that pertain to individual incorporated areas, should not be considered all encompassing.

Table 3.3.2.5.4 - County Specific Data – Lightning, *Source: NCEI*

No Lightning events were recorded from 1 July 2009 to 30 June 2015 for BRECKINRIDGE, LARUE, MARION, MEADE or WASHINGTON Counties.

GRAYSON

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
LEITCHFIELD	2/22/2012	0	0	$15,000	0

HARDIN

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
(FTK)GODMAN AAF FT K	7/27/2010	1	2	$0	0
SUMMIT	7/19/2012	0	0	$300,000	0

NELSON

LOCATION	DATE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
BARDSTOWN	7/26/2012	0	1	$0	0

Table 3.3.2.5.5 - Summary of Lightning Data, Costs

LIGHTNING	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDGE	$289,285	25	54.5	0.04	0.36	$5,308	$11,571	0.00	0.00	0.01	0.01
Cloverport											
Hardinsburg											
Irvington											
GRAYSON	$423,574	31	54.5	0.04	2.36	$7,772	$13,664	0.00	0.00	0.04	0.08
Caneyville											
Clarkson											
Leitchfield	$51,500	2	54.5	0	1	$945	$25,750	0.00	0.00	0.02	0.50
HARDIN	$869,962	34	54.5	1.11	2.36	$15,963	$25,587	0.02	0.03	0.04	0.07
Elizabethtown											
Radcliff	$100,000	1	54.5	0	0	$1,835	$100,000	0.00	0.00	0.00	0.00
Sonora											
Upton											
Vine Grove											
West Point											
LARUE	$61,022	33	54.5	0	0	$1,120	$1,849	0.00	0.00	0.00	0.00
Hodgenville											
MARION	$154,253	35	54.5	0.14	0.39	$2,830	$4,407	0.00	0.00	0.01	0.01
Bradfordsville											
Lebanon											
Loretto											
Raywick											
MEADE	$129,715	28	54.5	0	0	$2,380	$4,633	0.00	0.00	0.00	0.00
Brandenburg											
Ekron											
Muldraugh											
NELSON	$907,717	41	54.5	2.12	2.34	$16,655	$22,139	0.04	0.05	0.04	0.06
Bardstown	$30,000	3	54.5	0	1	$550	$10,000	0.00	0.00	0.02	0.33
Bloomfield											
Fairfield											
New Haven	$525,000	2	54.5	2	1	$9,633	$262,500	0.04	1.00	0.02	0.50
WASHINGTON	$223,179	36	54.5	0.12	0.34	$4,095	$6,199	0.00	0.00	0.01	0.01
Mackville											
Springfield											
Willisburg											
LTADD	$3,765,207	271	54.5	5.57	11.15	$69,086	$13,894	0.10	0.02	0.20	0.04

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30 2015.

Table 3.3.2.5.6 - Summary of Lightning Data, Events

LIGHTNING	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	25	54.5	0	0	21	2.18	45.87%	0	0	0.42
Cloverport										
Hardinsburg										
Irvington										
GRAYSON	31	54.5	1	1	26	1.76	56.88%	0.1	0.05	0.52
Caneyville										
Clarkson										
Leitchfield	2	54.5	1	1	2	27.25	3.67%	0.1	0.05	0.04
HARDIN	34	54.5	2	3	29	1.60	62.39%	0.2	0.15	0.58
Elizabethtown										
Radcliff	1	54.5	0	1	1	54.50	1.83%	0	0.05	0.02
Sonora										
Upton										
Vine Grove										
West Point										
LARUE	33	54.5	0	0	26	1.65	60.55%	0	0	0.52
Hodgenville										
MARION	35	54.5	0	0	27	1.56	64.22%	0	0	0.54
Bradfordsville										
Lebanon										
Loretto										
Raywick										
MEADE	28	54.5	0	0	24	1.95	51.38%	0	0	0.48
Brandenburg										
Ekron										
Muldraugh										
NELSON	41	54.5	1	5	34	1.33	75.23%	0.1	0.25	0.68
Bardstown	3	54.5	1	3	3	18.17	5.50%	0.1	0.15	0.06
Bloomfield										
Fairfield										
New Haven	2	54.5	0	1	2	27.25	3.67%	0	0.05	0.04
WASHINGTON	36	54.5	0	0	29	1.51	66.06%	0	0	0.58
Mackville										
Springfield										
Willisburg										
LTADD	263	49	4	9	216	0.19	536.73%	0.4	0.45	4.32

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30 2015.

3.3.2.6 Hail

I. Background

According to Merriam Webster, hailstones are layered and can be irregular and clumped together. Hail is composed of transparent ice or alternating layers of transparent and translucent ice at least 1 millimeter (0.039 inch) thick. This ice is deposited on the hailstone as it travels through the cloud. The ice is suspended aloft by air and strong upward motion until its weight is too much to be supported by the updraft and it falls to the ground. Although varied in size, the diameter of hail in the U.S. averages between 2.5cm (1 inch) and golf ball-sized (1.75 inches).

1Hail stones in Meade Co. April 2015. *Source: Meade County Emergency Management. Photo Geraldine Shanahan.*

Hailstones larger than 2 cm (0.80 inch) are considered large enough to cause damage. In the United States, the National Weather Service will issue a severe thunderstorm warning if it predicts hail that is 2.5 cm (1 inch) or greater in diameter.

Any thunderstorm that produces hail that reaches the ground is known as a hailstorm. Hailstones can grow to 15 cm (6 inches) and weight more than 0.5 kilograms (1.1 pounds).

Formation

The National Center for Atmospheric Research states that hail is possible within most thunderstorms because it is produced by cumulonimbi, and can occur within 2 nautical miles of the parent storm. Hail formation requires an environment of strong, upward air motion within the parent thunderstorm, high liquid content, great vertical extent, large water droplets, and lowered heights of the freezing level. Although hail and sleet are often confused for one another, and both are forms of solid precipitation, sleet falls generally in cold weather while hail growth is greatly inhibited at cold temperatures.

Facts

- The speed at which hail is falling when it hits the ground is determined by the size of the hailstone, the friction of the air it is falling through, the motion of the wind it is falling through, collisions with raindrops or other hailstones, and melting that occurs as the stones fall through warmer air.
- Speeds can range from 20 mph to 110 mph.
- The heaviest hailstone weighed 2.25 pounds and fell in the Gopalganj District of Bangladesh on April 14, 1986,

- The hailstone with the largest diameter officially measured 8 inches and fell in Vivian, South Dakota on July 23, 2010.
- The hailstone with the largest circumference officially measured 18.75 inches and fell in Aurora, Nebraska on June 22, 2003.
- Hailstones can accumulate, and depths of up to a metre have been reported.
- On July 29, 2010, a foot of hail accumulation was reported in Boulder, Colorado.

Source: National Weather Service and National Severe Storms Laboratory

Hazards/Vulnerability

According to the Federal Aviation Association, hail is one of the most significant thunderstorm hazards to aircraft. Hailstones that exceed .5 inches in diameter can cause serious damage to an aircraft within seconds. Accumulations of hailstones on the ground can be a major hazard to aircraft trying to land.

Table 3.3.2.6.1 - Hail Conversion Chart

Diameter of Hailstones (inches)	Description
0.50	Marble
0.70	Dime
0.75	Penny
0.88	Nickel
1.00	Quarter
1.25	Half Dollar
1.50	Walnut
1.75	Golf Ball
2.00	Hen Egg
2.50	Tennis Ball
2.75	Baseball
3.00	Tea Cup
4.00	Grapefruit
4.50	Softball

Accumulations of hailstones on the ground can also cause flooding by blocking drains, and hail carried by floodwaters can turn into a snow-like slush that accumulates at lower elevations. Accumulation of hailstones on streets and highways can cause traffic accidents.

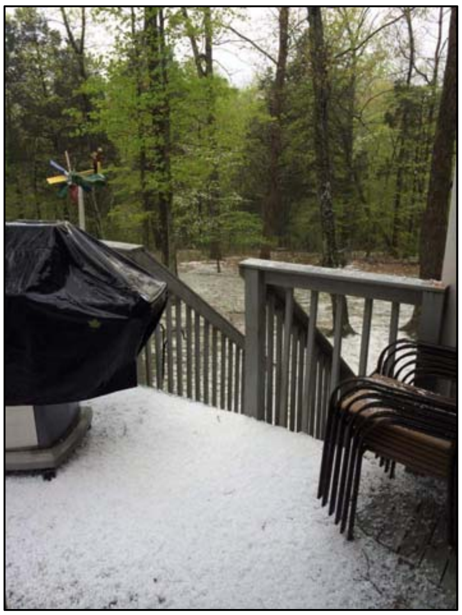
Hail can cause damage to automobiles, aircraft, skylights, glass, livestock, and most commonly, agricultural crops. Wheat, corn, soybeans and tobacco crops are the most sensitive crops to hail damage. Hailstorms have historically been the cause of costly and deadly events throughout history.

TORRO Hailstorm Intensity Scale (www.torro.org.uk/hscale.php)

	Intensity Category	Typical Diameter (mm)	
H0	Hard Hail	5	No Damage
H1	Potentially Damaging	5 - 15	Slight general damage to plants, crops
H2	Significant	10 - 20	Significant damage to fruit, crops, vegetation
H3	Severe	20 - 30	Severe damage to fruit and crops, damage to glass & plastic structures, paint & wood scored
H4	Severe	25 - 40	Widespread glass damage, vehicle bodywork damage
H5	Destructive	30 - 50	Wholesale destruction of glass, tiled roof damage, significant risk of injury
H6	Destructive	40 - 60	Grounded aircraft bodywork dented, brick walls pitted
H7	Destructive	50 - 75	Severe roof damage, risk of injuries
H8	Destructive	60 - 90	Severe damage to aircraft bodywork (severest recorded in British Isles)
H9	Super Hailstorm	75 - 100	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open.
H10	Super Hailstorm	> 100	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open.

II. Analysis

To analyze Hail as a threat to the Lincoln Trail Region the generalized threat of hail was identified and historical data on it was researched. The sources of this information are the National Weather Service and the National Climatic Data Center. As the sub-committees reviewed data gathered from these two sources it became very clear that additional sources needed to be consulted. Property and crop damage was not included in the following tables. Insurance estimates from several local providers, indicated a drastically different scenario. For example, in 2002, straight-line winds hurled golf ball and larger size Hail causing an estimated $109M in damages to residential, commercial and city owned properties across the Lincoln Trail Region. Trees were reported down throughout the region. In Marion County, the hardest hit of the eight counties, an estimated two thirds of the county was affected. Thirty windows in the Marion County courthouse were damaged. One local insurance provider reported over 2000 auto and 1000 property claims due to hail.



Hail stones in Meade County, February and March, 2015. *Source: Meade County Emergency Management.*

Other local events of note:

Grayson, Hardin & LaRue Counties

4/26/2011 – National Weather Service reported hail of 2 inches or more. Damage was reported to buildings at Hardin County Fairgrounds. Storms also included confirmed tornados, wind and flooding.

LaRue County

5/19/2013 - Sheriff's Department Reported: "The ground in some areas in LaRue County was white from the amount of hail that fell Sunday afternoon…the hail reached golf ball size."

Summary of Hail in the Lincoln Trail Region

Hailstorms do not adhere to geographic boundaries and have affected each of the eight counties in the Lincoln Trail Region. Many of these storms contained golf ball size or larger hail. The average hailstorm in the Lincoln Trail Region causes damage estimated to be

$231,554 per event. The following tables summarize the history of hail events that have been recorded in a given county/jurisdiction within the Lincoln Trail Region since 1950. The impact of these storms is shown by the number of lives lost, individual injuries reported, and estimated economic losses. The level of impact is evidenced through the number of lives lost, individual injuries reported, and the estimated property and crop damage costs. This information was reported to the National Climate Data Center and subsequently rolled into data from the National Centers for Environmental Information (NCEI). Data for the original Regional Plan was only available through 2003. The 2010 update provided data through June 30, 2009. This update shows only individual events for the period 1 July 2009 through 30 June 2015. The summary tables illustrate data for entire periods covered by the different sources. Note that there are many variations in recording the locations of the events over time. In the past, data was not recorded at a county level. More recently, scientists have used nearest place names. Because of this, data in the summation tables pertaining to individual incorporated areas should not be considered all encompassing.

Table 3.3.2.6.2 - County Specific Data – Hail, *Source: NCEI*

BRECKINRIDGE

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
MC DANIELS	5/15/2010	1	0	0	0	0
HARDINSBURG ARPT	5/17/2010	0.88	0	0	0	0
HARNED	5/17/2010	1.25	0	0	0	0
GARFIELD	3/23/2011	1	0	0	0	0
MC QUADY	3/23/2011	1	0	0	0	0
BIG SPG	4/23/2011	1	0	0	0	0
HARDINSBURG ARPT	4/23/2011	1	0	0	0	0
CLOVERPORT	4/26/2011	1	0	0	0	0
MC DANIELS	4/26/2011	0.88	0	0	0	0
MC QUADY	4/26/2011	1	0	0	0	0
CLOVERPORT	6/15/2011	1	0	0	0	0
MC DANIELS	6/15/2011	1.5	0	0	0	0
HARDINSBURG ARPT	3/15/2012	1	0	0	0	0
MC DANIELS	4/26/2012	1	0	0	0	0
CUSTER	5/1/2012	1	0	0	0	0
IRVINGTON	5/31/2012	1	0	0	0	0
UNION STAR	5/31/2012	1	0	0	0	0
BASIN SPG	4/17/2013	1	0	0	0	0
GARFIELD	4/17/2013	1.75	0	0	0	0
IRVINGTON	4/17/2013	1.5	0	0	0	0
MC DANIELS	10/6/2014	1.25	0	0	0	0
BRECKINRIDGE CO.	4/2/2015	0.75	0	0	0	0
BRECKINRIDGE CO.	4/2/2015	1	0	0	0	0

GRAYSON

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
CLARKSON	5/15/2010	1.5	0	0	0	0
BIG CLIFTY	6/2/2010	1	0	0	0	0
LEITCHFIELD	4/19/2011	0.88	0	0	0	0
DUFF	4/26/2011	1	0	0	0	0
SHORT CREEK	4/26/2011	1	0	0	0	0
CLARKSON	6/15/2011	1	0	0	0	0
YEAMAN	6/15/2011	2.5	0	0	0	0
BIG CLIFTY	2/29/2012	1	0	0	0	0
BIG CLIFTY	2/29/2012	1	0	0	0	0
LEITCHFIELD	2/29/2012	1.75	0	0	0	0
CANEYVILLE	3/2/2012	1.75	0	0	0	0
CANEYVILLE	3/2/2012	1	0	1	0	0
LEITCHFIELD	3/2/2012	1.75	0	0	0	0
CANEYVILLE	4/3/2014	1.75	0	0	0	0
LEITCHFIELD	4/3/2014	1.75	0	0	0	0
SKAGGSTOWN	6/23/2014	1.5	0	0	0	0
CLARKSON	10/6/2014	1	0	0	0	0
LEITCHFIELD	10/6/2014	1	0	0	0	0
GRAYSON CO.	4/2/2015	0.75	0	0	0	0
GRAYSON CO.	4/2/2015	0.88	0	0	0	0

HARDIN

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
GLENDALE JCT	5/15/2010	0.88	0	0	0	0
ELIZABETH TOWN	5/17/2010	1	0	0	0	0
ELIZABETH TOWN	5/17/2010	1	0	0	0	0
HOWE VLY	5/17/2010	1.25	0	0	0	0
RADCLIFF	3/23/2011	1	0	0	0	0
ELIZABETH TOWN	4/20/2011	0.88	0	0	0	0
VINE GROVE	4/23/2011	0.88	0	0	0	0
EASTVIEW	4/26/2011	0.88	0	0	0	0
ELIZABETH TOWN	4/26/2011	0.88	0	0	0	0
ELIZABETH TOWN	3/15/2012	1	0	0	0	0
ELIZABETH TOWN	7/19/2012	1.75	0	0	0	0
ROGERSVILLE	12/17/2012	1	0	0	0	0
ELIZABETH TOWN	5/22/2014	1.25	0	0	0	0
HARDIN CO.	4/25/2015	0.88	0	0	0	0

LARUE

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
BROOKS	4/24/2010	0.88	0	0	0	0
BROOKS	4/24/2010	0.88	0	0	0	0
MAGNOLIA	5/15/2010	1	0	0	0	0
UPTON	5/15/2010	1	0	0	0	0
MATHERS MILL	6/2/2010	0.88	0	0	0	0
GATTON	3/15/2012	1.5	0	0	0	0
HODGENVILLE	4/17/2013	1	0	0	0	0
MAGNOLIA	4/17/2013	1	0	0	0	0
HODGENVILLE	5/19/2013	1	0	0	0	0
HODGENVILLE	5/19/2013	1.75	0	0	0	0
LARUE CO.	4/8/2015	0.75	0	0	0	0

MARION

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
GRAVEL SWITCH	3/23/2011	1	0	0	0	0
LEBANON	3/23/2011	0.88	0	0	0	0
LEBANON	3/23/2011	0.75	0	0	0	0
GRAVEL SWITCH	3/2/2012	1.75	0	0	0	0
GRAVEL SWITCH	3/2/2012	1.75	0	0	0	0
GREENBRIAR	7/13/2013	1.5	0	0	0	0
LEBANON	7/13/2013	1	0	0	0	0
BURKES SPG	7/13/2013	1.25	0	0	0	0

MEADE

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
BRANDENBURG	3/2/2012	2.75	0	0	0	0
DOE VLY ESTATES	3/2/2012	1.25	0	0	0	0
RHODELIA	3/14/2012	1.5	0	0	0	0
BRANDENBURG	3/17/2012	1	0	0	0	0
BRANDENBURG	5/29/2012	1	0	0	0	0
MEADE CO.	4/25/2015	1	0	0	0	0
MEADE CO.	4/25/2015	0.75	0	0	0	0
MEADE CO.	4/25/2015	1	0	0	0	0

NELSON

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
BARDSTOWN	3/12/2010	0.88	0	0	0	0
COXS CREEK	3/12/2010	0.88	0	0	0	0
BOSTON	4/23/2011	1	0	0	0	0
NAZARETH	4/23/2011	1	0	0	0	0
BARDSTOWN	4/26/2011	1.25	0	0	0	0
CHAPLIN	4/26/2011	0.88	0	0	0	0
BARDSTOWN	5/23/2011	0.88	0	0	0	0
NELSON CO.	4/8/2015	0.75	0	0	0	0
NELSON CO.	4/25/2015	0.75	0	0	0	0
NELSON CO.	4/25/2015	1	0	0	0	0
NELSON CO.	4/25/2015	1.5	0	0	0	0
NELSON CO.	4/25/2015	1.25	0	0	0	0
NELSON CO.	4/25/2015	0.75	0	0	0	0

WASHINGTON

LOCATION	DATE	MAGNITUDE	DEATHS DIRECT	INJURIES DIRECT	PROPERTY DAMAGE	CROP DAMAGE
WILLISBURG	3/15/2012	1	0	0	0	0
ST CATHERINE	5/1/2012	1	0	0	0	0
BEARWALLOW	7/13/2013	1.25	0	0	0	0
WASHINGTON CO.	4/8/2015	1	0	0	0	0
WASHINGTON CO.	4/8/2015	0.88	0	0	0	0
WASHINGTON CO.	4/25/2015	1.5	0	0	0	0
WASHINGTON CO.	4/25/2015	2.5	0	0	0	0
WASHINGTON CO.	4/25/2015	0.75	0	0	0	0

Table 3.3.2.6.3 - Summary of Hail Data, Costs

HAIL	Total Cost	Number Events	Number Years	Total Loss of Life	Total Injuries	Average Cost Per Year	Average Cost Per Event	Average Loss of Life Per Year	Average Loss of Life Per Event	Average Injuries Per Year	Average Injuries Per Event
BRECKINRIDGE	$4,925,750	77	51.5	0.01	0.52	$95,646	$63,971	0.00	0.00	0.01	0.01
Cloverport	$0	8	51.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Hardinsburg	$15,000	13	51.5	0	0	$291	$1,154	0.00	0.00	0.00	0.00
Irvington	$0	7	51.5	0	0	$0	$0	0.00	0.00	0.00	0.00
GRAYSON	$2,438,935	84	50.5	0.01	0.5	$48,296	$29,035	0.00	0.00	0.01	0.01
Caneyville	$0	10	50.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Clarkson	$0	4	50.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Leitchfield	$0	19	50.5	0	0	$0	$0	0.00	0.00	0.00	0.00
HARDIN	$26,768,252	95	51.5	0.01	0.52	$519,772	$281,771	0.00	0.00	0.01	0.01
Elizabethtown	$0	19	51.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Radcliff	$0	4	51.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Sonora	$1,000	7	51.5	0	0	$19	$143	0.00	0.00	0.00	0.00
Upton	$0	1	51.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Vine Grove	$0	1	51.5	0	0	$0	$0	0.00	0.00	0.00	0.00
West Point	$0	2	51.5	0	0	$0	$0	0.00	0.00	0.00	0.00
LARUE	$1,969,355	59	58.5	0.06	0.56	$33,664	$33,379	0.00	0.00	0.01	0.01
Hodgenville	$0	5	58.5	0	0	$0	$0	0.00	0.00	0.00	0.00
MARION	$35,497,179	58	53.5	0.06	2.56	$663,499	$612,020	0.00	0.00	0.05	0.04
Bradfordsville	$0	1	53.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Lebanon	$30,000	6	53.5	0	2	$561	$5,000	0.00	0.00	0.04	0.33
Loretto	$0	2	53.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Raywick	$0	1	53.5	0	0	$0	$0	0.00	0.00	0.00	0.00
MEADE	$25,032,572	68	59.5	0.01	2.52	$420,715	$368,126	0.00	0.00	0.04	0.04
Brandenburg	$35,000	13	59.5	0	0	$588	$2,692	0.00	0.00	0.00	0.00
Ekron	$0	2	59.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Muldraugh	$0	0	59.5	0	0	$0		0.00		0.00	
NELSON	$22,857,556	71	53.5	0.06	1.56	$427,244	$321,937	0.00	0.00	0.03	0.02
Bardstown	$0	16	53.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Bloomfield	$0	1	53.5	0	0	$0	$0	0.00	0.00	0.00	0.00
Fairfield	$0	0	53.5	0	0	$0		0.00		0.00	
New Haven	$0	4	53.5	0	0	$0	$0	0.00	0.00	0.00	0.00
WASHINGTON	$10,875,034	51	53.5	0.06	3.56	$203,272	$213,236	0.00	0.00	0.07	0.07
Mackville	$0	0	53.5	0	0	$0		0.00		0.00	
Springfield	$150,000	6	53.5	0	3	$2,804	$25,000	0.00	0.00	0.06	0.50
Willisburg	$0	3	53.5	0	0	$0	$0	0.00	0.00	0.00	0.00
LTADD	$130,364,632	563	59.5	0.28	12.3	$2,191,002	$231,554	0.00	0.00	0.21	0.02

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

By updating and reviewing this table over time, it may be possible to see if certain types of hazard events are increasing in the past 10-20 years.

These values should be considered low. More events that have occurred than are documented by the sources used in this table.

All data is compiled at the county level due to extremely limited city specific data, therefore all data and analysis represents incorporated and unincorporated areas inclusively.

Compilation of SHELDUS, NCDC & NCEI. 1967- June 30 2015.

Table 3.3.2.6.4 - Summary of Hail Data, Events

HAIL	Number of Events in Historic Record	Number of Years in Historic Record	Number of Events in Past 10 Years	Number of Events in Past 20 Years	Number of Events in Past 50 Years	Historic Recurrence Interval (years)	Historic Frequency % chance/year	Past 10 Year Record Frequency Per Year	Past 20 Year Record Frequency Per Year	Past 50 Year Record Frequency Per Year
BRECKINRIDGE	77	51.5	36	52	74	0.67	149.51%	3.6	2.6	1.48
Cloverport	8	51.5	5	8	8	6.44	15.53%	0.5	0.4	0.16
Hardinsburg	13	51.5	7	12	13	3.96	25.24%	0.7	0.6	0.26
Irvington	7	51.5	4	7	7	7.36	13.59%	0.4	0.35	0.14
GRAYSON	84	50.5	34	54	82	0.60	166.34%	3.4	2.7	1.64
Caneyville	10	50.5	5	9	10	5.05	19.80%	0.5	0.45	0.2
Clarkson	4	50.5	4	4	4	12.63	7.92%	0.4	0.2	0.08
Leitchfield	19	50.5	9	18	19	2.66	37.62%	0.9	0.9	0.38
HARDIN	95	51.5	33	54	92	0.54	184.47%	3.3	2.7	1.84
Elizabethtown	19	51.5	12	19	19	2.71	36.89%	1.2	0.95	0.38
Radcliff	4	51.5	2	3	4	12.88	7.77%	0.2	0.15	0.08
Sonora	7	51.5	4	7	7	7.36	13.59%	0.4	0.35	0.14
Upton	1	51.5	1	1	1	51.50	1.94%	0.1	0.05	0.02
Vine Grove	1	51.5	1	1	1	51.50	1.94%	0.1	0.05	0.02
West Point	2	51.5	2	1	2	25.75	3.88%	0.2	0.05	0.04
LARUE	59	58.5	20	23	54	0.99	100.85%	2	1.15	1.08
Hodgenville	5	58.5	4	5	5	11.70	8.55%	0.4	0.25	0.1
MARION	58	53.5	11	18	50	0.92	108.41%	1.1	0.9	1
Bradfordsville	1	53.5	0	1	1	53.50	1.87%	0	0.05	0.02
Lebanon	6	53.5	3	6	6	8.92	11.22%	0.3	0.3	0.12
Loretto	2	53.5	1	2	2	26.75	3.74%	0.1	0.1	0.04
Raywick	1	53.5	1	1	1	53.50	1.87%	0.1	0.05	0.02
MEADE	68	59.5	20	40	63	0.88	114.29%	2	2	1.26
Brandenburg	13	59.5	8	13	13	4.58	21.85%	0.8	0.65	0.26
Ekron	2	59.5	0	2	2	29.75	3.36%	0	0.1	0.04
Muldraugh	0	59.5	0	0	0	0.00	0.00%	0	0	0
NELSON	71	53.5	22	39	64	0.75	132.71%	2.2	1.95	1.28
Bardstown	16	53.5	6	15	16	3.34	29.91%	0.6	0.75	0.32
Bloomfield	1	53.5	0	1	1	53.50	1.87%	0	0.05	0.02
Fairfield	0	53.5	0	0	0	0.00	0.00%	0	0	0
New Haven	4	53.5	1	3	4	13.38	7.48%	0.1	0.15	0.08
WASHINGTON	51	53.5	11	18	44	1.05	95.33%	1.1	0.9	0.88
Mackville	0	53.5	0	0	0	0.00	0.00%	0	0	0
Springfield	6	53.5	2	6	6	8.92	11.22%	0.2	0.3	0.12
Willisburg	3	53.5	1	3	3	17.83	5.61%	0.1	0.15	0.06
LTADD	563	50.5	187	298	523	0.09	1114.85%	18.7	14.9	10.46

NOTE: The historic frequency of a hazard event over a given period of time determines the historic recurrence interval. For example: If there have been 10 Thunderstorm events in the County in the past 5 years, statistically you could expect that there will be 2 events a year.

Realize that from a statistical standpoint, there are several variables to consider. 1) Accurate hazard history data and collection are crucial to an accurate recurrence interval and frequency. 2) Data collection and accuracy has been much better in the past 10-20 years (NCDC weather records). 3) It is important to include all significant recorded hazard events which will include periodic updates to this table.

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Compilation of SHELDUS, NCDC & NCEI. 1967- June 30 2015.

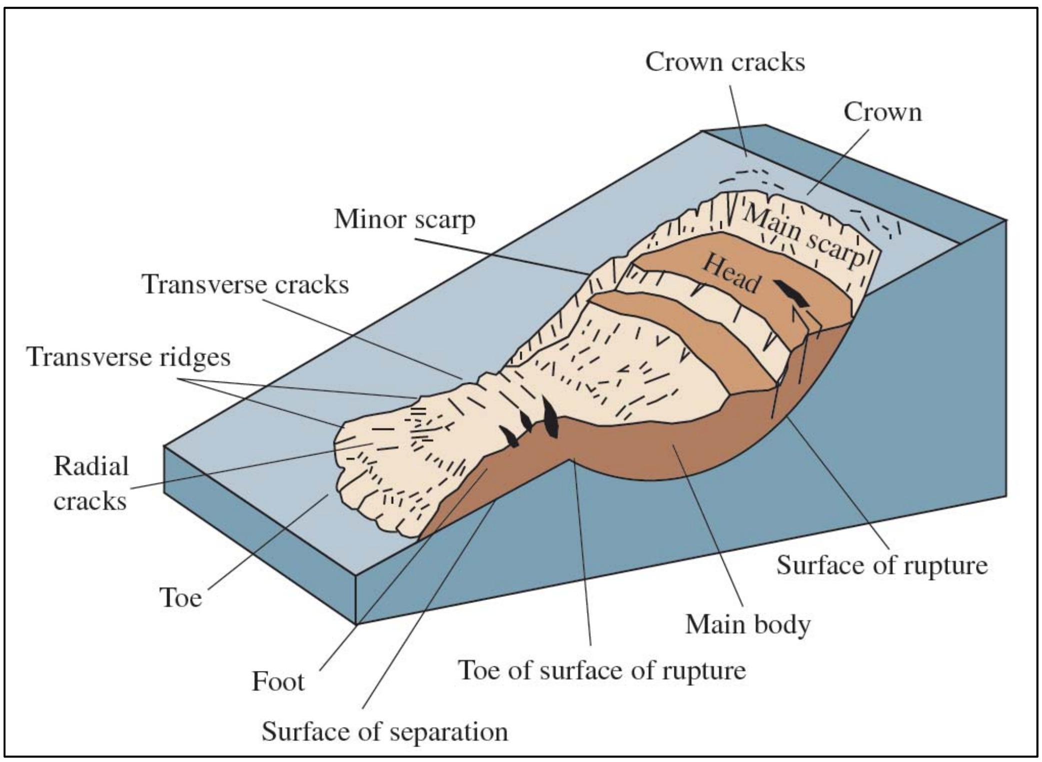
3.3.2.7 <u>Landslides</u>

<u>I. Background</u>

Definition

According to the United States Search and Rescue Task Force, "landslides are rock, earth, or debris flows on slopes due to gravity. They can occur on any terrain given the right conditions of soil, moisture, and the angle of the slope. Integral to the natural process of the earth's surface geology, landslides serve to redistribute soil and sediments in a process that can be in abrupt collapses or in slow gradual slides."

While there are numerous kinds of landslides, they can be triggered by rains, floods, earthquakes, and other natural events, as well as human-made causes such as grading, terrain cutting and filling, excessive development and vibrations. The factors that cause landslides can be geophysical or man-made and can occur in developed areas, undeveloped areas, or any area where the terrain was altered for roads, houses, utilities, buildings, and even residential lawns. Landslides occur in all fifty states with varying frequency and more than half of U.S. States have landslide rates sufficient to be classified as a significant natural hazard.



Slump-earth flow showing nomenclature, *Source: USGS Fact Sheet 2004-3072.*

Cause

Landslide is a term frequently used to mean any fairly rapid movement of rocks and sediment downslope. However, a more accurate term to use is "mass wasting." Mass wasting refers to a large variety of mass movement processes that wear away to the Earth's surface.

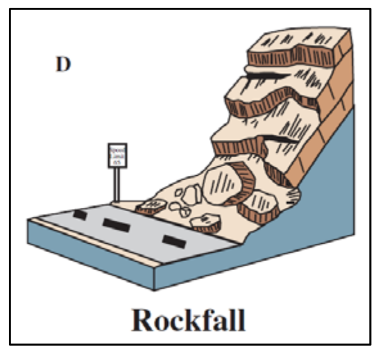
There are three main factors that control the type and rate of mass wasting that occurs at the Earth's surface:

- Slope gradient: The steeper the slope of the land, the more likely that mass wasting will occur.
- Slope consolidation: Sediments and fractured or poorly cemented rocks and sediments are weak, and more prone to wasting.
- Water: When slope materials become saturated with water, they may lose cohesion and begin to flow easily.

The three basic types of mass wasting are:

- Falls – rocks fall or bounce through the air
- Slides – rocks and/or sediment slide along the Earth's surface
- Flows – sediment flows across the Earth's surface

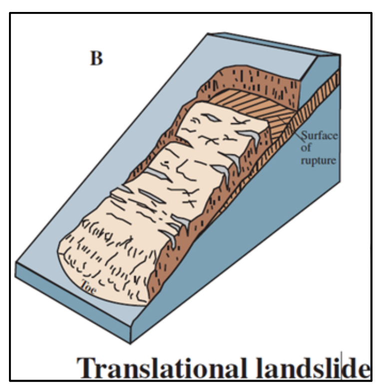
Falls occur as a result of weathering. Steep mountain or hillside slopes are constantly wasting away and are characterized by rocks falling and bouncing down slopes. These falls are triggered by freezing and thawing water, the growth of plants and their roots, earthquakes, or by people hiking on a slope. Falls occur in a matter of seconds, so they are difficult to observe.



USGS Fact Sheet 2004-3072.

Slides occur when a mass of slope material moves as an entire block. The most common form of a slide is a **slump**. A slump happens when a portion of the hillside moves downslope as a result of gravity.

A landslide is called a **flow** if the material moving downslope is being transported as a very thick fluid, rather than as a unified block of material.



USGS Fact Sheet 2004-3072.

