The sensitivity level, a measurement of the public concern for scenic quality, was also analyzed using six different indicators of public concern: types of users, amount of use, public interest, adjacent land uses, special areas, and other factors. The sensitivity level of the public concern for scenic quality is rated on a high (H), moderate (M), or low (L) scale. The site has an L sensitivity rating, as an area with low scenic values resulting from a low sensitivity to changes in visual quality by the type of users in the area, a low amount of use by viewers, low public interest in changes to the visual quality of the site, and a lack of special natural and wilderness areas.

19.3.2 Air Quality and Noise

19.3.2.1 General Regional Climate

Geomorphic, or physiographic, regions are broad-scale subdivisions of the nation that are based on terrain texture, rock type, geologic structure, and history. There are eight regions, subdivided into 25 provinces, and further subdivided to 85 sections within the U.S. (Fenneman, 1946). The characteristics and locations of these landforms influence local and regional climate and weather patterns.

The proposed RPF site lies at the southern edge of the Central Lowlands physiographic province, within a very few miles of the adjacent Ozark Plateau province, both of which lie within the larger Interior Plains physiographic region. The Central Lowlands includes most of the Corn Belt and lies within the heartland of America.

The proposed RPF location places the facility in the Humid Continental-Warm Summer climatic zone. This type of climate has a characteristic long, warm summer with moderate relative humidity. The winters are cool to cold and mark a period of lower precipitation than during the remainder of the year. Because of its geographical location far inland, the region is subject to significant seasonal and daily temperature variations. Air masses moving over the state during the year include cold continental polar air from Canada, warm and humid maritime tropical air from the Gulf of Mexico and the Caribbean Sea, and dry eastward flowing air masses from the Rocky Mountains located to the west. Prolonged periods of extreme hot or cold temperatures are unusual (MU, 2006b).

The general geostrophic airflow pattern and the prevailing jet stream track shuttle precipitation-producing mid-latitude cyclones (lows) across the state from west-to-east throughout the year. Consequently, precipitation events in all seasons move through from a westerly direction (MU, 2006b).

Spring, summer, and early fall precipitation occurs in the form of rain and thunderstorms. Severe thunderstorms typically occur during the period from mid- to late-spring through early summer. Hail may be expected as a product of these storms. Wind speeds of up to 97 km/hr (60 mi/hr) or more may be experienced once or twice a year during a severe thunderstorm (MU, 2006b). Winter precipitation is generally light to moderate and occurs in the form of rain or snow or a mixture of both with an occasional, though infrequent, thunderstorm. Occasional heavy snowfall episodes occur infrequently, and when they do occur, the accumulation does not last for any significant duration. Surface temperature conditions sometimes produce freezing rain or drizzle, although normally not more than a couple times each season.

The historical climate data within this section were obtained primarily from the National Oceanic and Atmospheric Administration (NOAA) High Plains Regional Climate Center historical climate data summaries for Columbia (NOAA, 2013a and 2013b). In addition, MU has a weather station at South Farm, less than 1.6 km (1 mi) away from the proposed site and approximately 6.4 km (4 mi) from Columbia. The weather station is used in conjunction with the MU agricultural program. The university makes the weather data available via its website. Simple searches may be performed and various averages can be obtained through this database.

Other sources were used as needed (e.g., Decker, 2013) to augment NOAA data, particularly to better understand the immediate area around the proposed site.

19.3.2.1.1 Temperature

Though temperatures reached a record high of 41.7°C (107 degrees Fahrenheit [°F]) in 2012, in general, temperatures rarely exceed 38°C (100°F) in the summer and rarely fall below -18°C (0°F) in the winter. The mean maximum temperatures in Columbia, collected from the reporting station at the Columbia Regional Airport (Station 231791) over a 43-year period, ranged from 2.8°C (37.2°F) in January to 31.4°C (88.5°F) in July. Daily temperatures during that period showed a wider variance, from -28.8°C (-20°F) in December to 44°C (111°F) in July. A summary of average and extreme temperature data for 1969 through 2012 is shown in Table 19-19.

Table 19-19. Columbia, Missouri, Average and Extreme Monthly Climate, Historic Temperature Summary, 1969–2012

Measurement		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average max. temperature	°C	2.9	6.1	12.7	18.9	23.6	28.5	31.4	30.7	26.0	19.6	12.0	5.1	18.1
	°F	37.2	43.0	54.9	66.1	74.4	83.3	88.5	87.3	78.8	67.2	53.6	41.2	64.6
Average min. temperature	°C	-6.8	-4.3	1.2	6.8	12.1	17.0	19.6	18.4	13.7	7.4	1.5	-4.3	6.8
	°F	19.7	24.2	34.2	44.3	53.7	62.6	67.2	65.2	56.7	45.3	34.7	24.2	44.3
Daily extreme high	°C	23.3	27.8	29.4	32.2	33.3	[a]89	43.9	43.3	38.3	34.4	28.3	24.4	43.9
	°F	74.0	82.0	85.0	90.0	92.0	[a]107	111.0	110.0	101.0	94.0	83.0	76.0	111.0
Daily extreme low	°C	-28.3	-26.1	-20.6	-7.2	-1.7	4.4	8.9	5.6	0.0	-5.6	-17.8	-28.9	-28.9
	°F	-19.0	-15.0	-5.0	19.0	29.0	40.0	48.0	42.0	32.0	22.0	0.0	-20.0	-20.0
Average mean	°C	-1.9	0.9	6.9	12.9	17.8	22.8	25.4	24.6	19.9	13.5	6.7	0.4	12.5
	°F	28.5	33.6	44.5	55.2	64.1	73.0	77.8	76.3	67.8	56.3	44.1	32.7	54.5

Source: WRCC, 2013a, "Period of Record General Climate Summary – Temperature, 1969 to 2012, Station 231791 Columbia WSO AP," www.wrcc.dri.edu/cgi-bin/cliGCStT.pl?mo1791, Western Regional Climate Center, Reno, Nevada, accessed August 2013.

[a] Occurred during 2008–2012 time period.

Average temperature data for the Columbia, Missouri, weather station was reviewed for the most recent five years having data available (2008 to 2012). The lowest average temperature was -4.1°C (24.65°F), recorded in January 2010, and the highest average temperature was 29.5°C (85.06°F), recorded in July 2012. The five-year annual average temperature was 13.1°C (55.58°F).

A five-year temperature summary is presented in Table 19-20. The five-year average temperature for the same time period, reported at the South Farm weather station, was 12.3°C (54.2°F). The average minimum temperature was 6.9°C (44.5°F), and the average maximum temperature was 17.9°C (64.3°F) (MU, 2014).

Table 19-20. Columbia, Missouri, Five-Year Temperature Summary, 2008–2012

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2008	°C	-0.6	-0.9	6.1	11.6	17.1	23.3	24.7	22.8	19.0	16.0	2.4	-1.1	12.2
	°F	31.0	30.3	42.9	52.9	62.8	73.9	76.4	73.0	66.3	60.9	36.3	30.1	54.0
2009	°C	-3.1	2.4	8.1	11.7	17.9	23.3	22.5	21.9	18.6	10.2	9.8	-1.1	11.8
	°F	26.5	36.3	46.5	53.1	64.2	73.9	72.5	71.4	65.5	50.3	49.6	30.0	53.3
2010	°C	-4.1	-2.7	7.4	16.1	18.0	24.6	25.6	25.5	19.8	14.8	7.6	-1.6	12.6
	°F	24.7	27.1	45.3	60.9	64.4	76.2	78.0	77.9	67.6	58.6	45.7	29.1	54.6
2011	°C	-3.9	-0.1	6.6	14.0	16.9	24.0	27.5	24.9	17.6	14.2	8.9	3.1	12.8
	°F	24.9	31.9	43.9	57.2	62.5	75.1	81.6	76.7	63.7	57.5	48.1	37.5	55.0
2012	°C	1.7	4.3	14.9	15.0	21.6	25.0	29.5	25.8	19.6	12.0	7.7	7.5	16.1
	°F	35.0	39.7	58.8	59.0	70.9	77.1	85.1	78.5	67.3	53.6	45.8	45.5	61.0
Mean	°C	-2.0	0.6	8.6	13.7	18.3	24.0	25.9	24.2	18.9	12.8	8.5	-0.2	13.1
	°F	28.4	33.1	47.5	56.6	64.9	75.3	78.7	75.5	66.1	55.0	47.3	31.7	55.6

Source: WRCC, 2013b, "Station Monthly Time Series, Columbia, Missouri, 2008-2012, Station 231791 Columbia WSO AP," www.wrcc.dri.edu/cgi-bin/wea_mnsimts.pl?laKCOU, Western Regional Climate Center, Reno, Nevada, accessed August 2013.

19.3.2.1.2 Precipitation

According to the historical data from Station 231791, precipitation in the Columbia area averages approximately 103.1 cm (40.6 in.) per year. Of that amount, the mean snowfall is 57.7 cm (22.7 in.) per year. The city has measurable amounts of precipitation 111 days per year. The maximum annual precipitation of 159 cm (62.49 in.) was measured in 1993, and the minimum annual precipitation of 60 cm (23.66 in.) was measured in 1980. On a monthly basis, rainfall amounts range from a high of 12.4 cm (4.89 in.) in May to a low of 4.62 cm (1.82 in.) in January (WRCC, 2013a).

According to the historical data from Station 231791, snow falls from November through April. During that period, a high of 16 cm (6.3 in.) was recorded in February 2011, and a low of 1.5 cm (0.6 in.) was recorded in 1980. A summary of average and extreme precipitation data for 1969 through 2012 is shown in Table 19-21.

Table 19-21. Columbia, Missouri, Average and Extreme Monthly Climate, Historic Precipitation Summary, 1969–2012

Measurement		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average total precipitation	cm	4.62	5.44	8.10	11.23	12.42	10.24	9.58	10.06	9.53	8.28	7.72	6.02	103.12
	in	1.82	2.14	3.19	4.42	4.89	4.03	3.77	3.96	3.75	3.26	3.04	2.37	40.60
High	cm	15.09	15.70	25.63	29.69	31.27	26.11	30.84	25.88	30.63	[a] 27.9	26.47	17.68	158.72
	in	5.94	6.18	10.09	11.69	12.31	10.28	12.14	10.19	12.06	[a] 10.99	10.42	6.96	62.49
Low	cm	0.13	0.28	1.98	2.26	[a] 3.33	0.89	0.61	0.53	1.14	[a] 0.91	1.07	1.22	60.10
	in	0.05	0.11	0.78	0.89	[a] 1.31	0.35	0.24	0.21	0.45	[a] 0.36	0.42	0.48	23.66
1-day max	cm	4.47	6.10	9.98	11.43	12.14	8.15	15.09	10.85	7.11	12.40	7.04	6.88	15.09
	in	1.76	2.40	3.93	4.50	4.78	3.21	5.94	4.27	2.80	4.88	2.77	2.71	5.94
Average total snowfall	cm	15.75	[a] 16.00	7.37	1.52	0.00	0.00	0.00	0.00	0.00	0.00	4.57	12.70	57.66
	in	6.20	[a] 6.3	2.90	0.60	0.00	0.00	0.00	0.00	0.00	0.00	1.80	5.00	22.70
High snowfall	cm	59.69	59.18	54.86	18.03	0.00	0.00	0.00	0.00	0.00	0.25	21.08	45.21	134.11
	in	23.50	23.30	21.60	7.10	0.00	0.00	0.00	0.00	0.00	0.10	8.30	17.80	52.80

Source: WRCC, 2013a, "Period of Record General Climate Summary – Temperature, 1969 to 2012, Station 231791 Columbia WSO AP," www.wrcc.dri.edu/cgi-bin/cliGCStT.pl?mo1791, Western Regional Climate Center, Reno, Nevada, accessed August 2013.

[a] Occurred during 2008–2012 time period.

A recent five-year precipitation summary of the station data was obtained and reviewed. For each month during this time period, a portion of the data was missing, with the missing data ranging from approximately 15–30 percent of the total data. Precipitation data from the South Farm weather station was also reviewed. The averages shown on the site were different than the Columbia weather station by a factor of five. Thus, the Columbia weather station historical summary serves as the more complete picture of precipitation at the proposed RPF site.

19.3.2.1.3 Humidity

Average relative humidity data for the Columbia, Missouri, weather station was reviewed for 2008 to 2012. The lowest average relative humidity was 51.89 percent, recorded in August 2012, and the highest average relative humidity was 82.13 percent, recorded in September 2008. The five-year annual average was 69.18 percent. The five-year relative humidity data summary is shown in Table 19-22.

Table 19-22. Relative Humidity Data for Columbia, Missouri, 2008–2012

Year	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)	Annual (%)
2008	60.51	72.02	66.68	64.85	69.49	71.40	74.38	78.87	82.13	77.52	65.87	71.48	71.18
2009	64.95	63.73	63.28	66.52	68.42	73.66	74.46	76.90	75.92	76.62	68.08	72.33	70.41
2010	75.69	73.42	70.33	61.24	74.71	76.64	79.19	75.19	76.17	58.65	64.86	72.85	71.58
2011	71.86	71.51	71.26	64.73	74.61	72.69	76.29	75.19	70.82	59.46	71.92	74.84	71.27
2012	64.05	63.72	63.58	65.03	61.33	54.89	52.96	51.89	69.64	66.76	62.25	70.91	61.46
Mean	67.41	68.88	67.03	64.47	69.71	69.86	71.46	71.61	74.94	65.37	66.78	72.88	69.18

Source: WRCC, 2013b, "Station Monthly Time Series, Columbia, Missouri, 2008-2012, Station 231791 Columbia WSO AP," www.wrcc.dri.edu/cgi-bin/wea_mnsimts.pl?laKCOU, Western Regional Climate Center, Reno, Nevada, accessed August 2013.

19.3.2.1.4 Wind

Extreme wind speeds are uncommon in central Missouri. When they do occur, they are usually caused by pressure gradients and temperature contrasts present in the mid-latitude cyclones that pass through the state. These cyclones may spawn storms that produce high winds from gust fronts, microbursts, and tornadoes. Non-storm-related extreme winds are rare. Occasionally, cold high-pressure air filling in behind a front causes high wind, especially in the winter when temperature contrasts are large.

Average wind speed data for the Columbia, Missouri, weather station was reviewed for 2008 to 2012. The lowest mean wind speed was 8.8 km/hr (5.47 mi/hr) in August 2008, and the highest was 19.1 km/hr (11.87 mi/hr) recorded in December 2008. The five-year annual average was 14.25 km/hr (8.86 mi/hr). The five-year mean wind speed data summary is shown in Table 19-23.

Table 19-23. Mean Wind Speed for Columbia, Missouri, from 2008–2012

Year	rate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2008	(km/hr)	18.85	17.03	16.96	17.53	15.76	13.97	11.28	8.80	10.01	11.59	14.32	19.10	14.93
	(mi/hr)	11.71	10.58	10.54	10.89	9.79	8.68	7.01	5.47	6.22	7.20	8.90	11.87	9.28
2009	(km/hr)	15.24	17.96	18.31	17.99	12.38	12.47	10.32	11.91	10.40	14.58	14.71	17.03	14.44
	(mi/hr)	9.47	11.16	11.38	11.18	7.69	7.75	6.41	7.40	6.46	9.06	9.14	10.58	8.97
2010	(km/hr)	13.74	13.73	15.96	17.06	12.79	11.43	10.06	9.88	12.17	16.30	14.73	13.41	13.10
	(mi/hr)	8.54	8.53	9.92	10.60	7.95	7.10	6.25	6.14	7.56	10.13	9.15	8.33	8.14
2011	(km/hr)	13.63	16.87	17.08	18.49	15.14	14.45	10.09	10.38	11.89	13.66	18.88	14.15	14.56
	(mi/hr)	8.47	10.48	10.61	11.49	9.41	8.98	6.27	6.45	7.39	8.49	11.73	8.79	9.05
2012	(km/hr)	16.98	15.64	16.53	15.19	13.42	13.68	10.56	11.35	11.57	13.79	14.97	14.18	13.97
	(mi/hr)	10.55	9.72	10.27	9.44	8.34	8.50	6.56	7.05	7.19	8.57	9.30	8.81	8.68
Mean	(km/hr)	15.69	16.24	16.96	17.25	13.90	13.20	10.46	10.46	11.20	14.08	15.92	16.25	14.26
	(mi/hr)	9.75	10.09	10.54	10.72	8.64	8.20	6.50	6.50	6.96	8.75	9.89	10.10	8.86

Source: WRCC, 2013b, "Station Monthly Time Series, Columbia, Missouri, 2008-2012, Station 231791 Columbia WSO AP," www.wrcc.dri.edu/cgi-bin/wea_mnsimts.pl?laKCOU, Western Regional Climate Center, Reno, Nevada, accessed August 2013.

Wind data from the South Farm weather station was also reviewed. The average shown on the site was different than the Columbia weather station by a factor of two. Thus, the Columbia weather station data provides a more comprehensive study of wind activity at the proposed site.

Two wind roses are presented to show the general historic wind flow patterns in the immediate area and the ROI. Figure 19-26 shows the wind pattern as measured at South Farm, located immediately north of the proposed RPF site. These data were collected by MU. Figure 19-27 shows the wind patterns recorded at the Columbia Remote Automatic Weather Station.

Both wind roses show that the prevailing surface wind direction is from the south. The South Farm wind rose shows a total average wind speed of 11.3 km/hr (7 mi/hr), while the Columbia wind rose shows a total average speed of 14.16 km/hr (8.8 mi/hr). Both wind roses show that the average frequency of higher speed winds falls into the 24–40 km/hr (15–25 mi/hr) range.

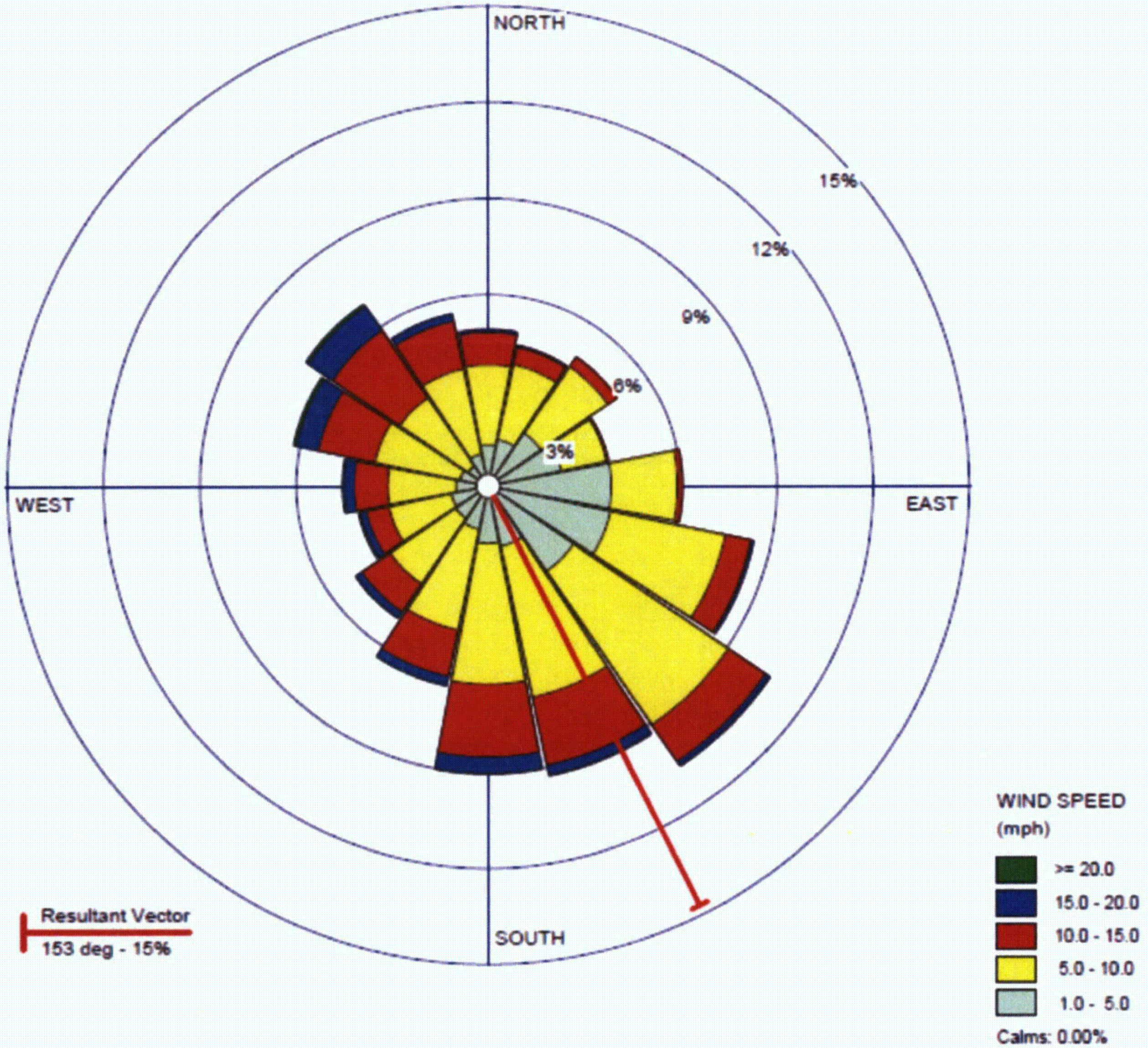


Figure 19-26. Wind Rose from South Farm, 2000–2010 (University of Missouri Agricultural Experiment Station)

