Appendix C | **Hydrologic Data Reports**

Appendix C1 | **2022 Groundwater Discharge and Usage**

2022

GROUNDWATER DISCHARGE AND USAGE

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2022 GROUNDWATER DISCHARGE AND USAGE

Groundwater discharges from the Edwards Aquifer either as springflow or as pumping from wells. Comal and San Marcos springs, the largest and second-largest springs in Texas, respectively, are fed by the Edwards Aquifer. This springflow greatly benefits the recreational economies in New Braunfels and San Marcos, and both springs provide habitat for threatened and endangered species. Figure 1 shows locations of the major springs in the Edwards Aquifer region. Wells drilled into the Edwards Aquifer throughout the region provide water for many diverse uses, including irrigation, municipal water supplies, industrial applications, and domestic/livestock consumption.

Estimates of total annual groundwater discharge from combined springflow and pumping for the Edwards Aquifer are provided in Table 1 for the period of record (1934–2022). Annual total groundwater discharge estimates range from a low of 388,800 acre-feet in 1955 to a high of 1,130,000 acre-feet in 1992. In 2022, the total groundwater discharged from the Edwards Aquifer from both wells and springs is estimated at 607,200 acre-feet: 219,900 acre-feet as springflow and 387,200 acre-feet as pumping from wells.

The portion of discharge as springflow is estimated by measuring streamflow downstream of the springs and converting the streamflow measurements to spring discharge by subtracting any estimated contributions from surface runoff. Total annual spring discharge has varied from a low of 69,800 acre-feet in 1956 to a high of 802,800 acre-feet in 1992. Monthly springflow estimates for 2022 at each of the six major Edwards Aquifer springs are provided in Table 2.

In Figures 2 and 3, flows at Comal and San Marcos springs are shown as mean annual flows compared with the long-term historical mean annual flow rate for the available period of record. The 2022 mean annual flow rate was less than the historical mean discharge at both Comal Springs and San Marcos Springs.

Discharge as well pumping can be classified as either reported or unreported discharge. Reported discharge refers to water pumped from the aquifer by a person or entity holding a groundwater withdrawal permit. These users, who are typically larger quantity users, meter their withdrawals and report the totals to the EAA. Unreported discharge refers to use that does not require a groundwater withdrawal permit from the EAA, such as domestic, livestock, or federal facility use. Unreported discharge is estimated based on numbers of wells and statistical estimates of per-well usage. In 2022, unreported discharge for domestic and livestock wells was estimated at 14,866 acre-feet, and non-reporting federal facility discharge was estimated at 5,482 acre-feet, for a total of 20,348 acre-feet of unreported discharge. Reported discharge totaled 366,873 acre-feet. The total of all reported and unreported pumping discharge is 387,221 acre-feet.

Table 3 provides a summary of well and spring discharge for 2022 based on type of use and county. The distribution of discharge from springflows and the different types of pumping for 2022 is shown graphically in Figure 4. Total annual discharge from pumping and springflow are compared in Figure 5 for the period of record from 1934–2022. The years when springflow exceeds pumping tend to be wet years when pumping demand is lowered by more frequent rainfall and higher aquifer levels produce increased springflows. Conversely, during dry years pumping tends to exceed springflow due to increased municipal and agricultural demand and lower aquifer levels. Since 1997, however, the increase in pumping demand during dry years has been limited by the withdrawal permit system and critical period pumping reductions implemented under the Edwards Aquifer Authority Act. Table 4 provides a historical list of total annual discharge by type of use for the period 1955–2022.