Areas prone to landslides include:

- Existing landslides, old or recent
- On or at the base or top of slopes
- In or at the base of minor drainage hollows
- At the base or top of an old fill slope
- At the base or top of a steep cut slope

Areas that are generally safe from Landslides include:

- On hard, non-joined bedrock that has not moved in the past
- On relatively flat-lying areas away from slopes and steep river banks
- At the top or along the nose of ridges, set back from the tops of slopes

Features that may be present prior to a major landslide include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavements or sidewalks
- Soil moving away from foundations
- Ancillary structures such as decks and patios tilting and/or moving relative to the main structure
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Sudden decrease in creek water levels though rain is still falling or has just recently stopped.
- Sticking doors and windows, and visible open spaces; indication jambs and frames are out of plumb.


Landslide area in Nelson County along the Chaplin River. *Source: LTADD Archive.*

A landslide occurs when the stability of a slope changes from a stable condition to an unstable one. A change in slope stability can occur from a number of factors that act alone or in concert with one another. Natural causes of landslides include:

- Groundwater (pore water) pressure acting to destabilize a slope
- Loss or absence of vertical vegetative structure, soil nutrients and soil structure; all of these factors can be the result of a wildfire
- Erosion of the toe of a slope by rivers or ocean waves
- Intense rainfall
- Weakening of a slope due to saturation by melting snow and glaciers or by heavy rains

- Earthquakes that add loads to barely stable slopes or earthquake-caused liquefaction that destabilizes slopes
- Volcanic eruptions

Human activities that can affect the occurrence of a landslide include:

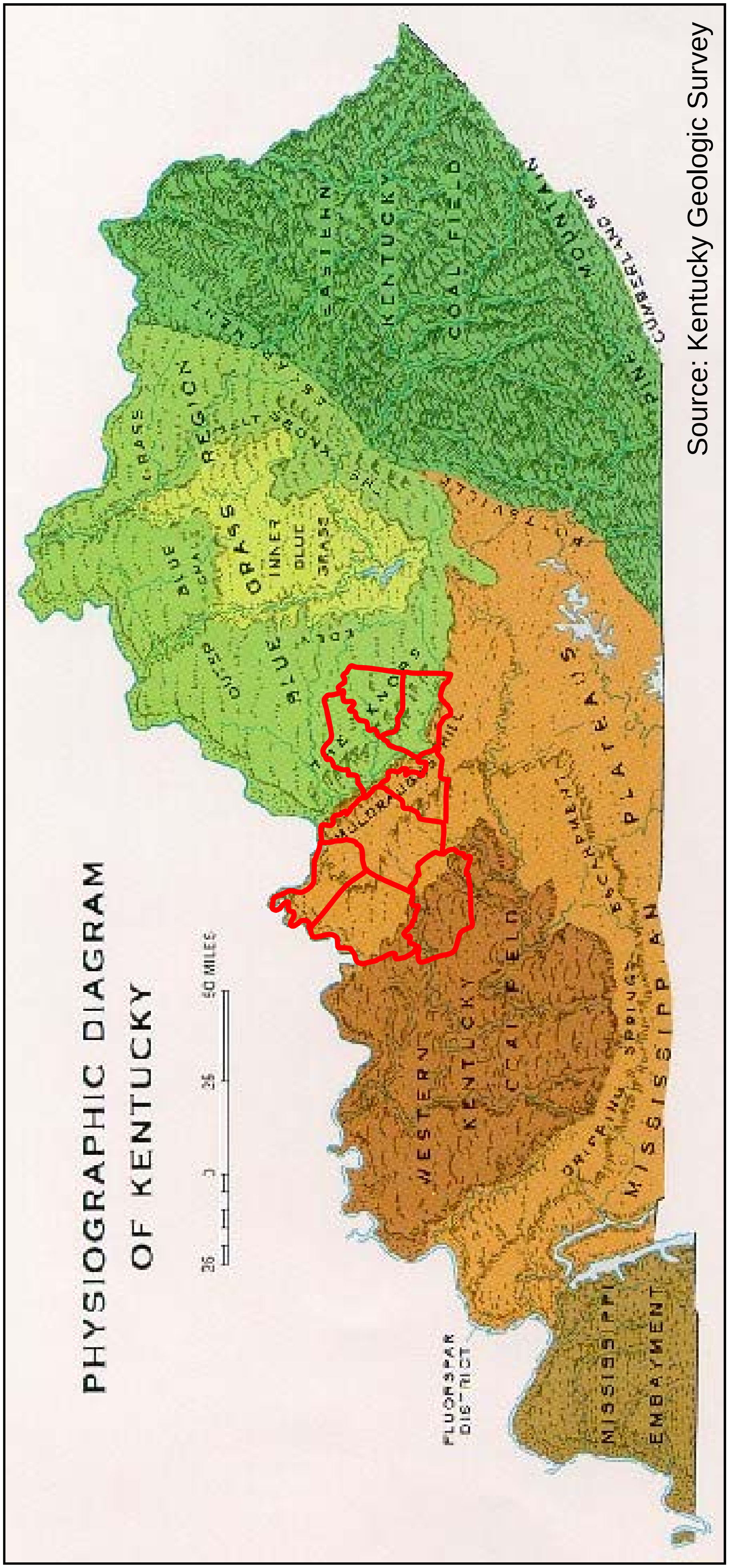
- Deforestation, cultivation and construction that contributes to the destabilization of a fragile slope
- Vibrations from machinery or traffic
- Blasting
- Earthwork that alters the shape of a slope or contributes new loads on an existing slope
- Removal of deep-rooted vegetation that binds colluvium to bedrock in shallow soils
- Construction, agricultural or forestry activities that changes the amount of water which infiltrates the soil

Hazards/Vulnerability

According to the United States Geological Survey Fact Sheet 2004-3072, landslides cause approximately $3.5 billion (in 2001 dollars) in damages, and kill between 25 and 50 people in the United States annually. Landslides occur in all fifty of the states in the U.S. The casualties in the United States are caused primarily by rockfalls, rockslides, and debris flows. Natural disasters are a prime example of humans living in conflict with the environment. Because landslides can cause catastrophic damage and loss of life, it is imperative to have a good understanding of what causes disasters in order to prevent them from occurring or to avoid development in areas prone to disasters. Sustainable land management and development is an essential tool in reducing the negative impacts that can happen as a result of landslides.

II. Analysis

It is helpful to understand the physiographic characteristics of the Lincoln Trail Region to analyze the risk of landslides in the area. The Kentucky Physiographic Regions map included, shows that our region lies in four Kentucky physiographic regions; the Knobs, the Western Coal Field, the Outer Bluegrass and the Mississipppian Plateau or Western Pennyroyal. Each has distinct characteristics that define it and help determine the propensity for landslides. Information for this analysis comes from ARCGIS, Kentucky Geological Survey and historical information from County Emergency Management Agencies.


Source: Kentucky Geologic Survey
PHYSIOGRAPHIC DIAGRAM
OF KENTUCKY
50 MILES
EASTERN
KENTUCKY
COALFIELD
PINE MOUNTAIN
INNER
BLUE
GRASS
WESTERN
KENTUCKY
COALFIELD
MISSISSIPPIAN
PLATEAUS
FLUORSPAR
DISTRICT
MISSISSIPPI
EMBAYMENT

According to the Kentucky Geological Survey, Kentucky has a combination of steep slopes, excessive water amounts, geology, and slope modifications that are the main causes of landslides. The Kentucky Transportation Cabinet has compiled 870 geotechnical reports documenting landslides that have affected roads in Kentucky and resulted in significant costs. Between fiscal years 2002 to 2009, the Transportation Cabinet's records show repairs due to landslides and rockfalls totaled $31.8 million. While damage totals specific

Rock Slide on the Blue Grass Parkway in Hardin County. *Source: Kentucky Geological Survey.*

to the Lincoln Trail Region are not documented, it is definite that some of Transportation Cabinets repairs were done on local roads. From 2003 to 2013, the Kentucky Hazard Mitigation Grant program funded or will fund projects to acquire landslide-damaged homes or to stabilize an area, totaling $5.3 million. In general, the State and local agencies that respond to or document landslides vary, and data pertaining to the collection, assessment, and documentation of occurrences is not consistent.

To date, Hazard Mitigation funds were used in Nelson County to buy out a home in danger of sliding down a slope. The property was purchased in 2006 and the structure demolished. The land was rezoned to green space in perpetuity. Meade County has imminent need to stabilize a bank slope on the Ohio River that threatens the local water supply, and Breckinridge County has project plans to stabilize slopes that threaten local roads.

Extent

While there are few documented reports of extensive damage as a result of landslide activity, the eight-county region has natural topographic and geologic features that render it susceptible to landslides when natural events such as ground water, intense rainfall, melting snow and seismic activity are factored in. This is substantiated by the 2006 *Landslide* review written by Yoshimatsu and Abe. Yoshimatsu and Abe identify the Analytical Hierarchic Process (AHP) as a method to determine areas susceptible to landslides. Aerial photographs of areas prone to landslides are "layered." Scores are assigned to each "layer" of the micro-topography and susceptibility to landslides is a function of the summation of scores assigned to each factor of the photographed micro-topography in the landslide prone area. Based on this technology, and the topographic features of the Lincoln Trail Area including karst topography, steep slopes, alluvial soils and underground water movement, coupled with the regional propensity for heavy rains and melting snow; it can be determined that the region has the potential for landslide hazards.

Table 3.3.2.7.1 - AHP Score of Ranking of Susceptibility of Landslides

Susceptibility Level	AHP Score	Percentage to Total Number of Landslides (%)
Level 1 (High)	62 > AHP Score	5%
Level 2 (Slightly High)	38 < AHP Score	25%
Level 3 (Slightly Stable)	24 < AHP Score	30%
Level 4 (Stable)	AHP Score < 24	40%

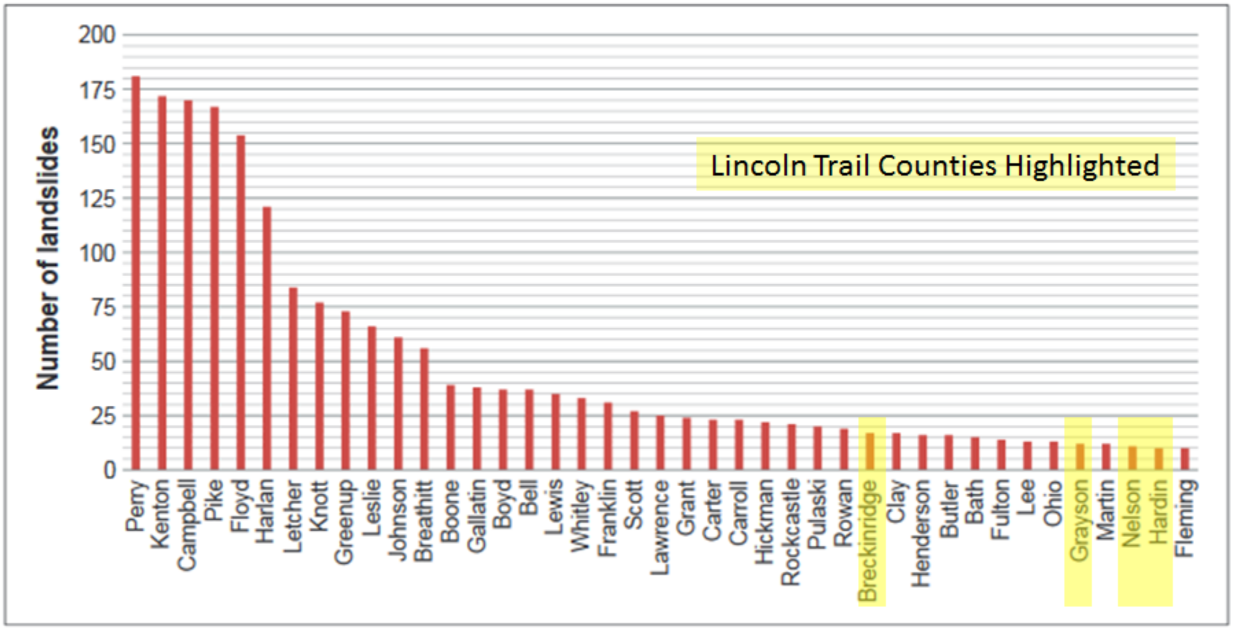
Source: Yoshimatsu, H.; & Abe, S. (2006). "A Review of Landslide Hazards in Japan and Assessment of Their Susceptibility Using an Analytical Hierarchic Process (HP) Method." *Landslides*, 3, 149-158

As previously cited, landslides in this region have the potential to destroy structures, interrupt transportation lines and decimate regional water sources.

Probablity

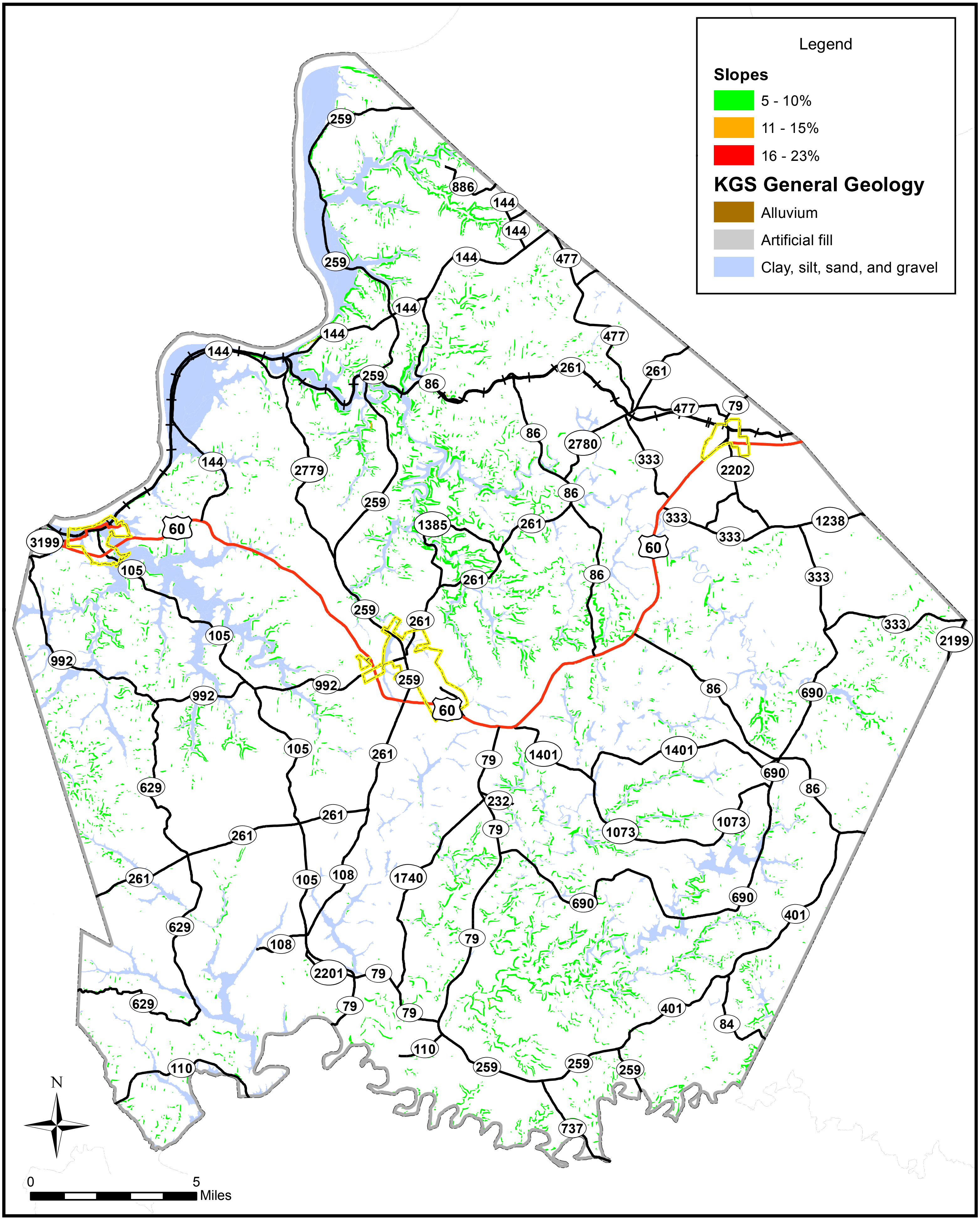
In 2011, Kentucky Geological Survey (KGS) began constructing a landslide inventory database. As of August 20, 2014 the Kentucky Landslide Inventory illustrated by the above chart was completed. The inventory shows the number of documented landslides in the database per county for those counties with 10 or more landslides. In the Lincoln Trail Region there are 49 documented landslides; 16 in Breckinridge County, 12 in Grayson County, 11 in Nelson County and 10 in Hardin County. This yields approximately 3.5 years of data. A raw value for probability for an event occurrence for the Lincoln Trail Region would be historic recurrence interval of 0.07 and a historic frequency, chance per year of 1400%.

Chart 3.3.2.7.1 - KGS Landslide Inventory, Distribution of Landslides



Modified from "Distribution of landslides by county (10 or more landslides)", *Source: KGS "Landslide Inventory: From Design to Application, 2014.*

Note that according to KGS, there is currently no best practice or standard methodology to develop a database that could effectively model landslide susceptibility or risk. Much depends on the ability to collect locations and occurrences.