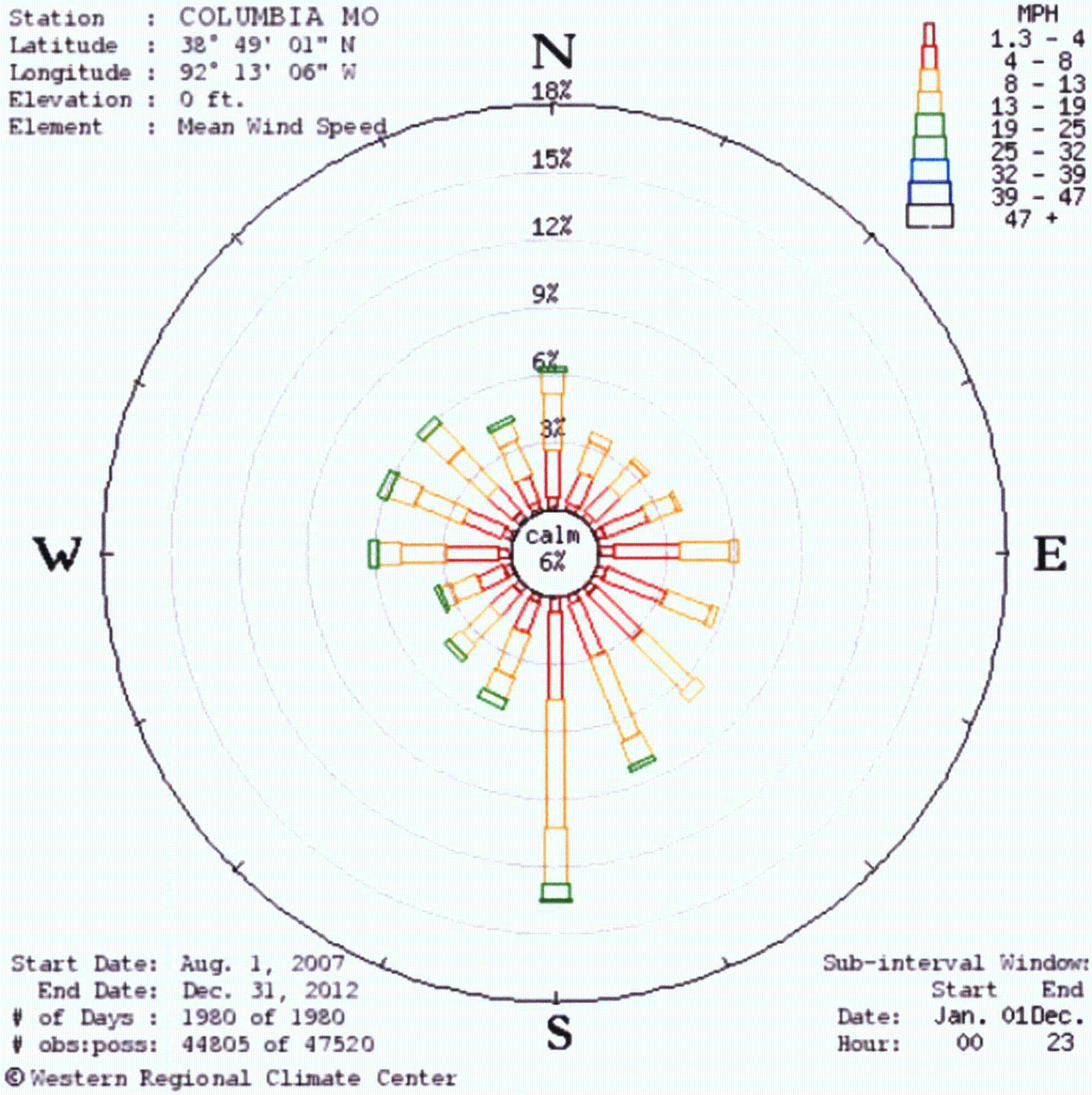


Figure 19-27. Wind Rose from Automatic Weather Station, Columbia, Missouri, 2007-2012 (Western Regional Climate Center)

19.3.2.1.5 Extreme Weather

The American heartland has the distinction of also being known as "tornado alley," a nonmeteorological term that references the area where 90 percent of tornadoes have occurred as a result of the mixing of cold, dry air from Canada and the Rocky Mountains with warm, moist air from the Gulf of Mexico and hot, dry air from the Sonoran Desert. This area exhibits considerable atmospheric instability, heavy precipitation, and many intense thunderstorms.

Tornados are extreme wind speed events that are classified according to the enhanced Fujita tornado intensity scale (EF scale). The scale matches wind speeds to the severity of damage caused by a tornado. The process involves determining the degree of damage according to a predefined damage scale of 28 indicators. The observed damage is associated with estimated wind speeds during the storm, and an EF scale number is assigned. Measuring tornadoes from EF-1 to EF-5, the scale uses more specific structural damage guidelines than the original Fujita tornado intensity scale (F scale), which was established in 1971. Table 19-24 shows the F and EF scales.

Table 19-24. Fujita Scale and Enhanced Fujita Scales Used to Determine Tornado Intensity

F number	F scale				EF number	EF scale	
	Fastest 1/4-mi		3-sec gust			3-sec gust	
	(km/hr)	(mi/hr)	(km/hr)	(mi/hr)		(km/hr)	(mi/hr)
0	64 – 116	40 – 72	72 – 126	45 – 78	0	105 – 137	65 – 85
1	117 – 180	73 – 112	127 – 188	79 – 117	1	138 – 177	86 – 110
2	182 – 253	113 – 157	189 – 259	118 – 161	2	178 – 217	111 – 135
3	254 – 333	158 – 207	260 – 336	162 – 209	3	218 – 265	136 – 165
4	334 – 418	208 – 260	337 – 420	210 – 261	4	266 – 322	166 – 200
5	419 – 512	261 – 318	421 – 510	262 – 317	5	Over 322	Over 200

EF scale = enhanced Fujita tornado intensity scale.
F scale = Fujita tornado intensity scale.

According to compiled information from several extreme weather databases, including the U.S. Tornado and Weather Extremes database (1950 to 2010), a total of 625 tornado events that had a recorded magnitude of two or above were documented in Missouri (World, 2013). Of that total, 50 tornado events of the same magnitude were recorded within 80 km (50 mi) of Columbia. A listing of severe weather events is shown in Table 19-25. Columbia, in a ranking of 1,237 other Missouri cities, ranked 810 for tornados. The tornado index value is calculated based on historical tornado events data and is an indicator of the tornado level in a region. According to this ranking, 809 Missouri cities have a higher chance of tornado events than Columbia (World, 2013).

Table 19-25. Listing of Severe Weather Events from 1950 to 2010 within an 80 km (50-mi) Radius of the Radioisotope Production Facility Site

Event	Total	Event	Total
Blizzard	1	Ice storm	25
Cold	45	Strong wind	26
Dense fog	29	Thunderstorm winds	1,236
Drought	23	Wildfire	2
Flood	466	Winter storm	84
Hail	1,340	Winter weather	51
Heat	72	Other	86
Heavy snow	31	**Total all events:**	**3,517**

Source: World, 2013, "Natural Disasters & Extremes," www.usa.com/columbia-mo-natural-disasters-extremes.htm#TornadoIndex, World Media Group, LLC, Bedminster, New Jersey, accessed August 2013.

According to the NOAA National Climatic Data Center Storm Events Database (NOAA, 2013b), for the time period January 1996 to May 2013, there were 420 severe storm events (defined as an individual type of storm event) recorded in either Boone County or the Boone Zone. The most notable of the 420 events are summarized in Table 19-26.

Table 19-26. Summary of Notable Storm Events In and Near the Region of Influence, Recorded from 1996 to 2013

Event	Boone County	Boone Zone	Events	Notes
Blizzard		✓	1	51 cm (20 in.) of snow recorded
Extreme cold/wind chill		✓	1	Wind chill 29–40°C (20–40°F) below zero recorded
Excessive heat (heat wave)		✓	14	–
Flash flood	✓		50	10, Countywide 1, Central portion of Missouri 7, Columbia
Funnel cloud	✓		1	–
Hail	✓		220	Equal/greater than 1.9 cm (0.75 in.)
Heavy rain	✓		1	7.6–15.2 cm (3–6 in.) recorded
Heavy snow		✓	5	15.2–30.5 cm (6–12 in.) recorded
Ice storm		✓	4	0.64–1.27 cm (0.25–0.5 in.) recorded
Lightening			13	Strikes that resulted in damage/injury
Thunderstorm wind	✓		118	50–75 kn recorded
[a]Tornado	✓		6	Two F-0, one F-1, two F-2, one F-3 recorded
Winter storm		✓	25	--

Source: NOAA, 2013b, "Storm Events Database," www.ncdc.noaa.gov/stormevents, National Oceanic and Atmospheric Administration, Washington, D.C., accessed August 2013.

[a] As rated with the enhanced Fujita tornado intensity scale.

19.3.2.2 Air Quality

Missouri is located in EPA Region 7. The Missouri DEQ is the regulatory agency responsible to protect and enhance the quality of the Missouri environment and its citizens. The MDNR operates an extensive network of ambient air monitors to comply with the Clean Air Act and its amendments.

The ambient air quality monitoring network for Missouri consists of State and local air monitoring stations, special purpose monitoring stations, and national core monitoring consistent with requirements in 40 CFR 58.10, "Annual Monitoring Network Plan and Periodic Network Assessment."

The only MDNR air monitor in Boone County is located at Finger Lakes and monitors for ozone (O_3) from May to October each year. The MDNR continuous air monitors nearest to the proposed RPF site, also in similar urban locales, are at the following locations:

- **Mark Twain State Park** – In Stoutsville, Monroe County, approximately 103 km (64 mi) northeast of the RPF site. Monitors for sulfur dioxide (SO_2), O_3, and inhalable particulates PM-10 (particulate matter, 10 micron [μ]) and PM-2.5 (particulate matter, 2.5 μ).
- **El Dorado Springs** – In Cedar County, approximately 261 km (162 mi) southwest of the site. Monitors for nitrogen dioxide (NO_2), inhalable particulate PM-2.5, and O_3.

Both air monitoring locations are well outside of the ROI.

The EPA has set national air quality standards for six common pollutants (also referred to as "criteria" pollutants). These standards are known as NAAQS. Missouri DEQ monitors for CO, NO_2, O_3, total suspended particulate, inhalable particulates (PM-10 and PM-2.5), and lead (Pb). Other pollutants or compounds are measured as part of air toxics or particulate speciation sampling. Legal descriptions of the standards are available in the 6 CSR Division 10, "Air Quality Standards, Definitions, Sampling and Reference Methods and Air Pollution Control Regulation for the Entire State of Missouri." The NAAQS are summarized in Table 19-27.

Table 19-27. National Ambient Air Quality Standards Applicable in Missouri

Pollutant	Average time	NAAQS	Primary standard	Secondary standard
Carbon monoxide	1 hr	Not to be exceeded more than once per year	35 ppm	–
	8 hr	Not to be exceeded more than once per year	9 ppm	–
Lead	3 months	Rolling 3-month average	15 μg/m^3	15 μg/m^3
	Quarterly	Quarterly average	1.5 μg/m^3	1.5 μg/m^3
Nitrogen dioxide	1 hr	3-year average of the maximum daily 98th percentile 1-hr average	100 ppb	None
	Annual	Annual arithmetic mean	53 ppb	53 ppb
PM-10	24 hr	Not to be exceeded more than once per year on average over 3 years	150 μg/m^3	150 μg/m^3
PM-2.5	24 hr	98th percentile of the 24-hr values determined for each year; 3-year average of the 98th percentile values	35 μg/m^3	35 μg/m^3
	Annual	3-year average of the annual arithmetic mean	15 μg/m^3	15 μg/m^3
Ozone	8 hr	3-year average of the annual 4th highest daily maximum 8-hr average concentration	0.075 ppm	0.075 ppm
Sulfur dioxide	24 hr	NA	0.14 ppm	None
	1 yr	NA	0.03 ppm	None
	1 hr/3 yr	To attain the 1-hr/3-yr standard, the 3-yr average of the 99th percentile of the daily maximum 1-hr average at each monitor within an area must not exceed 75 ppb	75 ppb	None

Source: MDNR, 2013a, "National Ambient Air Quality Standards," dnr.mo.gov/env/esp/aqm/standard.htm, Missouri Department of Natural Resources, Division of Environmental Quality, Jefferson City, Missouri, accessed August 2013.

NA = not applicable. NAAQS = National Ambient Air Quality Standards.

Nonattainment means that a geographic area has not consistently met the clean air levels set by the EPA in the NAAQS. There are several nonattainment areas in Missouri; however, none of them are within Boone County, Columbia, the ROI, or anywhere near the proposed RPF site. Most nonattainment areas are located in St. Louis (201 km [125 mi] to the southeast) and in the nearby counties of Dent, Franklin, Iron, Jefferson, Reynolds, St. Charles, and St. Louis.

Maintenance areas are geographic areas that had a history of nonattainment, but are now consistently meeting the NAAQS. Maintenance areas have been redesignated by EPA from "nonattainment" to "attainment with a maintenance plan," or designated by the Environmental Quality Commission. There are no maintenance areas within Boone County, Columbia, the ROI, or anywhere near the proposed RPF site. The closest maintenance area (for Pb) is located in Bixby, Missouri (Iron County), 238 km (148 mi) to the southeast. Other maintenance areas are found in the cities of Herculaneum (Pb), St. Louis (CO), and Kansas City (O_3).

19.3.2.2.1 Greenhouse Gases

There are currently no programs or policies established or drafted related to operations at Discovery Ridge. NWMI will develop a comprehensive program to avoid and control GHG emissions associated with the RPF. This program will include elements such as:

- Developing a GHG emission inventory
- Investigating and implementing methods for avoiding or controlling the GHG emissions identified in the inventory
- Encouraging carpooling or other measures to minimize GHG emissions due to vehicle traffic during construction and operation of the RPF
- Conducting periodic audits of GHG control procedures
- Implementing corrective actions when necessary

19.3.2.3 Noise

Noise is generally defined as "unwanted sound." At high levels, noise can damage hearing, cause sleep deprivation, interfere with communication, and disrupt concentration. In the context of protecting the public health and welfare, noise implies adverse effects on people and the environment.

Sound is the result of a source inducing vibration in the air, creating sound waves. These waves radiate in all directions from the source and may be reflected and scattered or, like other wave actions, may turn corners. Sound waves are a fluctuation in the normal atmospheric pressure, which is measurable. This sound pressure level is the instantaneous difference between the actual pressure produced by a sound wave and the average or barometric pressure at a given point in space. The fundamental method of measuring sound is in decibel (dB) units. The most commonly used noise metric for measuring noise is A-weighted decibels (dBA).

The following sections discuss the baseline noise conditions within the ROI. The ROI for noise is the 8 km (5 mi) radius from the centerline of the RPF site.

19.3.2.3.1 Baseline Noise Conditions

As discussed in Section 19.3.1, the proposed RPF site is located on Lot 15 of the Discovery Ridge industrial park near the MU campus, and is currently an agricultural field. Existing noise sources in the area consist of agricultural equipment (e.g., tractors, forklifts), HVAC systems associated with existing buildings, and traffic noise from U.S. Highway 63 and the surrounding areas. The highest noise levels in the area originate from the intermittent operation of agricultural equipment associated with the MU School of Agriculture, and range from 80 to 100 dBA (Baker, 1997). When agricultural equipment is not running, noise levels are similar to that of a suburban community area, typically around 55 dBA (Berger et al., 2003).

Traffic-related noise sources include airports, railways, and highways. The Columbia Regional Airport is approximately 12 km (7.5 mi) from the proposed NWMI site, and the Columbia Terminal (COLT), a freight-only railway, is approximately 2.7 km (1.7 mi) from the proposed site (Terracon, 2006). Both the airport and railway are located a sufficient distance from the proposed RPF site to attenuate the noise associated with these locations to background levels. U.S. Highway 63 is approximately 0.4 km (0.25 mi) from the proposed site. Based on the most recent peak 1-hr traffic count summary from the Missouri Department of Transportation, the expected noise levels at the proposed RPF site resulting from traffic on U.S. Highway 63 range from 54 to 58 dBA (MoDOT, 2009).

Noise receptors include nearby residents, commercial workers at ABC Laboratories and RADIL, agricultural students and faculty present in the agricultural research areas, recreational users of the three sports venues in the area, site visitors, and domesticated and research wildlife.

19.3.2.3.2 Past Noise Studies

There are no known noise studies that have been performed in the audible range of the proposed RPF site.

19.3.2.3.3 Sound Level Standards

Permissible noise levels in Discovery Ridge are governed by both the *Discovery Ridge Master Plan and Protective Covenants* (MU, 2009) and the Columbia Code of Ordinances (City of Columbia, 2013d). Section 2.2 of the Covenants document specifies that buildings cannot be used for "excessive noise," and Section 3.3 requires that preliminary building plans specify the extent of noise that may be created by operation of the building (MU, 2009). Section 16-265 of the Ordinances states that site preparation and building construction cannot be performed outside the hours of 7:00 a.m. to 7:00 p.m. on weekdays and 9:00 a.m. to 5:00 p.m. on Saturdays without a special permit from the Director of Public Works. Sections 16-264 and 16-266 of the Ordinances prohibit the creation of "excessive noise" in connection with loading or unloading any vehicle, or in the vicinity of schools, hospitals, churches, and courts (City of Columbia, 2013d).

19.3.3 Geologic Environment

19.3.3.1 Regional Geology

This section provides summary descriptions of geomorphic provinces and their tectonic development. The glacial history responsible for surface topography features found today in Missouri is also described. The descriptions are based on a review of relevant, readily available published reports and maps and, where available, records and unpublished reports from Federal and State agencies. Information on the site conditions has been acquired from these same sources and from site-specific investigations, including geotechnical field studies.

19.3.3.1.1 Geomorphic Provinces

Missouri is divided into three geomorphic provinces:

- **Interior Plains Province** – Also referred to as the Central Lowland Province (northern Missouri, north of the Missouri River)
- **Interior Highlands** (central Missouri, south of the Missouri River)
- **Atlantic Plains** – Also referred to as the Coastal Plains Province (the "boot heel" or southeastern corner of Missouri)

The proposed RPF site is located north of the Missouri River within the Interior Plains Province. The Interior Plains are defined by the general texture of the surface terrain, rock type, and geologic structure. The province is characterized by moderately dissected, glaciated, flat-to-rolling plains that slope gently toward the Missouri and Mississippi River valleys. Local relief is 6.1–50.3 m (20–165 ft). Drainage is dendritic; current geomorphic processes are fluvial erosion, transport and deposition, and minor mass wasting. Elevations range from 183–457 m (600–1,500 ft) above mean sea level, with the proposed RPF site averaging 245 m (805 ft) above mean sea level (USGS, 2013a).

19.3.3.1.1.1 Interior Plains Province

The Interior Plains Province is a vast region spread across the stable core (craton) of North America. This area formed when several small continents collided and welded together over a billion years ago, during the Precambrian Era. Precambrian metamorphic and igneous rocks now form the basement of the Interior Plains and make up the stable core of North America. Throughout the Paleozoic and Mesozoic Eras, the low-lying Interior Plains remained relatively unaffected by mountain building and tectonic collisions in the western and eastern margins of the continent. During the Mesozoic Era, the majority of the North American continental interior was above sea level, with two notable exceptions. The first occurred during the Jurassic Era (208–144 million years ago), when rising seas flooded the low-lying areas of the continent, and most of the Interior Plains were eventually submerged beneath the shallow Sundance Sea. The second exception occurred during the Cretaceous Period, when record high sea levels flooded the continental interior with shallow seas. During this time, the Interior Plains continued to receive deposits from the eroding Rocky Mountains to the west and Appalachian and Ouachita-Ozark Mountains to the east and south throughout the most recent Cenozoic Era. The flatness of the Interior Plains is a reflection of the platform of mostly flat-lying marine and stream deposits laid down in the Mesozoic and Cenozoic Eras. The overlying sedimentary rocks are composed mostly of limestone, sandstone, and shales (USGS, 2013a).

19.3.3.1.1.2 Interior Highlands Province

The southern portion of Missouri, south of the Missouri River, is located within the Interior Highlands Province. The Interior Highlands includes the Ozark and Ouachita Mountains of southern Missouri, Arkansas, and eastern Oklahoma. The rocky outcrops that make up the core of the Interior Highlands are Paleozoic age carbonates and other sedimentary rocks that were originally deposited on the sea floor. In the Ouachita Mountains, these ancient marine rocks are now contorted by folds and faults. The ancient, eroded mountains of the Interior Highlands stand surrounded by nearly flat lying sedimentary rocks and deposits of the Interior and Atlantic Plains provinces.

The Interior Highlands consist of thick bedrock units of sandstone and shale, with lesser amounts of chert and novaculite (a fine-grained silica rock, like flint), deposited in a deep sea that covered the area from Late Cambrian through Early Pennsylvanian time. The area was then folded and faulted in such a manner that resistant beds of sandstone, chert, and novaculite now form long, sinuous mountain ridges that tower 152–457 m (500–1,500 ft) above adjacent valleys formed in easily eroded shale (USGS, 2013a).

19.3.3.1.1.3 Atlantic Plains Province

The Atlantic Plain Province is the flattest of all the provinces and stretches over 3,540 km (2,200 mi) from Cape Cod to the border of Mexico and southward another 1609 km (1,000 mi) to the Yucatan Peninsula. The Atlantic Plains slope gently seaward from the Interior Highlands in a series of terraces. The gentle sloping continues far into the Atlantic and Gulf of Mexico, forming the continental shelf.