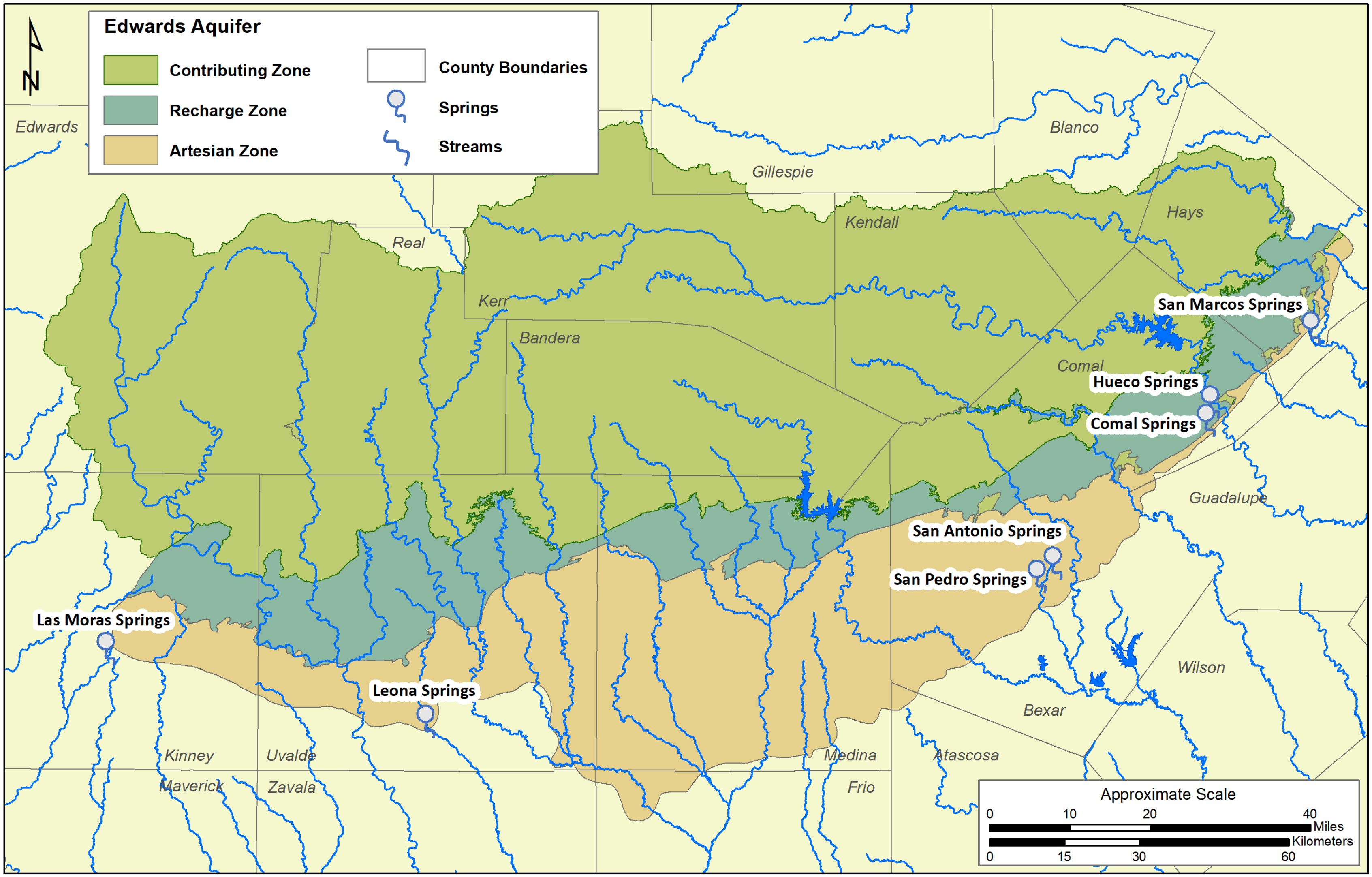

Figure 1. Locations of major Springs in the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer.

Table 1. Annual Estimated Groundwater Discharge Data by County for the Edwards Aquifer 1934–2022 (measured in thousands of acre-feet)