Legend
Slopes
5 - 10%
11 - 15%
16 - 23%
KGS General Geology
Alluvium
Artificial fill
Clay, silt, sand, and gravel
N
0
5
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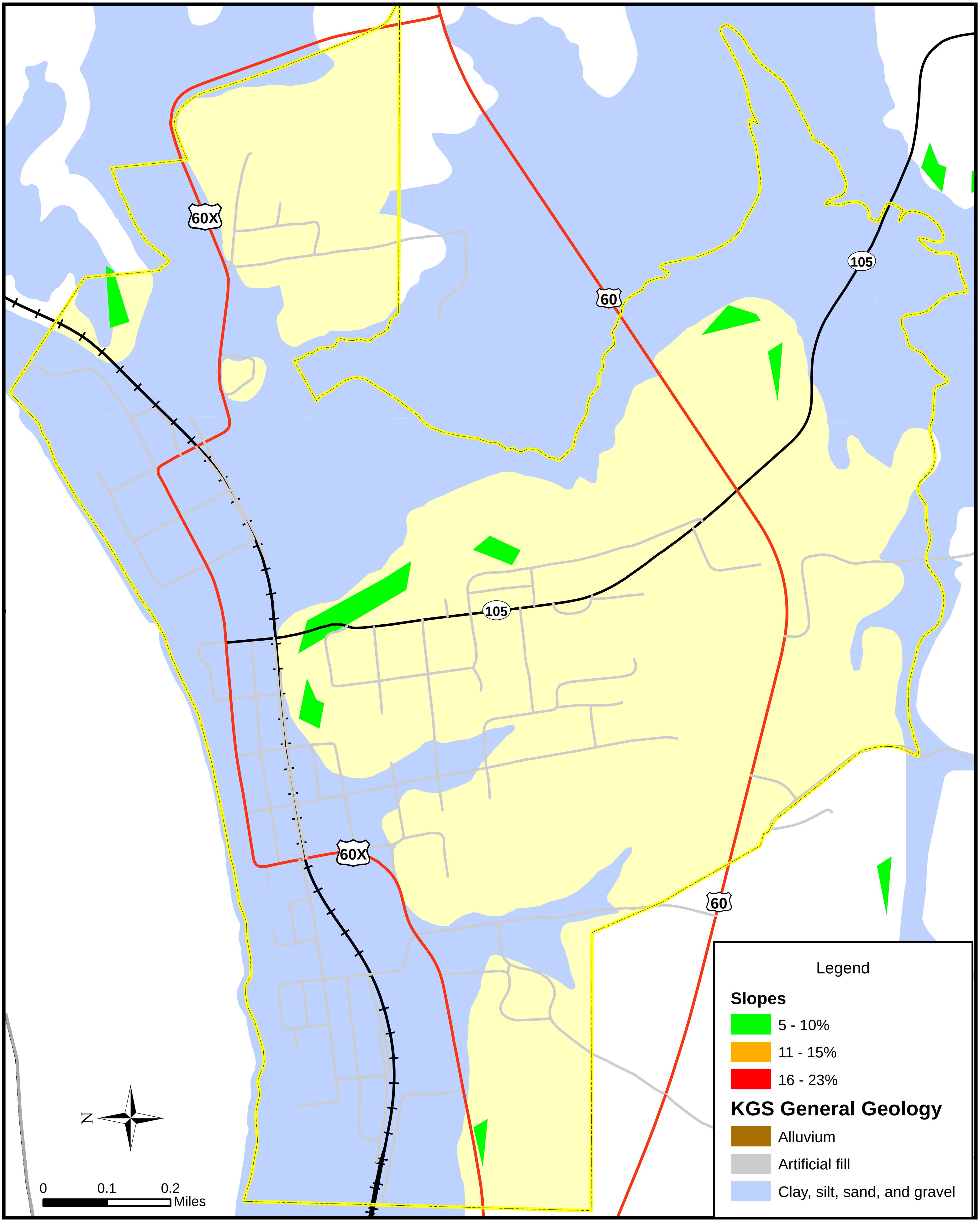
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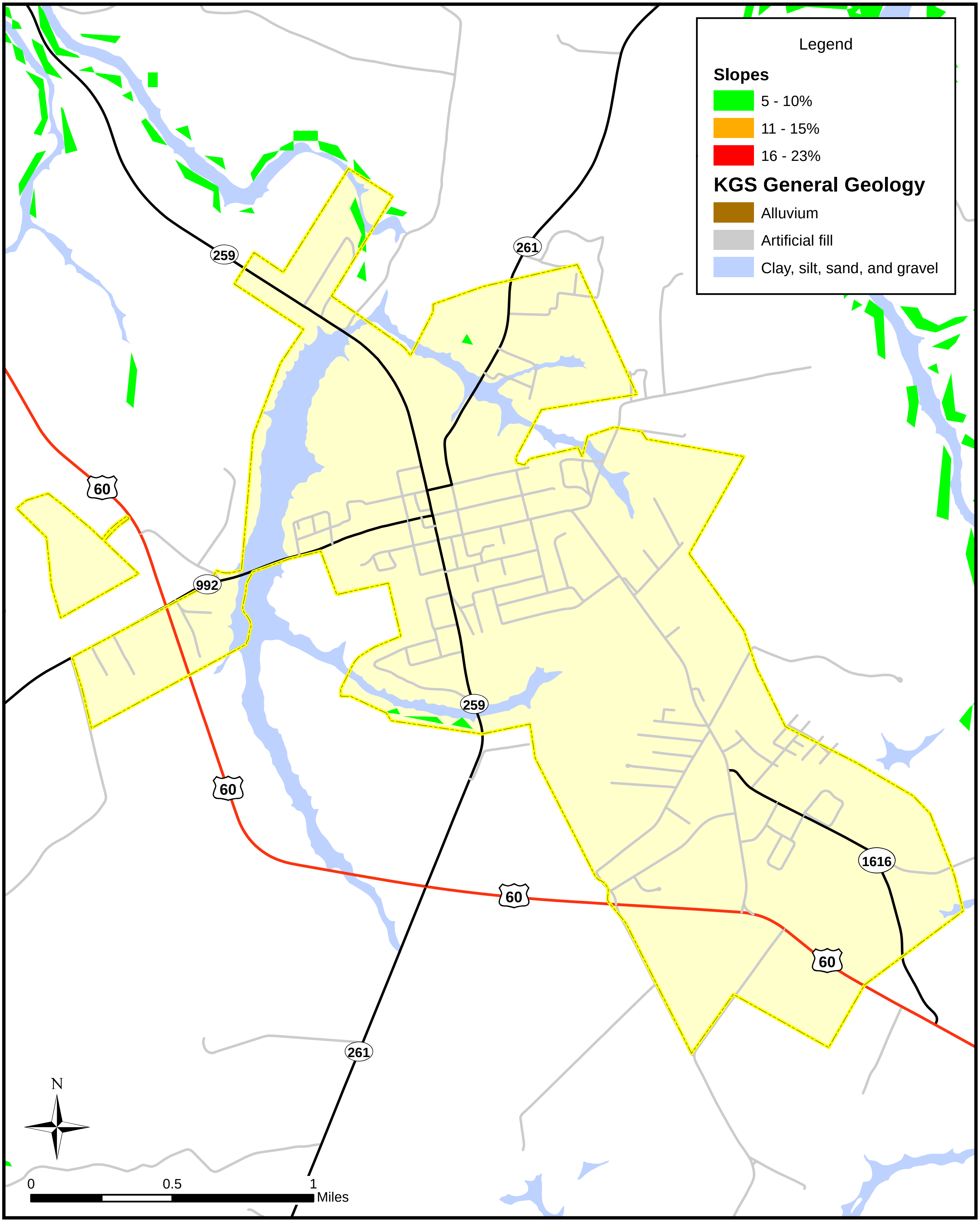
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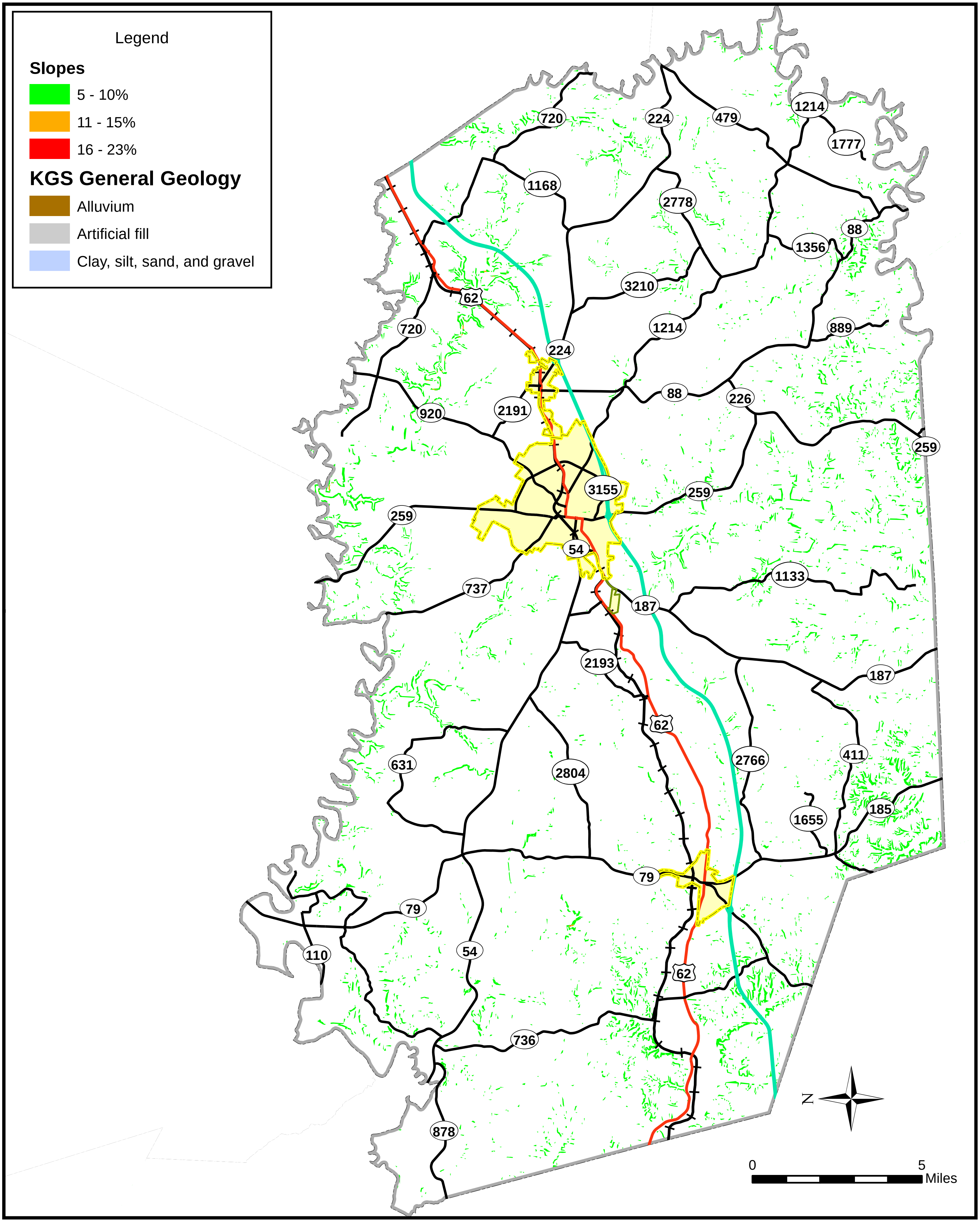
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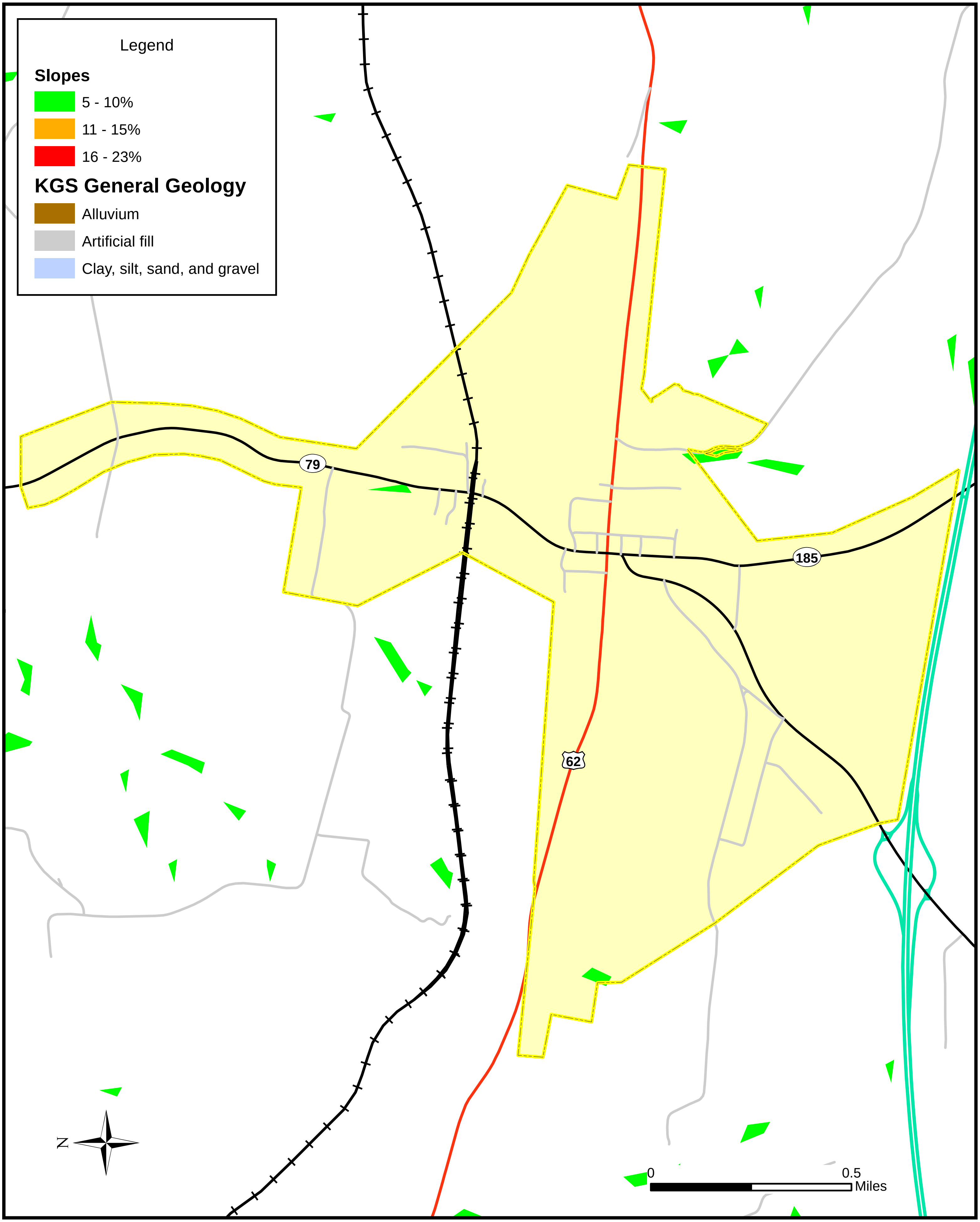
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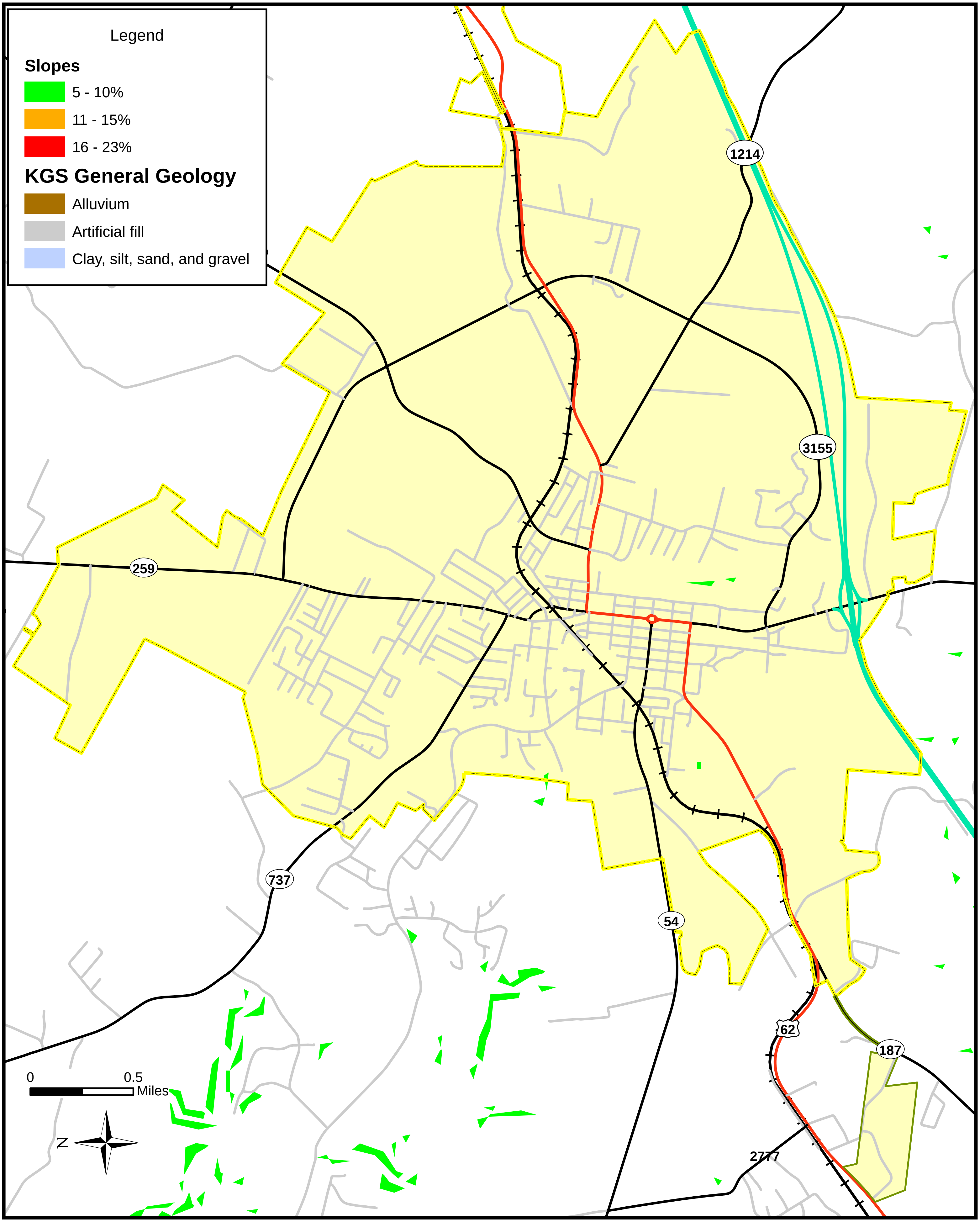
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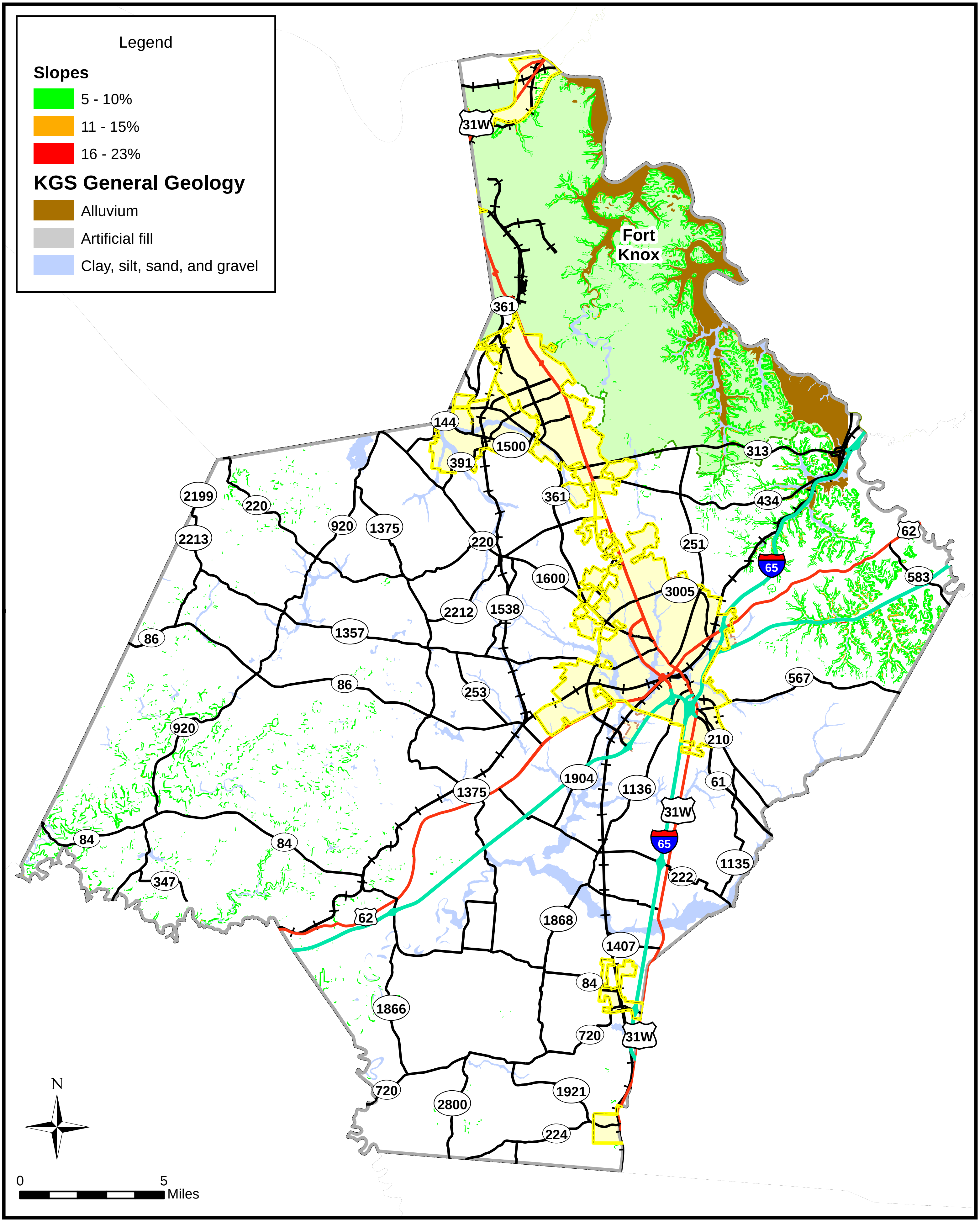
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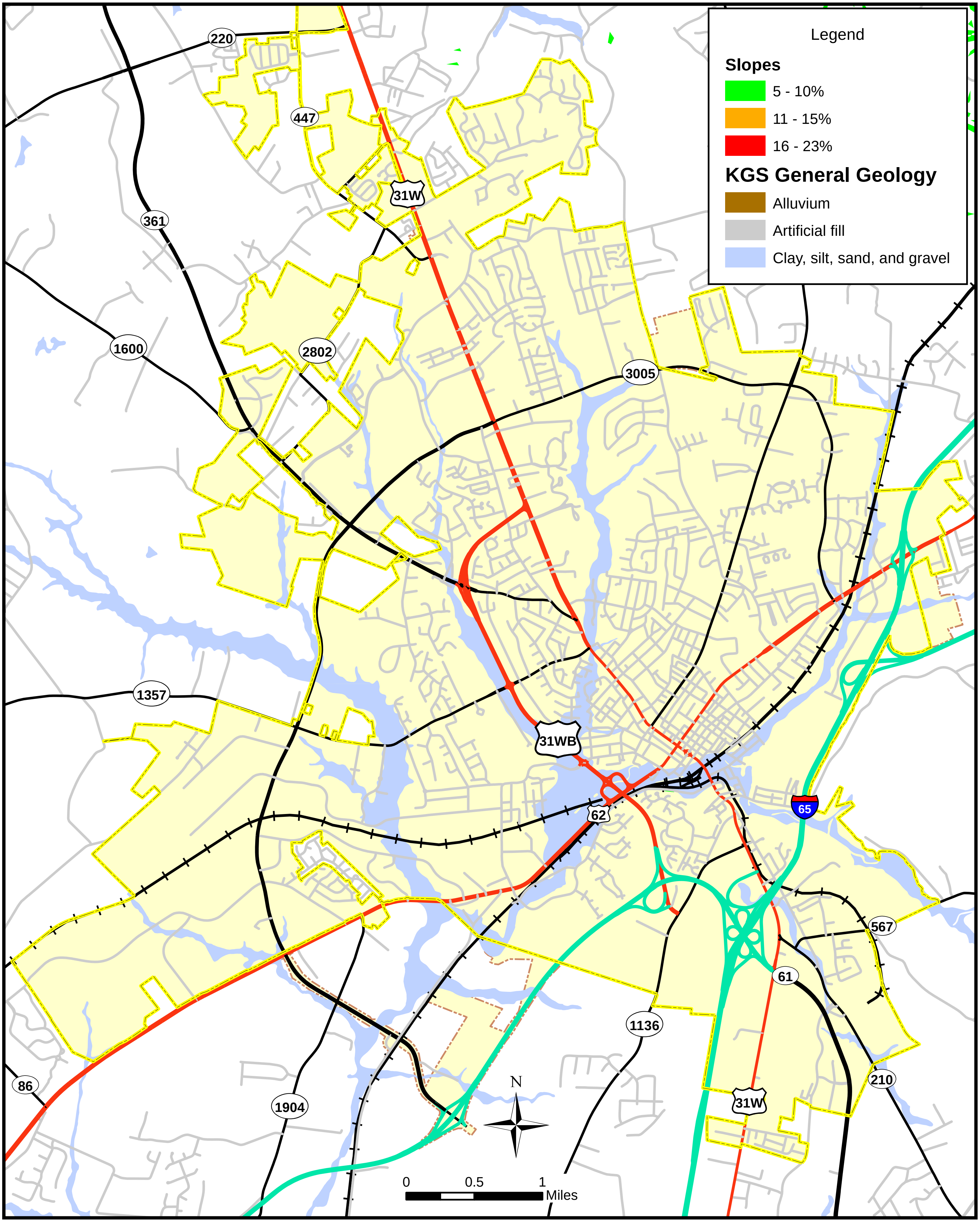
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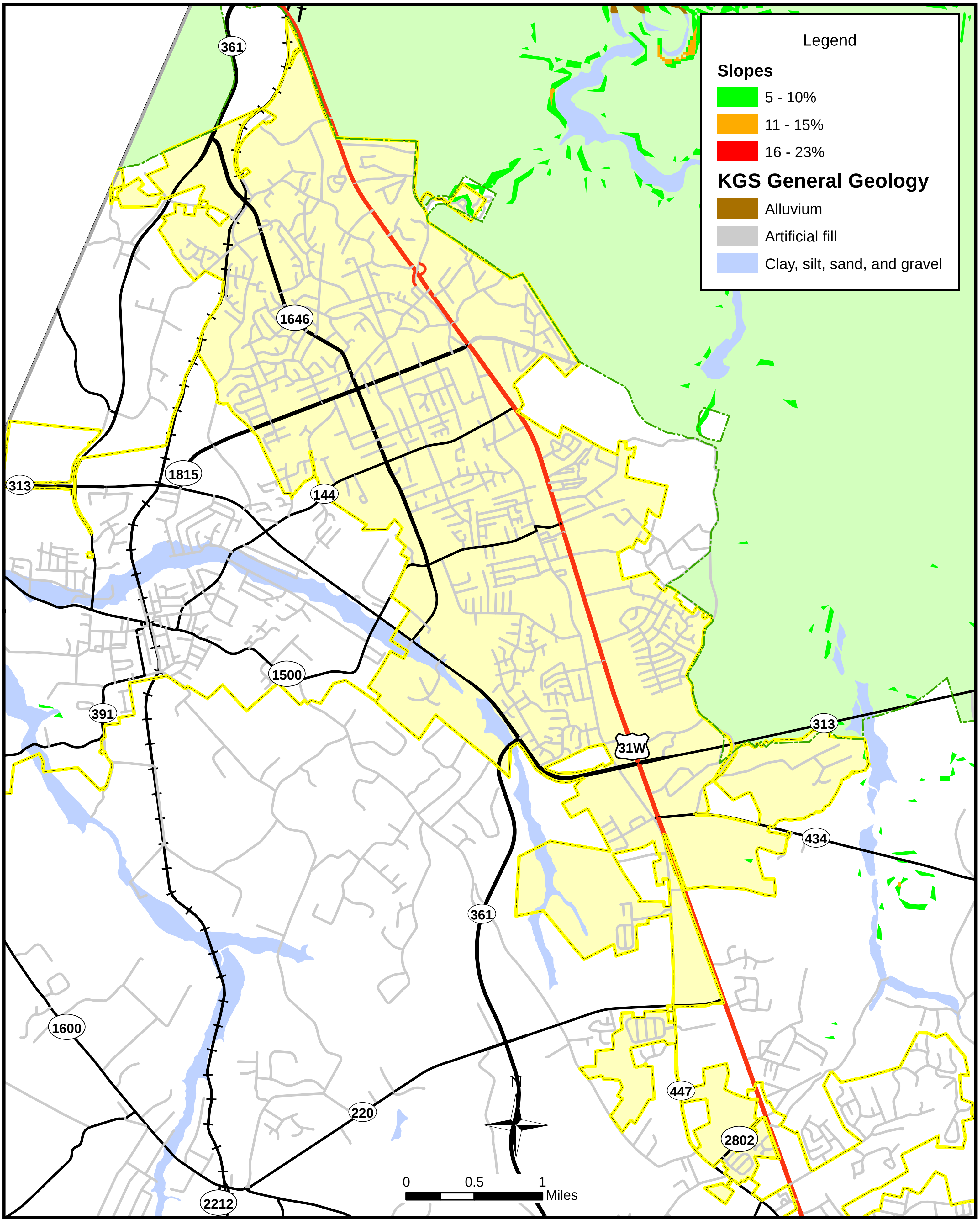
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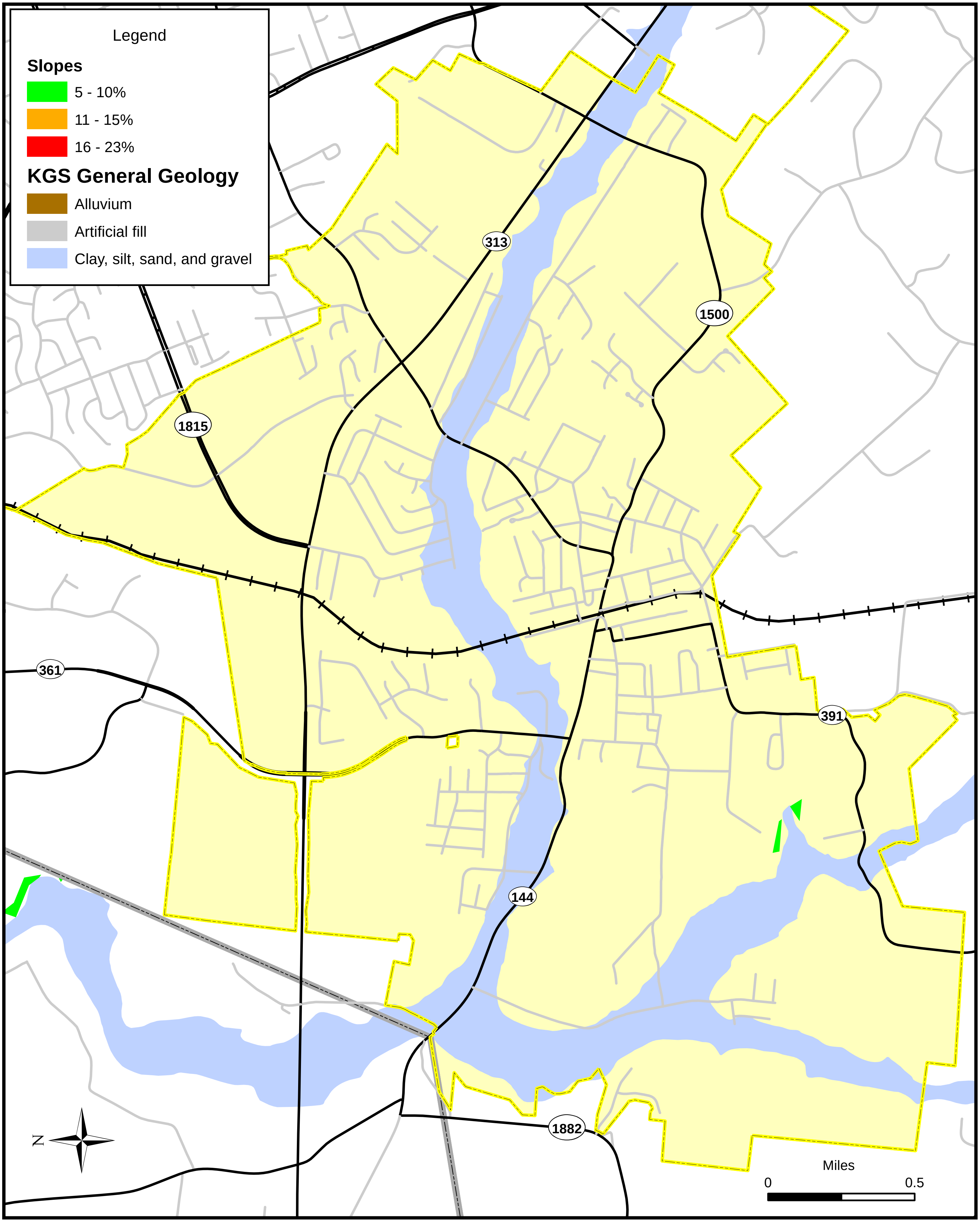
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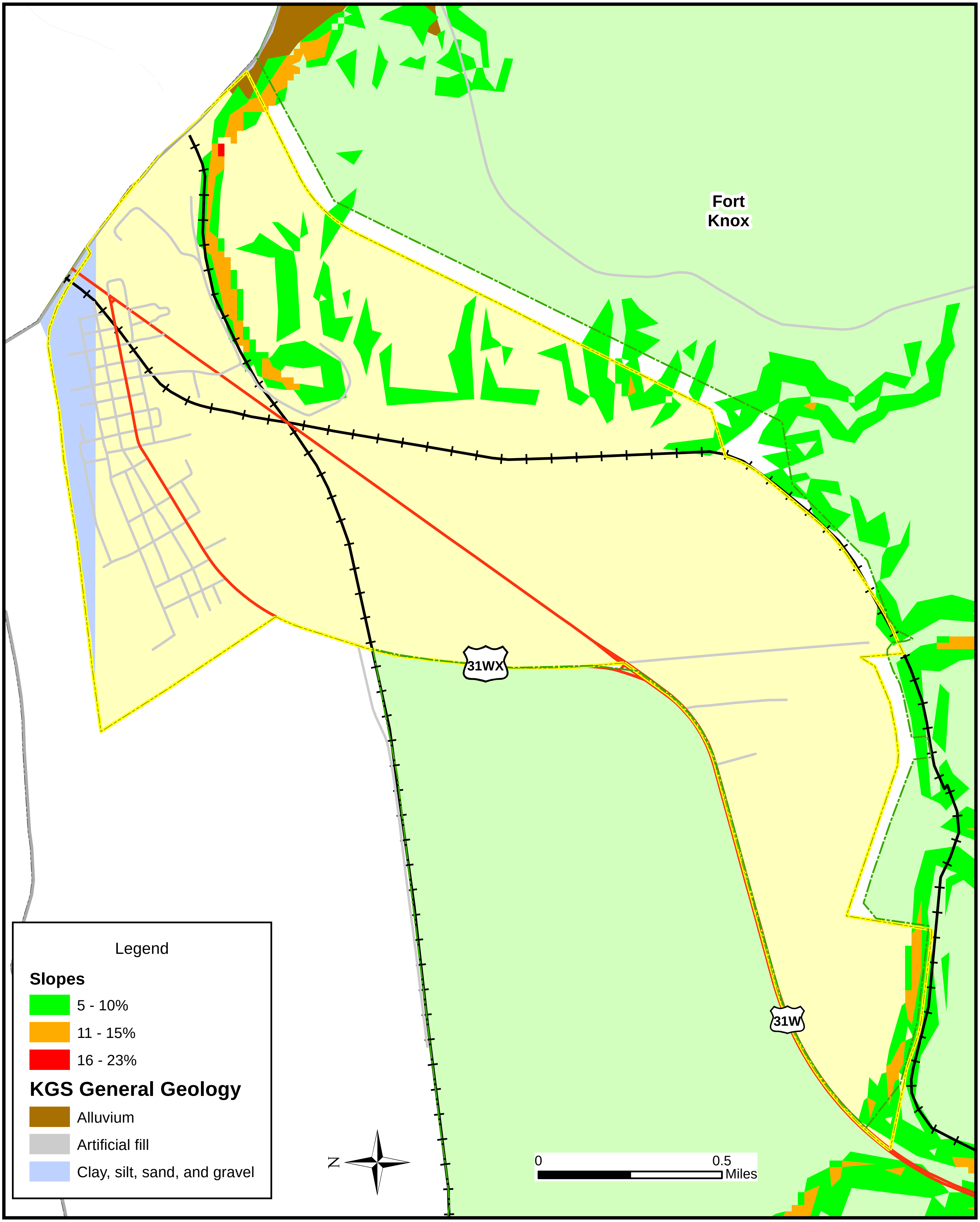
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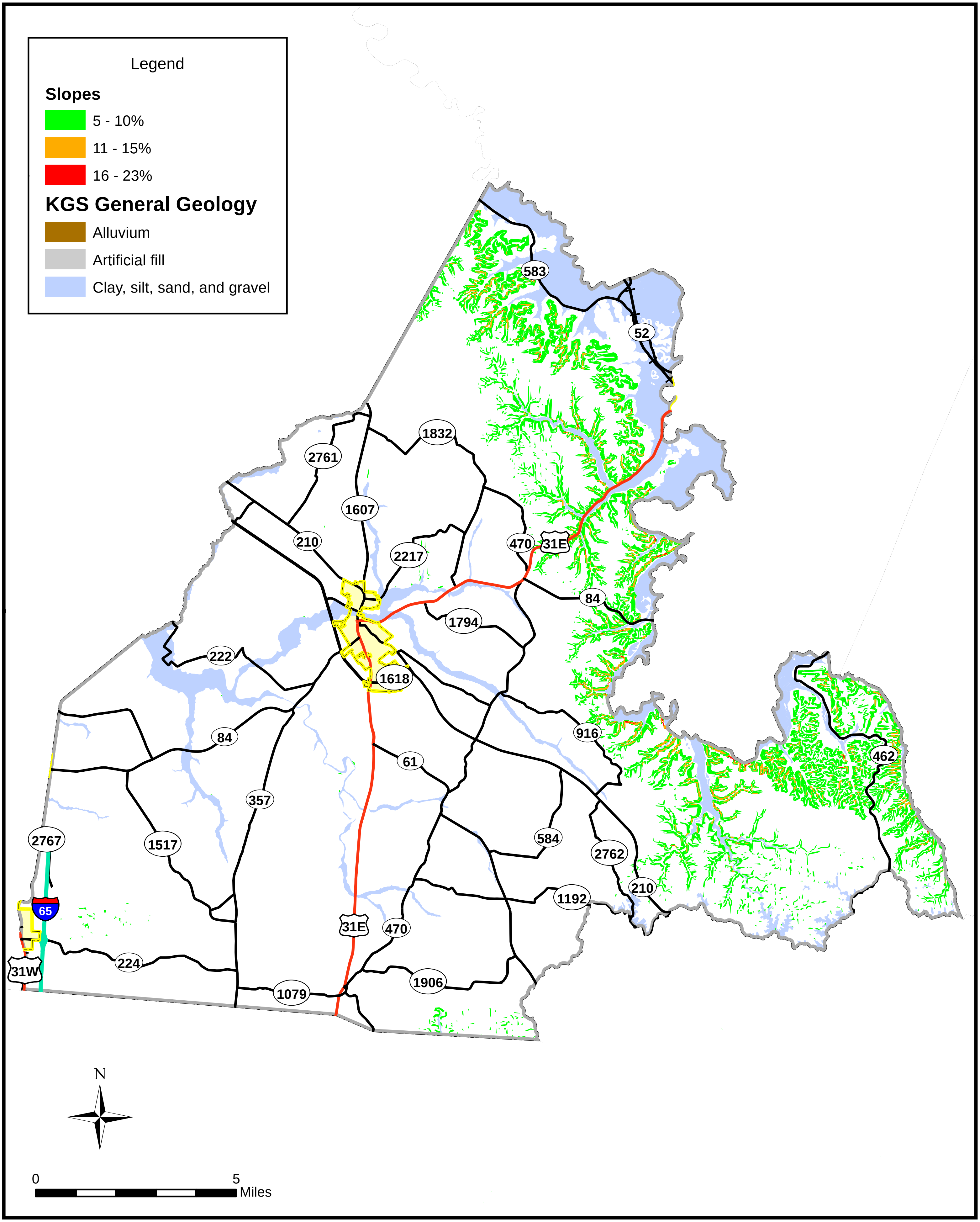
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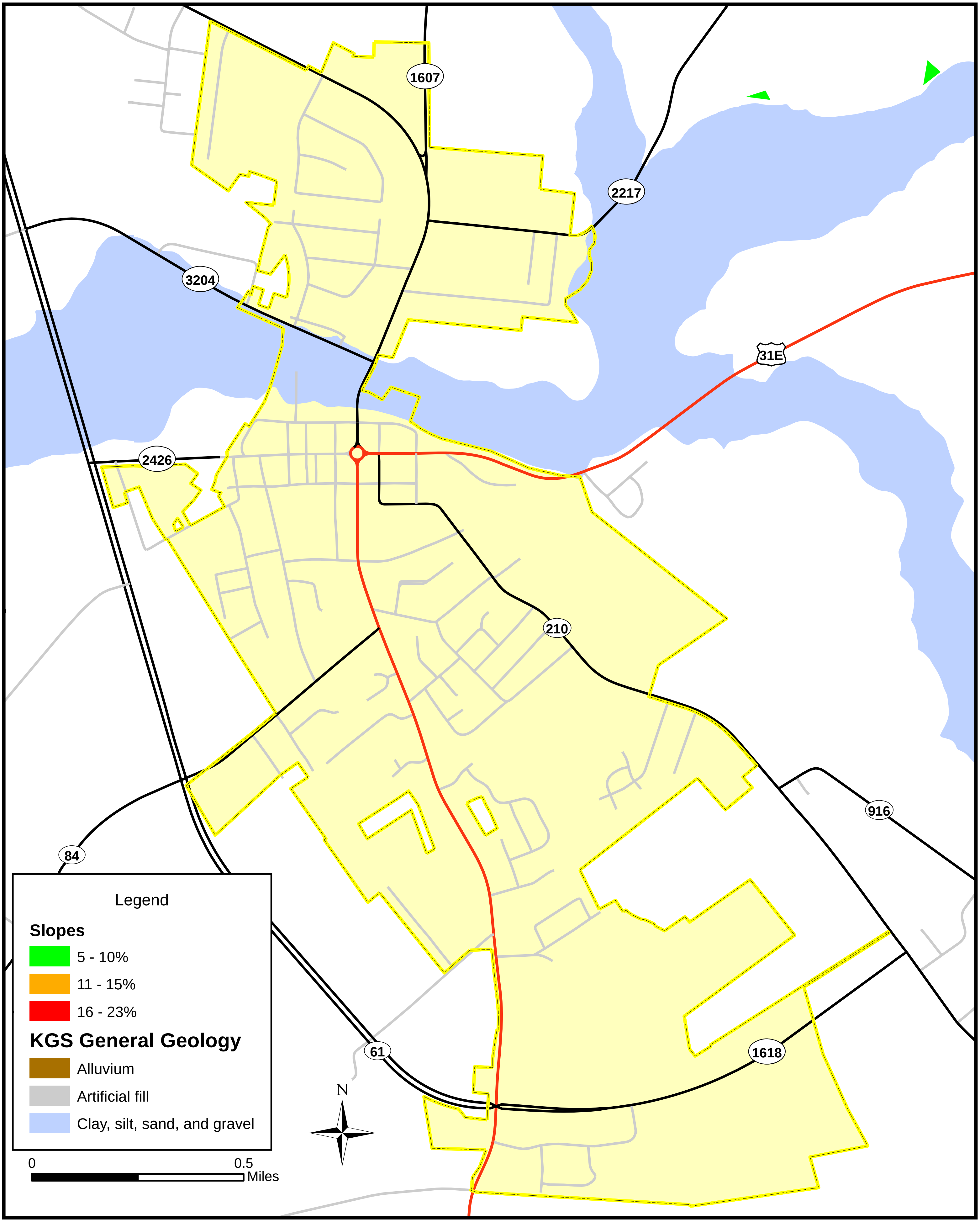
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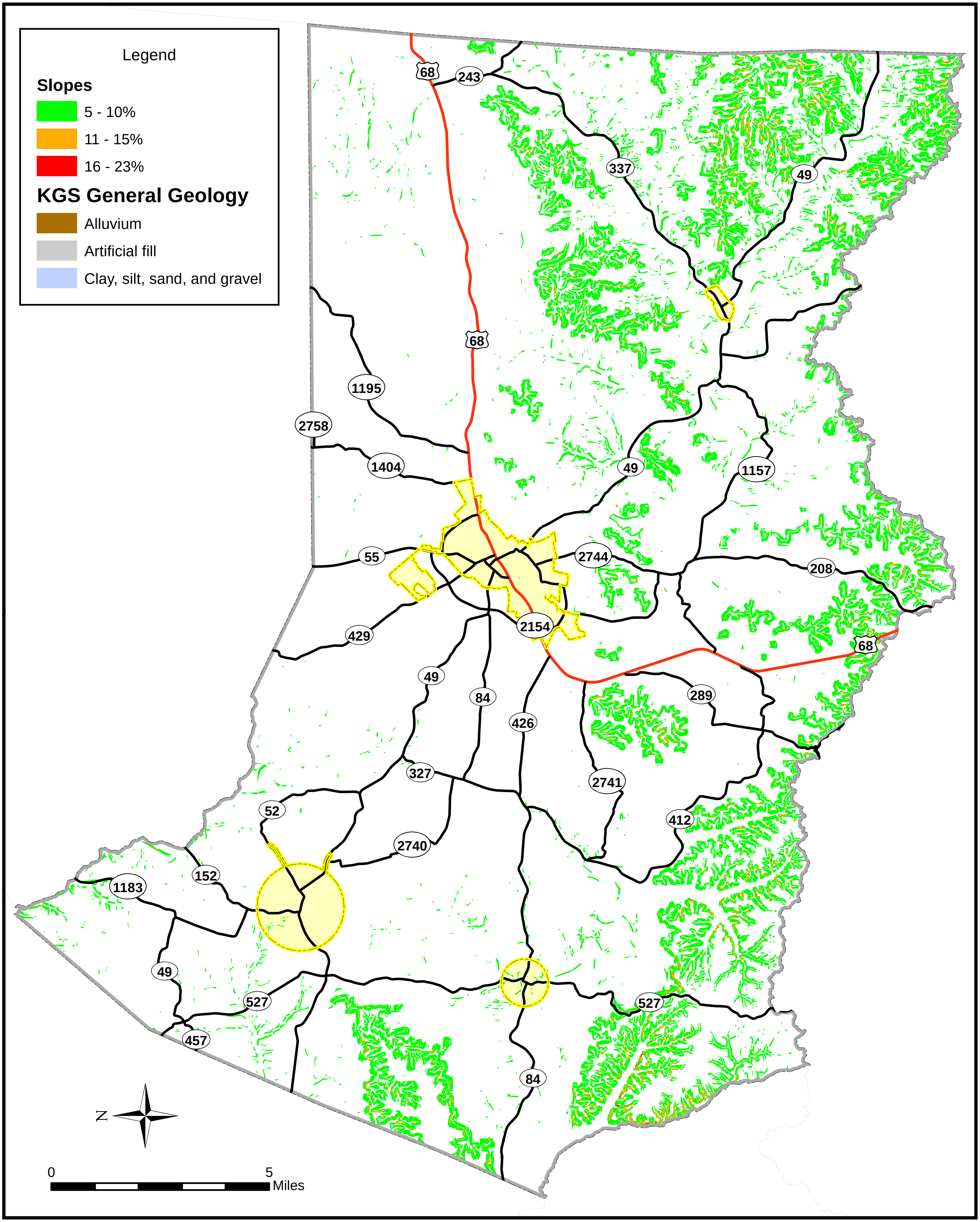