Eroded sediments from the Interior Highlands were carried east and southward by streams and gradually covered the faulted continental margin, burying it under a wedge composed of layered sedimentary and volcanic debris thousands of feet thick. The sedimentary rock layers that lie beneath much of the coastal plain and fringing continental shelf remain nearly horizontal or tilt gently toward the sea (USGS, 2013b).

19.3.3.1.2 Glacial History

The MDNR describes the glacial history of the area as follows:

> *Recent studies of ice cores, stalagmites, and other temperature dating methods have concluded that there have been 30 sustained periods of frigid temperatures in the last 3 million years. Of the classical glacial periods, only two: pre-Illinoian (Nebraskan-Kansan) and Illinoian are now recognized as having left glacial deposits in the state of Missouri. The pre-Illinoian was the most severe. Amongst its legacy was the changing of the course of the Missouri River to its present location, the scouring and filling of Northern Missouri topography, and extensive outwash gravels left to the south of the present Missouri River. Although the Ozarks were not glaciated in the recent past, a cover of Pleistocene loess of varying thicknesses extends over all of the state except for the highest parts of the Ozark Mountains. Residuum, otherwise known as soil, clay, and rock fragments degrade from exposed and subsurface bedrock. Gravity and streams move this residuum, depositing it in sometimes graded layers* (MDNR, 2013b).

In Boone County, the glacial till averages over 43 m (140 ft) thick in the northeastern portion of the county, and the loess material reaches a maximum depth of 6.1 m (20 ft) along the Missouri River Bluffs (Boone County, 2013a).

19.3.3.1.3 Local Topography and Soils of Boone County

The topography of Boone County ranges from highly dissected hills to flat floodplains and nearly flat uplands. Elevations range from approximately 274 m (900 ft) above mean sea level along the northern boundary of Boone County to approximately 165 m (540 ft) above mean sea level in the southern tip of the county. Several areas of the county contain well-developed cave and sinkhole formations.

Ordovician to middle Pennsylvania age dolomite, limestone, sandstone, coal, and shale deposits are visible throughout Boone County in geologic outcrops and roadcuts. The Mississippian age Burlington Limestone is easily weathered by acidic groundwater and contains some unique natural resources of Boone County, including the most famous Devil's Ice Box cave system, located approximately 2.4 km (1.5 mi) southwest of the proposed RPF site. There are numerous caves in Boone County and 418 documented sinkholes (Boone County, 2013a).

Pennsylvanian age deposits are overlaid by glacial till and loess. The soils of Boone County are included in parts of two major land resource areas:

- **Central Claypan Area** – The Central Claypan Area soils were formed in glacial till and cover the northeastern and east-central portions of Boone County. Claypan soils display extreme variability within the soil profile and across the landscape; therefore, plant growth within these soils must contend with distinctively contrasting physical, chemical, and hydrologic properties at different soil depths. The depth to the claypan soils varies from approximately 10 cm (3.93 in.) on ridge tops up to 100 cm (39.4 in.) on back slopes. The soil horizons preceding the claypan are depleted of clay minerals, cations, and have a very low pH. The claypan horizon typically has an abrupt upper boundary with 100 percent more clay than the preceding horizon, and very low permeability.

- **Central Mississippi Valley Wooded Slopes** – This major land resource area consists of a dissected glacial till plain composed of rolling narrow ridge tops and hilly to steep ridge slopes. The small streams in this area have narrow valleys with steep gradients. The major rivers have nearly level broad floodplains, and the valley floors are tens of meters below the adjoining hilltops. Most of the soils within the central Mississippi Valley wooded slopes area are found in silty loess or glacial till, are moderately to fine-grained in texture with a mixed mineralogy, and are well-drained to moderately well-drained. These soils are typically observed on ridge tops and support forest flora (Boone County, 2013a).

19.3.3.2 Geology at the Proposed Site

The ROI for the geologic resource is defined as the 8 km (5 mi) radius surrounding the RPF site. The geologic units that underlie the proposed RPF site and/or properties within the ROI, from youngest to oldest, are as follows:

- Quaternary Age Holocene Series (Qal)
- Pennsylvanian Age Desmoinesian Series Marmaton Group (Pm)
- Pennsylvanian Age Desmoinesian Series Cherokee Group (Pc)
- Mississippian Age Osagean Series Burlington Formation (Mo)
- Mississippian Age Kinderhookian Series (Mk)
- Late to Early Devonian Age (D)
- Early Ordovician Age Ibexian Series (Ojc)

Figure 19-28 provides a map of the features within the ROI.

19.3.3.2.1 Quaternary Age Holocene Series (Qal)

The surface topography of the proposed RPF site and surrounding properties consists of Quaternary age bedrock overburden characterized by upland areas covered by a thin loess blanket and glacial drift. "Highly plastic clays that exhibit volume change with variations in moisture are commonly encountered near the ground surface" (Terracon, 2011b). The surface topography of the proposed RPF site and surrounding properties consists of upland areas covered by a thin loess blanket and glacial drift. Previous investigations of Discovery Ridge noted that "Highly plastic clays that exhibit volume change with variations in moisture are commonly encountered near the ground surface" (Terracon, 2011b).

Figure 19-29 depicts the Quaternary age bedrock overburden at the proposed RPF site as clay loam till (No. 27). Clay loam till is also depicted on all adjacent properties to the north, east, south, and west. Additional Quaternary age deposits located within an 8 km (5-mi) radius of the proposed RPF site include alluvium (No. 10), loess (No. 18), sandy clay (No. 40), and thin, cherty clay solution residuum (No. 41).

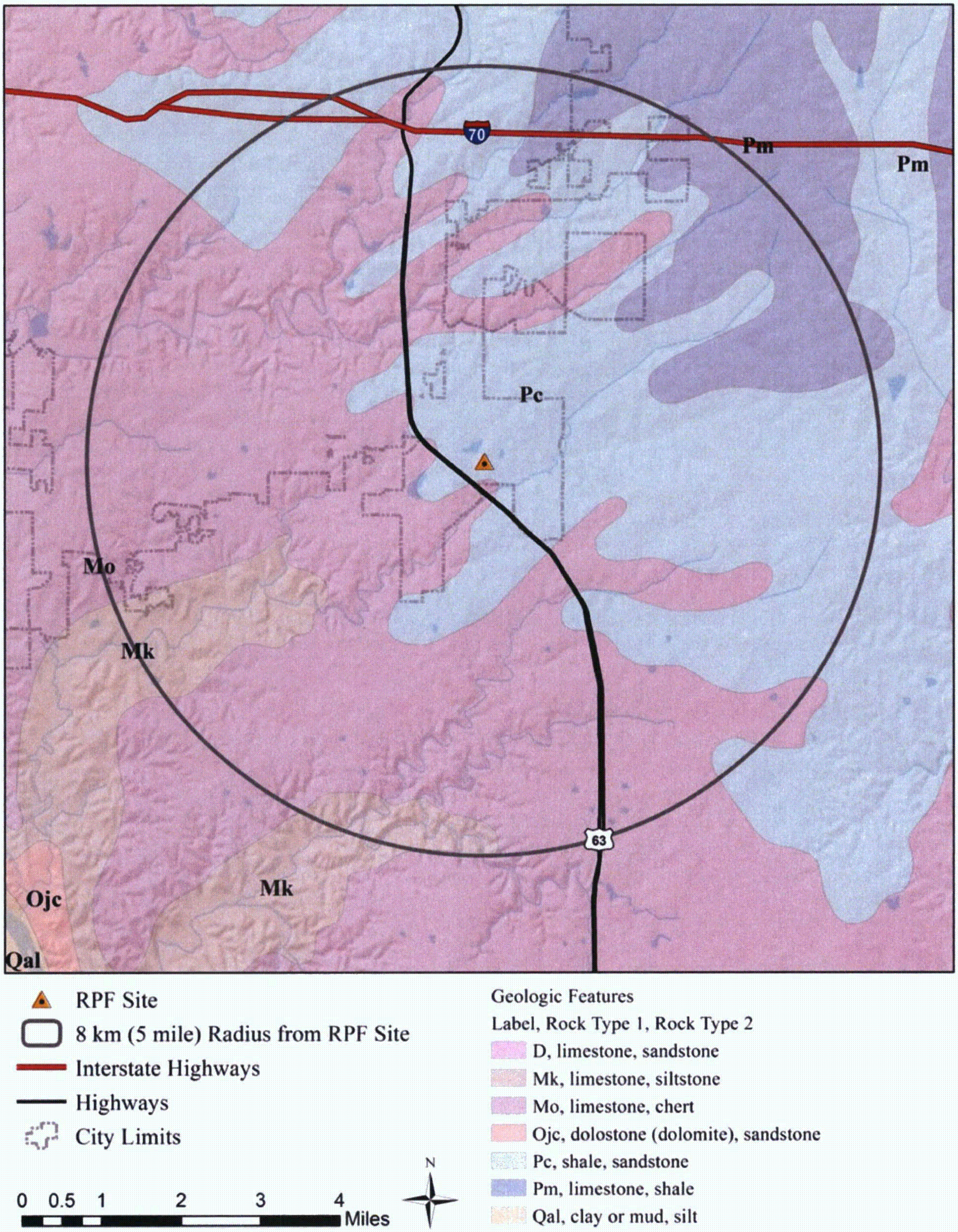
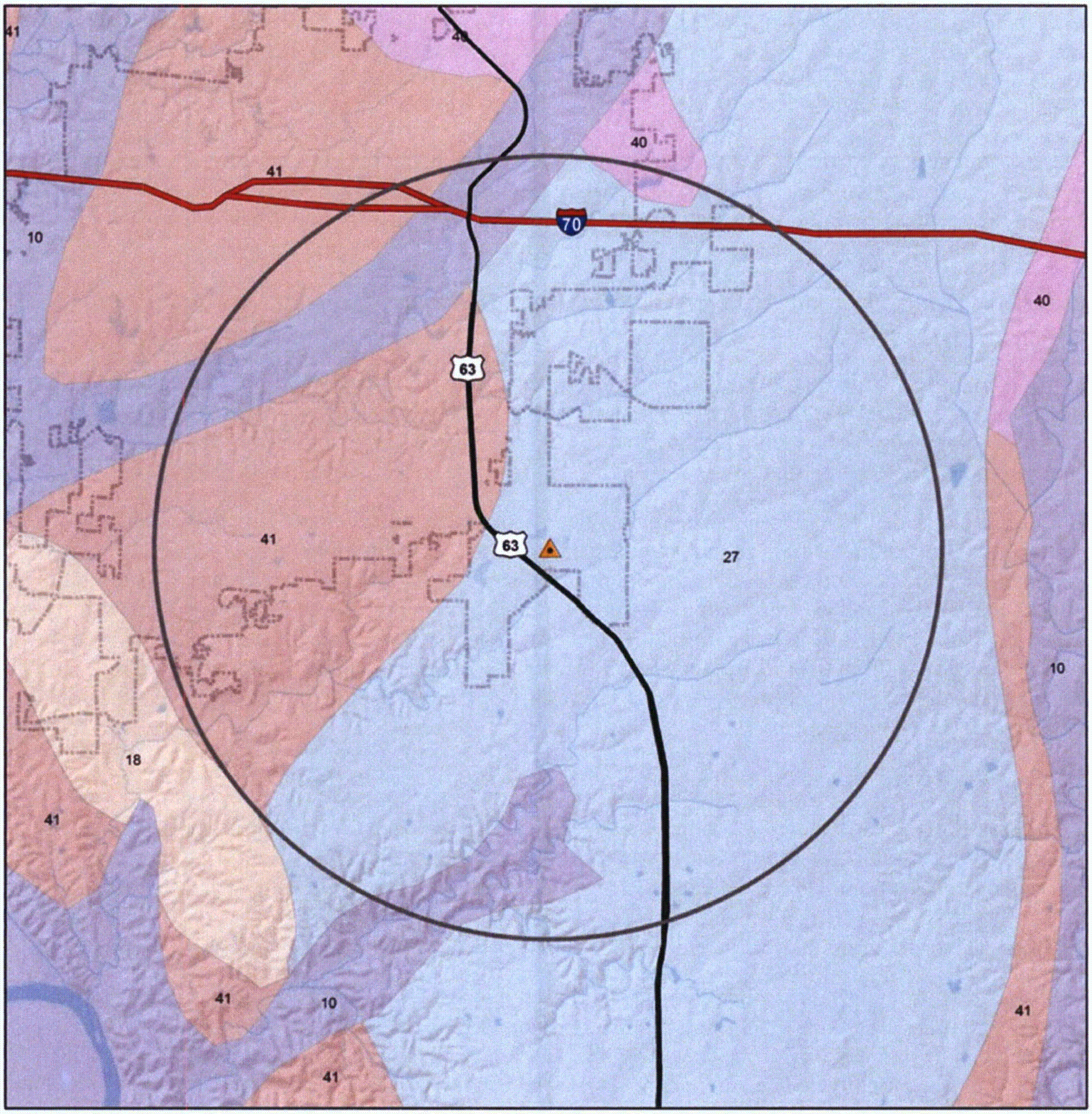


Figure 19-28. Geologic Features within an 8 km (5-mi) Radius of the Radioisotope Production Facility Site



RPF Site
8 km (5 mile) Radius from RPF Site
Highways
Interstate Highways
City Limits
0 0.5 1 2 3 4 Miles

Quaternary Geology of Missouri
DESCRIPTION
10 - Alluvium
27 - Clay loam till
18 - Loess
40 - Sandy clay
41 - Thin cherty clay solution residuum

USGS 1996. MO 1996 Quaternary Geology (SHP)
[digital data] ftp:msdis.missouri.edu/pub/Geological_Geophysical/MO_1996_Quaternary_Geology_shp.zip

Figure 19-29. Map of Missouri Quaternary Age Geology

The typical Quaternary age groundcover found in Boone County consists of alluvial (stream-deposited) clays, sand, and gravels (with a few poorly consolidated sandstones); glacial tills (sand and well-sorted gravels); and eolian (windblown) clays and loess (an extremely fine "rock flour," which forms solid masses) (MDNR, 2013c).

These glacial deposits mantle the upland areas and consist of a heterogeneous mixture of clay, sand, and pebbles of diverse rock types. The deposits vary greatly in thickness and are as much as 42.7 m (140 ft) thick in the northern portion of Boone County. This material is relatively impermeable and supplies very little water to wells (MU, 2006a).

19.3.3.2.2 Pennsylvanian Age Desmoinesian Series Marmaton Group (Pm) and Cherokee Group (Pc)

Pennsylvanian age strata (both Marmaton and Cherokee Groups) consists largely of clay and shale with minor accounts of coal and thin, impure limestone beds. The total thickness may be as much as 33.5 m (110 ft). These beds produce only small quantities of water and are not used in this area as a source of supply. The water found in this unit is usually high in iron and sulfur content (MU, 2006a).

Limestone and shale beds are generally thin and very widespread lateral units. Pennsylvanian deposits are quite extensive across Missouri, and they usually form thin to medium-bedded layers of distinctive composition, called cyclothems. A cyclothem results when a sea transgresses and regresses very rapidly along a coastal area, and in a repeating pattern. Often, this pattern consists of a sandstone (beach), silty shale or siltstone (tidal), freshwater limestone (lagoon), underclay (terrestrial), coal (terrestrial swampy forest), shale (near shore tidal), limestone (shallow marine), and black shale (deep marine). This sequence can then repeat itself as the sea first regresses from the land, and then transgresses again (MDNR, 2013c).

19.3.3.2.3 Mississippian Age Osagean Series Burlington Formation (Mo)

The Mississippian age Burlington Formation stratum is the most extensively studied Mississippian age strata in Missouri. This crystalline, extremely fossiliferous limestone covers most of the state and extends into Iowa and Arkansas. Typical characteristics include white-to-gray, medium-to-coarsely grained layers of chert nodules, and a coarse-grained sedimentary structure called "styolites" formed from pressure solution. The pores in the styolites are often filled with chert or quartz deposits (MDNR, 2013d).

Burlington limestone is the principle limestone exposed in quarries, creek banks, and road cuts near and around Columbia. The limestone is approximately 49 m (160 ft) thick in the Columbia area, but the thickness can be variable. The limestone may also contain minor amounts of pyrite and limonite. This formation has historically been economically important as a limestone resource where exposed and as host rock for lead and zinc deposits in the presently inactive Tri-State mining district of Missouri, Kansas, and Oklahoma (MU, 2006a).

Burlington limestone contains many relatively shallow drilled wells and yields sufficient quantities of relatively hard water for rural domestic supplies. The limestone is relatively soluble and contains many caverns and solutions passages. Solution features, including caves and sinkholes, are commonly present in this formation (MU, 2006a). Terracon reported the following:

> *No caves or sinkholes are known to exist, or are published to exist within approximately 1 mi of the Discovery Ridge Research Park. However, several areas of known karst activity are present west and southwest of this project area and are in various stages of development. Site grading and drainage may alter site conditions and could possibly cause sinkholes in areas that have no history of this activity.* (Terracon, 2011b)

19.3.3.2.4 Mississippian Age Kinderhookian Series Chouteau Limestone (Mk)

The Mississippian age Chouteau Limestone stratum is a very fine-grained carbonate and, for the most part, is an evenly bedded bluish gray limestone. The upper part is somewhat massive and high in magnesium. Chouteau limestone is relatively impermeable due to its fine texture, restricting the movement of water to joints and small fissures. This unit is a poor source of water but yields small quantities to a few wells (MU, 2006a).

19.3.3.2.5 Late to Early Devonian Limestone (D)

Devonian limestone strata deposits greatly vary in lithology, and range from very fine-grained to coarsely textured beds. Some of the beds are slightly sandy. In some areas of Columbia, Missouri, the Devonian limestone beds are approximately 9 m (30 ft) thick; in other well locations this limestone bed is completely absent. Devonian limestone is not a valuable water producer (MU, 2006a).

19.3.3.2.6 Early Ordovician Age Ibexian Series Dolomites (Ojc)

Ordovician age deposits found in the Columbia area include the following, from youngest to oldest (MU, 2006a):

- **St. Peter Sandstone** – This formation, which is a very important aquifer in eastern and northern Missouri, has no importance in the Columbia area. The formation is present only as localized masses in the depressions of older rocks.
- **Jefferson City Formation** – This predominantly dolomite formation averages approximately 122 m (400 ft) in thickness in the Columbia area, and wells drilled into the formation produce moderate quantities of relatively hard water. The formation probably has more rural domestic wells terminating in it than any other formation is this area.
- **Roubidoux Formation** – This formation consists of alternating sandstone and dolomite beds and averages approximately 30.5 m (100 ft) in thickness. This formation is a very dependable water producer.
- **Gasconade Formation** – This unit consists of mostly light-gray dolomite with sandstone (Gunter) at the base. The thickness is approximately 85.3 m (280 ft). This dolomite unit is very cavernous and contains many interconnected solution passages. The sandstone is approximately 4.6 m (15 ft) thick, is very permeable, has a wide aerial extent, and is a good source of water.

19.3.3.3 Site-Specific Volcanic Hazard Analysis

The proposed RPF site is located in a tectonically stable region of the North American continental plate, identified as the Interior Plains Province. Volcanoes tend to cluster along narrow mountainous belts, where folding and fracturing of the rocks provide channelways to the surface for the escape of magma. The lack of magma forming in the Interior Plains Province prevents the formation of volcanoes in the region.

19.3.3.4 Onsite Soil Types

The USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic database for Boone County (NRCS, 2014) lists the soil type beneath the proposed RPF site as the Mexico Silt Loam, 1-4 percent slopes (Map No. 50059). In addition to the Mexico silt loam, 27 other soils types are located within a 1.6 km (1-mi) radius of the proposed site, as depicted in Figure 19-30.