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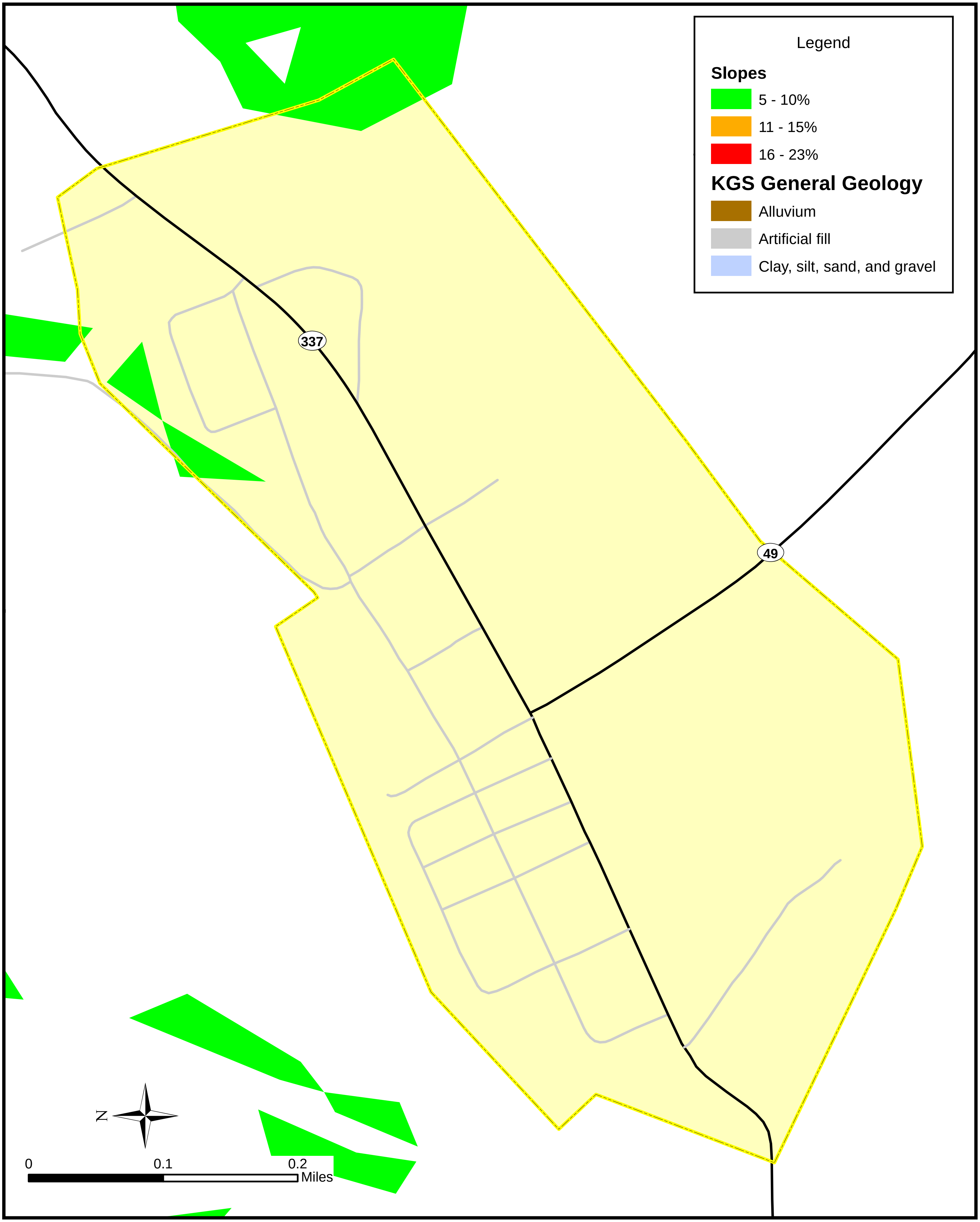
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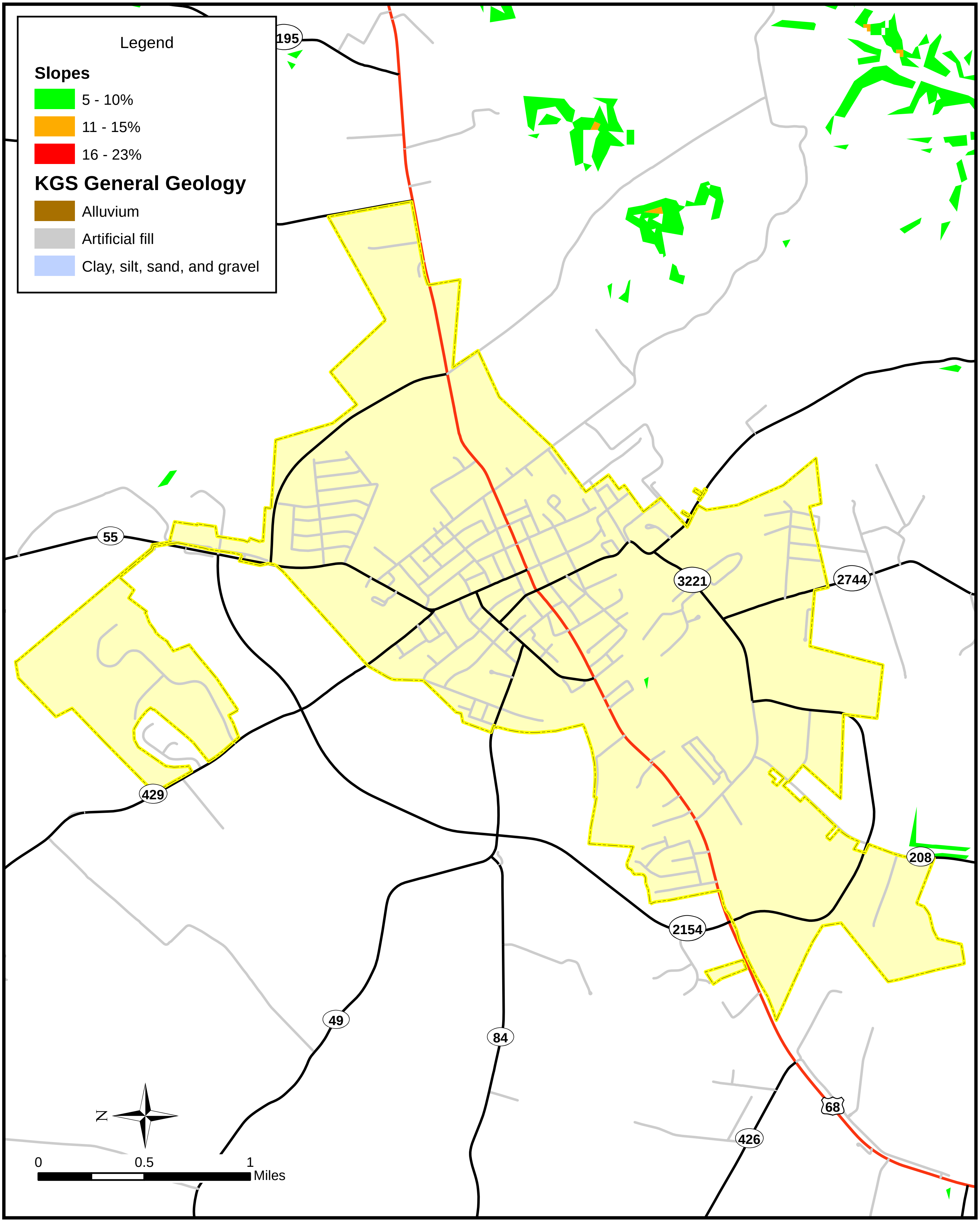
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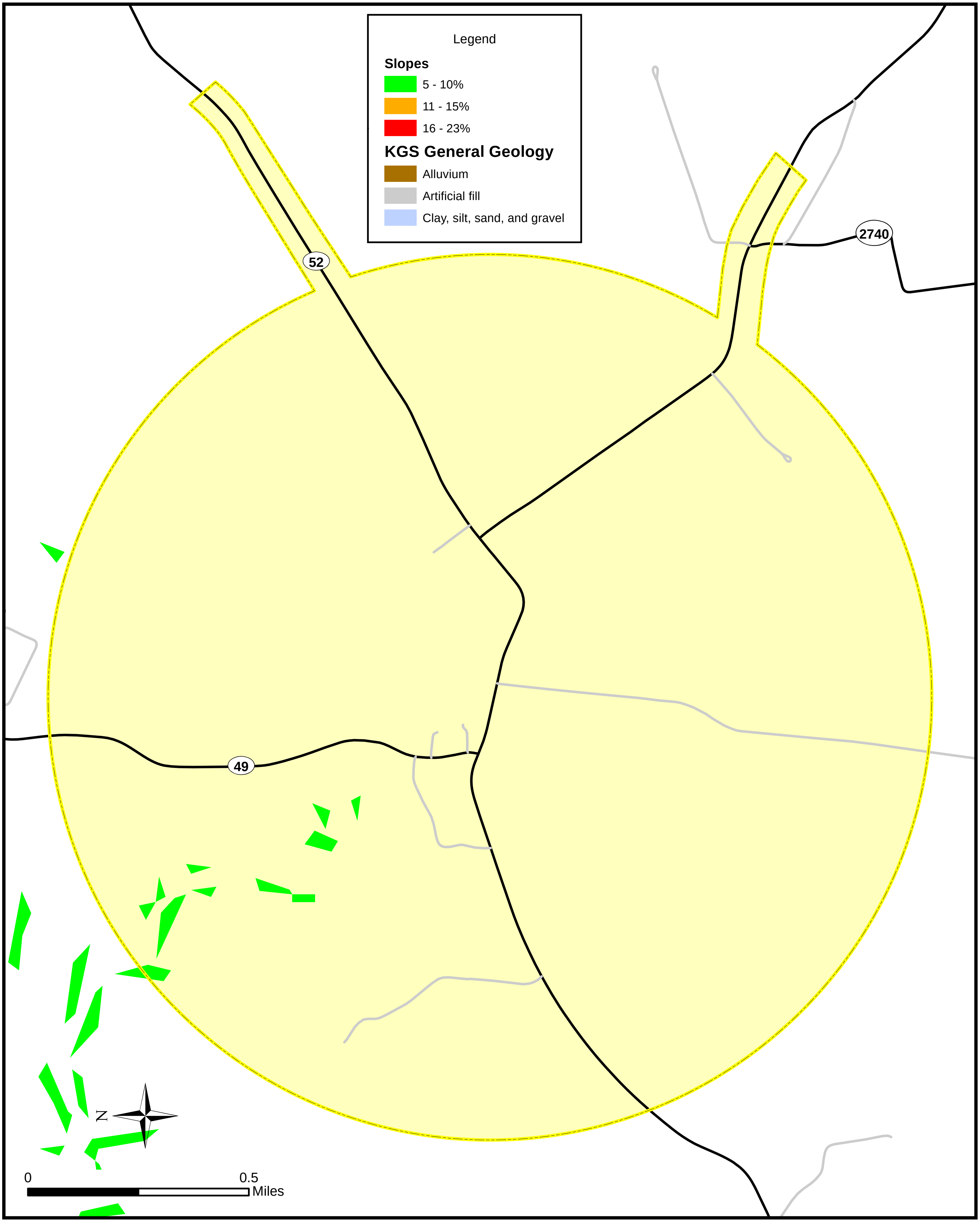
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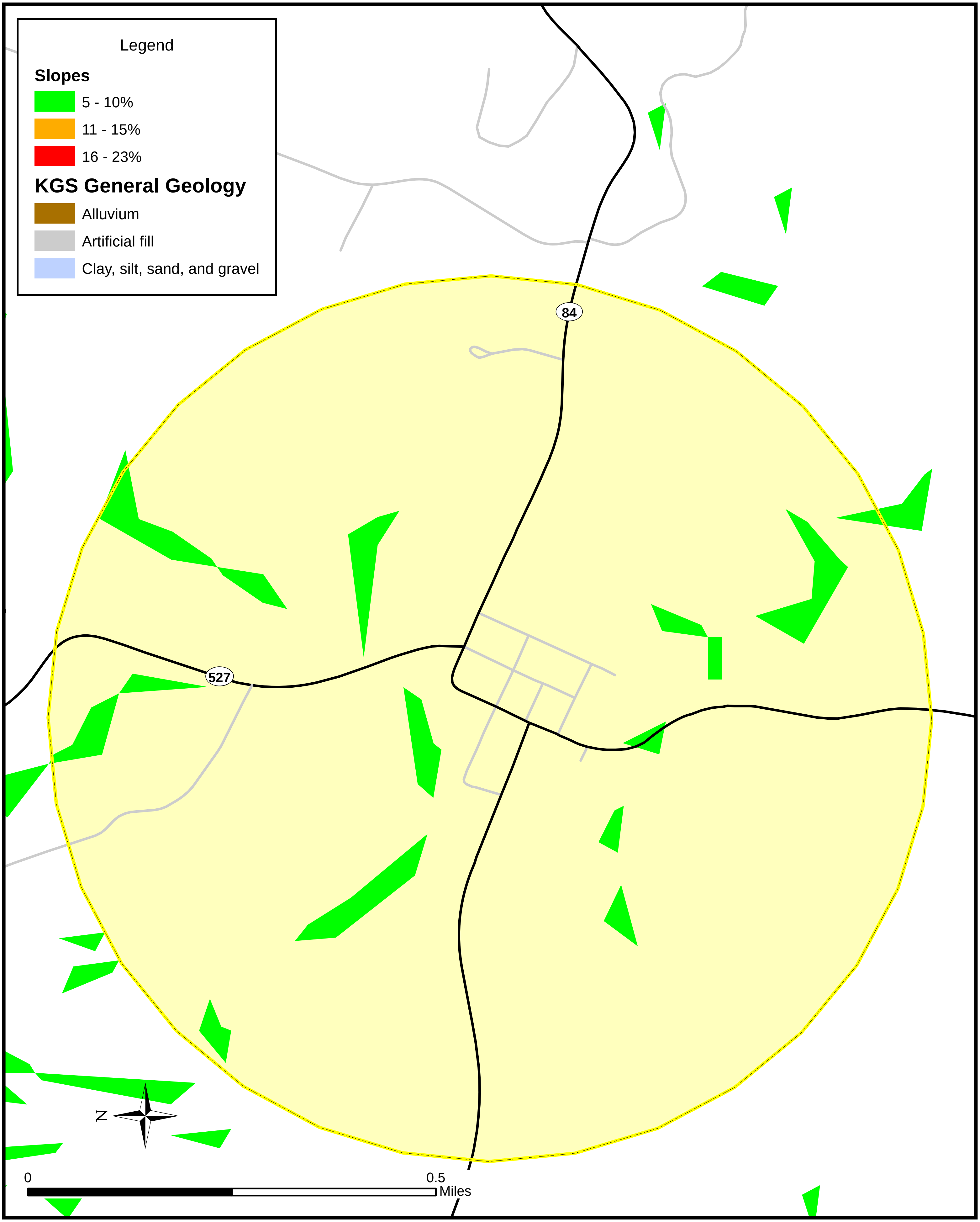
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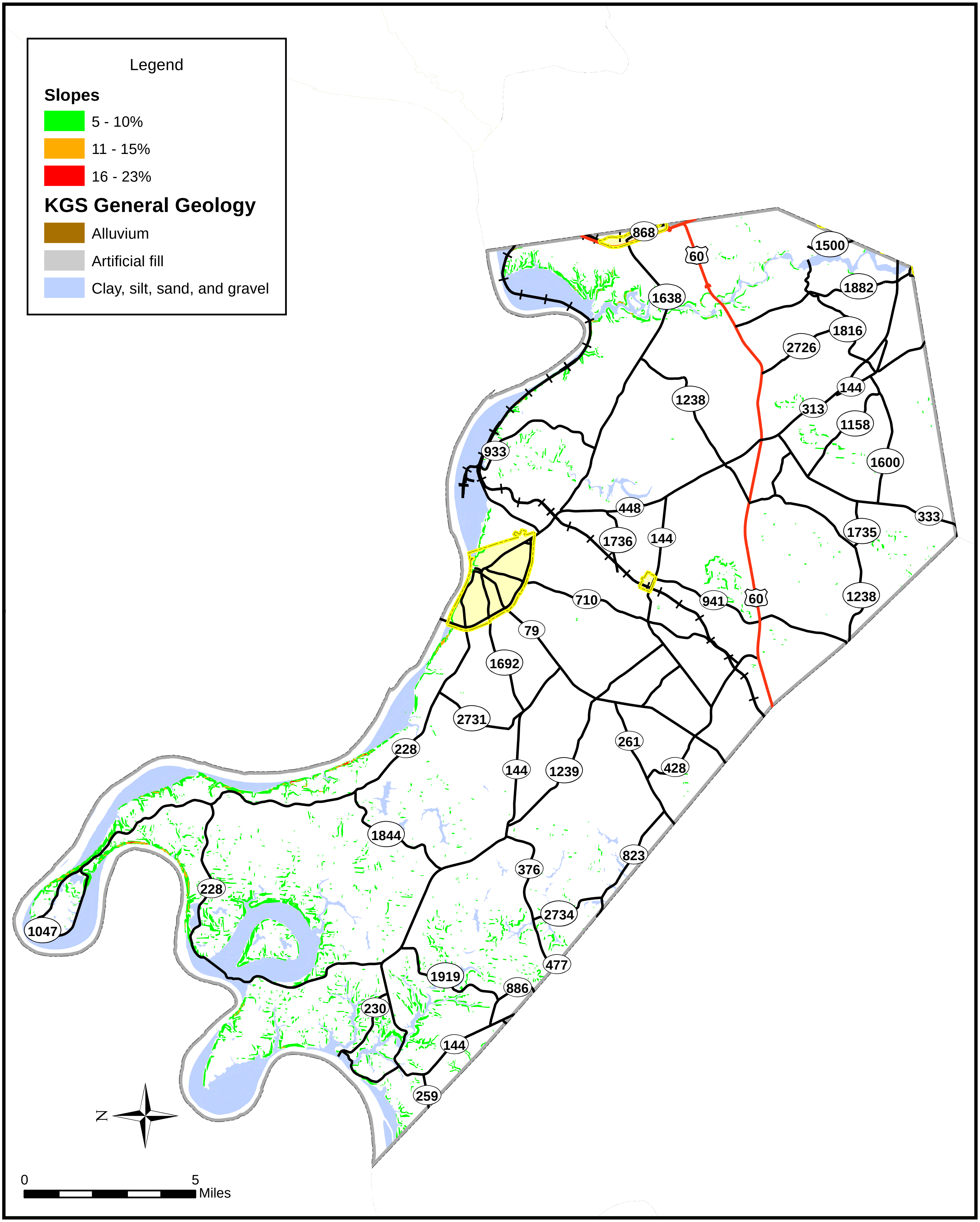
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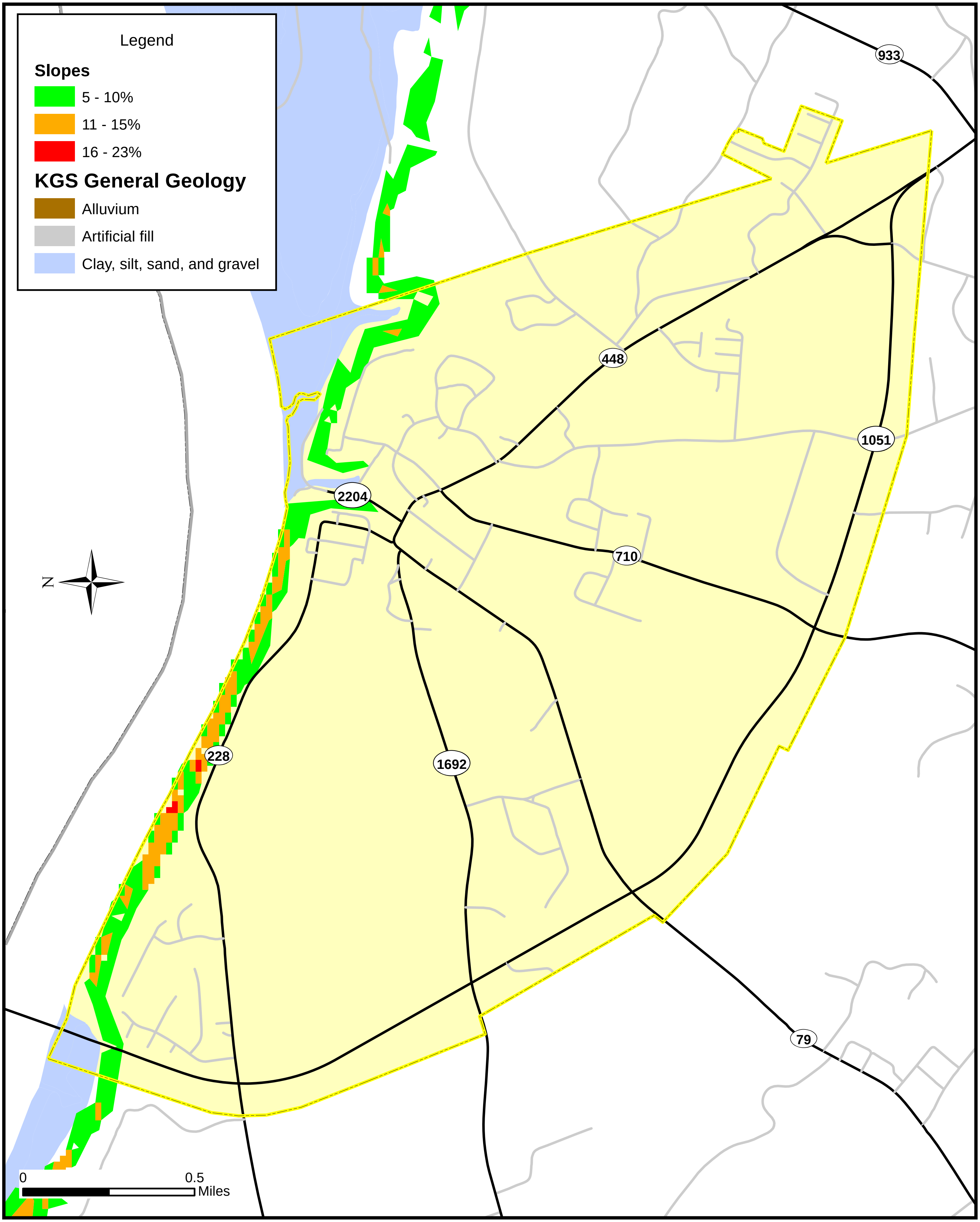
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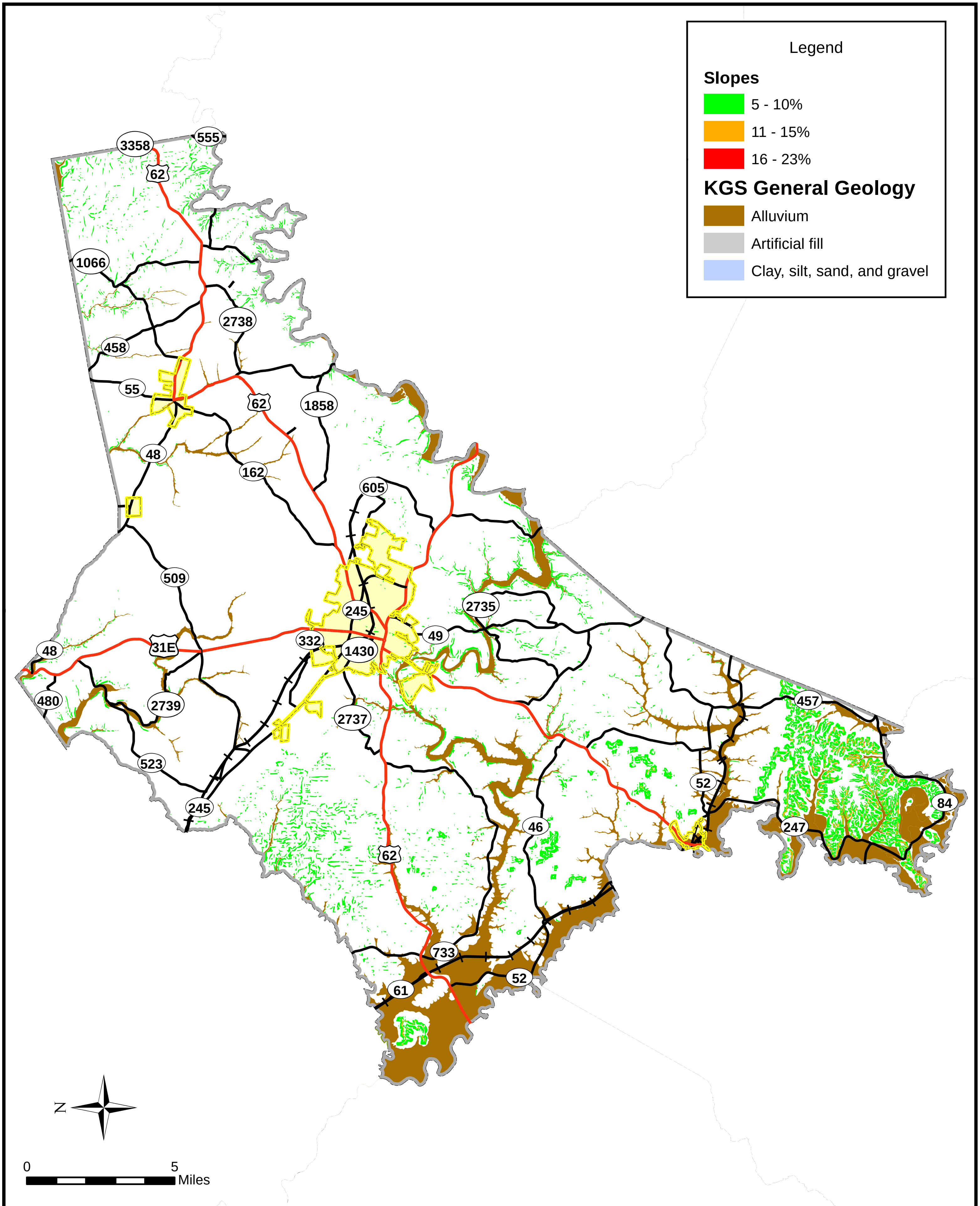
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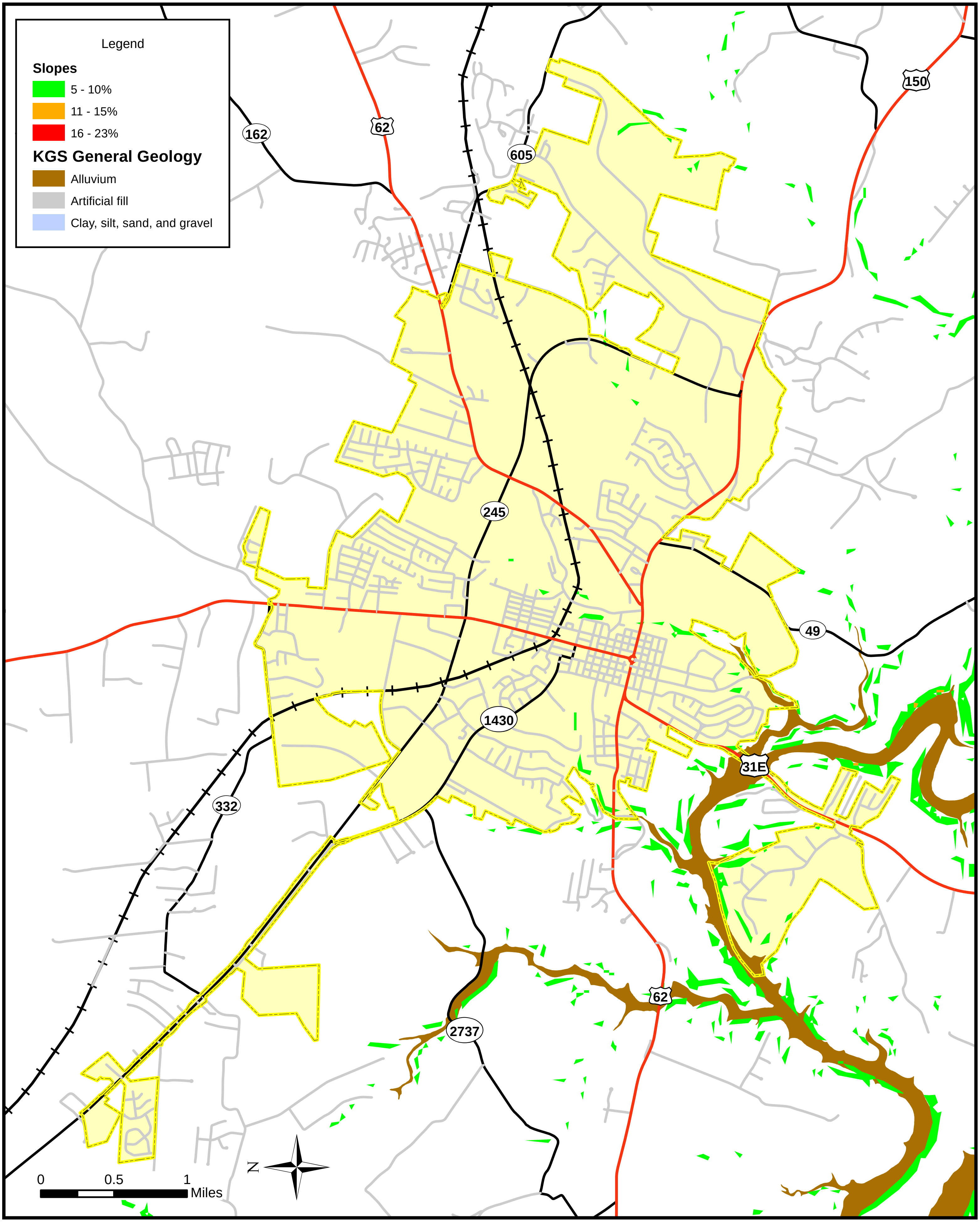
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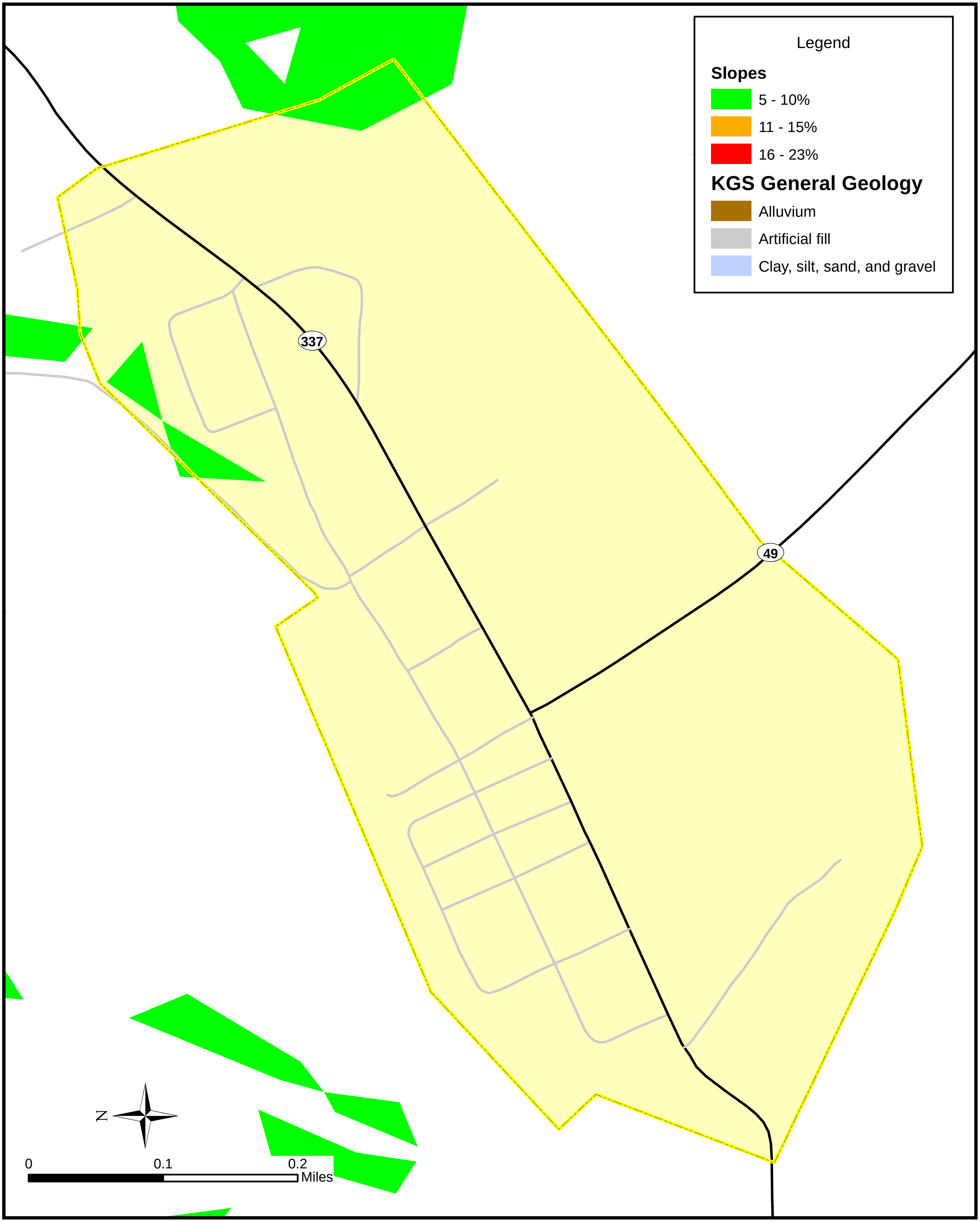
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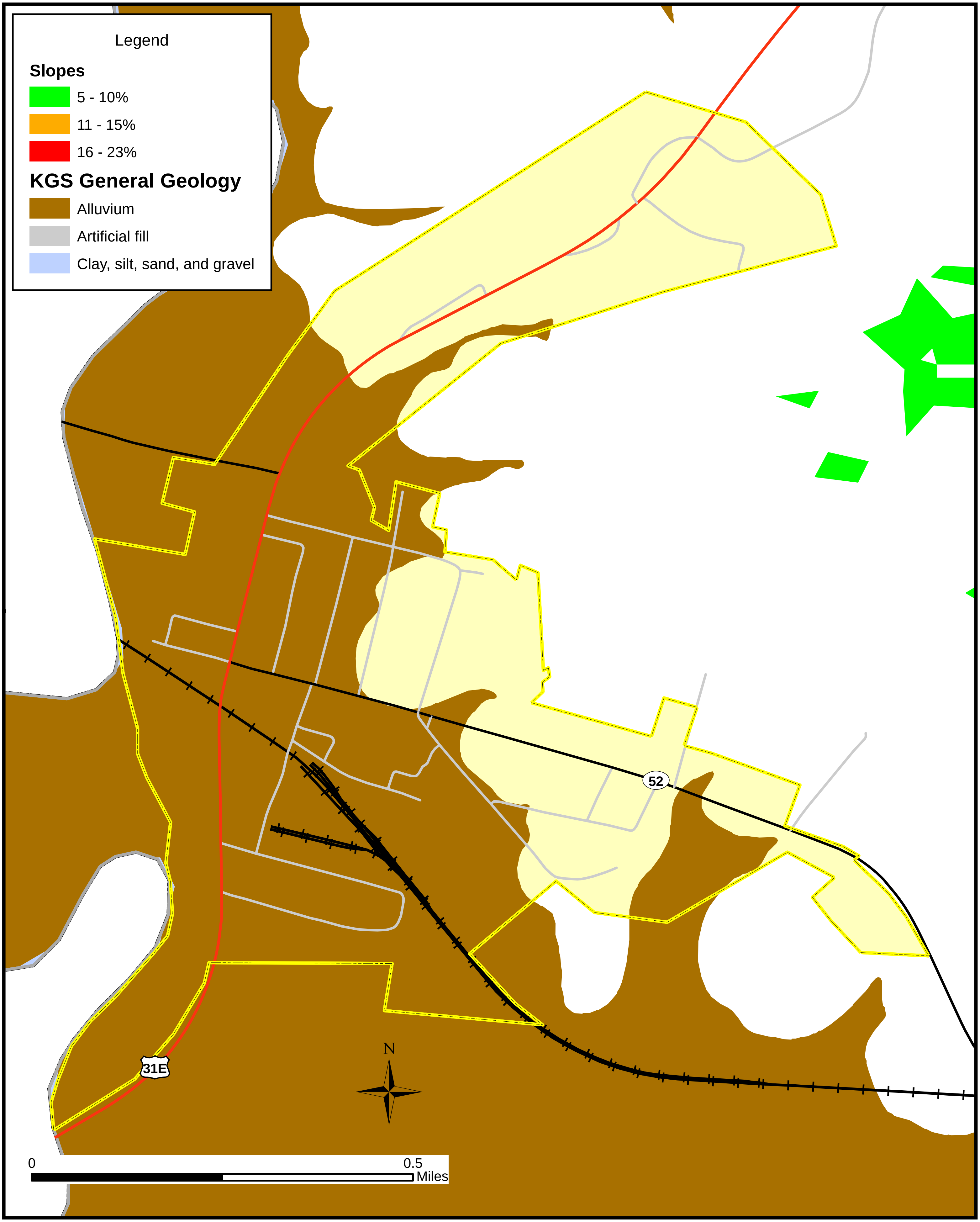
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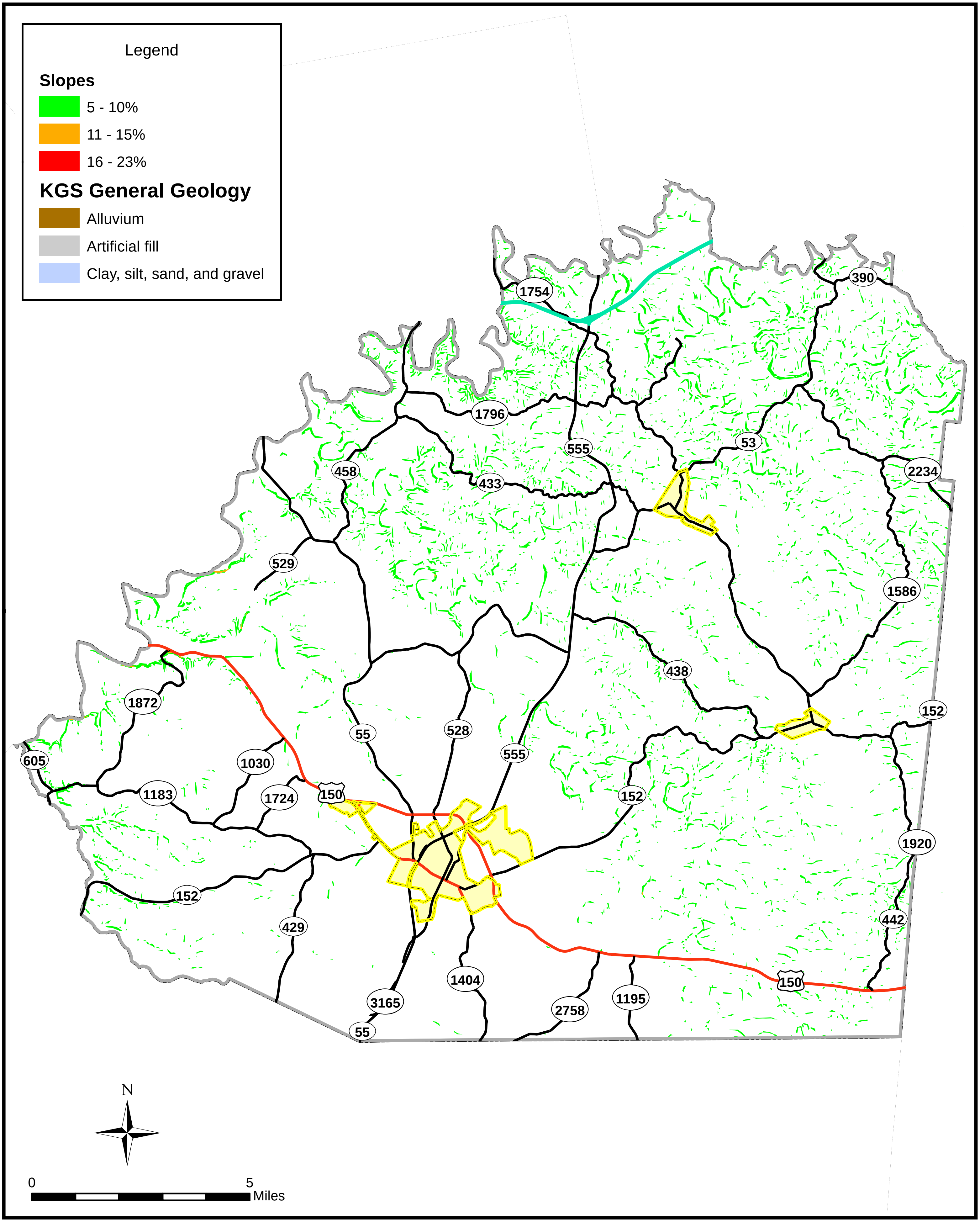
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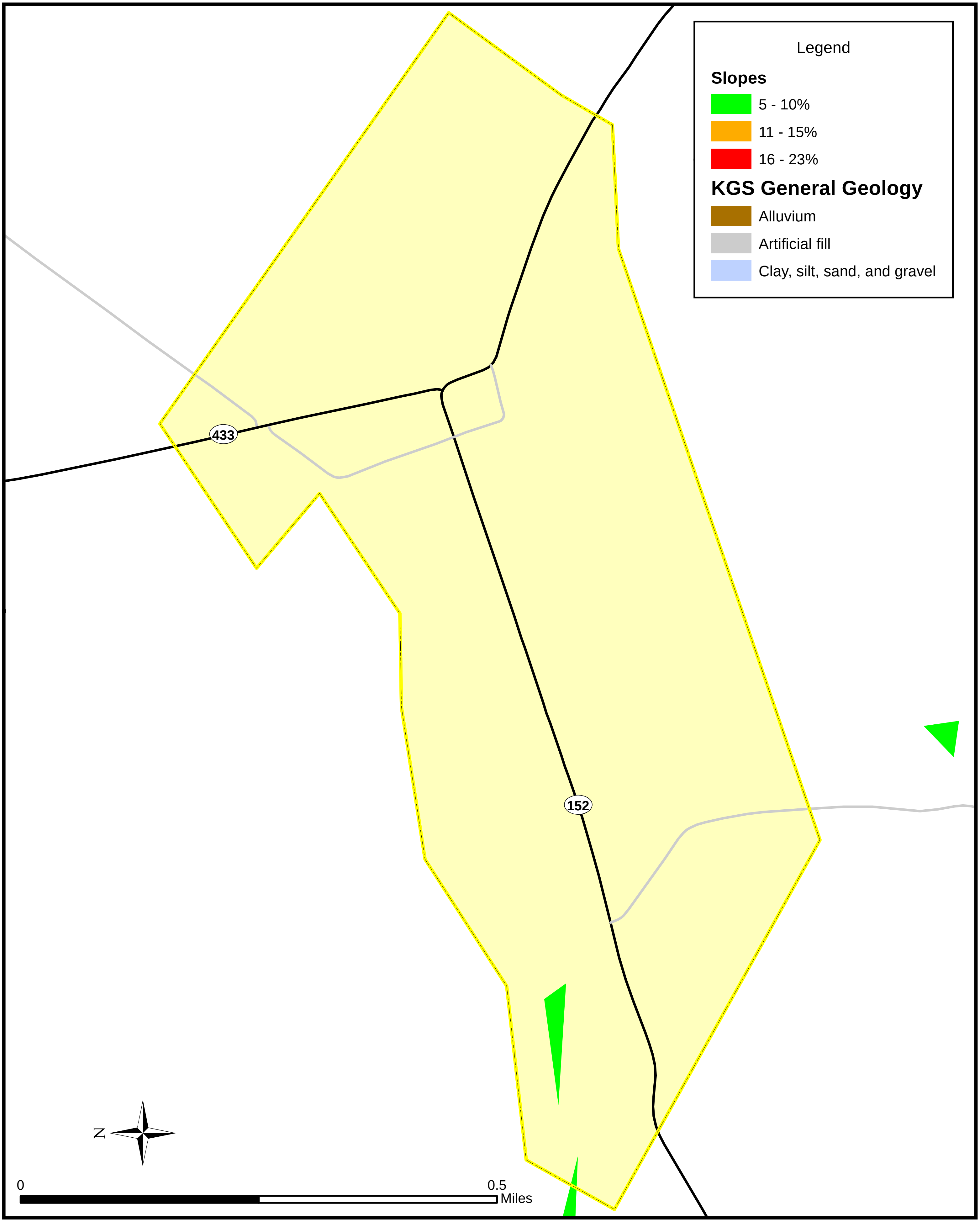
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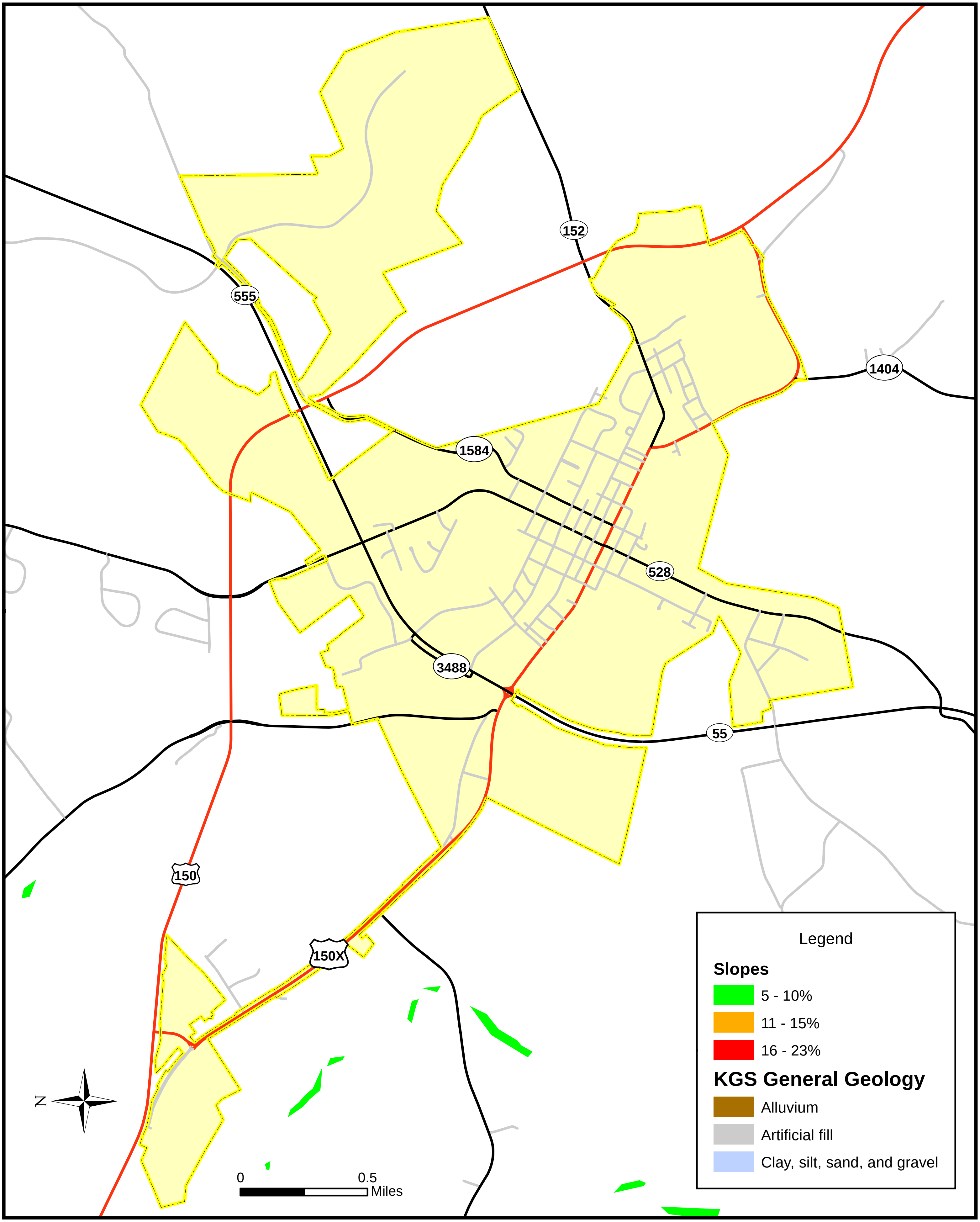
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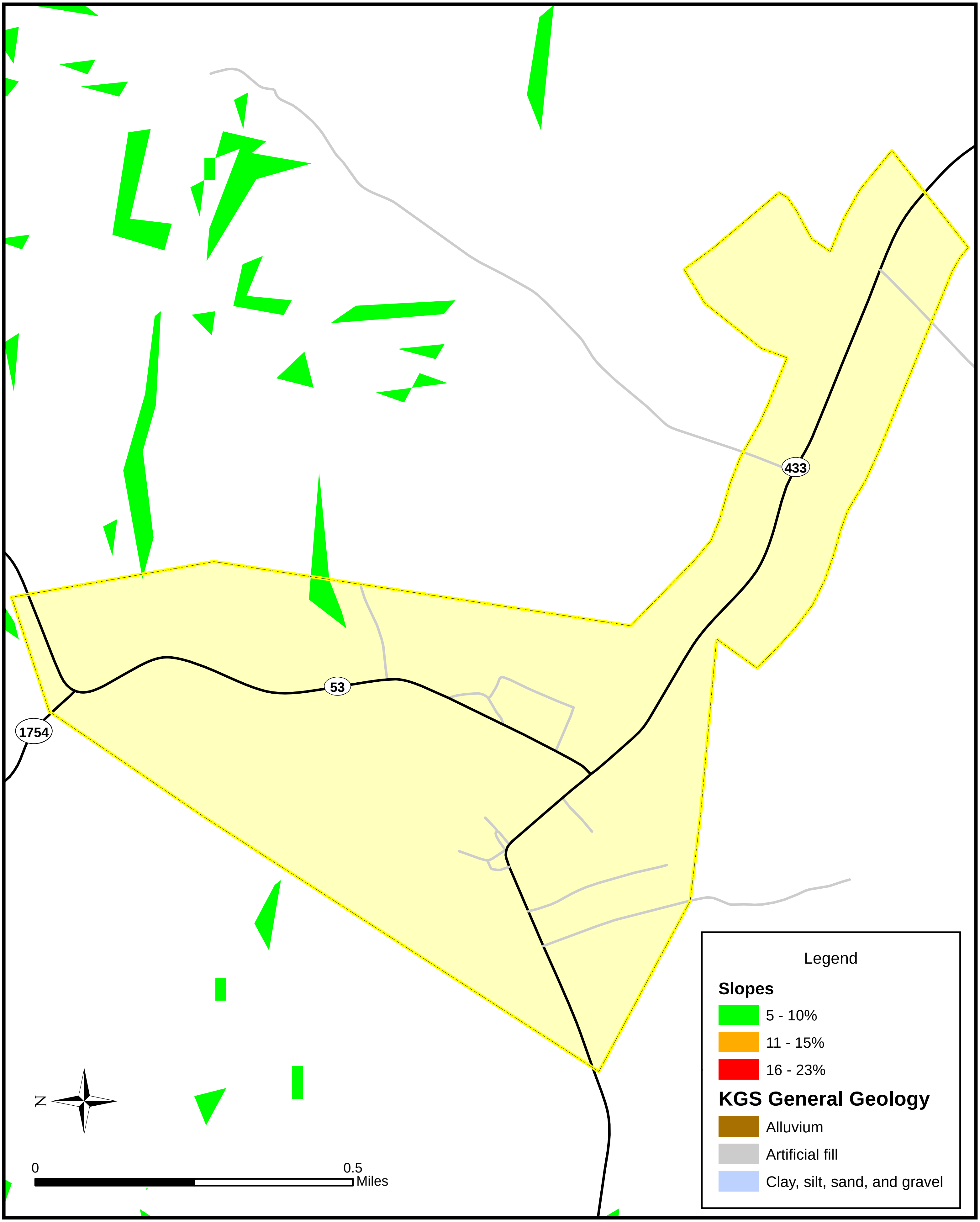
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3.3.2.8 Karst/Sinkhole

I. Background

Karst Topography:

According to the *Encyclopedia Britannica,* karst topography is characterized by barren, rocky ground, caves, sinkholes, underground rivers, and the absence of surface streams and lakes. This type of landscape results from the excavating effects of underground water movement on massive soluble limestone. While the term *Karst* originally was applied to a region of limestone on the Dalmatian coast of the Adriatic Sea, it has now been extended to mean all areas with similar features.

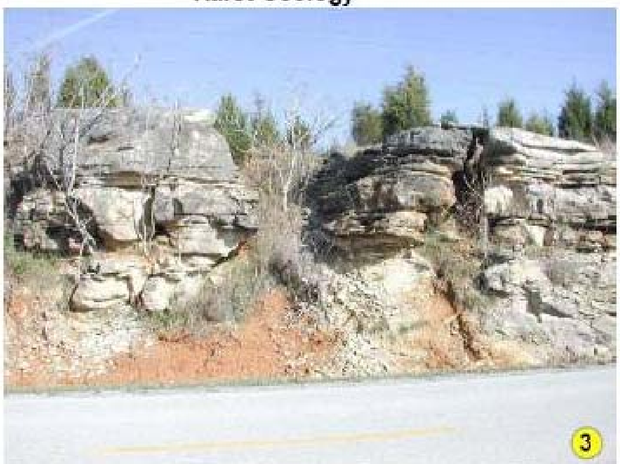
Karsts are found in widely scattered regions of the world such as the Causses of France; the Kwangsi area of China; the Yucatan Peninsula; and the Middle East, they are also found in Kentucky, Texas, Tennessee, Missouri, Pennsylvania and Florida in the United States. Although the karst topography in Kentucky is mostly on limestone, it can also occur in different types of rock such as dolomite, gypsum, and salt.

Certain conditions promote karst development such as well-jointed, dense limestone near the ground surface, a moderate to heavy rainfall; and good groundwater circulation. Limestone or calcium carbonate, is easily dissolved by slightly acidic water, which occurs widely in nature. Rain becomes slightly acidic as it passes through the air and picks up carbon dioxide (CO_2). Rainwater percolates along both horizontal and vertical cracks, dissolving the limestone and carrying it away in solution. Limestone pavements are produced when surface material is removed, and the vertical fissures along joints gradually widen and deepen, producing a grooved and jagged terrain. As the water continues to flow underground, it widens and deepens the cracks until they become cave systems or underground stream channels. All but a few of the cave areas in the world are areas of karst topography. A karst landscape is characterized by sinkholes, sinking streams, caves and springs.

Kentucky is one of the most famous karst areas in the world. Much of the beautiful scenery throughout Kentucky is the result of the development of karst landscape. The springs and wells inherent to karst landscape, provide water to many Kentucky cities. About fifty-five percent of Kentucky is underlain by rocks that could develop karst, given enough time, and about thirty-eight percent of the state has some karst development. Twenty-five percent of the state is known to have well-developed karst features. Karst topography forms the world's longest cave system; the Mammoth Cave System in Kentucky is over 350 miles long.

Karst topography is found throughout the Lincoln Trail ADD region. Parts of Meade and Breckinridge Counties, in the vicinity of Irvington and Brandenburg have extensive areas of karst topography that can be seen by driving the roadways through these communities. Saunders Springs Nature Preserve in the Fort Knox Military Reservation just west of Radcliff is an excellent example of karst topography. In addition, many large springs can be found west of Fort Knox in Meade and Breckinridge Counties. There are springs and caves within Otter Creek Park in Meade County and a spring at the Lincoln Birthplace National Historic Site in LaRue County called Sinking Spring.

Karst Geology



This old roadcut in the Salem Limestone (unit 2) reveals the dissolution process that creates underground cavities and, when the cavity roofs collapse, sinkholes. Photo by Dan Carey, Kentucky Geological Survey.

Limestone formation in Meade County, 2005.

Sinkholes

When a cave becomes large enough and its top extends close enough to the surface, the top collapses. This produces depressions called sinkholes. Sinkholes are characteristic features of karst topography. Sinkholes can coalesce into larger depressions called poljen. Sinkholes collect surface water running off the surrounding land, and the runoff goes directly into the groundwater. A sinkhole is an area of ground that has no natural external surface drainage. When it rains, water stays inside the sinkhole and usually drains into the subsurface. Sinkholes vary in size from a few feet to hundreds of acres, and range in depth from between one foot to several hundred feet. Some sinkholes hold water to form natural ponds.

Types of Sinkholes

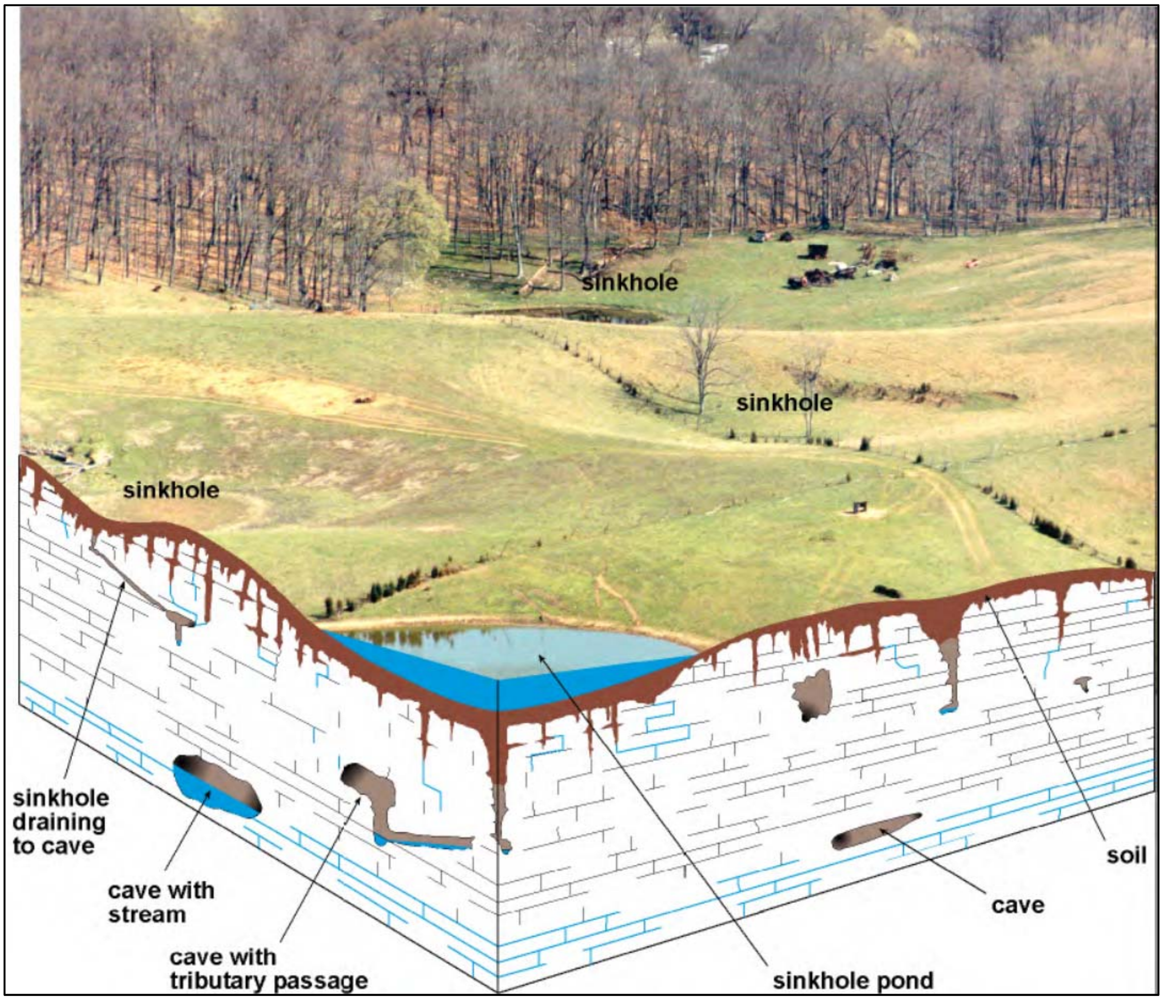
Dissolution sinkholes are formed when bedrock is dissolved and carried away underground. These sinkholes develop gradually, over time, with occasional episodes of soil or cover collapse.

Cover-subsidence sinkholes develop gradually where the covering sediments are permeable and contain sand. In areas where cover material is thicker or sediments contain more clay, cover-subsidence sinkholes are relatively uncommon, are smaller, and may go undetected for long periods.

Cover-collapse sinkholes can develop abruptly over a period of a few hours, and cause catastrophic damage. These sinkholes occur where covering sediments contain a significant amount of clay. Over time, surface drainage, erosion, and deposition of a sinkhole turn it into a shallower bowl-shaped depression. Land Subsidence which can be a result of this action is included in a separate narrative at the end of this section.

Geologic Hazards in Karst

Human safety and economic losses are the results of most naturally occurring geologic hazards. There are two common karst-related geologic hazards: cover-collapse sinkholes and sinkhole flooding.



Karst System. *Source: Kentucky Geological Survey*

According to the Kentucky Geologic Survey, *cover-collapse* sinkhole occurs in the soil or other loose material overlying bedrock. As overlying soil is repeatedly wetted and dried, small amounts of soil are dislodged and carried away by the cave conduit draining the sinkhole. The collapse only occurs in the overlying soil, and not in the limestone bedrock.

Cover-collapse sinkholes can vary in size from 1 or 2 feet deep and wide, to tens of feet deep and wide. Soil thickness and cohesiveness determine the size of a cover-collapse sinkhole. Cover-collapse sinkholes in Kentucky are rarely more than 20 feet in diameter due to the thickness of soil, sand or clay, and bedrock fragments that overlay the limestone bedrock. Unlike cover-collapse sinkholes in Florida that swallow entire houses and businesses, that is unlikely to happen in Kentucky where the overlay is less dense. However, cover-collapse sinkholes in Kentucky do severely damage buildings, drain farm ponds, damage roads, and wreck farming equipment.

The most effective way to avoid cover-collapse sinkhole hazards and damage is to avoid buying or building a structure on any sinkhole that has been filled. Before buying property, look for previous damage such as foundation damage and/or door frames and windows that are out of square. Also check all surrounding land for shallow impressions and arch-shaped cracks in the soil.

Sinkhole flooding occurs when there is more precipitation than the conduits and caves can handle. Unlike a normal stream channel, the cave conduit channel has a fixed diameter and cannot expand as flow increases. There are two types of sinkhole flooding. In the first type, the sinkhole conduit may be constricted and unable to carry water away as fast as it flows in. This can occur when the throat of the sinkhole is clogged by trash and junk, soil eroded from fields or construction sites, and sometimes by rock fall within the conduit. Or, at times, the diameter of the conduit is too narrow to handle the volume of water flow. The second type of sinkhole flooding is caused by discharge capacity being limited farther downstream. This can happen when caves are blocked by trash or rock fall, have limited conduit size, or from backflooding from other sinkholes. Sinkholes that may drain normally during moderate rain, may become springs and discharge water from their throats during intense storms.

Sinkhole plain before a rain. Sinkhole plain after a rain.

Source: Kentucky Geological Survey

All structures built in a sinkhole or karst valley are prone to flooding, and little can be done to mitigate future flood damage, except to move the structure. Some sinkholes are so large, that it is difficult to determine that a building site is actually a closed depression. It is always the best practice to consult a topographical map, inspect an area to determine its relative elevation, look for previous signs of water damage, and research historic flooding events.

Probability/Impact

The Lincoln Trail Region is dotted with sinkholes and underlain by karst topography. Extensive mapping of the area has been incorporated into local land use plans and most of these karst/sinkhole sites have not been developed or had structures built on them. The maps included in this section illustrate how prevalent karst topography is in the Lincoln Trail Region. However, there is little quantitative data on historic sinkhole-related events that enables the prediction of the probability of occurrence, or to articulate the extent of impact that the hazard poses for the Lincoln Trail Region. The prevalence of karst topography in the region results in a 100% chance that either a sinkhole collapse or sinkhole flooding event could occur in any given year. Either scenario could result in the destruction or damage of structures and infrastructure and/or the loss of human life. The impact of local sinkhole hazards, is exemplified by the Quiggins Sinkhole Flooding event. Since quantitative impact reports for sinkhole hazards do not exist within the Lincoln Trail Region, research must focus on the type of karst topography prevalent in the area. The region is mostly underlain with a system of roofed-over creeks as opposed to actual sinkholes. Consequently, the majority of sinkhole related hazards have been those related to sinkhole flooding, and have been aggregated into damages and hazard events associated with flooding. Thus, the Quiggins Sinkhole flooding stands as an identified example of the impact and existence of regional sinkhole hazards.

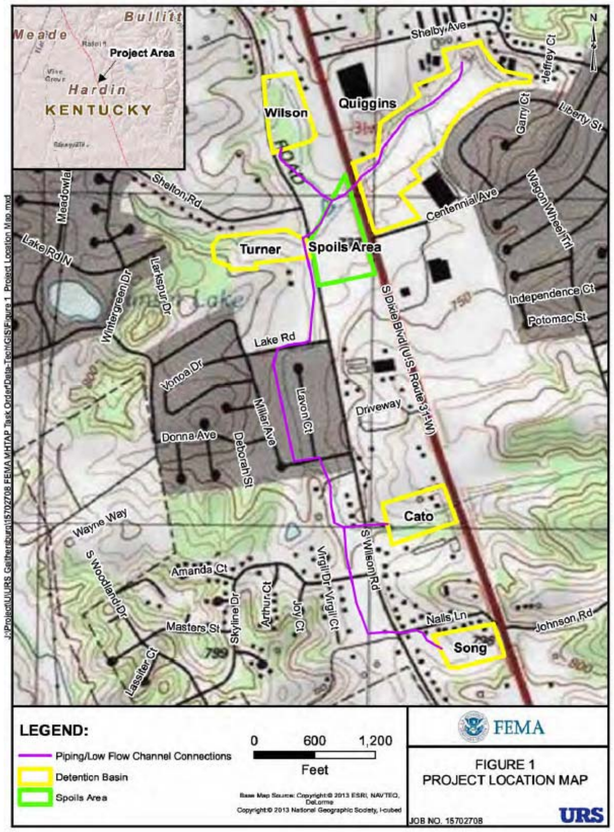
A large area sinkhole is located in Radcliff in Hardin County. The significance and impact of the hazard was enough to justify the 2015 FEMA Hazard Mitigation Grant financing of a sinkhole mitigation project that exceeds $5 million. The Quiggins Sinkhole lies within the Happy Valley watershed and is concentrated around 24 acres of land. A primary hydrology study and FEMA environmental analysis used for the project's application relied on impacts to housing and public works within this area in the City of Radcliff. From this single event, hydrology studies determined damages based upon recurrence probability. Work to prevent sinkhole related flooding is currently underway and should improve water management in the area. The Quiggins Sinkhole Flood Mitigation Project will construct four retention basins and expand a fifth to mitigate the effects of widespread flooding. The Quiggins Sinkhole is one of 86 known sinkholes into which the City of Radcliff drains. Using the recurrence intervals cited, only impacts to housing and public works within the 24-acre site, for this one sinkhole were calculated.

Table 3.3.2.8.1 - Quiggins Sinkhole Impact Costs

Recurrence Interval	Housing Damages (In Dollars)	Public Works Damages (In $)	Total Damages (In Dollars)
200	$969,123	$91,697	$1,737,628
100	$623,019	$80,381	$1,296,687
50	$420,027	$69,455	$1,002,128
25	$264,344	$59,310	$761,419
10	$171,617	$46,824	$564,045
5	$56,176	$37,849	$373,388
2	$13,210	$27,704	$245,397
1	$358,408*	$19,900	$525,190
* Refers to "Less Than One-Year Damages"			

When adjusted for inflation, the total benefits of mitigating the impacts of one sinkhole, using assumptions of one representative hazard event that occurred in Radcliff in 2008, was calculated at $5,679,173.

Ongoing work on Quiggins Project, *Source: Greg Thompson, News-Enterprise, March 2016.*



Quiggins Sinkhole Flood Mitigation Project Location Map. *Source: FEMA Environmental Assessment Feb. 2015.*

In addition to sinkhole flooding effects, the prevalence of karst terrain within the Lincoln Trail Region must be considered when analyzing and thinking about the number and value of significant historic sites located in the area that may be situated on or near sinkholes. Rich in Lincoln history, the Lincoln Trail Region is home to many valuable historic sites such as the Joseph Holt House located on KY 144 in Breckinridge County and Lincoln's grandfather's homestead, the Lincoln Homestead, located outside of Springfield in Washington County. The Abraham Lincoln Birthplace, part of the National Parks system, is located outside of Hodgenville in LaRue County, on a site that was called the Sinking Springs Farm, an area underlain by twelve (12) sinkholes. All of these sites are valuable historic sites, priceless and irreplaceable. The 2003 Executive Order 13287: Preserve America states: "The Federal government shall recognize and manage the historic properties in its ownership as assets that can support department and agency missions while contributing to the vitality and economic well-being of the Nation's communities." The federal government recognizes not only the intrinsic value of historic sites, but also the economic benefits associated with them that positively impact local property values, jobs, tourism and revenue. Consequently, the impact of sinkhole collapse at the Birthplace site would have a significant financial impact far exceeding the hazard event itself.