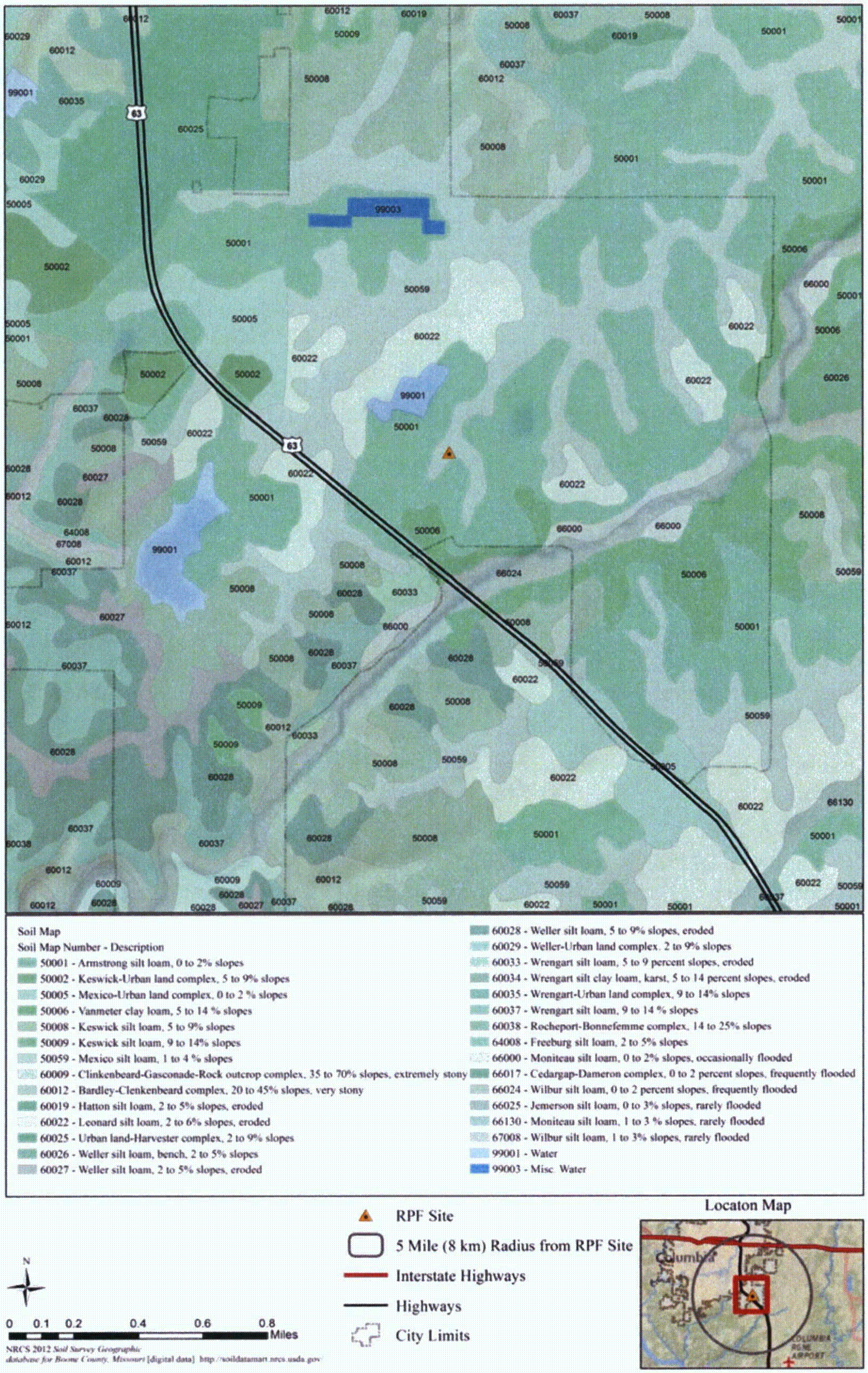


Figure 19-30. Soil Map within a 1.6 km (1-mi) Radius of the Proposed Radioisotope Production Facility Site

19.3.3.4.1 Site Soil Physical Characteristics

The soils were formed primarily from glacial processes that occurred in the region. Reworked loess is the primary parent material of the soil. The site soil composition, physical characteristics, and typical profile for the Mexico Silt Loam, 1–4 percent slopes (Map No. 50059) are listed in Table 19-28.

Table 19-28. Description of Soil Type, Mexico Silt Loam, 1–4 percent Slopes, Eroded

[a]Description	
Map Unit Setting *Landscape*: Till plains, uplands *Elevation*: 183 -396 m (600–1,300 ft) *Mean annual precipitation*: 94–119 cm (37-47 in.) *Mean annual air temperature*: 52–57°F *Frost-free period*: 184–228 days	**Map Unit Composition** *Mexico and similar soils*: 85% *Minor components*: 15%
Description of Mexico Setting *Landform*: Hillslopes, interfluves *Landform position (two-dimensional)*: Summit, backslope *Landform position (three-dimensional)*: Side slope, interfluve *Down-slope shape*: Concave, convex, linear *Across-slope shape*: Linear, convex *Parent material*: Loess over pedisediment	**Properties and qualities** *Slope*: 1–4% *Depth to restrictive feature*: More than 203 cm (80 in.) *Drainage class*: Poorly drained *Capacity of the most limiting layer to transmit water (Ksat)*: Very low to moderately low 0-0.15 cm/hr (0.00–0.06 in./hr) *Depth to water table*: Approximately 15.2 -45.7cm (6–18 in.) *Frequency of flooding*: None *Frequency of ponding*: None *Maximum salinity*: Nonsaline (0.0-2.0 mmho/cm) *Available water capacity*: High (approximately 27.4 cm [10.8 in.])
Typical profile *0 -17.8 cm (0–7 in)*: Silt loam *17.8 – 30.5 cm (7–12 in)*: Silty clay loam *30.5 – 66.4 cm (12–26 in)*: Silty clay *66.4 – 86.4 cm (26–34 in)*: Silty clay loam *86.4 – 203 cm (34–80 in)*: Silty clay loam	**Minor Components** **Leonard** *Percent of map unit*: 5% *Landform*: Hills *Landform position (two-dimensional)*: Shoulder *Landform position (three-dimensional)*: Head slope *Down-slope shape*: Concave *Across-slope shape*: Concave *Ecological site*: Mollic loess upland prairie (R113XY002MO) *Other vegetative classification*: Mixed/transitional (mixed native vegetation)
Armstrong *Percent of map unit*: 5% *Landform*: Hills *Landform position (two-dimensional)*: Backslope *Landform position (three-dimensional)*: Side slope *Down-slope shape*: Convex *Across-slope shape*: Convex *Other vegetative classification*: Mixed/transitional (mixed native vegetation)	**Mexico, severely eroded** *Percent of map unit*: 5% *Landform*: Hills *Landform position (two-dimensional)*: Backslope, shoulder *Landform position (three-dimensional)*: Side slope *Down-slope shape*: Linear *Across-slope shape*: Concave, convex

[a] Source: USDA, 2013a, "Web Soil Survey," Online Mapping Tool, websoilsurvey.nrcs.usda.gov, U.S. Department of Agriculture, Washington, D.C., accessed July 10, 2013.

19.3.3.4.2 Site Soil Chemical Characteristics

The site soil chemical characteristics of the Mexico Silt Loam, 1–4 percent slopes (Map No. 50059) and the definitions of each chemical characteristic are listed in Table 19-29.

Table 19-29. Site Soil Chemical Characteristics for Boone County, Missouri

Map unit and soil name	Depth		Cation-exchange capacity (mEq/100 g)	Effective cation-exchange capacity (mEq/100 g)	Soil reaction (pH)	Calcium carbonate (%)	Gypsum (%)	Salinity (mmho/cm)	Sodium adsorption ratio
	cm	in.							
50059 Mexico Silt Loam, 1–4% slopes	0–17.8	0–7	11–24	9.1–20	5.6–7.3	0	0	0.0–2.0	0
	17.8–30.5	7–12	14–20	12–18	5.2–7.1	0	0	0.0–2.0	0
	30.5–66.4	12–26	22–38	17–30	4.5–5.2	0	0	0.0–2.0	0
	66.4–86.4	26–34	21–36	21–28	4.7–6.8	0	0	0.0–2.0	0
	86.4–203	34–80	20–29	16–23	4.9–7.1	0	0	0.0–2.0	0

Source: NRCS, 2014, "Soil Data Mart," soildatamart.nrcs.usda.gov/ReportViewer.aspx?File=a27391c0-b6ab-4278-871f-6f091cc147fa.PDF&Name= Chemical_Soil_Properties&Wait=1, Natural Resources Conservation Service, Washington, D.C., accessed July 16, 2013.

19.3.3.5 Prime Farmland

Prime farmland, as defined by the USDA, is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. Prime farmland can be cultivated land, pastureland, forestland, or other land, but is not urban or built-up land or water areas. The soil qualities, growing season, and moisture supply are those needed for the soil to economically produce sustained high yields of crops when properly managed, including management of water and applying acceptable farming methods (NRCS, 2013).

In general, prime farmland has an adequate and dependable supply of moisture from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, an acceptable salt and sodium content, and few or no rocks. The land is permeable to water and air. Prime land is not excessively erodible or saturated with water for long periods, and is either not frequently flooded during the growing season or is protected from flooding. Areas of prime farmland in Missouri that do not require draining or flooding protection are comprised largely of Weller silt loam, Jemerson silt loam, and Lenzburg silty clay loam.

Farmland that is considered of statewide importance is land, in addition to prime farmlands, that is of statewide importance for the production of food, feed, fiber, forage, and oilseed crops. Criteria for defining and delineating this land are to be determined by the appropriate State agency or agencies. Generally, additional farmlands of statewide importance include those that are nearly prime farmland and that economically produce high yields of crops when treated and managed according to acceptable farming methods. Some may produce as high a yield as prime farmlands if conditions are favorable. In some states, additional farmlands of statewide importance may include tracts of land that have been designated for agriculture by State law. Farmlands of statewide importance in Missouri primarily include the Weller silt loam, Weller–Urban land complex, Wrengart silty clay loam, and Hatton silt loam (NRCS, 2013). Of these, the predominant soil type found in both prime farmland and farmlands of statewide importance is Weller silt loam. Approximately 4218 ha (10,424 acres), or one-fifth of the 8 km (5-mi) ROI, are prime or important farmland (NRCS, 2013). The proposed RPF site and the research park lie in areas not listed as prime farmland (Figure 19-31).

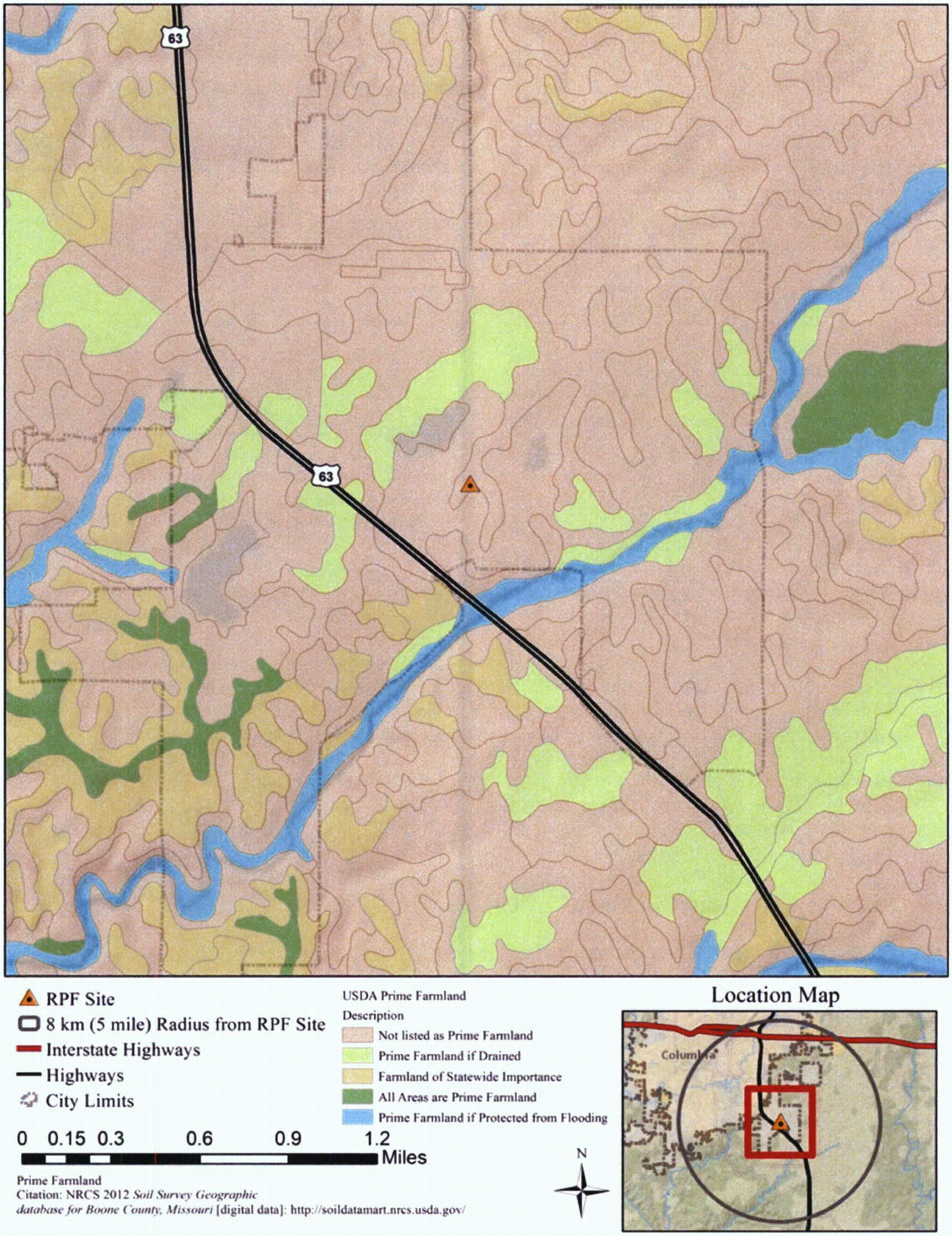


Figure 19-31. Map Showing U.S. Department of Agriculture Prime Farmland

Table 19-30 shows the breakdown of prime farmland and farmland of statewide importance within the ROI.

Table 19-30. Prime Farmland and Farmland of Statewide Importance

Description	Total	
	Acres	Hectares
Not listed as prime farmland	2,305	933
Prime farmland if drained	8,743	3,538
Farmland of statewide importance	9,102	3,683
All areas are prime farmland	1,322	535
Prime farmland if protected from flooding	2,793	1,130
Total	**24,265**	**9819**

Source: NRCS, 2013, "National Soil Survey Handbook," soils.usda.gov/technical/handbook/contents/part622.html, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, D.C., accessed July 25, 2013.

19.3.3.6 Shrink-Swell Potential

There are moderate to highly plastic clays at Discovery Ridge from approximately 0.9–3.7 m (3–12 ft) below ground surface (Terracon, 2011b). Such soils are commonly referred to as "expansive" or "swelling" soils because they expand or swell as their moisture content increases. These soils, in turn, contract or shrink as their moisture content decreases. Footings, floor slabs, and pavements supported on expansive soils will often shift upward or downward causing possible distortion, cracking, or structural damage (Terracon, 2011b).

19.3.3.7 Erosion

Erosion is a naturally occurring process that is unnaturally accelerated by land development. The highest risks for erosion occur in areas with fine soils, on steep slopes, and in areas undergoing active construction activities. Impervious surfaces do not allow water infiltration into the soils and instead cause increased stormwater runoff.

Soils denuded of vegetation and impervious surfaces are two potential effects of land development that contribute to greater peak flows, longer duration of high flows, and increased sedimentation. Eroded material is often deposited downstream where the material decreases culvert and channel capacity.

The soils beneath the proposed RPF site are Mexico silt loam and are listed as hydrologic soil Group D (NRCS, 2014). Group D soils have a very slow infiltration rate when thoroughly wet, leading to high runoff potential. Mexico Silt Loam consists chiefly of clays that have a high shrink-swell potential and have a high water table (NRCS, 2013).

19.3.3.8 Previous Geological Studies by Others

19.3.3.8.1 Preliminary Geotechnical Investigation

In 2011, Terracon completed a preliminary geotechnical investigation for the Discovery Ridge Certified Site Program, which included Lot 2 and Lots 5 through 18 of Discovery Ridge (Terracon, 2011b). The proposed RPF site (Lot 15) is within the investigation area. The purpose of the investigation was to provide preliminary geotechnical recommendations concerning earthwork and the design and construction of foundations, floor slabs, and pavements for Discovery Ridge properties. As part of the study, nine soil borings (B-1 through B-9) were installed to depths ranging from 4–6 m (13–20 ft) below ground surface to determine shallow subsurface soil geotechnical properties and shallow groundwater depth. Soil boring B-5 is nearest to the proposed RPF site, along the eastern boundary between Lots 14 and 15.

Discovery Ridge surface soils from 0.6–0.15 m (0.2–0.5 ft) below ground surface were found to be brown, friable topsoil with significant amounts of organic matter. Subsurface soils from approximately 0.9-3.6 m (3–12 ft) below ground surface were lean clay, lean-to-fat clay, and fat clay with moderate-to-high plasticity. Material beneath 3.6 m (12 ft) is listed only as limestone. Plasticity and liquid limit tests were completed for soils encountered from only four soil borings, as shown in Table 19-31.

Table 19-31. Plasticity and Liquid Limit Testing

Soil boring	Depth		Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
	(m below ground surface)	(ft below ground surface)			
B-1	0.9-1.5	3–5	43	15	28
B-3	0.3-0.9	1–3	41	16	25
B-5	0.3-0.9	1–3	31	21	10
B-9	0.3-0.9	1–3	44	21	23

Source: Terracon, 2011b, *Preliminary Geotechnical Engineering Report Discovery Ridge–Certified Site Program Lots 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18*, Terracon Consultants, Inc., prepared for University of Missouri and Trabue, Hansen & Hinshaw, Inc., Terracon Project No. 09105094.1, February 11, 2011.

At the time of drilling, some of the soils displayed moisture levels greater their measured plastic limits. "Soils with moisture levels above their measured plastic limits may be prone to rutting and can develop unstable subgrade conditions during general construction operations" (Terracon, 2011b). Moderate to high plasticity clays were observed at the site. Such soils are commonly referred to as "expansive" or "swelling" soils because they expand or swell as their moisture content increases. These soils in turn, contract or shrink as the moisture content decreases. Footings, floor slabs, and pavements supported on expansive soils often shift upward or downward causing possible distortion, cracking, or structural damage.

19.3.3.9 Regional and Local Tectonics

The most significant seismological feature in Missouri is the New Madrid Seismic Zone (NMSZ), located in the southeastern corner of the state and extending into parts of the contiguous states of Arkansas, Tennessee, Kentucky, and Illinois. The NMSZ is the most seismically active region in the U.S. east of the Rocky Mountains and is located approximately 483 km (300 mi) southeast of the proposed RPF site. During the winter of 1811–1812, the NMSZ was the location of some of the highest intensity seismic events ever noted in U.S. history. Hundreds of aftershocks, some severely damaging, continued for years.

Records show that since 1900, moderately damaging earthquakes have struck the NMSZ every few decades. Prehistoric earthquakes similar in size to those of 1811–1812 occurred in the middle 1400s and around 900 A.D. Strongly damaging earthquakes struck the southwestern end of the NMSZ near Marked Tree, Arkansas, in 1843 (magnitude 6.0), and the northeastern end near Charleston, Missouri, in 1895 (magnitude 6.6) (USGS, 2011a).

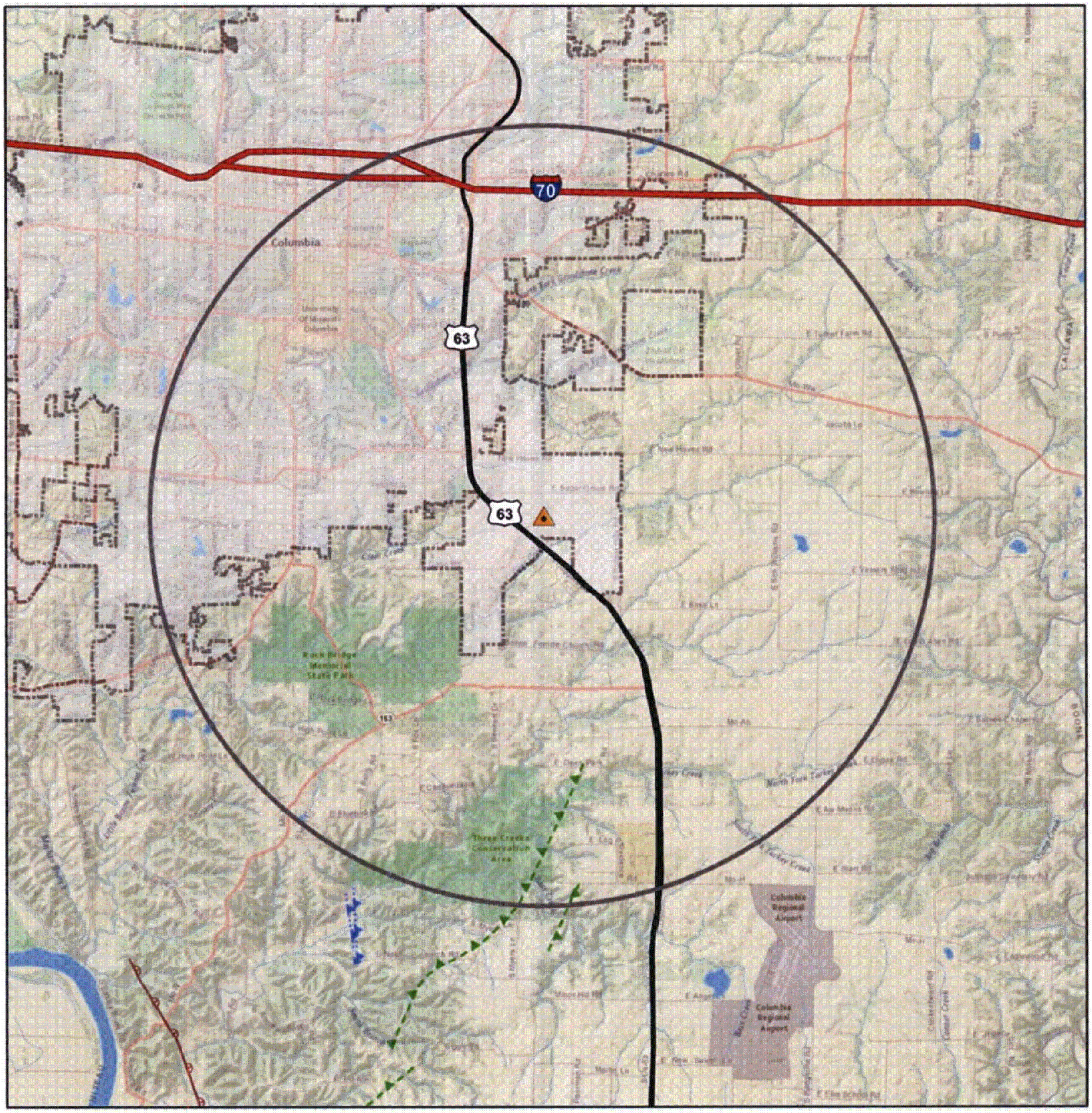
The NMSZ is made up of reactivated faults that formed when what is now North America began to split or rift apart approximately 500 million years ago. The resulting rift system died out before an ocean basin was formed, but a deep zone of weakness was created, referred to as the Reelfoot rift (USGS, 2011b). This fault system extends 241 km (150 mi) southward from Cairo, Illinois, through New Madrid and Caruthersville, Missouri, down through Blytheville, Arkansas, to Marked Tree, Arkansas. The Reelfoot rift dips into Kentucky near Fulton and into Tennessee near Reelfoot Lake, extending southeast into Dyersburg, Tennessee. The rift then crosses five state lines and crosses the Mississippi River in at least three places. The fault system is buried beneath as much as 8 km (5 mi) of sediment for much of the fault length and typically cannot be seen at the surface (USGS, 2011b).