Extent

To exemplify impact, the Radcliff Quiggins Sinkhole Flooding event was used and shall be used again to address the extent of a sinkhole/karst hazard. Based on one 2008 event, multiple hydrology studies and an environmental assessment conducted by FEMA, determined that it was feasible that over $5.5 million in damages could potentially result from the Quiggins Sinkhole in Radcliff. It was determined that the Quiggins Sinkhole was capable of discharging floodwaters at 11.9 cubic feet per second (cfs), analogous to the flow capacity of a 12-inch pipe. This could easily result in major flooding with as little as one inch of rainfall over a six hour period according to FEMA's 2/12/2015 "Environmental Assessment: Quiggins Sinkhole Flood Mitigation Project. City of Radcliff, Hardin County, Kentucky, DR-KY-1818-0012."

3.3.2.8.1 Land Subsidence

NOTE: This section previously stood alone as a specific Hazard in the Lincoln Trail Hazard Mitigation Plans from 2005 & 2010. It has been moved to this section as of the 2015 Plan.

I. Background

According to the U.S. Geological Survey (USGS), land subsidence is defined as the gradual settling or sudden sinking of the Earth's surface due to subsurface movement of earth materials.

USGS goes on to say that while land subsidence is a global problem, it impacts the United States substantially. More than 17,000 square miles in 45 states, have been affected by subsidence. The principal causes of land subsidence are aquifer-system compaction, drainage of organic soils, underground mining, hydrocompaction, natural compaction, sinkholes, and thawing permafrost. More than 80% of land subsidence in the United States is a consequence of human impact on subsurface water, and is an often, overlooked environmental consequence of our land water-use practices. Increased development of our land and water resources threatens to exacerbate existing land-subsidence problems and initiate new ones.

Cause of Subsidence

Several causes of land subsidence have been identified and include dissolution of limestone, mining, extraction of natural gas, groundwater-related subsidence, faulting induced, isostatic subsidence, drainage of organic soils, and seasonal effects. This section will only describe those that have a potential of threat in the Lincoln Trail Region.

Dissolution of limestone occurs in karst terrains where dissolution of limestone by fluid flow in the subsurface causes the creation of voids or caves. When the roof of a void becomes too weak, it can collapse and overlying rock and earth fill fall into the void and causes subsidence on the surface. This type of subsidence can result in sinkholes that can be hundreds of meters deep.

Seasonal effects impact land subsidence. Many soils contain significant proportions of clay that are affected by changes in soil moisture due to their very small particle size. Seasonal drying of soils results in a reduction of soil volume and a lowering of the soil surface. If building foundations are above the level to which the seasonal drying reaches they will move and this can result in damage to the building in the form of tapering cracks. Trees and other vegetation can have a significant effect on local drying of soils. Cumulative drying over a number of years occurs as the tree grows and this can lead to the opposite of subsidence, known as heave or swelling of the soil, when the tree declines or is felled. As the cumulative moisture deficit is reversed, over a period of time that can last as many as 25 years, the surface level around the tree will rise and expand laterally. This can be more damaging to buildings unless the foundations have been strengthened or designed to cope with the effect.

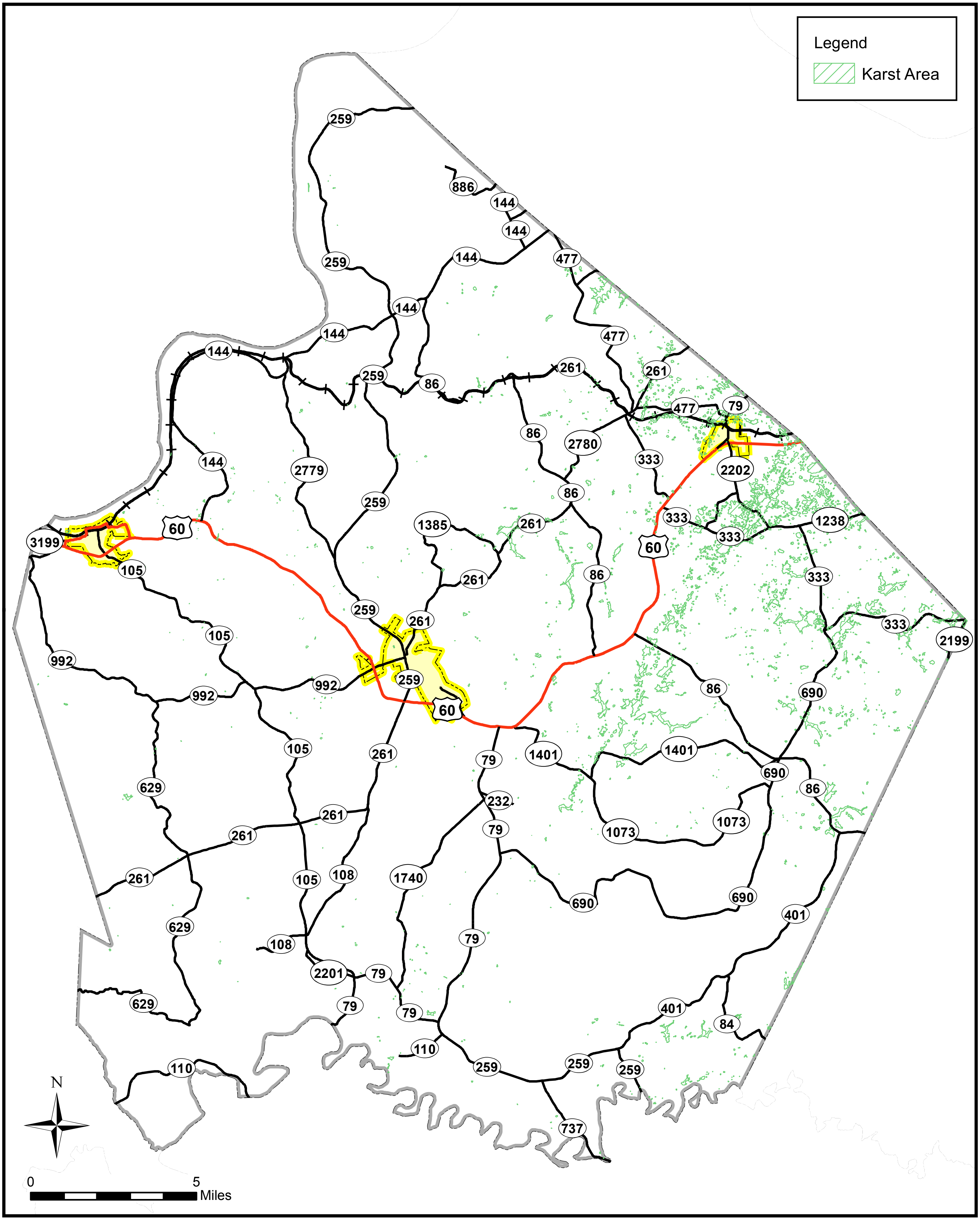
II. Analysis

To analyze land subsidence as a hazard in the Lincoln Trail Region, much research was done. Sources included FEMA, the Kentucky Geological Survey, the United States Geological Survey and County Emergency Management Agencies.

Lincoln Trail Region Subsidence

Subsidence is common in the Lincoln Trail Region; mostly as the result of erosion in areas along creek banks and in the karst topography. Quarry activity is common in the region, but the limestone rock extracted leaves highwalls that are fairly stable. Use of preventative agricultural practices and the proper use of land use management when siting construction projects will alleviate most of the effects of land subsidence in the Lincoln Trail region.

On the Ohio River in Meade County – Feb. 25, 2010,
Source: LTADD Archive.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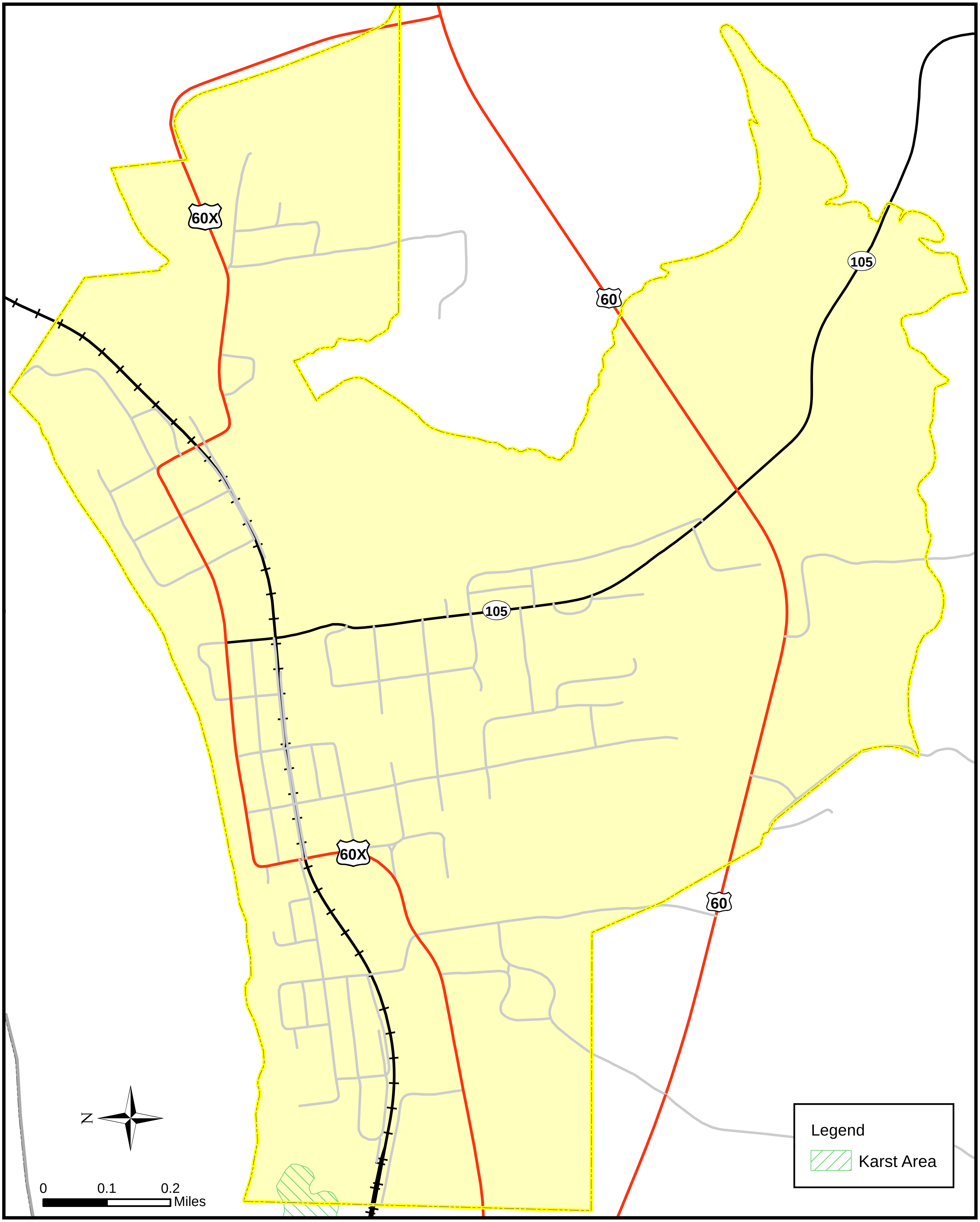
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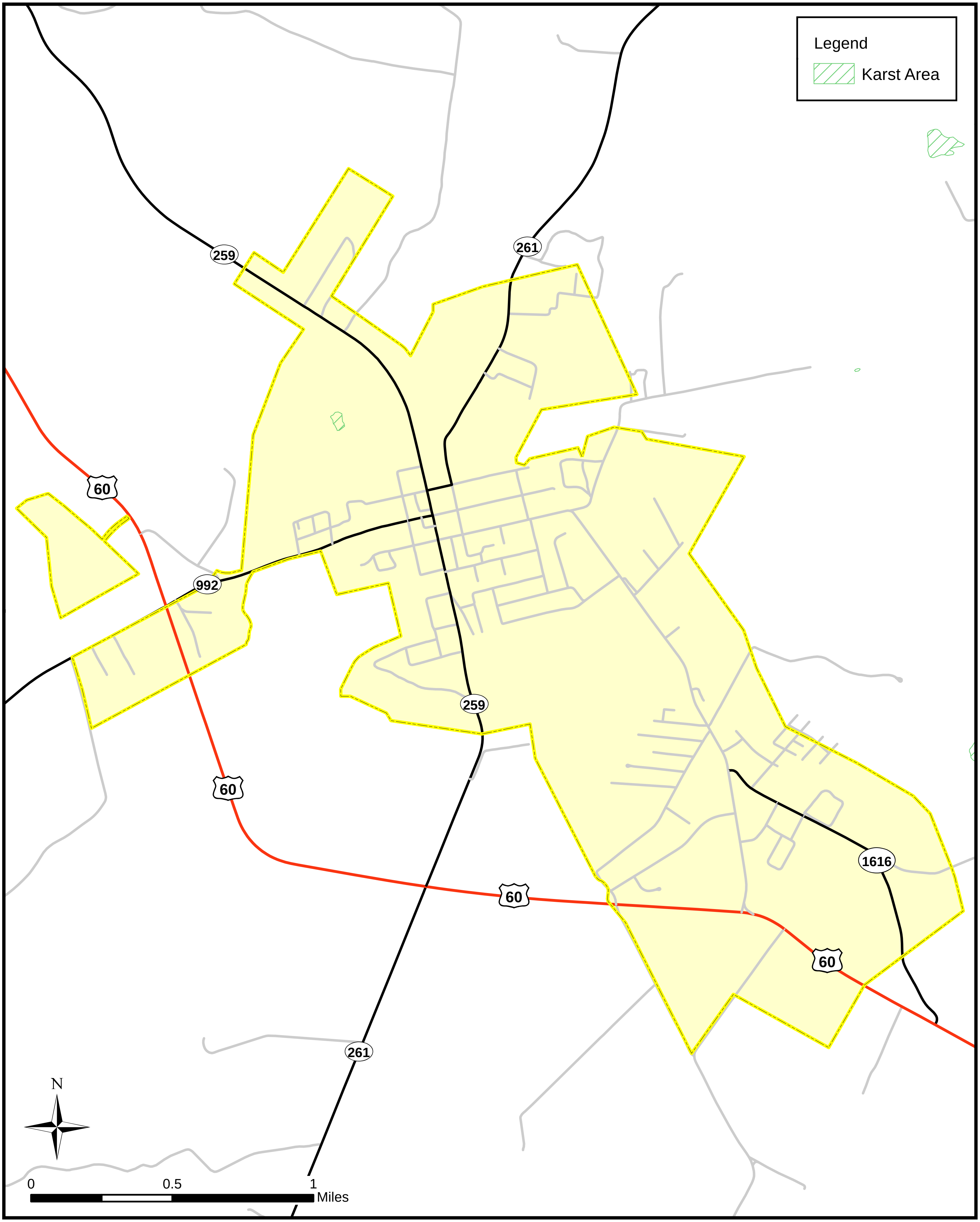
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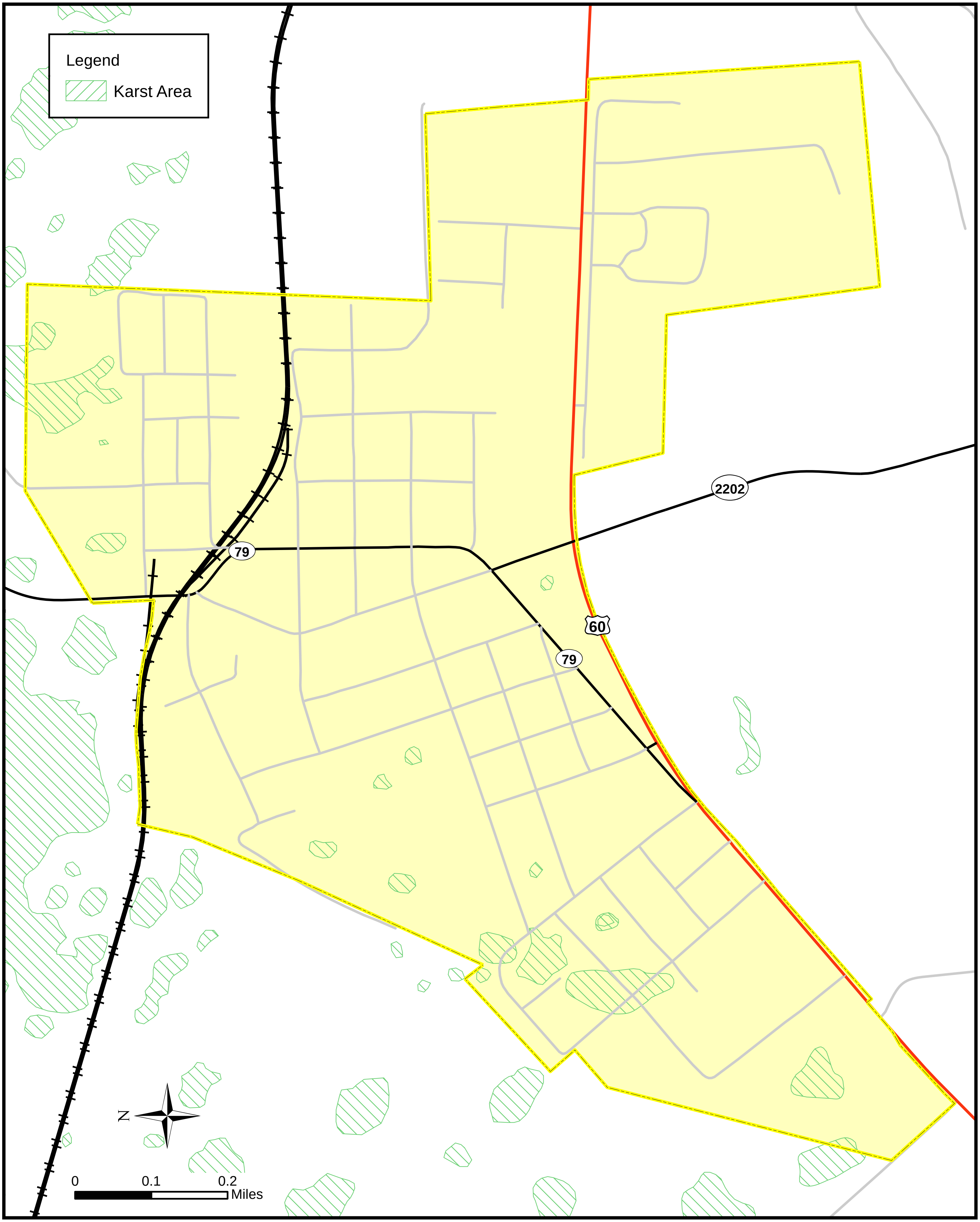
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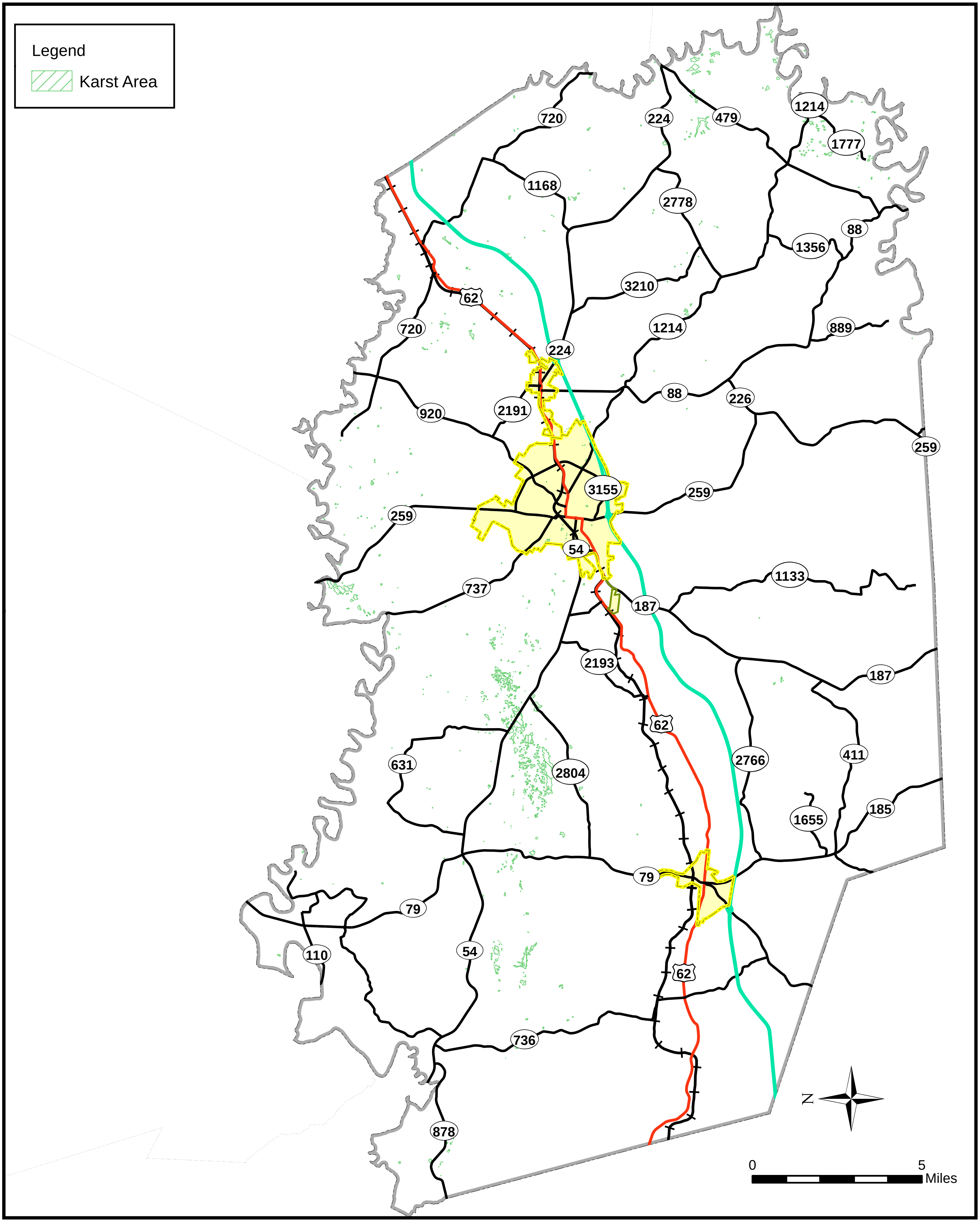
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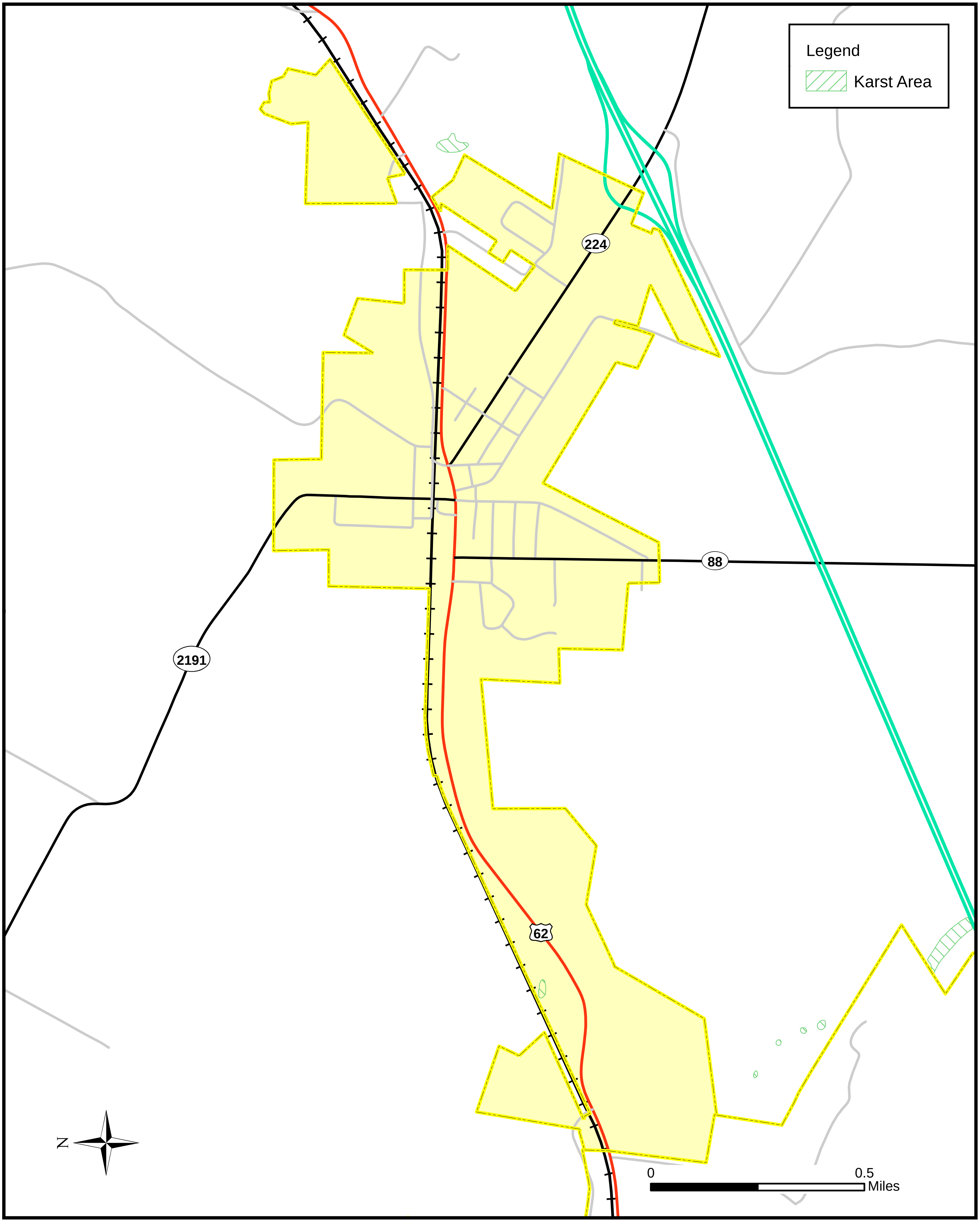
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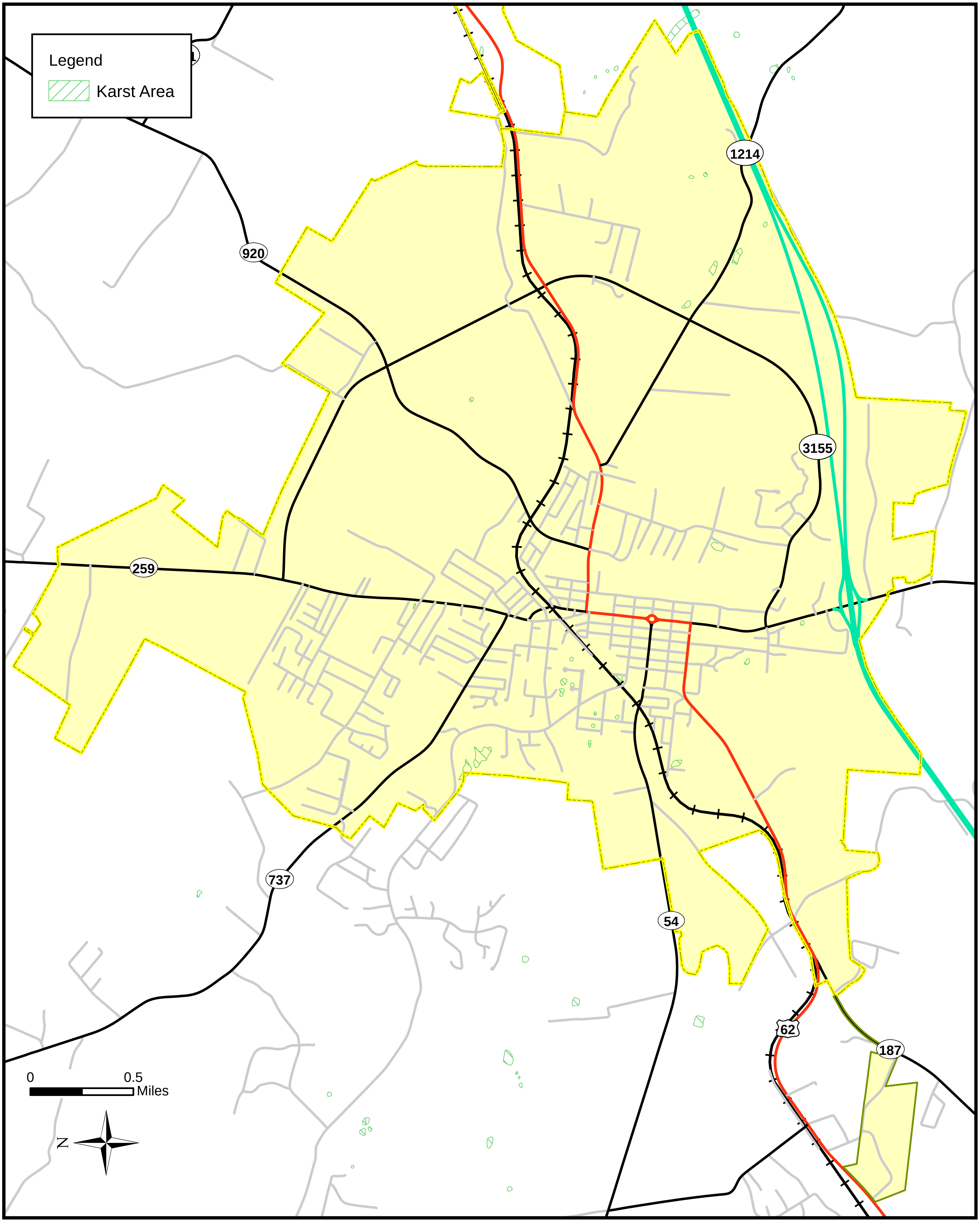
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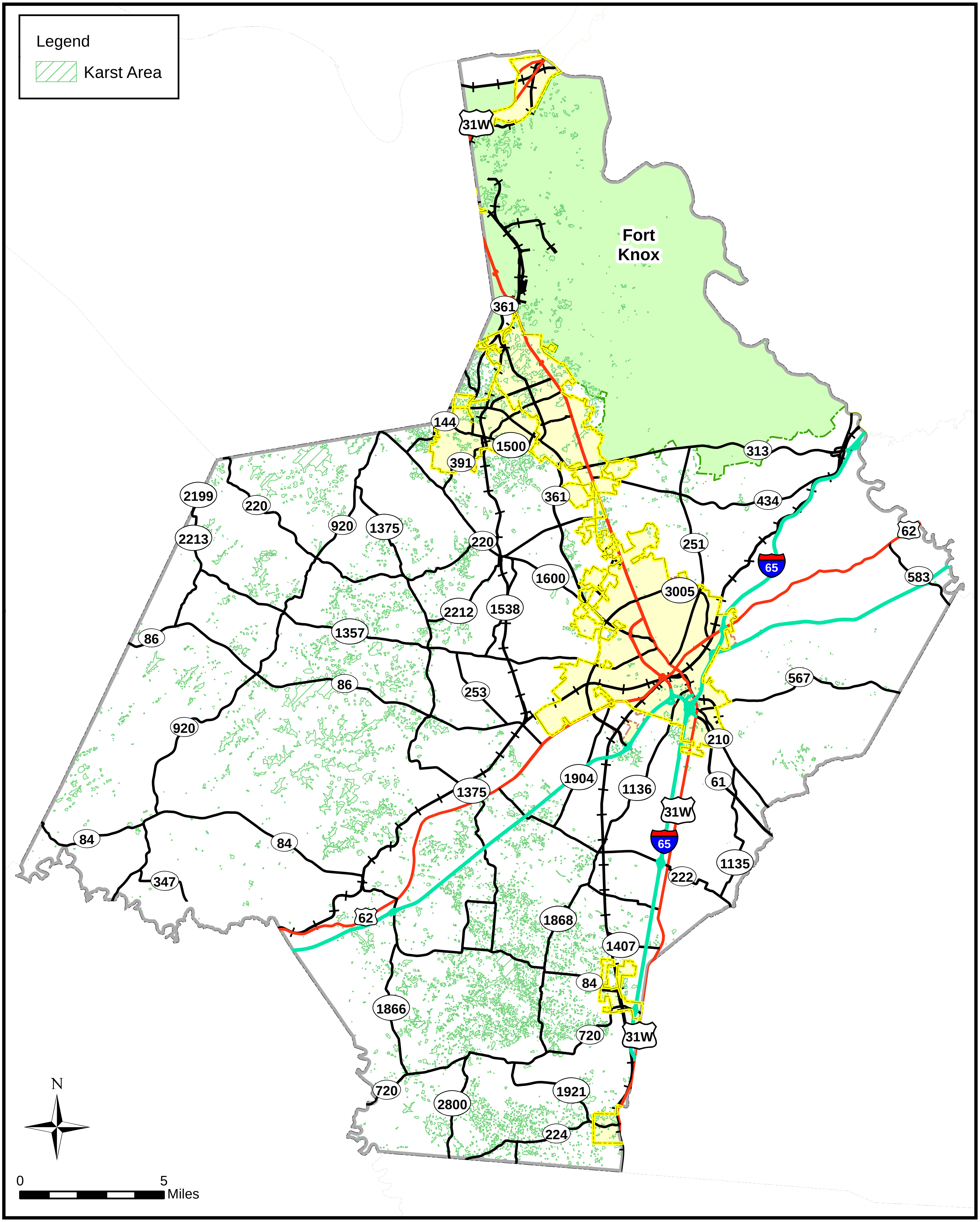
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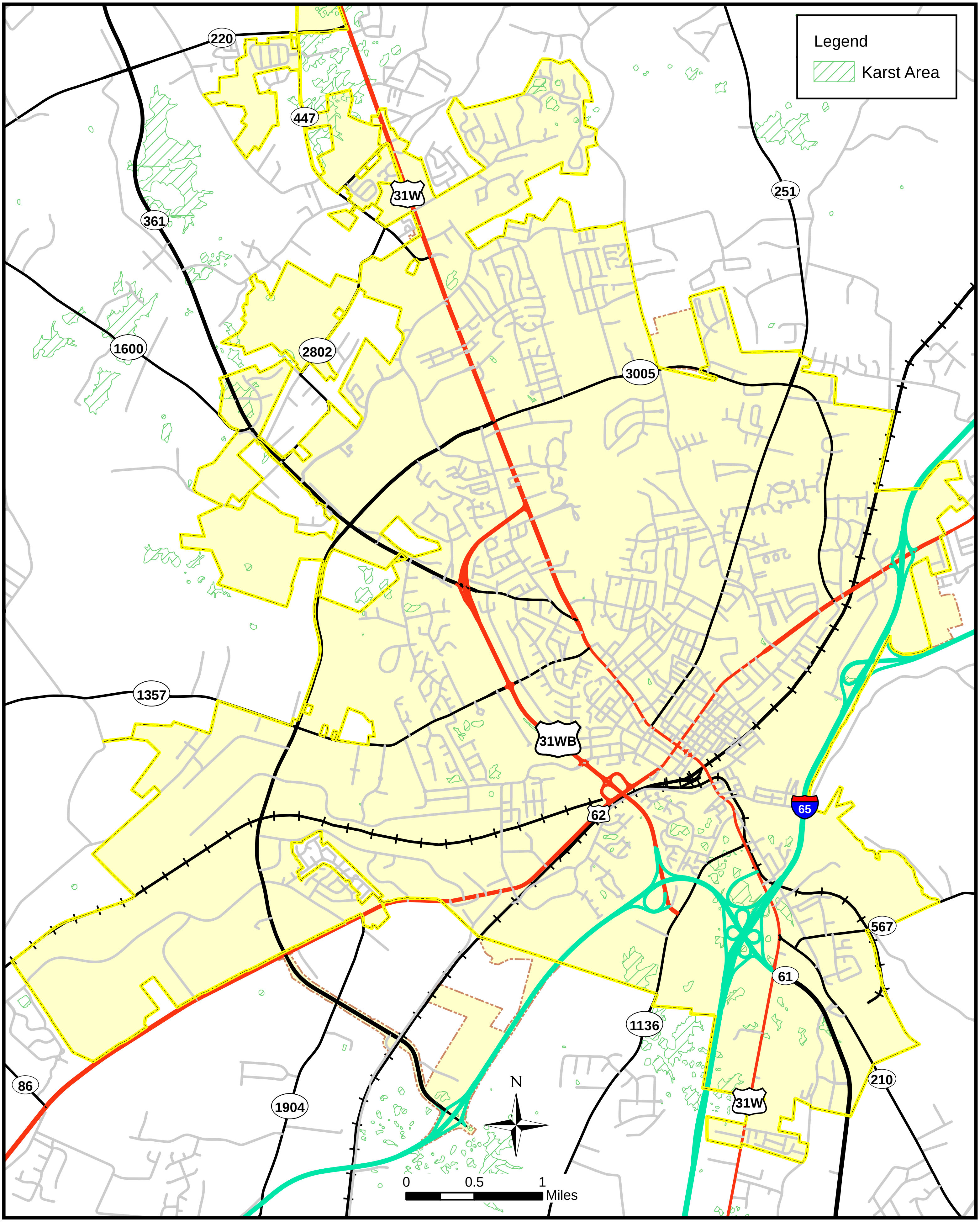
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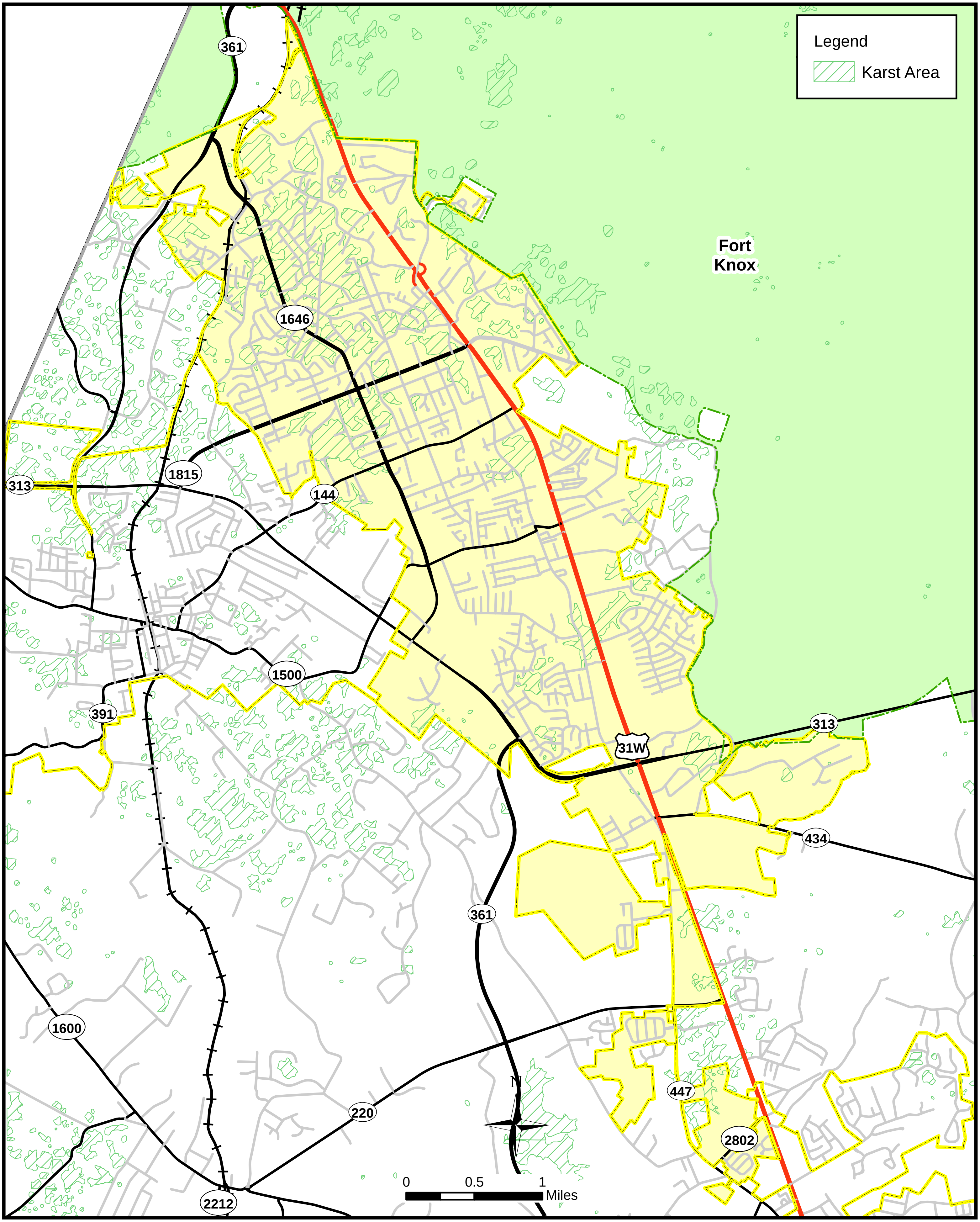
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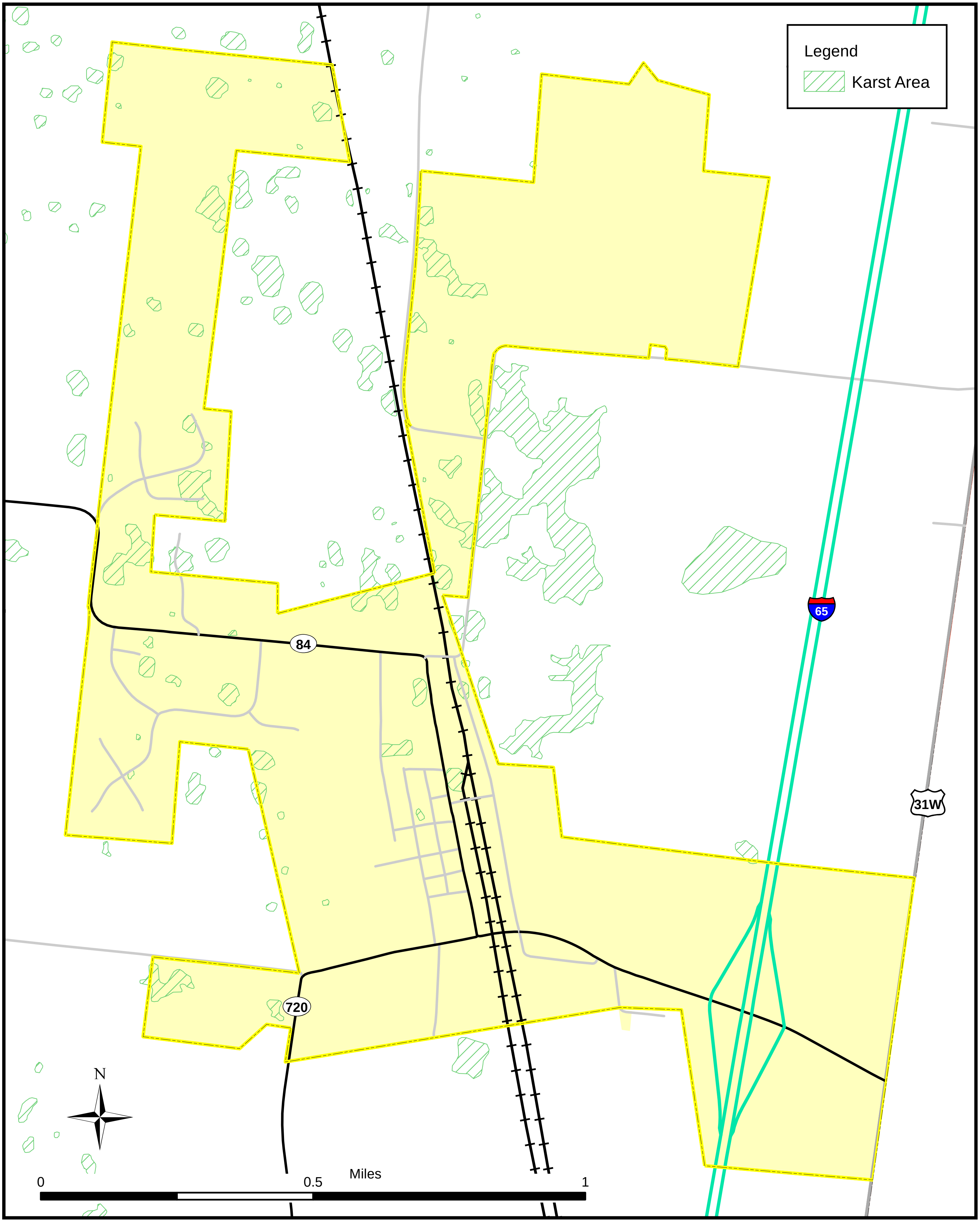
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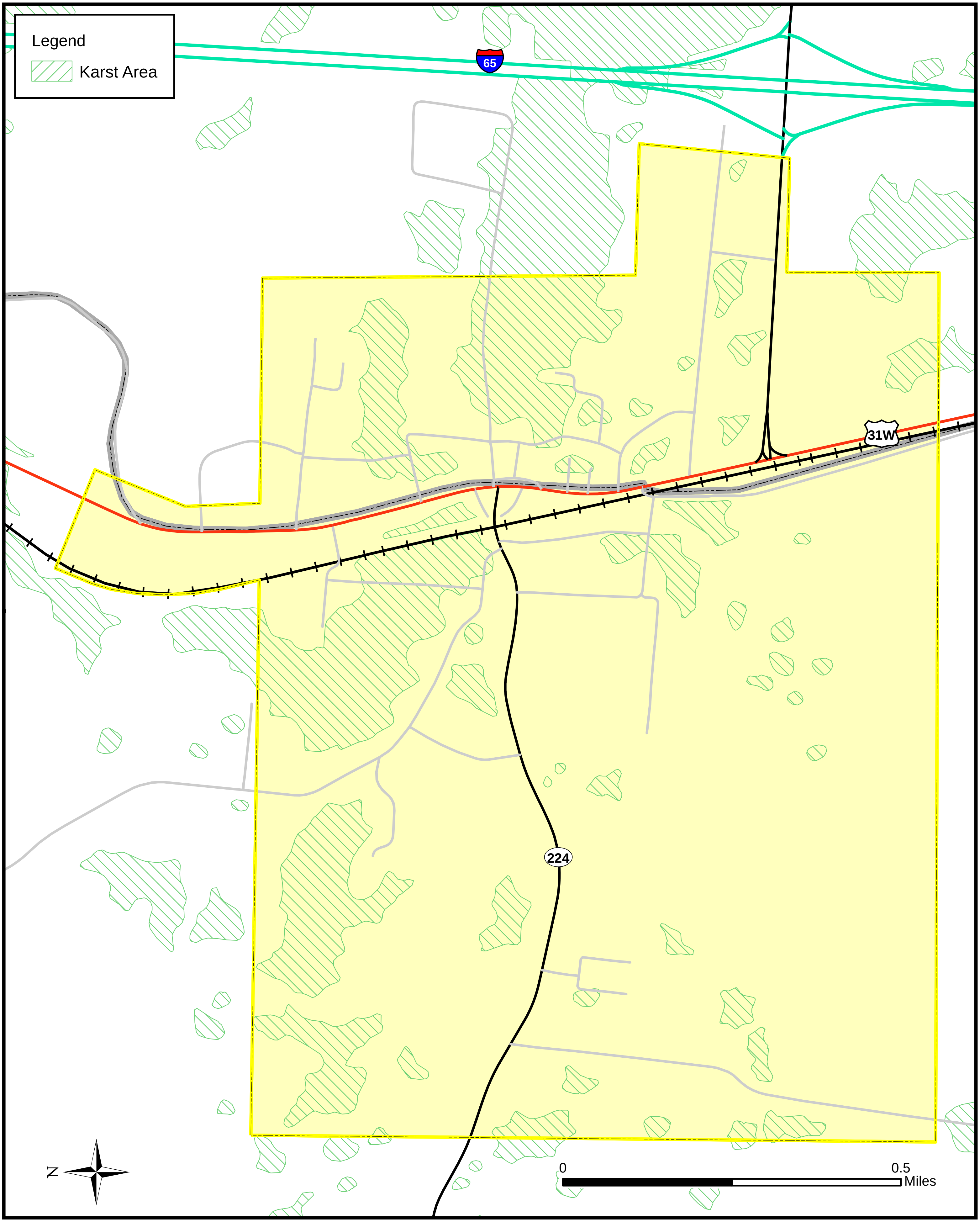
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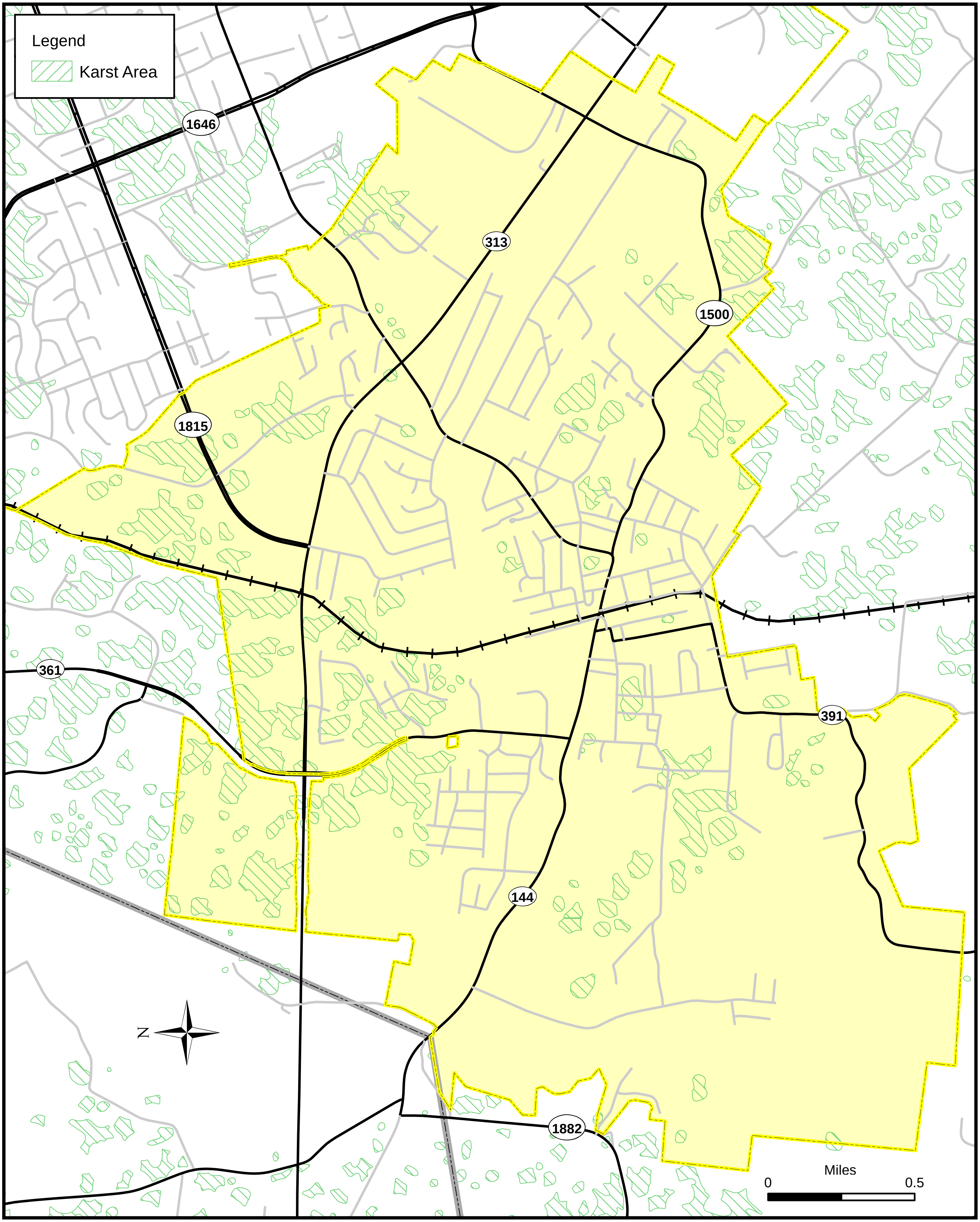