Four of the largest faults are recognized as alignments of abundant small earthquakes, and movements along two of these faults dammed rivers and created lakes during the earthquakes of 1811–1812. A few more deeply buried faults were detected during oil and gas exploration, and a few small faults are known from geologic mapping (USGS, 2011b).

The remainder of the state, including the proposed RPF site located in central Missouri, is typical of the stable midcontinent U.S. However, this area is not immune to seismic activity.

19.3.3.9.1 Local Fault Zones

There is one major fault zone located within the ROI of the proposed RPF site (Figure 19-32). The Fox Hallow Fault is located approximately 5.6 km (3.5 mi) southeast of the site. The Fox Hollow Fault is a small fault, striking northeast and fades into a monocline at its two ends. The fault is reportedly a normal fault with a throw of approximately 37 m (120 ft) down to the southwest, and shows Mississippian age Chouteau limestone beds faulted against Ordovician age Jefferson Dolomite (Union Electric Company, 2008).



- RPF Site
- 8 km (5 mile) Radius from RPF Site
- Interstate Highways
- Highways
- City Limits

0 0.5 1 2 3 4 Miles

Fault Structures

NAME

- Bonne Femme Creek graben
- Fox Hollow fault and monocline
- Sapp monocline

MoDNR 2010. MO 2010 Tectonic Fault Structures (SHP)
MoDNR/DGLS/GSP [digital data]: ftp://msdis.missouri.edu/pub/
Geological_Geophysical/MO_2010_Tetonic_Fault_Structures_shp-.zip

Figure 19-32. Geologic Faults Map

19.3.3.10 Seismic Hazard Assessment

Earthquakes occur on faults within bedrock, usually several miles deep. According to the USGS, earthquakes in the central and eastern U.S. typically are felt over a much broader region than in the western U.S. East of the Rocky Mountains, an earthquake can be felt over an area ten times larger than a similar magnitude earthquake on the west coast.

The written record of earthquakes in Missouri prior to the nineteenth century is virtually nonexistent. Historical earthquakes along the NMSZ in southeastern Missouri have been some of the largest in U.S. history since European settlement. The Great New Madrid Earthquake of 1811–1812 was a series of over 2,000 earthquakes that caused destruction over a very large area. According to information from Missouri's State Emergency Management Agency Earthquake Program, some of the earthquakes measure at least 7.6 in magnitude and five of them measured 8.0 or greater (USGS, 2011a). The 1811–1812 series changed the course of the Missouri River, and some shocks were felt as far away as Washington, D.C., and Boston, Massachusetts (MMRPC, 2010). The NMSZ has experienced numerous earthquakes since the 1811–1812 series, and at least 35 aftershocks of Modified Mercalli Intensity (MMI) of V (i.e., felt by nearly everyone, many awakened) or greater that have been recorded Missouri since 1811. Numerous earthquakes originating outside of Missouri boundaries have also affected the state. Table 19-32 lists the historical earthquakes that have affected Missouri.

Table 19-32. Recorded Missouri Earthquake History (3 pages)

Date	Location	Magnitude	Recorded damage
12/16/1811 (1811–1812 series)	New Madrid Region, Missouri	7.7	Generated great waves on the Mississippi River causing major flooding, high river back cave-ins. Topographic changes affected an area of 78,000 to 130,000 km^2 (30,116 to 50,193 mi^2). Later geologic evidence indicated that the epicenter was likely in northeast Arkansas. The main shocks were felt over an area covering at least 5,180,000 km^2 (2,000,000 mi^2). Chimneys were knocked down in Cincinnati, Ohio, and bricks were reported to have fallen from chimneys in Georgia and South Carolina. The first shock was felt distinctively in Washington, D.C., 1,127 km (700 mi) away.
12/23/1812 (1811–1812 series)	New Madrid, Missouri	7.5	Second major shock more violent than the first.
2/7/1812 (1811–1812 series)	New Madrid, Missouri	7.7	Three main shocks reaching MMI of XII, the maximum on scale. Aftershocks continued to be felt for several years after the initial tremor. Historical accounts and later evidence indicate that the epicenter was close to the town of New Madrid, Missouri. This quake produced the largest liquefactions fields in the world.
1/4/1843	New Madrid, Missouri	Not listed	Cracked chimneys and walls in Memphis, Tennessee, and reportedly collapsed one building. The earth sank in some places near the town of New Madrid, Missouri, and an unverified report indicated that two hunters were drowned during the formation of a lake. The total felt area included at least 1,036,000 km^2 (400,000 mi^2).

Table 19-32. Recorded Missouri Earthquake History (3 pages)

Date	Location	Magnitude	Recorded damage
4/24/1867	Eastern Kansas	Not listed	Reports indicated that an earthquake occurred in eastern Kansas and was felt as far eastward as Chicago, Illinois. The earthquake may have been noticeable in Columbia.
8/31/1886	Charleston, South Carolina	Not listed	An MMI of II earthquake recorded in St. Louis, Missouri, and was felt as far westward as Columbia. There were no reports of structural damage.
10/31/1895	Charleston, Missouri	6.6	Largest earthquake to occur in the central Mississippi River valley since the 1811–1812 series. Structural damage and liquefaction phenomena were reported along a line from Bertrand, Missouri, in the west to Cairo, Illinois, to the east. Sand blows were observed in an area southwest of Charleston, Puxico, and Taylor, Missouri; Alton, and Cario, Illinois; Princeton, Indiana; and Paducah, Kentucky. The earthquake caused extensive damage (including downed chimneys, cracked walls, shattered windows, and broken plaster) to schools, churches, and private residences. Every building in the commercial area of Charleston was damaged. Cairo, Illinois, and Memphis, Tennessee, suffered significant damage. Near Charleston, 1.6 ha (4 acres) of ground sank and a lake formed. The shock was felt over all or portions of 24 states and in Canada. Ground shaking was recorded along the Ohio River Valley.
1903	New Madrid, Missouri	5.1	No information given.
4/9/1917	St. Genevieve/ St. Mary's Area, Missouri	Not listed	A sharp disturbance at St. Genevieve and St. Mary's, Missouri. According to the Daily Missourian, No. 187, dated April 9, 1917, the earthquake was not felt in Columbia. However, on the following day, several people reported feeling the shock and attributed it to an explosion. No damage was reported in Columbia. Reportedly felt over a 518,000 km^2 (200,000 mi^2) area from Kansas to Ohio and Wisconsin to Mississippi.
5/1/1920	Missouri or Illinois	Not listed	This earthquake reportedly shook buildings across St. Louis. Two shocks were felt in Mt. Vernon, Illinois, and three were felt in Centralia, Illinois. The epicenter of this earthquake is unknown and is thought to have originated east of Columbia in Illinois. In the Evening Missourian, No. 207, dated May 1, 1920, the U.S. Weather Bureau reported that the shock was not felt in Columbia. However, in a later investigation a few people reported feeling a slight tremor.
8/19/1934	Rodney, Missouri	Listed as strong	At nearby Charleston, windows were broken and chimneys collapsed or were damaged. Similar effects were observed in Cairo, Mounds, and Mounds City, Illinois, and at Wickliffe, Kentucky. The area of destructive intensity included more than 596 km^2 (230 mi^2)

Table 19-32. Recorded Missouri Earthquake History (3 pages)

Date	Location	Magnitude	Recorded damage
11/23/1939	Western Illinois	Not listed	An earthquake occurred near Red Bud, Illinois, and a reported MMI of II was recorded in Columbia, Missouri. The approximately distance from the epicenter to Columbia was 213 km (132 mi).
3/3/1963	Near Menorkanut, Missouri	Not listed	MMI of III was recorded in Columbia. The approximately distance from the epicenter to Columbia was 317 km (197 mi).
10/21/1965	Eastern Missouri	Not listed	MMI of V in Columbia. The approximate distance from the epicenter to Columbia was 163 km) (101 mi).
11/9/1968	Wabash Valley Seismic Zone, southern Illinois	5.4	Strongest magnitude in central U.S. since the 1895 earthquake. Moderate damage to chimneys and walls at Hermann, St. Charles, St. Louis, and Sikeston, Missouri. Shaking was felt. Areas include all or portions of 23 states from Minnesota to Georgia and from Pennsylvania to Kansas, and in multi-story buildings in Boston, Massachusetts and southernmost Ontario, Canada.
1987	Wabash Valley Seismic Zone, near Olney, Richland County, SE Illinois	5.0	Chimneys and bricks fell, underground pipes were damaged, and sidewalks and streets cracked in at least four cities in Illinois, Indiana, and Kentucky. Shaking was felt in 17 states, from Pennsylvania to Kansas and from Alabama to Minnesota and southernmost Ontario, Canada.
2002	Wabash Valley Seismic Zone, Posey County, SW Indiana	4.6	Moderate earthquake caused chimney damage and cracked windows in and near Evansville, Indiana. Shaking was reported in seven states, including Missouri.

Sources:

USGS, 2013c, "Three Centuries of Earthquakes Poster," pubs.usgs.gov/imap/i-2812/i-2812.jpg, U.S. Geological Survey, Reston, Virginia, accessed July 23, 2013.

USGS, 2002, "Earthquakes in the Central United States 1699 -2002," pubs.usgs.gov/imap/i-2812/i-2812.jpg, U.S. Geological Survey, Reston, Virginia, June 18, 2002.

MU, 2006a, *Missouri University Research Reactor (MURR) Safety Analysis Report*, MU Project# 000763, University of Missouri, Columbia, Missouri, August 18, 2006.

MMI = Modified Mercalli Intensity.

In 2002, the USGS released the following projected hazards for Boone County, if an earthquake occurred along the NMSZ in the following 50 years (USGS, 2003):

- 25 to 40 percent chance of a magnitude 6.0 and greater earthquake
- 7 to 10 percent chance of a magnitude 7.5–8.0 earthquake

According to the USGS, Boone County is one of the 47 counties in Missouri that would be severely impacted by a 7.6 magnitude earthquake with an epicenter on or near the NMSZ.

According to the *Boone County Hazard Mitigation Plan* for 2010 (MMRPC, 2010), the Missouri State Emergency Management Agency has made projections of the highest earthquake intensities that would be experienced throughout Missouri if various magnitude earthquakes occur along the NMSZ (Figure 19-33), as measured by the MMI scale.

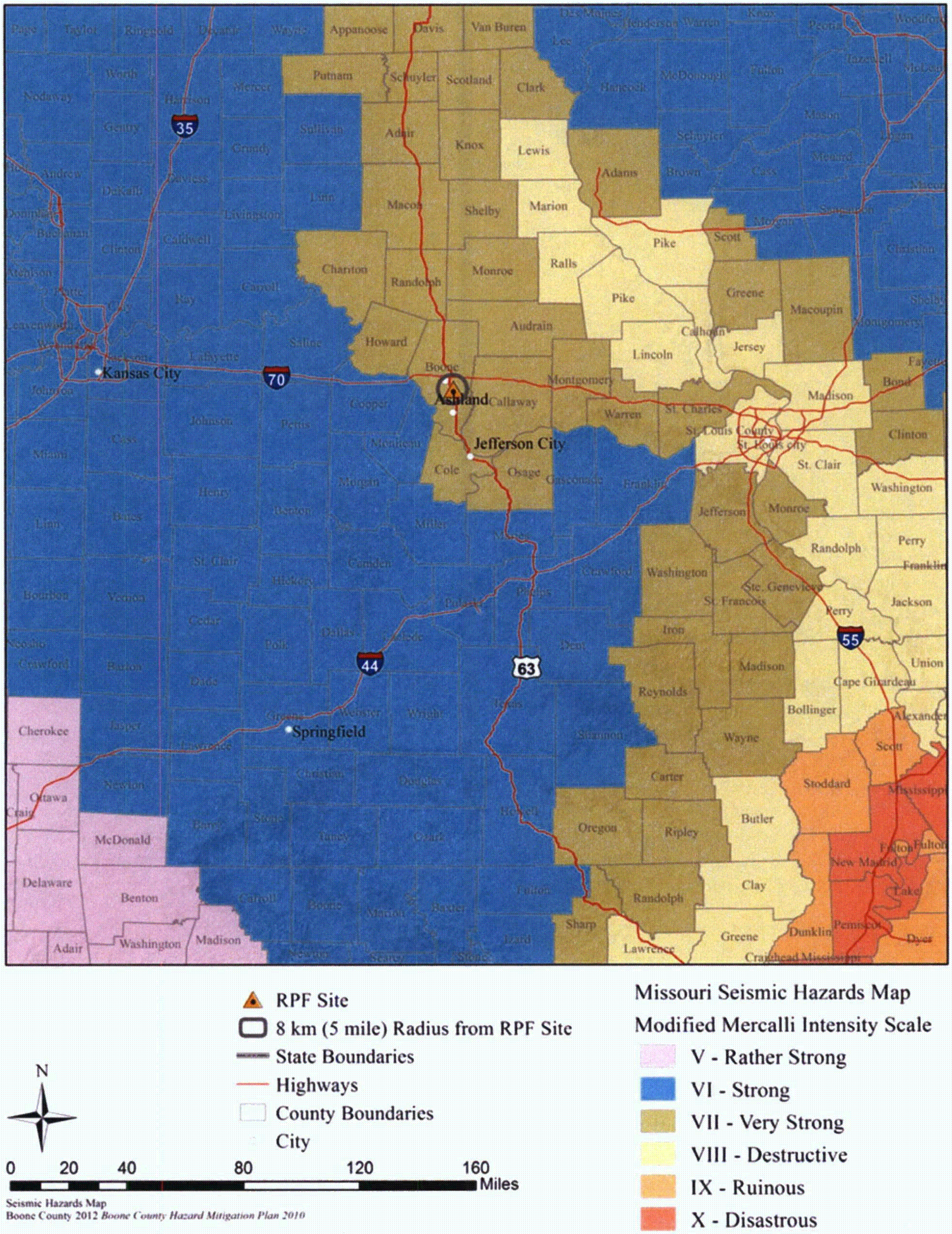


Figure 19-33. Hazard Mitigation Map

The pertinent earthquake hazard information for Boone County is summarized in Table 19-33.

Table 19-33. Projected Earthquake Hazards for Boone County

Magnitude at NMSZ	Probability of occurrence (2002–2052)	Intensity in Boone County (MMI)	Expected damage
6.7	25–40%	VI, strong	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books fall off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.
7.6	7–10%	VII, very strong	Difficult to stand; significant damage to poorly or badly designed buildings, adobe houses, old walls, spires, and other; damage would be slight to moderate in well-built buildings; numerous broken windows; weak chimneys break at roof lines; cornices from towers and high buildings fall; loose bricks fall from buildings; heavy furniture is overturned and damaged; and some sand and gravel streambanks cave in.

Source: MMRPC, 2010, *Boone County Hazard Mitigation Plan*, www.mmrpc.org/the-region/boone-county, Mid-Missouri Regional Planning Commission, State of Missouri Emergency Management Agency, Ashland, Missouri, July 15, 2010.

MMI = Modified Mercalli Intensity.
NMSZ = New Madrid Seismic Zone.

The USGS National Seismic Hazard Maps display earthquake ground motions for various probability levels across the U.S. and are applied in seismic provisions of building codes, insurance rate structures, risk assessments, and other public policy. Updates to these maps incorporate new findings on earthquake ground shaking, faults, seismicity, and geodesy. The resulting maps are derived from seismic hazard curves calculated on a grid of sites across the U.S. that describe the frequency of exceeding a set of ground motions. In accordance with the 2008 USGS Scientific Investigation Map (No. 3195), the proposed RPF site is within the third lowest earthquake hazard area with peak acceleration potentials of 2–3 (USGS, 2008). This category indicates an estimated horizontal ground shaking level between 8-in-100 to 16-in-100 chance of being exceeded in a 50-year period.

According to the *Boone County Hazard Mitigation Plan* for 2010 (MMRPC, 2010), the entire county is at risk for effects of an earthquake along the NMSZ. Areas near the Missouri River could be particularly vulnerable due to the soil or alluvium along river channels being susceptible to liquefaction from amplification waves (MMRPC, 2010).

19.3.3.11 Other Geologic Hazards

Tectonic uplift and subsidence, ground-shaking amplification, landslides, and liquefaction are four specific hazards associated with earthquakes. The severity of these hazards depends on several factors, including soil and slope conditions, proximity to the fault, earthquake magnitude, and the type of the earthquake. Other geological hazards present in karst environments (i.e., Boone County) and prevalent in Missouri include caves and sinkholes.

19.3.3.12 Tectonic Uplift and Subsidence

Faulting due to compressive forces elevates rocks of the up-thrown side of the fault, while the down-thrown side of the fault undergoes tilting and subsidence. A regional example of this is the Ozark Plateau.

19.3.3.13 Earthquake Ground-Shaking Amplification

Earthquakes generate seismic waves at a wide variety of frequencies, and certain frequencies may be amplified by site-specific soil conditions. Soils and soft sedimentary rocks near the surface can modify bedrock ground shaking caused by an earthquake. This modification can increase (or decrease) the strength of shaking or change the frequency of the shaking. The nature of the modification is determined by the thickness of the geologic materials and their physical properties (e.g., stiffness).

Areas with thin sedimentary deposits experience less severe amplification than areas with thick deposits. In areas with thick sedimentary deposits, low frequency seismic energy is amplified, yielding slow, rolling-type shaking that can damage tall buildings, bridges, and overpasses. Areas with thin sand and gravel layers deposited on top of bedrock amplify high-frequency seismic waves that yield intense ground vibrations causing more damage to shorter buildings (USGS, 2011b).

Lateral spreading can occur during periods of extended seismic ground shaking. This is commonly seen in areas with saturated soils near bays or rivers. During the 1811–1812 New Madrid series of earthquakes, lateral spreading produced extensive ground deformation along the banks of the Mississippi River (USGS, 2009).

19.3.3.14 Earthquake-Induced Landslides

Earthquake-induced landslides are secondary hazards that occur from ground shaking, primarily in areas with steep slopes. Not all earthquake-induced landslides occur in the first few minutes following an earthquake, some can occur days later. A landslide occurs when the force that is pulling the slope downward exceeds the strength of the earth materials that compose the slope.

Large areas between the Missouri and Mississippi Rivers are blanketed by Pleistocene loess and glacial drift. Particularly susceptible to slumps and earth flows are loess along major river valleys and their tributaries, clayey till on slopes underlain by shale, and some Pennsylvanian shale units in southwestern Iowa, northwestern Missouri, and eastern Oklahoma.

The 1811–1812 earthquakes caused many types of ground failures, including landslides along the Mississippi River bluffs from Mississippi to Kentucky (USGS, 2009).

19.3.3.15 Liquefaction

Liquefaction is a process by which water-saturated sediment temporarily loses strength and acts as a fluid when exposed to strong seismic shaking. The shaking causes the grains to lose grain-to-grain contact, so the sediment tends to flow. Liquefaction most likely occurs in loose sandy soil with a shallow water table (which is common for areas around floodplains or bays). Liquefaction often leads to overpressured fluids that can erupt to the surface, forming features known as sand blows. The 1811–1812 earthquakes caused ground subsidence by soil liquefaction across the Mississippi River flood plain and along tributaries to the Mississippi River over at least 15,000 square kilometers (km^2) (9,320.6 square miles [mi^2]). Liquefaction along the Mississippi River Valley during the 1811–1812 earthquakes created one of the world's largest sand-blown fields. According to the USGS, recent sand blows dot the landscape surrounding New Madrid, Missouri (USGS, 2011b).

19.3.3.16 Caves and Sinkholes

In the U.S., the most damage in areas composed of karst terrain tend to occur in the states of Florida, Texas, Alabama, Missouri, Kentucky, Tennessee, and Pennsylvania. Karst, as defined by the USGS, "is a terrain with distinctive landforms and hydrology created from the dissolution of soluble rocks, principally limestone and dolomite. Karst terrain is characterized by springs, caves, sinkholes, and a unique hydrogeology that results in aquifers that are highly productive but extremely vulnerable to contamination" (MMRPC, 2010).

According to the MDNR, 59 percent of the state is underlain by thick, carbonate rock units that host a wide variety of karst features (MDNR, 2013c). The Missouri Speleological Survey reports that there are now more than 6,000 known caves in Missouri (MSS, 2013). Of those recorded, the most famous is the Devil's Ice Box in Rock Bridge State Park. According to the Boone County Stormwater Program (Boone County, 2013a), there are 418 documented sinkholes with a depth of 6.1 m (20 ft) or greater within the county. All of these sinkholes are relatively stable but some do discharge into the cave system and groundwater. About 290 of these sinkholes are located between U.S. Interstate 70 and Ashland, Missouri, in the southwestern corner of Boone County. The karst regions of the southwestern portion of the county make the area a prime location for this hazard. Development on karst terrain can present certain hazards such as unstable soil foundation for structures, flooding, groundwater contamination, and public safety hazards related to sinkhole collapses.

Sinkholes, like landslides, are a form of ground movement that can happen suddenly and without warning, causing major damage. Sinkholes are common where the bedrock below the land surface is composed of limestone, dolomite, or gypsum that can naturally be dissolved by circulating groundwater (USGS, 2007).

While many sinkholes occur as circular, bowl-shaped depressions, others are not readily visible on the surface because voids are plugged or capped with soil or thin layers of rock. The sinkholes begin with slow soil piping (erosion) over a long period. When the soil above the void can no longer support itself, the soil collapses to reveal a deep hole that connects to an underlying bedrock opening. These voids may be discovered during excavation, by drilling or through geophysical exploration. Residential and commercial development in a karst area can pose environmental and logistical problems. Aside from structurally impacting foundations of homes and other buildings, sinkholes often serve as direct conduits for rapid surface water infiltration into the underlying groundwater aquifer. Contaminants near or at the surface can quickly enter the aquifer and pollute drinking water supplies. Increased stormwater runoff resulting from parking lots, highways, and household guttering often is diverted into sinkholes. The increased inflow of water not only can transport contaminants but also can lead to the accelerated development and growth of sinkholes (MDNR, 2013e).

Sinkholes vary in size. They can be small and have little impact on people, or they can be catastrophic and destroy property, underground utilities, buildings, lagoons, and contaminate groundwater resources (USGS, 2007).

During the geotechnical investigation conducted by Terracon in 2011, there was no evidence of shallow bedrock, karst features, and/or extensive pervious deposits of water-bearing sand observed in the soil cuttings from Boreholes B-1 through B-9. In addition, Terracon reported that they did not observe evidence of subsidence or sinkholes within the Discovery Ridge project area (Terracon, 2011b).

19.3.4 Water Resources

The ROI for the water resource is defined as the 8 km (5-mi) radius surrounding the RPF site. About 66 percent of Missouri water resources are obtained from surface water bodies, and the remaining 34 percent are obtained from groundwater wells. During a normal precipitation year, approximately 45.4 trillion L (12 trillion gal) of water are supplied to Missouri by runoff from precipitation within the state. Rainfall averages approximately 97 cm (38 in.) statewide, with approximately 25.4 cm (10 in.) becoming surface water runoff or groundwater recharge. The remaining 71 cm (28 in.) are returned to the atmosphere by evaporation or plant use.

Surface water sources provide the bulk of water withdrawals statewide. In 1990, freshwater surface water withdrawals in Missouri were estimated at 1,866 ML/day (493 Mgal/day), compared to 700 ML/day (185 Mgal/day) from groundwater sources. The majority of these withdrawals came from surface water intakes along major streams and rivers where streams have adequate low flows. The Missouri and Mississippi Rivers supply municipal water to approximately one-third of the state population (DuCharme and Miller, 1996).

More than 500,000 Missourians rely on other surface water sources, including human-made reservoirs, for their water needs. Although many of the state's larger reservoirs (e.g., Truman Reservoir, Mark Twain Lake) serve some water supply purposes, a substantial segment of the population uses much smaller lakes constructed specifically to meet local water needs. Sufficient water supplies from these locations are readily available for local public water supply districts and municipalities. Approximately 123 reservoirs are currently in use as public water supply sources in Missouri, and all but eight of these reservoirs are located in northern and western Missouri (DuCharme and Miller, 1996).

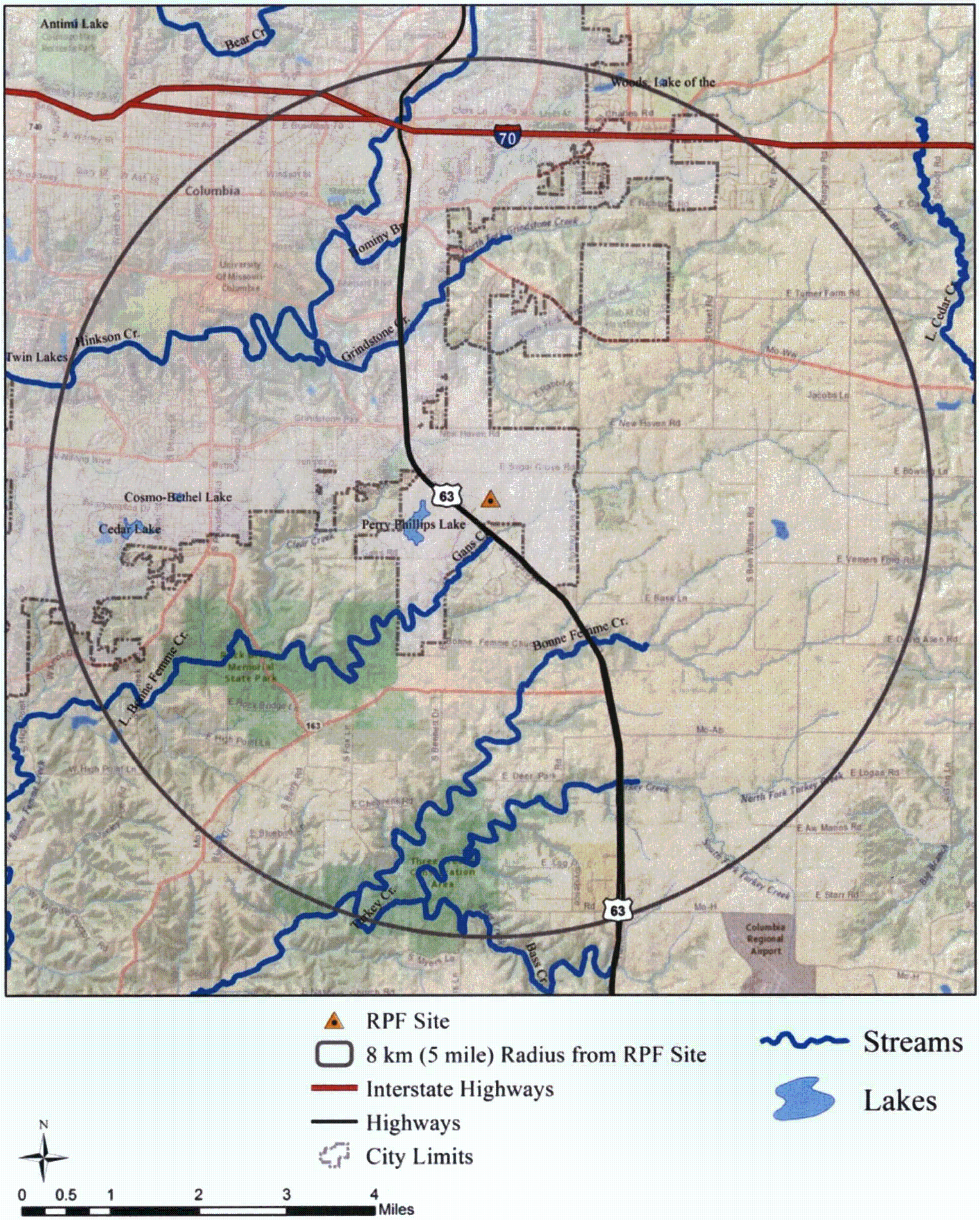
Missouri groundwater resources come primarily from two sources: bedrock aquifers and shallower alluvial aquifers. Most public water supply facilities currently operating in Missouri rely, to some extent, on groundwater wells as a source of water supply. Most self-supplied residential, commercial, and industrial water withdrawals are extracted via groundwater wells.

19.3.4.1 Surface Hydrology

Surface waters in central and southern Boone County drain into the Missouri River through a number of tributaries, including Bonne Femme, Cedar, Little Cedar, Hinkson, Jemerson, and Perche Creeks (Figure 19-34). The other major drainage feature in the county is a system of karst topography west and south of Columbia. Numerous sinkholes, some filled with water, overlie a complex network of caves and springs. Gans Creek, which drains Discovery Ridge and the proposed RPF site, is located within the Bonne Femme Watershed.

19.3.4.1.1 Bonne Femme Watershed

The Bonne Femme Watershed is comprised of two major sub-watersheds: the Bonne Femme and the Little Bonne Femme. Topographical contours of the land define the Bonne Femme Watershed, which encompasses approximately 241 km^2 (93 mi^2) (approximately 15 percent) of Boone County, including the proposed RPF site (BFSC, 2007). The RPF site is located within the northern portion of this watershed (Little Bonne Femme sub-watershed) and is approximately 0.4 km (¼-mi) north of Gans Creek (see Figure 19-35).



MDNR 2012 *Section 303d Listed Impaired Streams and Lakes* [digital data]. ftp://msdis.missouri.edu/pub/Environment_Conservation/MO_2012_Section_303d_Impaired_Lakes_shp.zip

Figure 19-34. Streams of Southern Boone County, Missouri

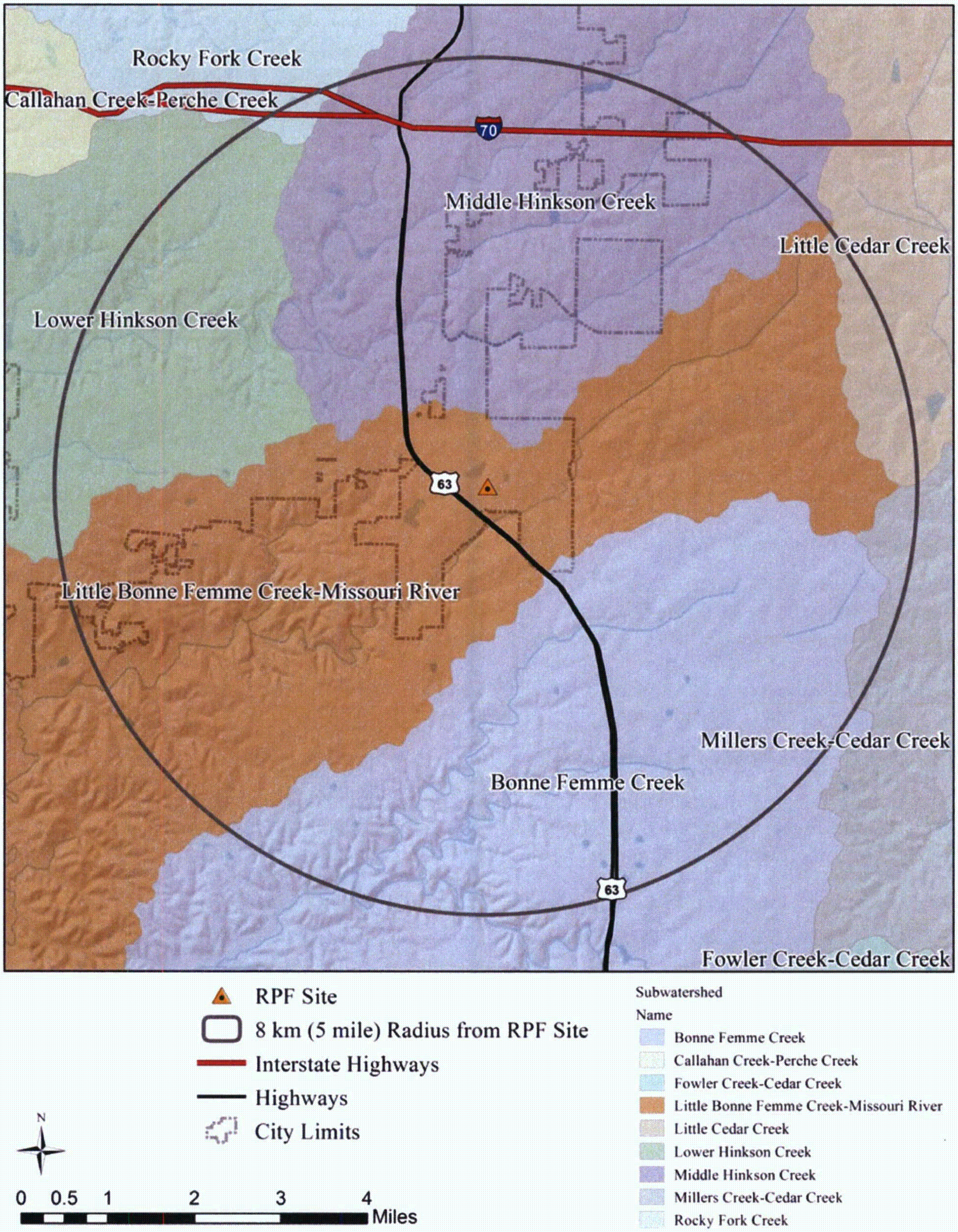


Figure 19-35. Map Showing Bonne Femme Watershed

Both the Bonne Femme and Little Bonne Femme creeks flow from east to west in a dendritic alignment into the Missouri River and are interconnected by the Devil's Icebox Cave Branch. Where Gans Creek meets Clear Creek, the Little Bonne Femme begins and flows south toward the Mayhan Branch. The Little Bonne Femme enters the Missouri River approximately 0.8 km (0.5 mi) south of this confluence. To the south, the Bonne Femme meets with the Fox Hollow Branch and then flows into the Missouri River (BFSC, 2007).

The most distinctive characteristic of the Bonne Femme Watershed is its karst topography. Within the karst terrain, the hydrology becomes complex because of losing and gaining sections of streams. Rough estimates show approximately 33 stream segments composing approximately 37 km (23 mi) of losing streams (143 km [89 mi] of gaining stream) within the watershed. There are two main recharge areas tied to these losing and gaining sections of stream, including (1) Devil's Ice Box recharge zone (3,397 ha [8,394 acres] of drainage), and (2) Hunter's Cave recharge zone (3,330 ha [8,228 acres] of drainage) (BFSC, 2007).

A mixture of land uses occurs within the Bonne Femme watershed. The predominant land use accounting for 61.5 percent of the watershed is agricultural activities, including row crop productions, pasture, and range lands. Forested areas make up nearly one-third of the watershed, mainly within the central and western portion of the watershed. These forested areas also encompass most of the publicly owned lands, including Rock Bridge Memorial State Park and Three Creeks Conservation Area (BFSC, 2007).

19.3.4.1.2 Water Quality of Bonne Femme Watershed

Water quality monitoring studies began in the Bonne Femme Watershed in 1999 and included two sites: Hunters and Devil's Icebox Spring Branches. In 2001, the monitoring program was expanded to include six surface sub-watersheds (Clear Creek, Upper Bonne Femme Creek [at U.S. Highway 63], Turkey Creek, Lower Bonne Femme Creek [at Nashville Church Road], Little Bonne Femme Creek, and Fox Hollow Creek), and the two cave systems. In 2003, two additional sub-watersheds (Gans Creek and Bass Creek) were included to the monitoring plan (BFSC, 2007).

19.3.4.1.2.1 General Stream Parameters

Samples were collected quarterly from the eight sites beginning with the third quarter of 2004. Samples were analyzed for general stream parameters, including temperature, pH, specific conductance, dissolved oxygen, and turbidity (BFSC, 2007). The results of the monitoring are listed in Table 19-34.

Table 19-34. General Stream Water Properties by Site (2 pages)

Site	Temperature		pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Dissolved oxygen (% saturation)	[a]Turbidity (NTU)
	°C	°F					
Clear Creek	13.1	55.6	7.88	525	11.84	111.2	3.6
Gans Creek	11.7	53.1	7.76	397	11.57	105.2	17.5
Devils Icebox Cave	11.6	52.9	7.53	424	11.05	101.7	22.9
Upper Bonne Femme Creek	13.6	56.5	7.22	478	9.79	95.7	28.3
Turkey Creek	13.8	56.8	7.49	586	12.04	117.1	22.7
Hunters Creek	11.5	52.7	7.73	409	11.37	103.7	11.9
Bass Creek	13.7	56.7	7.80	455	14.39	140.3	12.6

Table 19-34. General Stream Water Properties by Site (2 pages)

Site	Temperature °C	Temperature °F	pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Dissolved oxygen (% saturation)	[a]Turbidity (NTU)
Lower Bonne Femme Creek	12.8	55.0	7.47	408	11.39	108.6	12.1
Little Bonne Femme Creek	12.6	54.7	7.63	446	11.06	99.4	19.4
Fox Hollow	14.6	58.3	7.60	520	10.92	107.0	3.3
Average across the sites	12.9	55.2	7.61	465	11.54	109.0	15.4
[a]Least significant difference	[b]NS	[b]NS	0.28	[b]NS	[b]NS	[b]NS	[b]NS

Source: BFSC, 2007, *Bonne Femme Watershed Plan*, www.cavewatershed.org/plan.asp, Bonne Femme Stakeholder Committee, Boone County Planning and Building Department, Columbia, Missouri, February 2007.

[a] This value is the minimum difference between sites to be considered statistically different.

[b] NS = not significantly different across sites. Data are averaged over 10 quarters (third quarter 2004 to fourth quarter 2006).

NTU = nephelometric turbidity units.

The following excerpt from the 2007 Bonne Femme Watershed Plan provides greater detail regarding the results of data analysis and general stream parameters for the sites listed in Table 19-34.

> *The pH concentration in the Upper Bonne Femme Creek site was lower than all other sites. This result is likely due to the fact that the Upper Bonne Femme Creek sub-watershed is primarily utilized for row crops (67% of the sub-watershed), and the lower pH may reflect the impact of fertilizer usage. The Upper Bonne Femme Creek and Turkey Creek occasionally had very high specific conductance levels exceeding 700 µS/cm. These results may have been due to the use of salt on U.S. Highway 63 during the winter months. Eight of ten sites had average dissolved oxygen levels that were at or near 100% saturation. The lowest observed dissolved oxygen levels occurred in the third quarter of each year when the stream water temperature was highest. The lowest dissolved oxygen level observed was 5.11 mg/L (62.6% saturation); therefore, no site was under the state standard level of 5.0 mg/L. The high saturation levels observed at Turkey and Bass Creeks reflected the persistent nuisance algal growth conditions at these sites. Turbidity measures the clarity of the water and, thus, both suspended sediment and algae can contribute to lower clarity and higher turbidity. Highest turbidity was observed under runoff conditions when the suspended sediment content of the water is high. Turbidity levels were occasionally elevated under low flow conditions, suggesting that algal growth was negatively impacting water clarity, especially in the second and third quarters of the year.* (BFSC, 2007)

Bacteria analyses – Two indicator groups of waterborne pathogens (fecal coliform and *E. coli*) were monitored in the streams within the Bonne Femme Watershed. Both groups are considered indicator organisms associated with improper waste management. Fecal coliforms represent a broad array of bacterial species present in mammal feces, while *E. coli* is a single bacterial species that is also present in mammal feces. These indicator bacteria generally do not survive long in soils or water; thus, their consistent detection in water over time indicates one or more sources of continual input.

The two sites with the highest fecal coliform concentrations, Turkey Creek and Fox Hollow, had statistically greater concentrations than the five sites with the lowest concentrations (Clear Creek, Gans Creek, Bass Creek, Hunters Cave, and Lower Bonne Femme Creek). Table 19-35 lists the average concentrations.

Table 19-35. Average Fecal Coliform and *E. coli* Concentrations

Site	[a]Fecal coliform (log10[cfu/100 mL])	[a]*E. Coli* (log10[cfu/100 mL])
Clear Creek	1.72	1.54
Gans Creek	2.07	1.91
Devils Icebox Spring Branch	2.30	2.06
Upper Bonne Femme Creek	2.17	1.95
Turkey Creek	2.46	2.38
Hunters Cave	1.93	1.73
Bass Creek	2.00	1.84
Lower Bonne Femme Creek	1.97	1.86
Little Bonne Femme Creek	2.14	1.94
Fox Hollow	2.49	2.26
Average across the sites	2.13	1.95
[b]Least significant difference	0.35	0.35

Source: BFSC, 2007, *Bonne Femme Watershed Plan*, www.cavewatershed.org/plan.asp, Bonne Femme Stakeholder Committee, Boone County Planning and Building Department, Columbia, Missouri, February 2007.

[a] Statistical analysis was performed on log transformed data.

[b] This value is the minimum difference between sites to be considered statistically different.

According to the 2007 Bonne Femme Watershed Plan:

> *The three sub-watersheds with the highest levels of bacterial contamination (Turkey Creek, Fox Hollow, and Devil's Icebox Spring Branch) have consistently greater inputs of fecal bacteria compared to the other sites. Although these data do not indicate the source of the fecal bacteria, there are three likely sources in the Bonne Femme watershed – onsite sewers, livestock, and wildlife.* (BFSC, 2007)

Specific water-borne pathogens – In the third quarter of 2005, the USDA Agricultural Research Service conducted additional analyses of three specific water-borne pathogens: *E. coli O157:H7*, salmonella, and shigella. These three organisms are known human pathogens capable of causing food-borne gastrointestinal illnesses, but they are also associated with feces and, therefore, may contaminate streams and lakes, causing disease through oral contact or ingestion of contaminated water. Like fecal coliforms and generic *E. coli*, these disease-causing bacteria can enter surface waters through sewage overflows, polluted stormwater runoff, and polluted agricultural runoff.

> *Each of the three pathogens was detected at most of the ten sites monitored, and at least one pathogen was detected at every site. Shigella was detected at eight of ten sites, but generally at lower frequency than Salmonella or E. coli O157:H7.*

Salmonella was the most commonly detected pathogen at four of the ten sites, with 33% of the samples collected from Turkey and Little Bonne Femme Creeks testing positive for Salmonella. E. coli O157:H7 was the most commonly detected of the pathogens, with at least one detection at every site. Five of the ten sites had multiple detections of E. coli O157:H7. Three sites (Gans Creek, Turkey Creek, and Lower Bonne Femme Creek) had E. coli O157:H7 detected in 33% of their samples, and Fox Hollow had E. coli O157:H7 detected in 58% of the samples.