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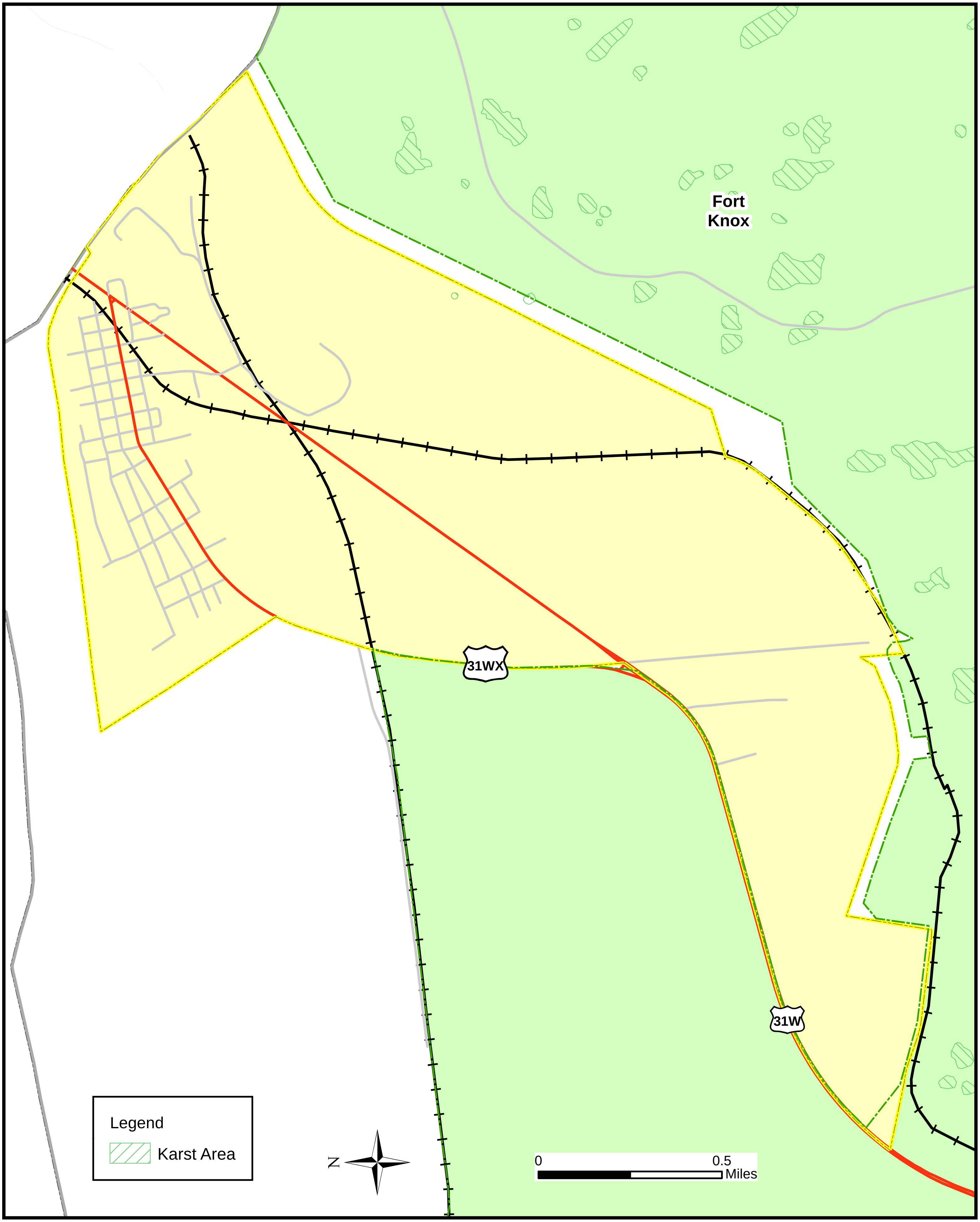
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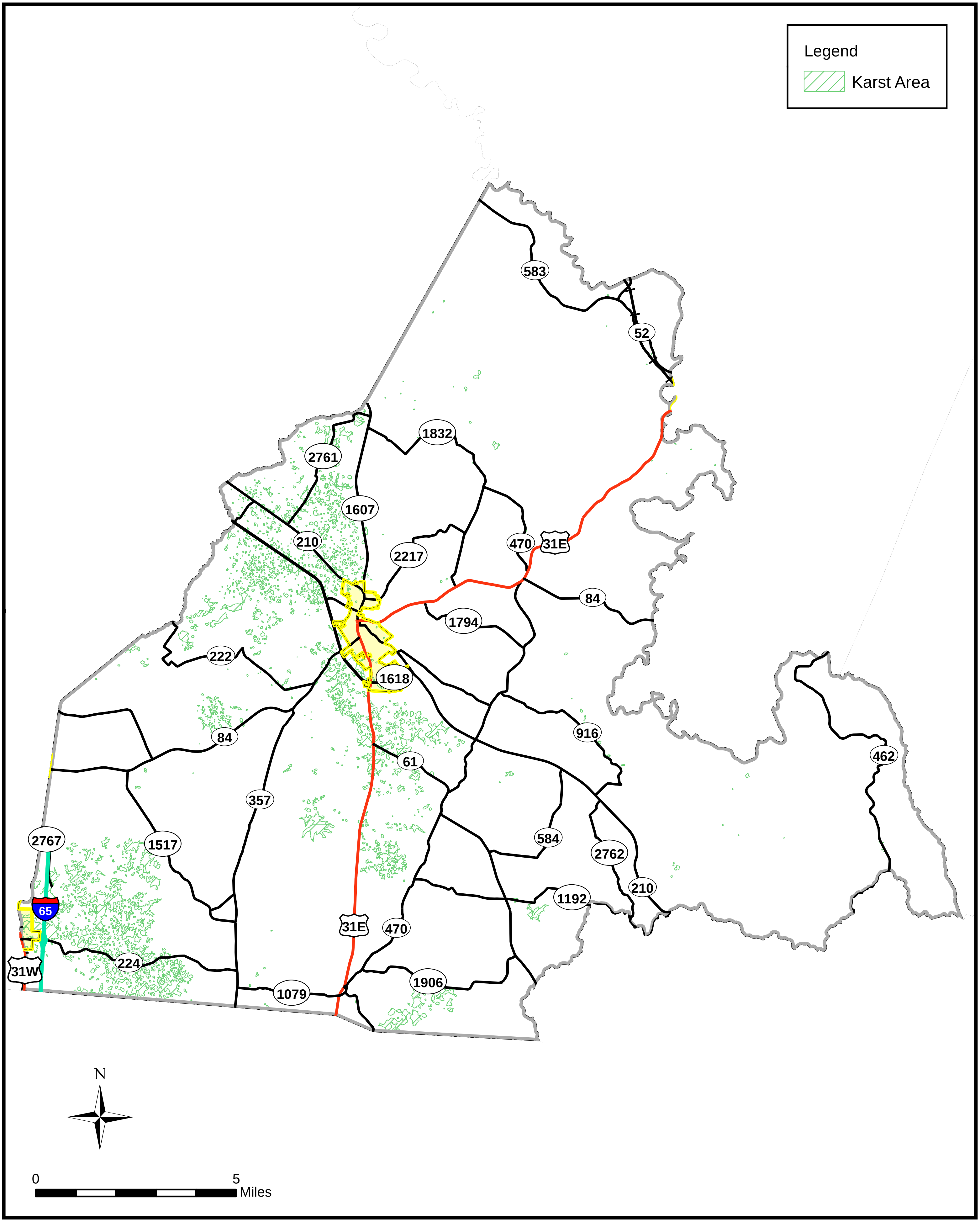
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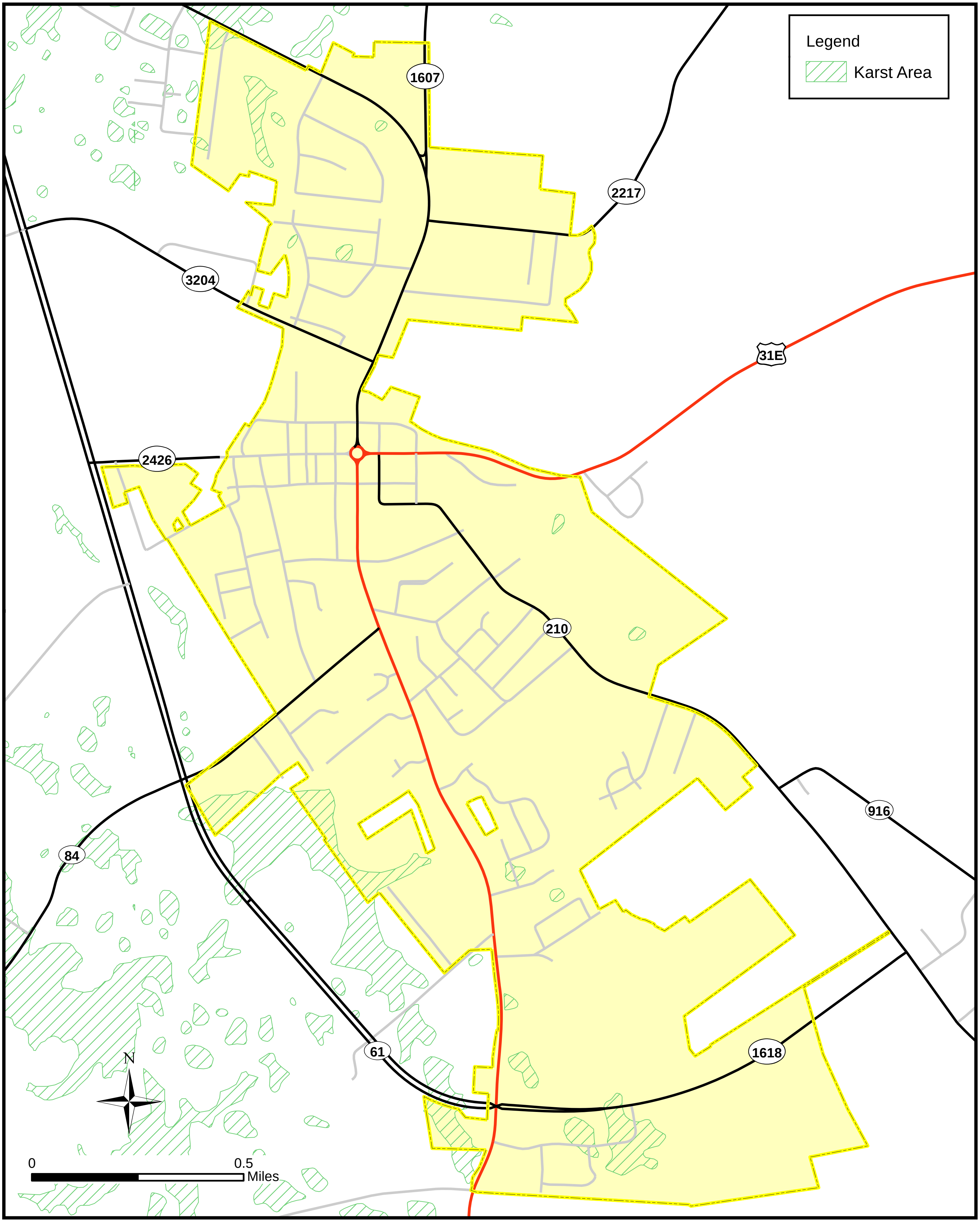
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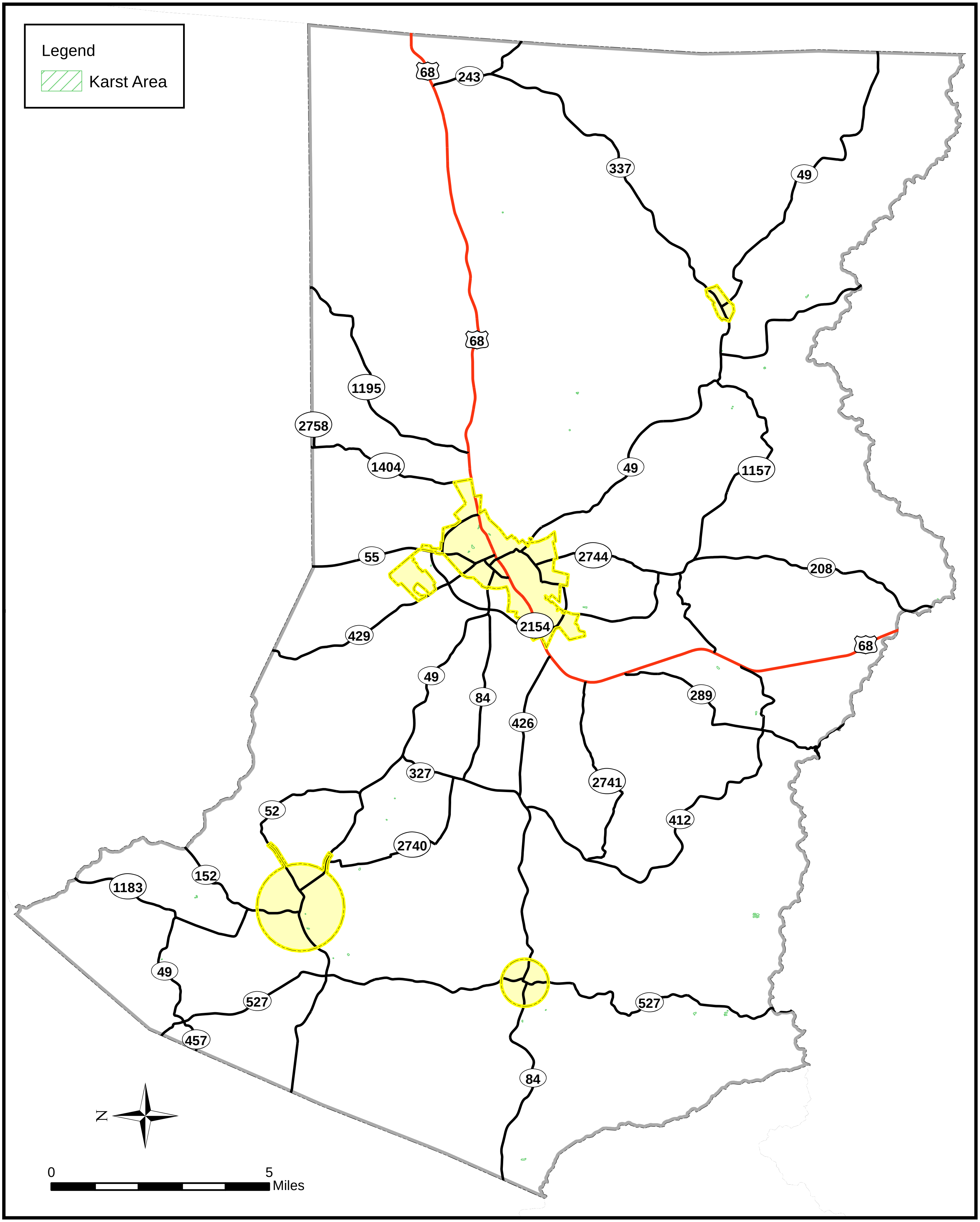
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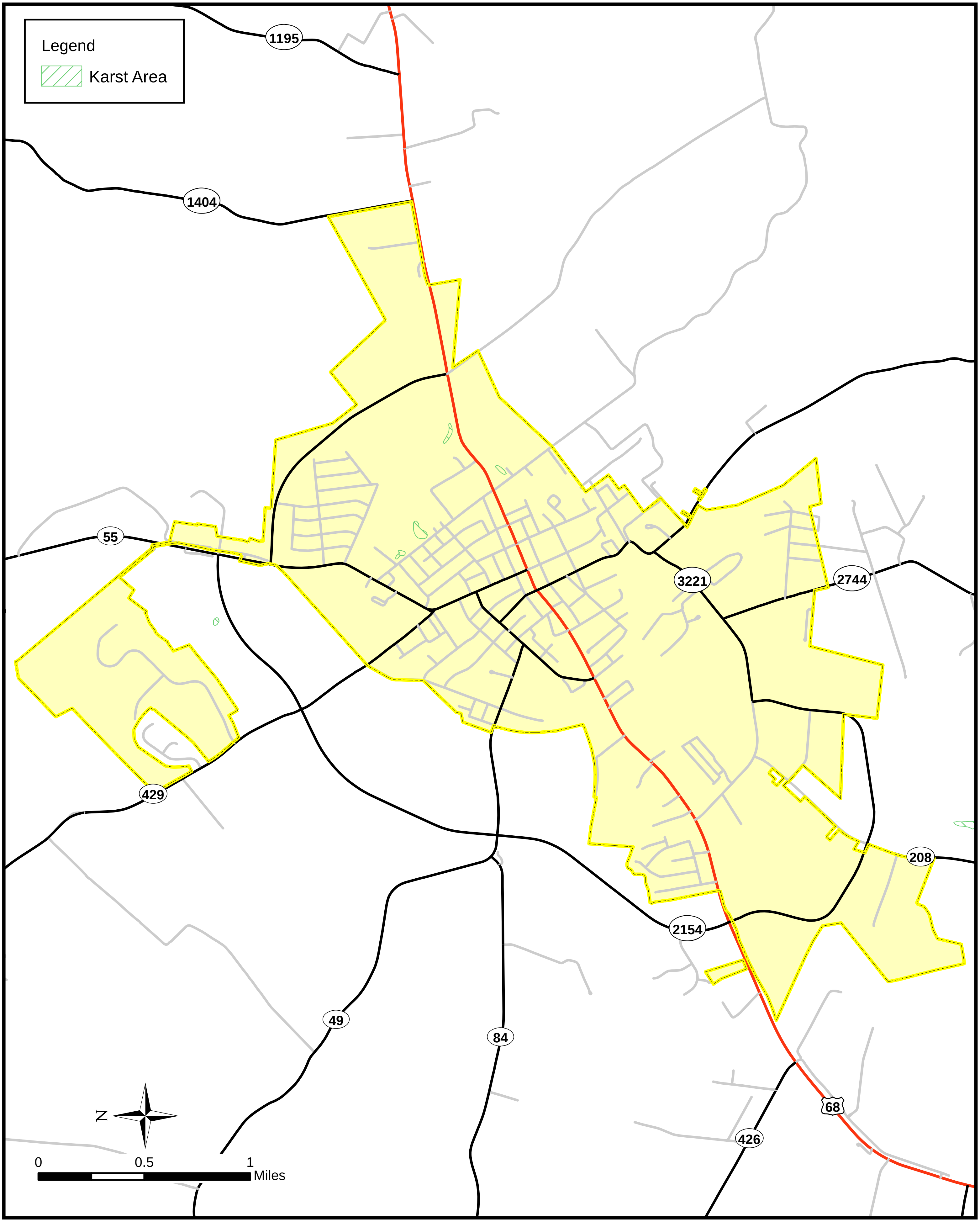
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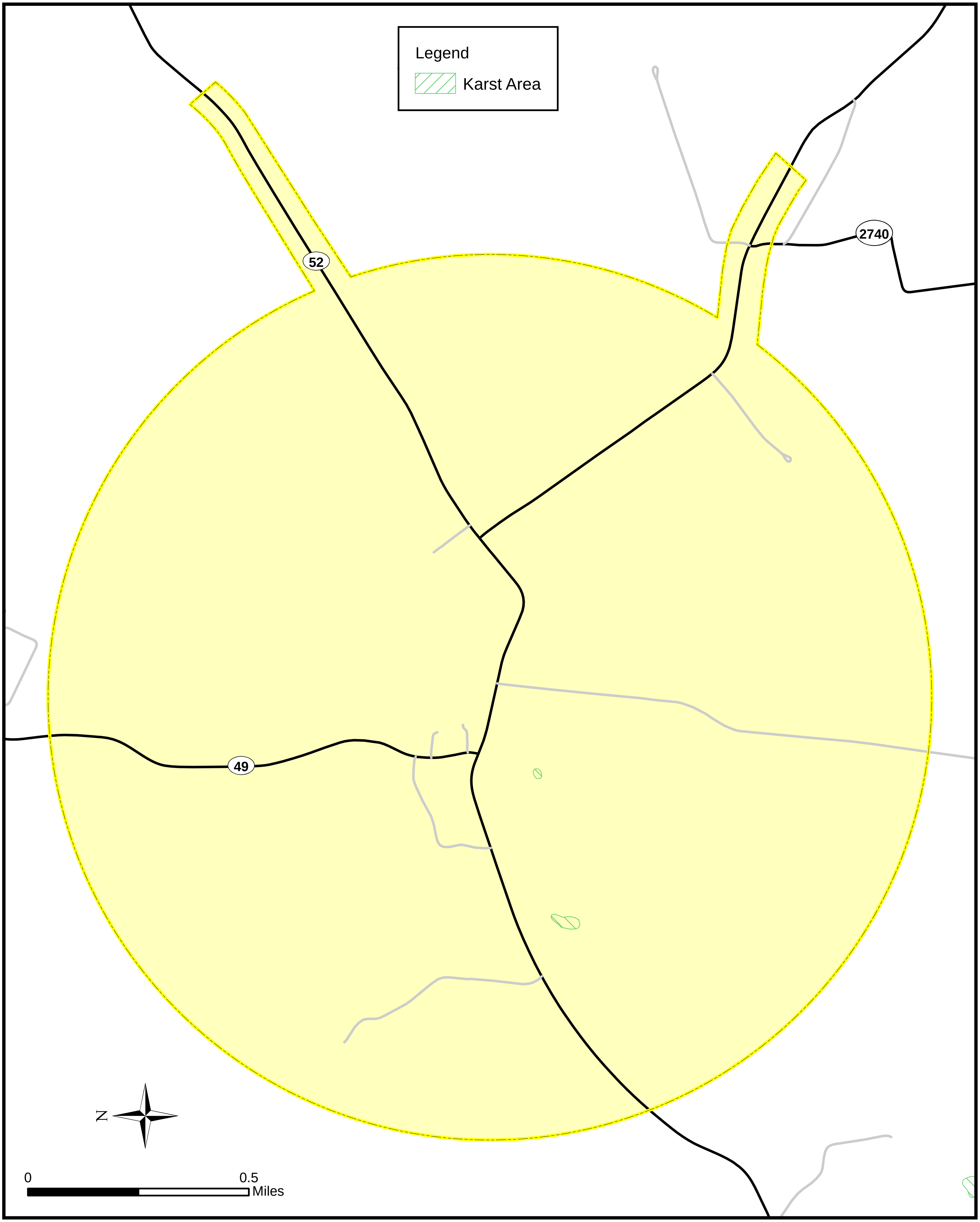
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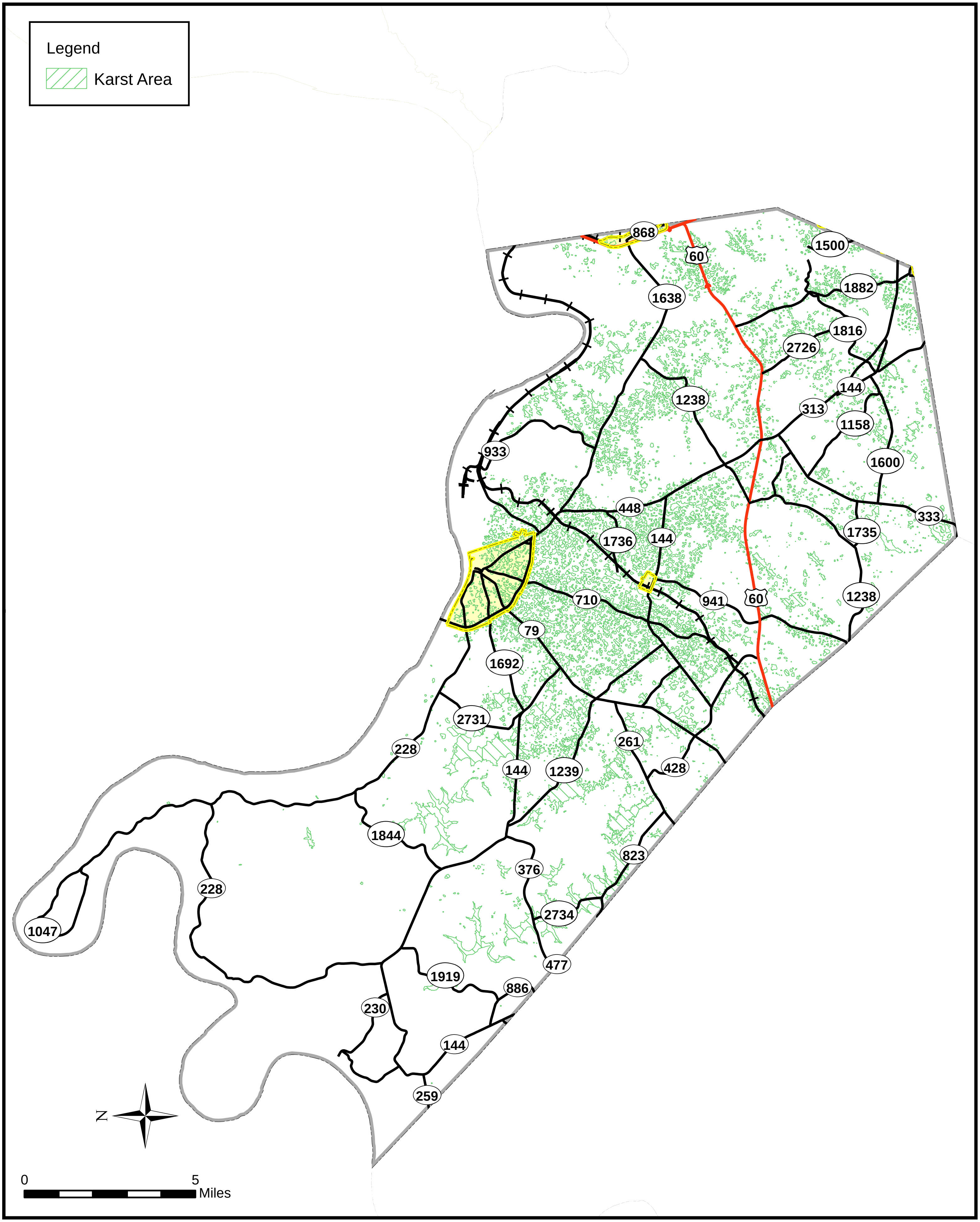
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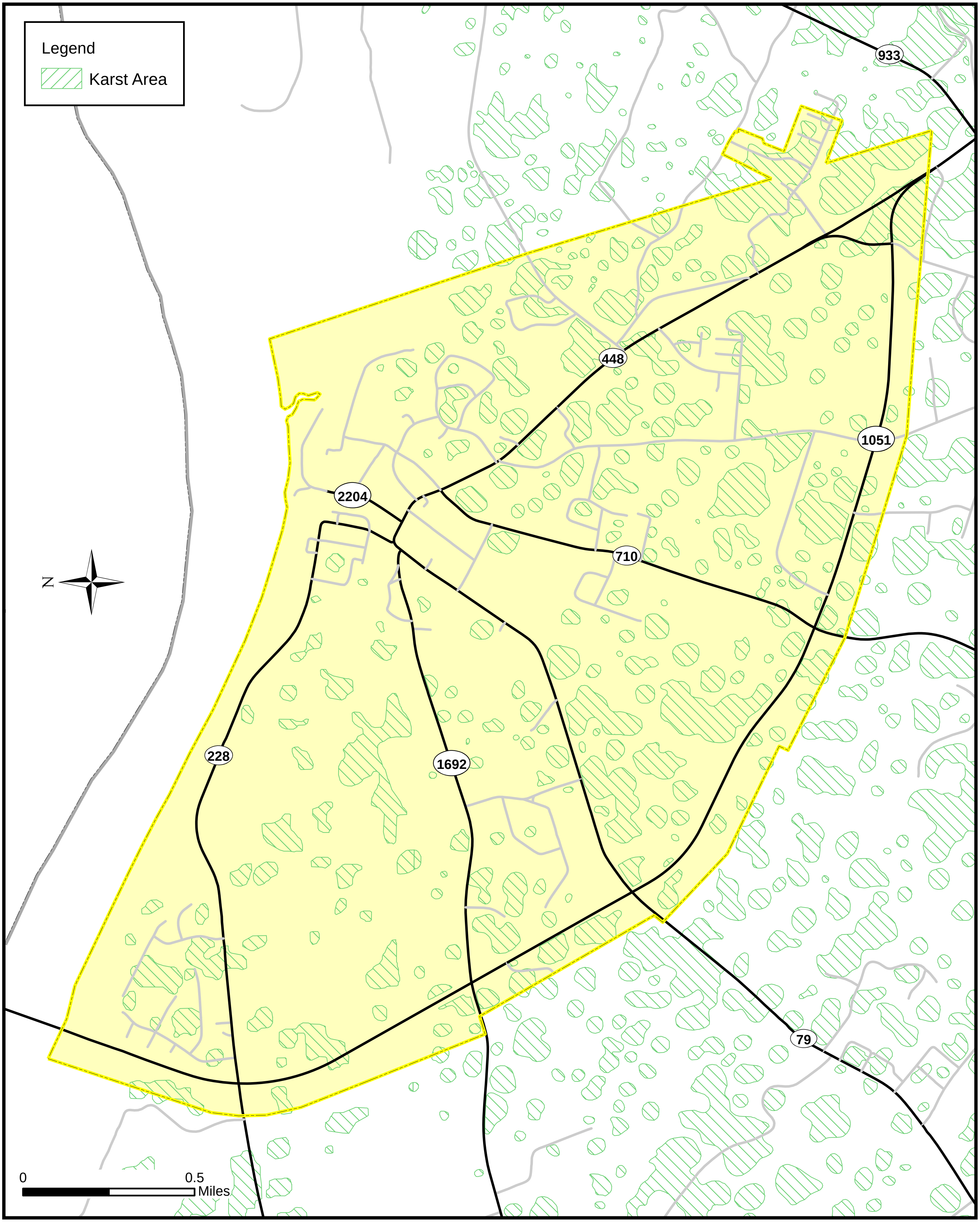
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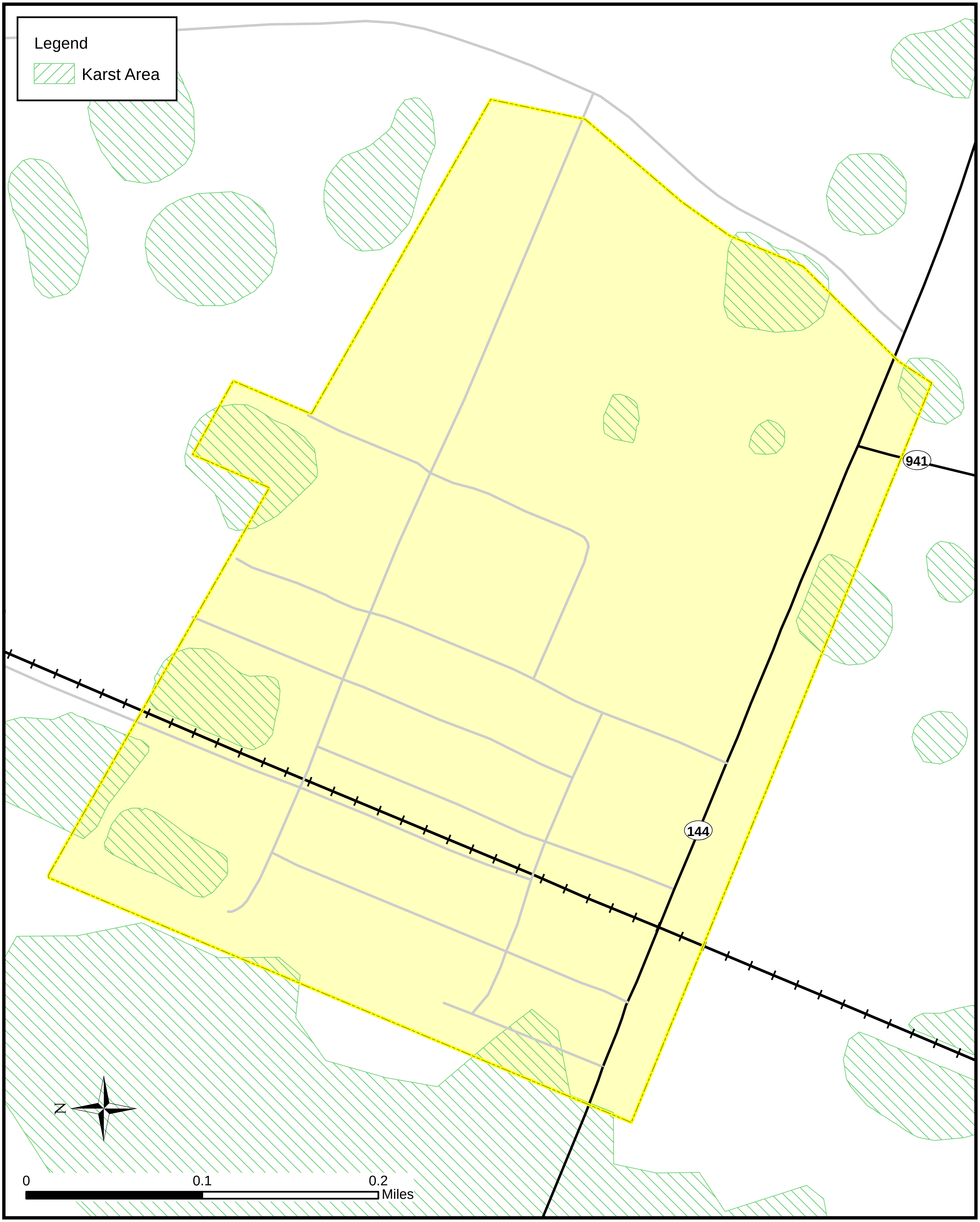
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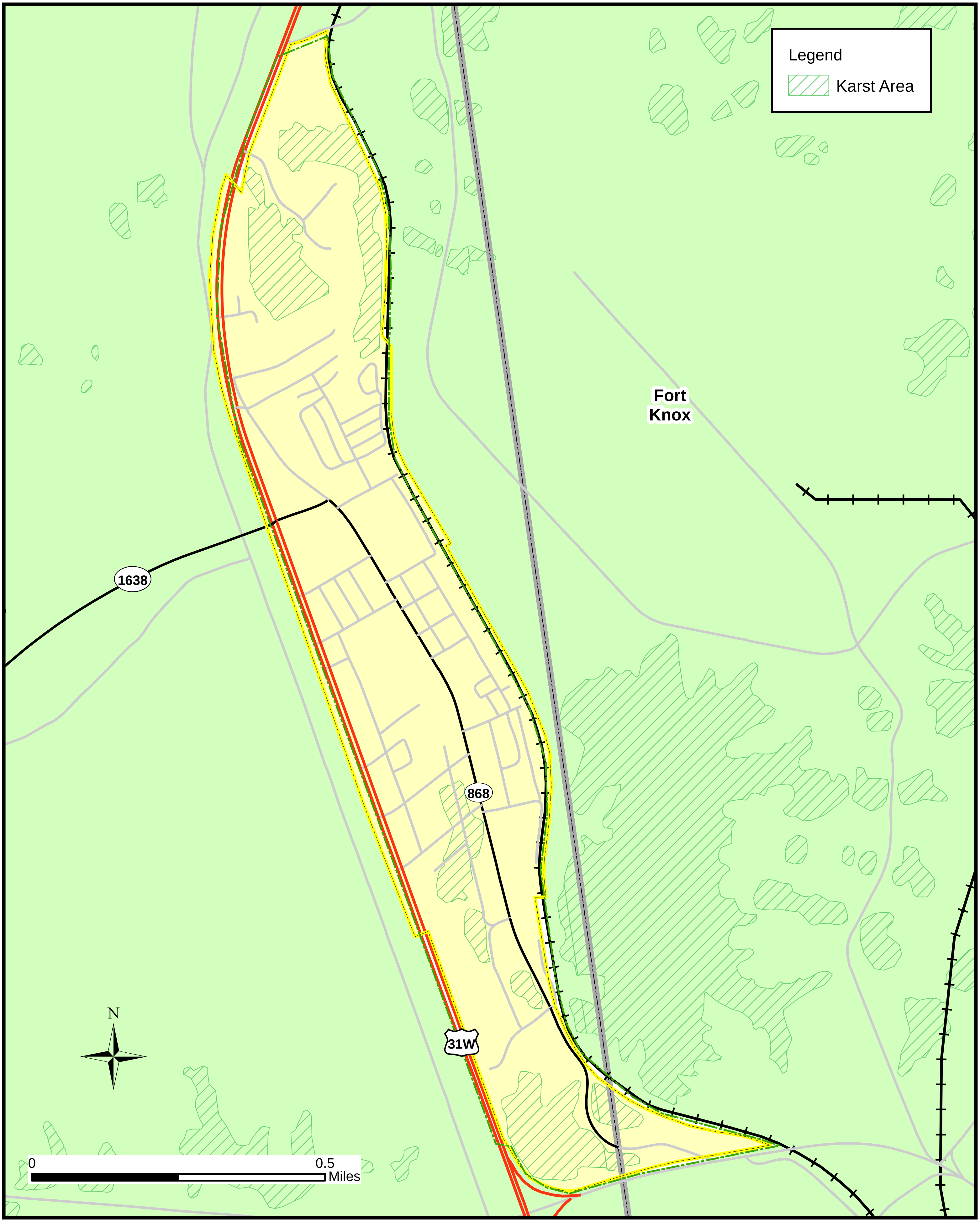
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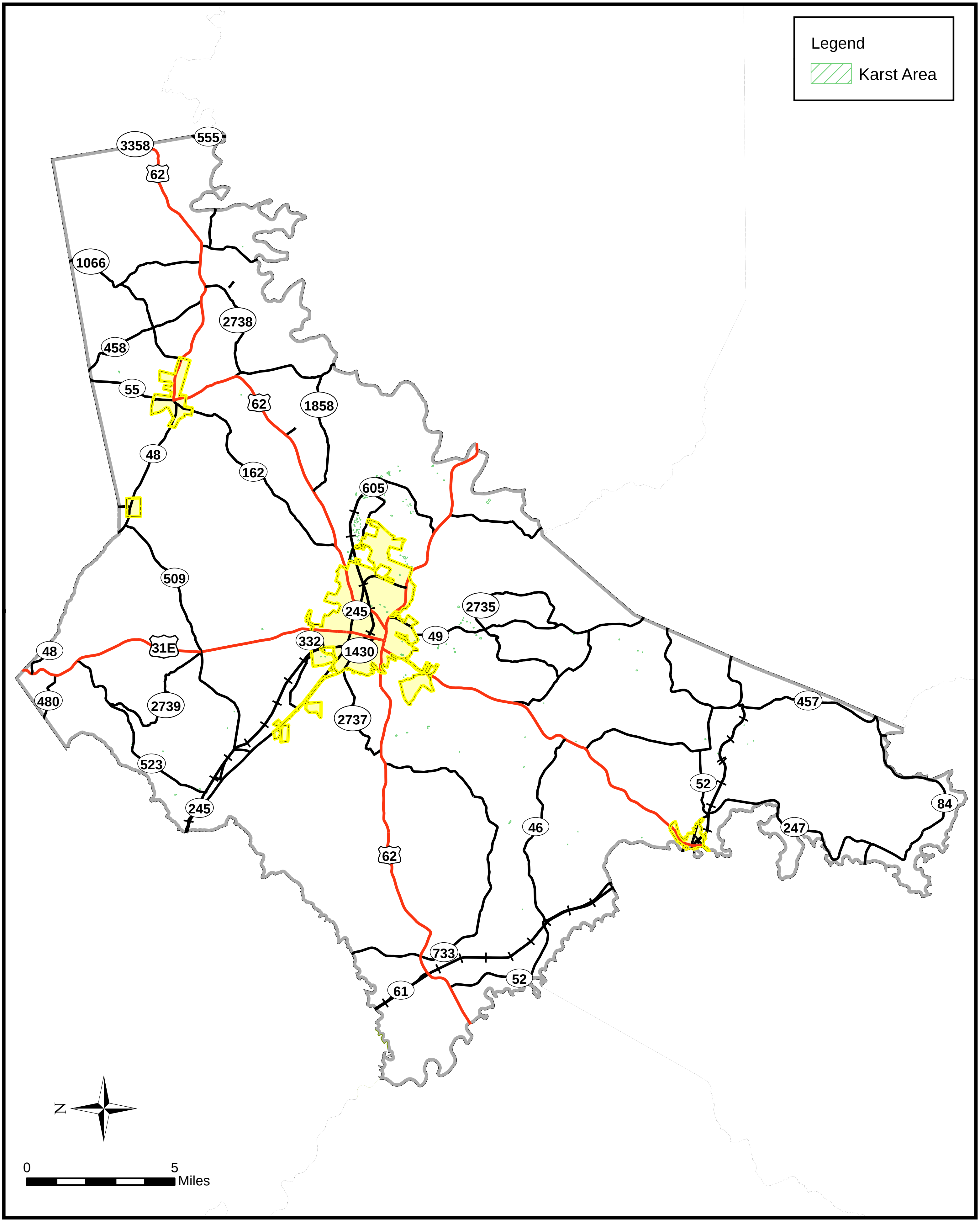
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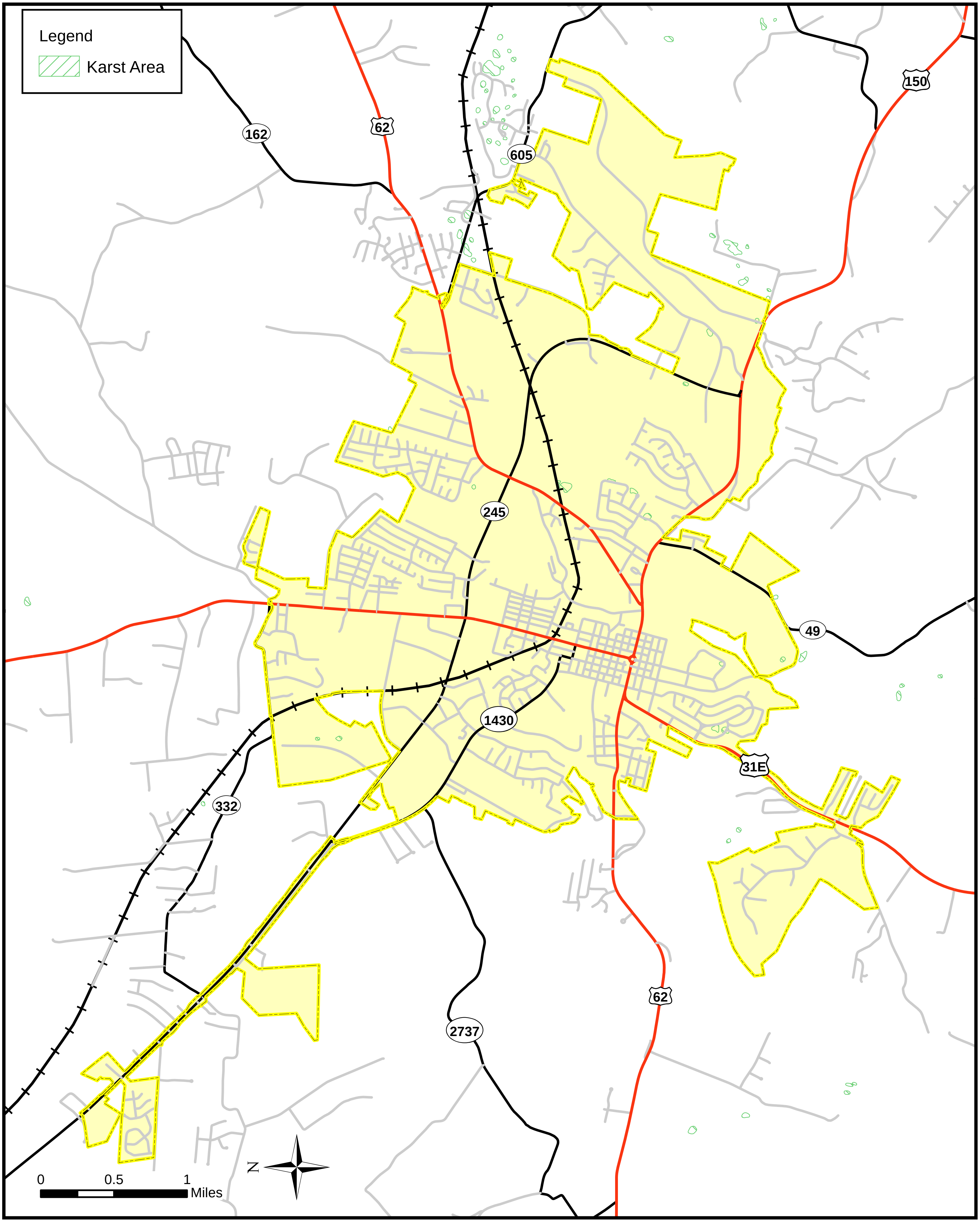
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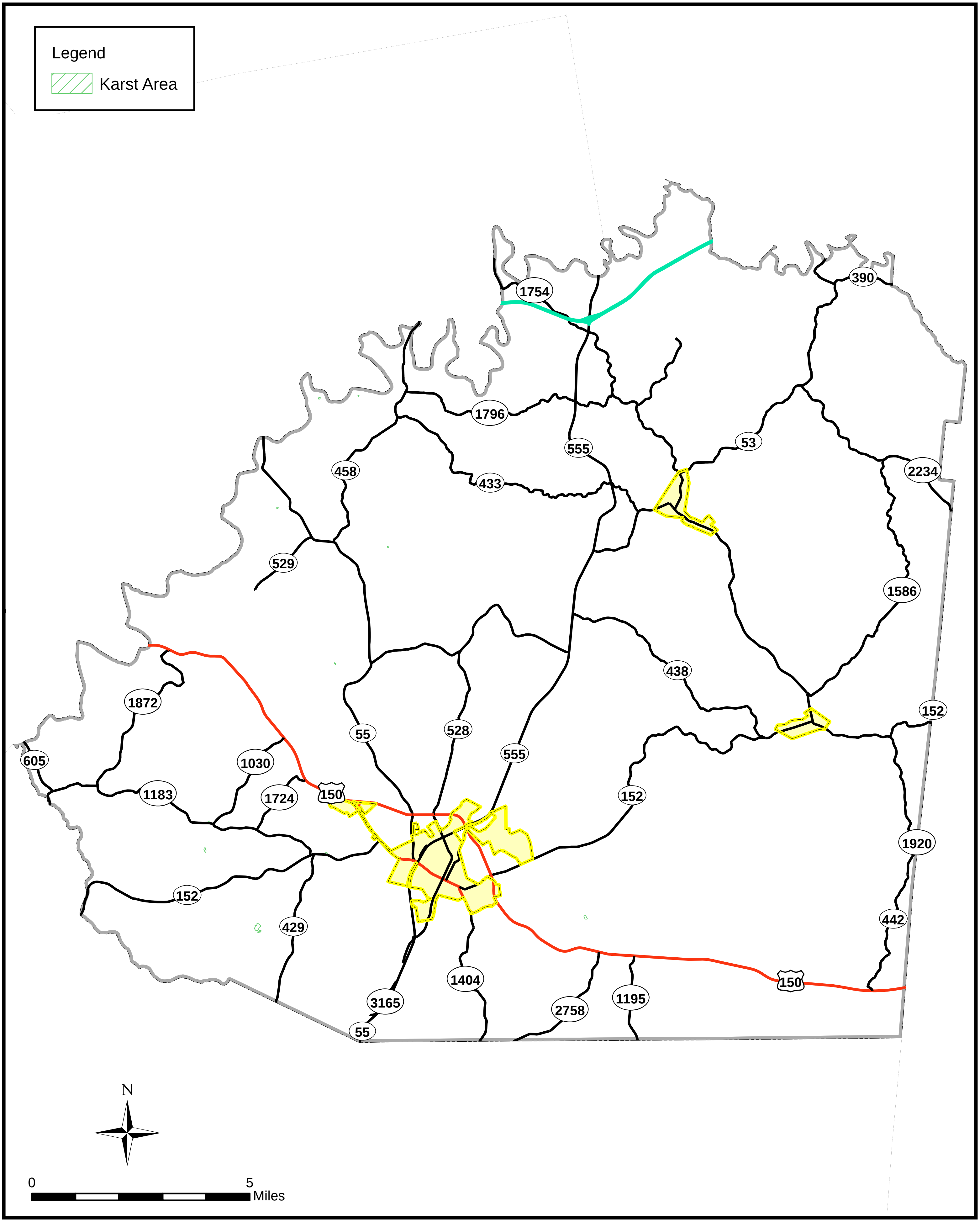
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