These data do not definitively indicate source, but they do point to cattle as a probable source of E. coli O157:H7 at those sites with frequent detections. Of the common carriers of E. coli O157:H7 (cattle, swine, and deer), swine can be eliminated as there are no sizable swine operations within the Bonne Femme watershed. Deer are likely responsible for the widespread nature of the detections, explaining the presence of E. coli O157:H7 at sites with otherwise low fecal contamination, such as Clear Creek and Hunters Cave. Although data on specific numbers of cattle by sub-watershed cannot be reliably compiled, there are major cattle operations in the four watersheds with the highest detection frequency of E. coli O157:H7. Furthermore, the Fox Hollow sampling site is immediately downstream from a large cattle grazing operation. (BFSC, 2007)

19.3.4.1.3 Impaired Waters

The USGS and the MDNR ambient water quality monitoring network collect water quality data each year pertaining to Missouri water resources. These data are stored and maintained in the USGS National Water Information System database. The MDNR is responsible for the implementation of the Federal CWA in Missouri. Section 305(b) of the CWA requires that each State develop a water quality monitoring program and periodically report the status of its water quality. Water quality status is described in terms of the suitability of the water for various uses, including drinking, fishing, swimming, and support of aquatic life. These uses formally are defined as "designated uses" in Federal and State regulations. Section 303(d) of the CWA requires that certain waters that do not meet applicable water quality standards must be identified and total maximum daily loads (TMDL) must be determined for these waters. TMDLs establish the maximum amount of an impairing substance that a water body can assimilate and still meet the water quality standards. A TMDL addresses a single pollutant for each water body (Barr, 2012).

Impaired waters within close proximity to the proposed RPF site are discussed in greater detail in the following sections.

19.3.4.1.3.1 Gans Creek

In accordance with Section 303(d) of the CWA, MDNR identified Gans Creek (Water Body ID No. 1004) as an impaired water body in 2012 (Figure 19-36).

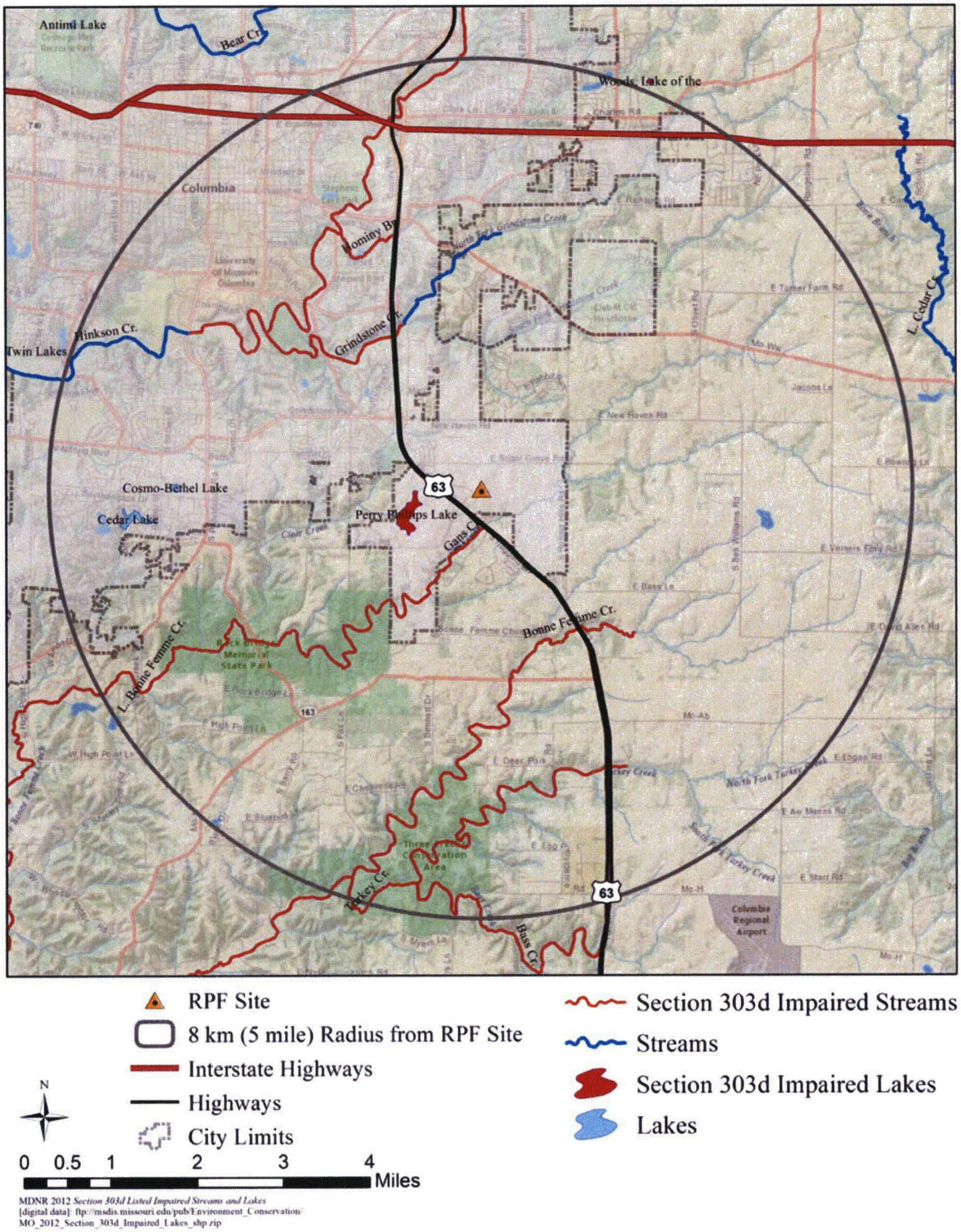


Figure 19-36. Impaired Streams Map

Gans Creek is listed as impaired by bacteria on the Missouri 2012 303(d) list of impaired waters, which was approved in whole by the EPA on November 13, 2012 (EPA, 2012). Gans Creek is designated for the whole body contact recreation (Category A use). 10 CSR 20-7.031, "Water Quality Standards," state that for waters designated for whole body contact recreation (Category A), the *E. coli* bacteria count, measured as a geometric mean, shall not exceed 126 colonies per 100 milliliters (mL) (3.4 ounces [oz]) of water during the recreational season (defined as being from April 1 to October 31).

> *DNR judges a stream to be impaired by bacteria if the water quality criterion for E. coli is exceeded in any of the last three years for which there is adequate data (minimum of five samples taken during the recreational season). High counts of E. coli are an indication of fecal contamination and an increased risk of pathogen-induced illness to humans. E. coli are bacteria found in the intestines of warm-blooded animals and are used as indicators of the risk of waterborne disease from pathogenic (disease causing) bacteria or viruses. Missouri's whole body contact bacteria criteria are based on specific levels of risk of acute gastrointestinal illness. The level of risk correlating to the Category A criterion is no more than 8 illnesses per 1,000 swimmers in fresh water (0.8 percent). Sufficient recreational season E. coli data to assess the Gans Creek was collected in 2008 and 2009. The geometric means of the data exceeded the whole body contact Category A criterion in both years. For this reason, Gans Creek has been assessed as impaired by E. coli.* (MDNR, 2013f)

The TMDL information for Gans Creek includes a segment stream length of 8.9 km (5.5 mi) and an affected watershed size of 39 km^2 (15 mi^2). The four designated beneficial uses of Little Bonne Femme Creek include:

- Livestock and wildlife watering
- Protection of warm water aquatic life
- Protection of human health (fish consumption)
- Whole body contact recreation – Category A

Category A whole body contact recreation is the only impaired designated beneficial use.

19.3.4.1.3.2 Little Bonne Femme Creek

In accordance Section 303(d) of the CWA, MDNR identified the Little Bonne Femme Creek (Water Body ID No. 1003) as an impaired water body in 2012.

Little Bonne Femme Creek is also listed as impaired by bacteria on Missouri 2012 303(d) list of impaired waters. Little Bonne Femme Creek is designated for the whole body contact recreation Category B use. Missouri's Water Quality Standards in 10 CSR 20-7.031(4)(C) state that for waters designated for whole body contact recreation Category B, the *E. coli* bacteria count, measured as a geometric mean, shall not exceed 206 colonies per 100 mL (3.4 oz) of water during the recreational season.

> *Missouri's whole body contact bacteria criteria are based on specific levels of risk of acute gastrointestinal illness. The level of risk correlating to the Category B criterion is no more than 10 illnesses per 1,000 swimmers in fresh water (1 percent). Sufficient recreational season E. coli data to assess the Little Bonne Femme Creek was collected in 2008 and 2009. The geometric means of the data exceeded the whole body contact Category B criterion in both years. For this reason, Little Bonne Femme Creek has been assessed as impaired by E. coli.* (MDNR, 2013g)

The TMDL information for Little Bonne Femme Creek includes a segment stream length of 14.5 km (9 mi) and an affected watershed size of 102 km^2 (39.2 mi^2). The four designated beneficial uses of Little Bonne Femme Creek include:

- Livestock and wildlife watering
- Protection of warm water aquatic life

- Protection of human health (fish consumption)
- Whole body contact recreation – Category B

Category B whole body contact recreation is the only impaired designated beneficial use.

19.3.4.1.3.3 Perry Phillips Lake

Perry Phillips Lake, located approximately 1.2 km (¾-mi) west of the proposed RPF site, was first listed as an impaired water body in 2010. This lake was originally given the State-listed water identification number MO 1003U-01. In 2012, that number was changed to MO 7628. The TMDLs are to be established by Missouri in 2015. Information available for this impaired water body is as follows (MDNR, 2013h):

State Listed Water ID Nos. MO 7628 and MO 1003U-01
Location: Boone County
Hydrologic Unit Code 8, No. 10300102
State Water Body Type: Lakes, reservoirs, and ponds
Impaired Segment Size (mi/acres): 32
Classified Segment Size (mi/acres): 32
Cause of Impairment: Mercury in fish tissue
Impaired Uses: GEN

19.3.4.2 Groundwater Resources

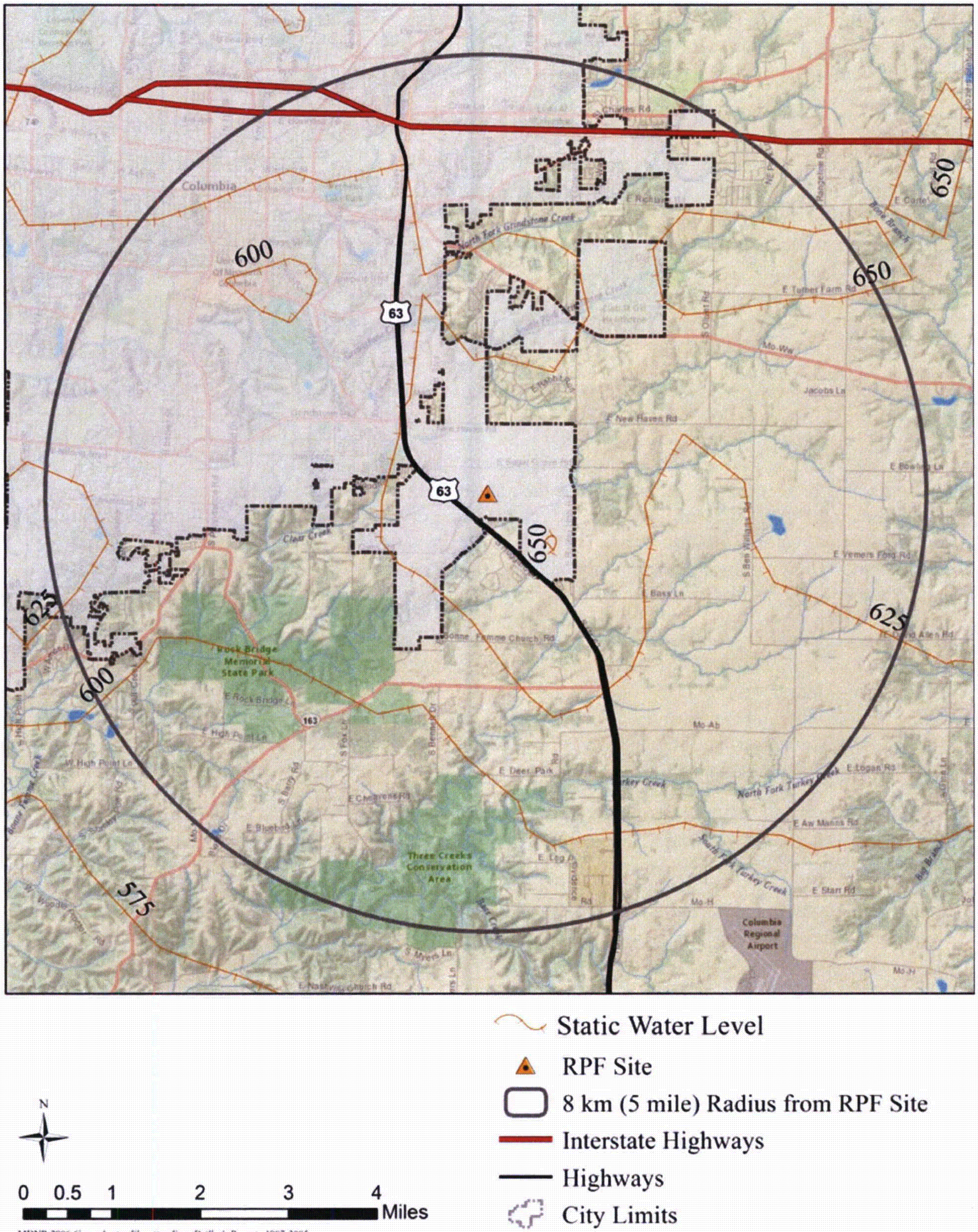
Less than one-half of the Missouri population obtains its water supply from groundwater resources. Groundwater is the major source of drinking water in the Ozarks and the Southeast Lowlands for both public and private supplies. The cities of St. Joseph, Independence, Columbia, and St. Charles use groundwater from the alluvial aquifer of the Missouri River. In the plains region of the state, many small communities are able to obtain adequate water from shallow alluvial wells near rivers or large creeks. Many individual households still rely on the shallow upland aquifer even though it yields only very small amounts of water (MDNR, 2012b).

Groundwater is the source of 74 percent of all rural domestic self-supplied water, 75 percent of all irrigation water, and 39 percent of all industrial self-supplied water, excluding water for thermoelectric power generation. The groundwater is generally suitable for most uses, except where it is saline. Median concentrations of total dissolved solids (TDS), hardness, nitrate, fluoride, and sulfate are less than the primary and secondary national drinking water regulations established by the EPA; however, localized contamination from manufactured organic compounds has been recognized in four of the six principal aquifers in Missouri, including both shallow and deep aquifers (USGS, 1986).

The six principal aquifers in Missouri include:

- Major river valleys
- Alluvial (in southeastern Missouri)
- Wilcox and Claiborne
- McNairy
- Ozark
- Mississippian aquifer (Kimmswick-Potosi)

The groundwater aquifer beneath the proposed RPF site is the Mississippian aquifer (also referred to as the Kimmswick-Potosi aquifer). Figure 19-37 is a map of the aquifer.



MDNR 2006 *Groundwater Elevation From Driller's Reports 1987-2005* [digital data]. ftp://msdis.missouri.edu/pub/Inland_Water_Resources/MO_2006_Groundwater_Elevation_shp.zip

Figure 19-37. Aquifer Map

The Mississippian aquifer is the principal aquifer supplying groundwater to Boone County. In accordance with drillers reports generated from 1987 to 2005, the estimated static water level in the area near the proposed RPF site was approximately 198.1 m (650 ft) below ground surface (MDNR, 2006).

19.3.4.2.1 Mississippian Aquifer

The Mississippian aquifer consists of consolidated dolomite, limestone, and some sandstone beds that are generally confined. The Keokuk limestone and Burlington limestone are the principal water-yielding formations within this aquifer. Both formations consist of crystalline limestone and yield water primarily from solution cavities. In most places, the aquifer is overlain by a confining unit of Pennsylvanian shale and sandstone and glacial till. The aquifer is typically underlain by a confining unit of Mississippian shale. Recharge occurs primarily from precipitation infiltrating overlying aquifers. The top of this aquifer is approximately 548.6 m (1,800 ft) below ground surface and is a primary source of water in seven counties north of the Missouri River (Miller and Appel, 1997).

19.3.4.2.2 Water Quality of the Mississippian Aquifer

The quality of water obtained from wells drilled into the Mississippian aquifer varies considerably across Missouri due to the aquifer containing both freshwater and slightly saline to very saline water. Total dissolved solids concentrations of water from the aquifer generally are greatest where the aquifer is overlain by a thick confining unit and least where it is unconfined or overlain by a thin or semi-confining unit. Very saline water is thought to have entered the Mississippian aquifer either by upward leakage from the underlying Cambrian-Ordovician aquifer or by the discharge of eastward-moving saline water from the upper aquifer unit of the Western Interior Plains aquifer system (Miller and Appel, 1997).

In a study conducted by the USGS in 1985, the Mississippian aquifer was determined to have low permeability with a median TDS concentration of approximately 500 milligram per liter (mg/L) (0.06 oz/gal). The maximum TDS concentration measured in this study was approximately 4,700 mg/L (0.572 oz/gal) to the north, where water becomes saline. The median concentration of fluoride was 1.0 mg/L (0.00012 oz/gal) and the median concentration of sulfate was 56.0 mg/L (0.0068 oz/gal). These were the largest median values of all of the six principal aquifers in Missouri (Miller and Appel, 1997).

According to the study, the Mississippian aquifer is intensively used for public water supply and irrigation; however, since the early 1900s, water quality in this aquifer has not changed appreciably (Miller and Appel, 1997).

A more recent assessment was conducted by the MDNR in 2002 (MDNR, 2002), which determined that the aquifers in Missouri consisting of Mississippian age limestone and Ordovician and Cambrian age dolomites and sandstones can yield 56.8–1,892.7 L/minute (min) (15–500 gal/min) of water. Yields locally exceed 3,785.4 L/min (1,000 gal/min) in some areas, including in Springfield, Columbia, and Rolla.

19.3.4.3 Preexisting Environmental Conditions

The RADIL facility at Discovery Ridge is a regulated State hazardous waste facility (SHWF) located approximately 0.16 km (0.1 mi) northwest of the proposed RPF site. A second SHWF, ABC Laboratories, is located approximately 0.54 km (0.33 mi) west of the proposed RPF site. These facilities are discussed in greater detail in the following sections and in Section 19.2.2.5. Based on a regulatory review and site assessments conducted by others, these SHWFs do not appear to represent environmental concerns to the proposed RPF site.

19.3.4.3.1 2011 Phase I Environmental Site Assessment Discovery Ridge, Lot 2 and Lots 5 through 18

A Phase I environmental site assessment included interviews with the MU Genetics Farm Manager and a USDA site employee to determine the historical uses of the Discovery Ridge area. The interviews revealed that minor amounts of herbicides and fertilizers are currently used on the MU Genetics Farm property (Lots 16, 17, and 18 of Discovery Ridge) (Terracon, 2011a).

The review identified one MDNR State-regulated RCRA large-quantity generator facility, ABC Laboratories (Lot 1 of Discover Ridge). However, this facility was not found to be a recognized environmental concern due to its regulatory status and duration of operation (built in 2007) (Terracon, 2011a). Additional information is listed in Table 19-36 and Sections 19.3.8.2 and 19.3.8.3.

Table 19-36. State-Regulated Facility

Listed facility name/Address	Database listings	Distance/direction from proposed RPF site	Potential contamination source
Analytical Bio Chemistry Laboratories 4780 Lenoir Street (Lot 1 of the Discovery Ridge Research Park)	RCRA-LQG	Approximately 0.54 km (0.33-mi) west	No

LQG = large-quantity generator.
RCRA = Resource Conservation and Recovery Act.
RPF = radioisotope production facility.

Other observations noted during the Phase I environmental site assessment that could pose preexisting environmental conditions included the following (Terracon, 2011a):

- Three pad-mounted transformers were observed on the southwestern portion of Lot 15 (proposed RPF site), one pad-mounted transformer was located on the southeastern portion of Lot 17, and three inactive pole-mounted transformers were observed on the northern portion of Lot 17. However, there were no signs or staining that would be evidence of possible polychlorinated biphenyl (PCB) release.
- Approximately 0.4 ha (1 acre) of fill dirt was observed on the northern portion of Lot 9. Per the MU South Farms Field Office, fill material had been placed onsite over the past two years and originated from the future location of the Missouri Conservation Facility located south of Gans Road, approximately 2.4 km (1.5 mi) south of the ROI.
- An intermittent stream was observed on Lots 9, 10, and 11 of the Discovery Ridge ROI, traversing the site in a north-to-south orientation. No evidence of chemical sheens was observed on the surface of the pools of water, and no noxious odors were observed emanating from within the intermittent stream at the site during site reconnaissance.

19.3.4.3.2 2011 Preliminary Geotechnical Engineering Investigation of Discovery Ridge Lot 2 and Lots 5 through 18

A 2011 preliminary geotechnical engineering investigation report stated the following (Terracon, 2011b):

- Fill soils were encountered in borings B-3 and B-4 at depths ranging from 0.9-3.7 m (3–12 ft) below ground surface. Boring B-3 was drilled on the central portion of Lot 2, and Boring B-4 was drilled on the central portion of Lot 8. The engineered fill material was placed as part of a mass grading project in 2008; that placement was observed and the soil density and moisture content tested during placement.

- Based on a USGS map and aerial photographs, a pond may have been located in the vicinity of Lot 16, and the existing pond located north of the RADIL facility previously extended west onto a portion of Lot 2.
- The near-surface soils have shrink/swell potential and are prone to volume change with variations in moisture content.
- The 2006/2009 International Building Code seismic site classification for the ROI is C. For Class C soils, the 2006/2009 code requires that a site soil profile determination extending to a depth of 30.5 m (100 ft) be conducted.
- The MMI scale for seismic events for Boone County, Missouri, is VII.
- Groundwater was observed in Boring B-5 (located midway between Lots 14 and 15) and in Boring B-6 (located on Lot 10) at depths ranging from approximately 3.7–5.6 m (12–18.5 ft) below ground surface.

19.3.4.3.3 2006 Phase I Environmental Site Assessment Discovery Ridge East of Lenoir Street and South of Sugar Grove Lane

According to the Phase I environmental site assessment (Terracon, 2006), the MU South Farms facility was identified as an SHWF. An interview with Mr. John Poehlmann, Director of the Missouri Agricultural Experiment Station and MU South Farms Superintendent, identified the historical uses of the facility. These uses include agricultural research of maize genetics crop research, swine nutrition, beef cattle management and grazing, agricultural equipment development, and cropping for grain silage and uptake of nutrients from lagoon application. According to Mr. Poehlmann, the nine buildings on the property within the ROI were built between 1970 and 2002, and there are pits for the collection of animal waste beneath one building that housed sheep and swine. The wastes were surface and injection applied as plant nutrients. The on-site lagoon operated under MDNR permit MO-G010024.

19.3.4.4 Historical and Current Hydrological Data

There is no historical or current hydrological data for the proposed RPF site.

19.3.4.5 Proposed Radioisotope Production Facility Water Use

Water use by the proposed RPF is described in Section 19.2.4.1 and would be supplied from the Columbia, Missouri, standard municipal water system.

19.3.4.6 Water Rights and Resources

Missouri water resources, including surface water and groundwater supplies, are applied to a variety of uses. Large consumptive water uses included thermal electrical generation, municipal, industrial, and agricultural uses. Nonconsumptive water uses include recreation, commercial navigation, hydroelectric power generation, and mining operations.

Missouri is called a riparian water law state, meaning that each individual landowner is entitled to make use of the water found on or beneath his/her property. The laws that address riparian rights are restrictive in that the landowner cannot make unlimited or unrestricted use of that water in any way he or she chooses. “Riparian lands,” as defined by the courts, include all lands above underground waters and beside surface waters (MDNR, 2000).

19.3.4.7 Quantitative Description of Water Use

19.3.4.7.1 Drinking Water Supply

The potable water supply to Discovery Ridge is provided by Public Water District No. 1. Additional detail on the water supply system is provided in Section 19.3.7.1.9.3.

19.3.4.7.1.1 Wastewater Treatment Systems

Two main wastewater collection providers service the metro area: the Columbia sewer utility and the Boone County Regional Sewer District. Several private, on-site wastewater treatment systems also serve the metro area. These systems require permits from and are inspected by the MDNR.

The ultimate wastewater service area is 311 km^2 (190 mi^2) and includes three major watersheds: the Perche, Hinkson, and Little Bonne Femme. In 2010, the actual connected population was approximately 100,000; this figure is projected to reach 160,000 users by 2030. Approximately 45.4–56.7 ML/day (12-15 Mgal/day) of wastewater are currently generated; this is estimated to increase to 106 ML/day (28 Mgal/day) by 2030 (City of Columbia, 2013a).

A large number of older homes are connected to private common collector sewers. These systems are shared by two or more residences; many are poorly designed and prone to backing up (Columbia Source Water Protection Task Force, 2013).

19.3.4.7.1.2 Stormwater Management

In 2012, Columbia maintained over 304,800 m (1 million linear feet) of storm sewers. With its client base surpassing 100,000 residents, a change in the type of NPDES storm sewer permit, granted by the EPA, was required. The city transitioned from a Phase II permit to a Phase I permit, an effort that included specific measures to address the minimization of pollution in city storm sewers and other areas (City of Columbia, 2013a).

19.3.4.7.2 Nonconsumptive Water Use

The MDNR reported that in 2000, the total water usage for Boone County totaled approximately 26,876 ML (7,100 Mgal) (MDNR, 2003). Water usage categories are listed in Table 19-37.

Table 19-37. Water Use in Boone County, 2000

Water use category	Water usage	
	ML/day	Mgal/day
Domestic	379–1,514	100–400
Irrigation	379–3,028	100–800
Electric	0–75,708	0–20,000
Industrial	0–379	0–100
Municipal	11,356–37,854	3,000–10,000
Recreation	57–227	15–60

Source: MDNR, 2003, *Major Water Use in Missouri: 1996-2000*, Water Resources Report No. 72, Missouri Department of Natural Resources, Geological Survey and Resource Assessment Division, Jefferson City, Missouri, 2003.

19.3.4.7.3 Water Impoundments

The MDNR regulates all non-Federal, nonagricultural dams that are at least 10.6 m (35 ft) in height. Currently, there are 590 dams regulated in Missouri. The MDNR inspects each regulated dam at least once every 5 years to determine if the dams pose a safety threat to the public.

As of March 9, 2007, the MDNR listed a total of 127 dams within Boone County (MDNR, 2007). Of these 127, a total of 17 dams are regulated by the MDNR. Two dams are located within 1.6 km (1 mi) of the proposed RPF site. The MU R1 Dam is located approximately 152.4 m (500 ft) northwest of the proposed RPF site. This dam is not a regulated water body. The Bristol Lake Dam is located approximately 0.8 km (0.5 mi) west-southwest of the proposed site and is listed as regulated. Additional information on each of these water bodies is provided in Table 19-38.

Table 19-38. Missouri Dam Report, by County

Name	ID No.	Location	Year completed	Height	Length	Drainage area	Lake area (acre)	Hazard class	Permit no.
Bristol Lake Dam	MO10019	S32 T48N R12W	1965	14 m (46 ft)	300 m (985ft)	146 ha (360 acres)	13.4 ha (33 acres)	2	R-223
University of Missouri R1 Dam	MO11606	S33 T48N R12W	1959	5.5 m (18 ft)	Unknown	56.7 ha (140 acres)	4.9 ha (12 acres)	2	NA

Source: MDNR, 2007, "Missouri Dam Report by County," www.dnr.mo.gov/env/wrc/damsft/Crystal_Reports/damsfty_state_nid.pdf, Missouri Department of Natural Resources, Jefferson City, Missouri, March 9, 2007.

NA = not applicable.

19.3.4.7.4 Major Water Users

In Missouri, a major water user is defined by the MDNR as any surface or groundwater user with a water source and the equipment necessary to withdraw or divert 378,541 L/day (100,000 gal/day) or more from any stream, river, lake, well, spring, or other water source. All major water users are required by law to register water use annually. In Boone County, there are a total of 19 major water users registered with the MDNR. The registration of major water users in Missouri helps the MDNR with the following:

- Providing information required for technical assessment of current and future requirements for the regulation of water
- Gaining foresight on water supplies
- Applying conservation measures during periods of limited or diminishing supplies of water
- Determining where to locate stream and reservoir gauges and the groundwater level observation wells

19.3.4.8 Contaminant Sources

The most likely contaminant sources that may be affecting groundwater and/or surface water resources within the Columbia area include unregulated discharges from commercial and industrial processes, land development, pesticides from agricultural land-use practices, stormwater runoff, sediment erosion, and wastewater discharges. Other contaminant sources may include solid waste landfills and surface or underground mining operations.

Development within a watershed can contribute to water quality problems. Loads of sediment, petroleum hydrocarbons, metals, nutrients, and other pollutants are also higher in developed areas. This further decreases the natural habitat value of the streams and riparian areas.

Pollutants are carried by stormwater from upland areas into receiving waters. Land use not only influences the quantity of stormwater runoff, but also the quality of the runoff. Areas of high imperviousness (e.g., industrial areas, streets) can have some of the highest pollutant loads, while open spaces have the lowest.

19.3.4.8.1 Columbia Source Water Protection Task Force Contaminant Inventory for 2012

The Columbia Source Water Protection Task Force completed a contaminant inventory for Columbia in 2012. The contaminant inventory was conducted to identify contaminant materials and develop a line of defense to protect the city's deep bedrock wells and the McBaine Bottoms Well Field.

Contaminant inventories reviewed included fuel and oils, pesticides, nutrients, synthetic organic chemicals, volatile organic compounds (VOC), animal waste, and/or raw sewage. Other potential contaminant sources can include gas stations or retailers that may stock chemicals such as pesticides, oil, gasoline, and cleaners.

The Columbia Source Water Protection Task Force (2013) did not identify any potential threats to the old deep bedrock wells; however, seven potential threats to the McBaine Bottoms wells were identified:

1. Malicious tampering with individual source water (or nearby monitoring wells)
2. Use of pesticides, herbicides, and fertilizers
3. Seepage from Columbia wastewater treatment wetlands
4. Groundwater migration from under the Eagle Bluffs conservation wetlands
5. Infiltration from the Missouri River
6. Future activities in the McBaine bottoms area
7. Petroleum pipelines through the well field

19.3.4.8.2 MDNR Surface Water Assessment for the State of Missouri

According to the 2012 Missouri Water Quality Report (MDNR, 2012b), there are 39,318 km (24,431 mi) of classified streams, approximately 48,280 km (30,000 mi) of unclassified streams, and a total of 122,566 ha (302,867 acres) of classified lakes in Missouri. Classified streams are defined as permanently flowing streams or streams that maintain permanent pools during dry weather. Unclassified streams are defined as streams that are without water during dry weather. All classified waters of Missouri, including significant public lakes, are classified for protection of aquatic life, livestock and wildlife watering, and fish consumption by humans. The water quality standards for these uses set the maximum allowable concentrations for 117 chemicals in these waters. A subset of these waters classified for drinking water supply and groundwater has maximum allowable concentrations for an additional 79 chemicals in the standards. Waters protected for whole body contact recreation (e.g., swimming, water skiing) also have a maximum allowable bacteria standard (MDNR, 2012b).

19.3.4.8.3 Major Surface Water Pollution Sources in Missouri's Classified Waters

The major surface water pollution sources and major contaminants in Missouri classified waters are listed in Table 19-39 and Table 19-40.

Table 19-39. Major Surface Water Pollution Sources in Missouri Classified Waters

Source	Streams impaired		Percent of total miles	Lake impaired		Percent of total acres
	km	miles		ha	acres	
Unknown	3,229.0	2,006.4	8%	704	1,740	1%
Agriculture	1,751.1	1,088.1	4%	259	640	[a]
Grazing activities	89.8	55.8	[a]	--	--	--
Crop production	--	--	--	3.6	9	[a]
Urban runoff and construction	1,660.5	1,031.8	4%	19,852	49,055	16%
Atmospheric deposition	1,132.3	703.6	3%	9,939	24,560	8%
Mining	871.5	541.5	2%	--	--	--
Tailings	829.9	515.7	2%	--	--	--
Other mining activities	41.5	25.8	[a]	--	--	--
Municipal and other domestic point sources	521.6	324.1	1%	19,600	48,434	16%
Hydromodification	170.4	105.9	[a]	100	246	[a]
Channelization	106.9	66.4	[a]	--	--	--
Flow regulation/ modification	46.7	29.0	[a]	--	--	--
Upstream impoundment	16.9	10.5	[a]	100	246	[a]
Industrial point sources	67.3	41.8	[a]	--	--	--
Rural nonpoint sources	23.8	14.8	[a]	83.4	206	--
Natural sources	3.7	2.3	[a]	--	--	--
Recreational activities	12.1	7.5	[a]	--	--	--

Source: Table 3, p. 7, of MDNR, 2012b, *Missouri Water Quality Report (Section 305[b] Report)*, Missouri Department of Natural Resources, Water Protection Program, Jefferson City, Missouri, May 2, 2012.

[a] Less than 1%.

Table 19-40. Major Contaminants in Missouri Classified Waters

Contaminant	Stream length impaired		Percentage of total miles	Lake impaired		Percentage of total acres
	km	miles		ha	acres	
Bacteria	4,739.5	2,945.0	12%	--	--	--
Metals	1,119.8	695.8	3%	9,939	24,560	8%
Mercury	401.4	249.4	1%	9,939	24,560	8%
Lead	230.0	142.9	1%	--	--	--
Cadmium	203.9	126.7	1%	--	--	--
Zinc	17.2	10.7	[a]	--	--	--
Nickel	9.2	5.7	[a]	--	--	--
Copper	1.4	0.9	[a]	--	--	--
Arsenic	--	--	--	--	--	
Low dissolved oxygen	1,470.9	914.0	4%	--	--	--
Unknown	716.6	445.3	2%	--	--	--
Dissolved oxygen supersaturation	117.5	73.0	[a]	99.6	246	[a]
Chloride	105.9	65.8	[a]	--	--	--
pH	69.2	43.0	[a]	--	--	--
Sediment deposition	58.1	36.1	[a]	--	--	--
Thermal modification	54.6	33.9	[a]	--	--	--
Sulfate	32.2	20.0	[a]	--	--	--
Ammonia	28.5	17.7	[a]	--	--	--
Pesticides	18.2	11.3	[a]	3.6	9	[a]
Nutrients	7.9	4.9	[a]	40,495	100,066	33%
Chlorophyll	--	--	--	20,136	49,757	16%
Nitrogen	--	--	--	19,254	49,307	16%
Phosphorus	--	--	--	245	854	[a]

Source: Table 4, pp. 7–8 of MDNR, 2012b, *Missouri Water Quality Report (Section 305[b] Report)*, Missouri Department of Natural Resources, Water Protection Program, Jefferson City, Missouri, May 2, 2012.

[a] Less than 1%.

19.3.4.8.4 Water Quality of Missouri Surface Water

The MDNR rates the quality of Missouri surface water by its conformance with the Missouri Water Quality Standards (10 CSR Division 20). The standards were first implemented in 1970 and are revised at least every three years. Table 19-41 lists the various uses of Missouri surface waters and the portions of the state waters that are protected for each use.

Table 19-41. Missouri Waters Protected for Various Uses

Designated use	Stream km	Stream mi	Percent of total	Lake ha	Lake acres	Percent of total
Protection of aquatic life and fish consumption	39,318	24,431	100	12,2563	30,2867	100
Subset: warm-water fishery	33,596	20,875	85	118018	291,635	96
[a]Cool-water fishery	5,241	3,257	13	0	0	0
[b]Cold-water fishery	479	298	1	4,545	11,232	4
Livestock and wildlife watering	39,318	24,431	100	12,2563	302,867	100
Whole body contact recreation	38,622	23,999	98	12,2563	302,867	100
Secondary contact recreation	14,279	8,872	36	103,840	256,601	85
Drinking water supply	5,488	3,410	14	54,102	13,3692	44
Industrial	2,558	1,590	7	2,816	6,959	2
Antidegradation: Outstanding National Resource Waters	275	171	--	--	--	--
Antidegradation: Outstanding State Resource Waters	327	[c]204	--	--	--	--
Total Classified Waters in Missouri	39,318	24,431	--	122,563	302,867	--

Source: Table 4, p. 15 of MDNR, 2012b, *Missouri Water Quality Report (Section 305[b] Report)*, Missouri Department of Natural Resources, Water Protection Program, Jefferson City, Missouri, May 2, 2012.

[a] Smallmouth bass, rock bass.

[b] Trout.

[c] Outstanding State Resource Waters also include 109 ha (270 acres) of marsh wetlands in three locations.

19.3.4.8.5 Missouri Department of Natural Resources Groundwater Assessment

Less than one-half of Missourians rely on groundwater as the source of their drinking water. Groundwater is the major source of drinking water in the Ozarks and the Southeast Lowlands for both public and private supplies. In the Ozarks, groundwater yields are usually large and of excellent quality. Many municipalities pump groundwater directly into the water supplies without treatment. Due to large amounts of rainfall and surface water runoff funneling through the geologic formations of the Ozarks, groundwater can be more easily contaminated. This is due to surface water flows directly entering groundwater through cracks, fractures, or solution cavities in the bedrock, with little or no filtration. Contaminants from leaking septic tanks, storage tanks, or surface waters affected by domestic wastewater, animal feedlots, and other pollution sources can move directly into groundwater through these cavities in the bedrock (MDNR, 2012b).

Groundwater is of good quality in the southeast lowlands. Contaminants are filtered by thick deposits of sand, silt, and clay as they move through the groundwater system. While shallow groundwater wells are subject to the same problems as seen in the Ozarks, with elevated levels of nitrate or bacteria, deep wells are generally unaffected by contaminants. Shallow groundwater in northern and western Missouri tends to be more mineralized and to have taste and odor problems due to high levels of iron and manganese. Like shallow wells in the southeast lowlands, wells in this part of Missouri can be affected by nitrates, bacteria, or pesticides. In urban areas, alluvial aquifers of large rivers such as the Missouri River have occasionally been locally contaminated by spills or improper disposal of industrial or commercial chemicals (MDNR, 2012b).

The major sources and contaminants of groundwater in Missouri are listed in Table 19-42. Table 19-43 summarizes the MDNR groundwater contamination summary for Missouri.

Table 19-42. Major Sources of Groundwater Contamination in Missouri

Contaminant source	[a]10 highest priority sources (X)	Significant risk factors	Contaminants
Agricultural activities			
Agricultural chemical facilities	--	--	--
Animal feedlots	--	--	--
Drainage wells	--	--	--
Fertilizer applications	X	A, C, D, E	Nitrate
Irrigation practices	--	--	--
Pesticide applications	X	A, B, C, D, E	Organic pesticides
Storage and treatment activities			
Land application	X	A, D, E	Nitrate, pathogens (bacteria, protozoa, viruses)
Material stockpiles	--	--	--
Aboveground storage tanks	--	--	--
Underground storage tanks	X	A, B, C, D, E	Petroleum compounds
Surface impoundments	--	--	--
Waste piles	--	--	--
Waste tailings	--	--	--
Disposal activities			
Deep injection wells	--	--	--
Landfills	--	--	--
Septic systems	X	A, D, E	Nitrate, pathogens (bacteria, protozoa, viruses)
Shallow injection wells	--	--	--
Other sources			
Hazardous waste generators	--	--	--
Hazardous waste sites	X	A, B, C, D	Organic pesticides, halogenated solvents, metals, radionuclides
Industrial facilities	X	A, B, C, E	Nitrate, ammonia, pentachlorophenol, dioxin
Material transfer operations	--	--	--
Mining and mine drainage	X	A, E	Metals
Pipelines and sewer lines	--	--	--
Salt storage and road salting	--	--	--
Salt water intrusion	X	C	Salinity/brine
Spills	X	A, B, C, E	Organic pesticides, petroleum compounds, halogenated solvents, ammonia
Transportation of materials	--	--	--
Urban runoff	--	--	--

Source: Tables 10 and 11, p. 28-29 of MDNR, 2012b, *Missouri Water Quality Report (Section 305[b] Report)*, Missouri Department of Natural Resources, Water Protection Program, Jefferson City, Missouri, May 2, 2012.

[a] Not in priority order.

A = Human health or environmental toxicity risk.
B = Size of population at risk.
C = Location of sources relative to drinking water sources.
D = Number and/or size of contaminant sources.
E = Hydrogeologic sensitivity.

Table 19-43. Missouri Department of Natural Resources Missouri Groundwater Contamination Summary

Hydrogeologic Setting: All Aquifers. Data Reporting Period: 2010-2011.

Source type	Number of sites	Number of sites that are listed and/or have confirmed releases	Number with confirmed groundwater contamination	[a]Contaminants	Number of site investigations (optional)	Number of sites that have been stabilized or have had the source removed (optional)	Number of sites with corrective action plans (optional)	Number of sites with active remediation (optional)	Number of sites with cleanup completed (optional)
NPL	25	25	25	1	-	-	-	-	-
CERCLIS (non-NPL)	30	30	30	1	-	-	-	-	-
DoD/DOE	305	37	33	1, 2, 3, 4	50	213	231	18	45
LUST	3,578	195	55	3	165	82	—	1,090	74
RCRA Corrective Action	89	89	55	1, 2, 3, 4	49	39	27	26	16
[b]Underground injection	22	22	22	1, 3	22		22	22	
State sites	856	856	387	1, 2, 3, 4	847	575	575	49	575
Nonpoint Sources	-	-	-	-	-	-	-	-	-
Other (specify)	-	-	-	-	-	-	-	-	-

Source: Table 11, p. 30 of MDNR, 2012b, *Missouri Water Quality Report (Section 305(b) Report)*, Missouri Department of Natural Resources, Water Protection Program, Jefferson City, Missouri, May 2, 2012.

[a] Contaminants: 1 = VOAs, SVOAs, solvents, PCBs, dioxin, PAHs, herbicides, pesticides, metals, explosives.
2 = VOAs, PCBs, pesticides, dioxin, metals, radionuclides, semivolatile organic compounds, etc.
3 = BTEX, TPH, methyl-t-butyl ether, PAHs, metals, SVOA.
4 = Creosote, pentachlorophenol, organic solvents, chlorinated solvents, petroleum, and asbestos.

[b] Includes sites where chemicals were injected into groundwater as part of approved remediation plan.

BTEX = benzene, toluene, ethylbenzene, and xylenes.
CERCLIS = Comprehensive Environmental Response, Compensation, and Liability Information System.
DoD = U.S. Department of Defense.
DOE = U.S. Department of Energy.
LUST = leaking underground storage tank.
NPL = National Priority List.
PAH = polycyclic aromatic hydrocarbon.
PCB = polychlorinated biphenyl.
RCRA = Resource Conservation and Recovery Act.
SVOA = semivolatile organic analyte.
TPH = total petroleum hydrocarbon.
VOA = volatile organic analyte.