Year	Uvalde[a]	Medina	Bexar[b]	Comal[c]	Hays	Total	Total Wells	Total Springs
1934	12.6	1.3	109.3	229.1	85.6	437.9	101.9	336.0
1935	12.2	1.5	171.8	237.2	96.9	519.6	103.7	415.9
1936	26.6	1.5	215.2	261.7	93.2	598.2	112.7	485.5
1937	28.3	1.5	201.8	252.5	87.1	571.2	120.2	451.0
1938	25.2	1.6	187.6	250.0	93.4	557.8	120.1	437.7
1939	18.2	1.6	122.5	219.4	71.1	432.8	118.9	313.9
1940	16.1	1.6	116.7	203.8	78.4	416.6	120.1	296.5
1941	17.9	1.6	197.4	250.0	134.3	601.2	136.8	464.4
1942	22.5	1.7	203.2	255.1	112.2	594.7	144.6	450.1
1943	19.2	1.7	172.0	249.2	97.2	539.3	149.1	390.2
1944	11.6	1.7	166.3	252.5	135.3	567.4	147.3	420.1
1945	12.4	1.7	199.8	263.1	137.8	614.8	153.3	461.5
1946	6.2	1.7	180.1	261.9	134.0	583.9	155.0	428.9
1947	13.8	2.0	193.3	256.8	127.6	593.5	167.0	426.5
1948	9.2	1.9	159.2	203.0	77.3	450.6	168.7	281.9
1949	13.2	2.0	165.3	209.5	89.8	479.8	179.4	300.4
1950	17.8	2.2	177.3	191.1	78.3	466.7	193.8	272.9
1951	16.9	2.2	186.9	150.5	69.1	425.6	209.7	215.9
1952	22.7	3.1	187.1	133.2	78.8	424.9	215.4	209.5
1953	27.5	4.0	193.7	141.7	101.4	468.3	229.8	238.5
1954	26.6	6.3	208.9	101.0	81.5	424.3	246.2	178.1
1955	28.3	11.1	215.2	70.1	64.1	388.8	261.0	127.8
1956	59.6	17.7	229.6	33.6	50.4	390.9	321.1	69.8
1957	29.0	11.9	189.4	113.2	113.0	456.5	237.3	219.2
1958	23.7	6.6	199.5	231.8	155.9	617.5	219.3	398.2
1959	43.0	8.3	217.5	231.7	118.5	619.0	234.5	384.5
1960	53.7	7.6	215.4	235.2	143.5	655.4	227.1	428.3
1961	56.5	6.4	230.3	249.5	140.8	683.5	228.2	455.3
1962	64.6	8.1	220.0	197.5	98.8	589.0	267.9	321.1
1963	51.4	9.7	217.3	155.7	81.9	516.0	276.4	239.6
1964	49.3	8.6	201.0	141.8	73.3	474.0	260.2	213.8
1965	46.8	10.0	201.1	194.7	126.3	578.9	256.1	322.8
1966	48.5	10.4	198.0	198.9	115.4	571.2	255.9	315.3
1967	81.1	15.2	239.7	139.1	82.3	557.4	341.3	216.1
1968	58.0	9.9	207.1	238.2	146.8	660.0	251.7	408.3
1969	88.5	13.6	216.3	218.2	122.1	658.7	307.5	351.2
1970	100.9	16.5	230.6	229.2	149.9	727.1	329.4	397.7
1971	117.0	32.4	262.8	168.2	99.1	679.5	406.8	272.7
1972	112.6	28.8	247.7	234.3	123.7	747.1	371.3	375.8
1973	96.5	14.9	273.0	289.3	164.3	838.0	310.4	527.6
1974	133.3	28.6	272.1	286.1	141.1	861.2	377.4	483.8
1975	112.0	22.6	259.0	296.0	178.6	868.2	327.8	540.4
1976	136.4	19.4	253.2	279.7	164.7	853.4	349.5	503.9
1977	156.5	19.9	317.5	295.0	172.0	960.9	380.6	580.3
1978	154.3	38.7	269.5	245.7	99.1	807.3	431.8	375.5
1979	130.1	32.9	294.5	300.0	157.0	914.5	391.5	523.0
1980	151.0	39.9	300.3	220.3	107.9	819.4	491.1	328.3

Table 1. (Continued)

Year	Uvalde[a]	Medina	Bexar[b]	Comal[c]	Hays	Total	Total Wells	Total Springs
1981	104.2	26.1	280.7	241.8	141.6	794.4	387.1	407.3
1982	129.2	33.4	305.1	213.2	105.5	786.4	453.1	333.3
1983	107.7	29.7	277.6	186.6	118.5	720.1	418.5	301.6
1984	156.9	46.9	309.7	108.9	85.7	708.1	529.8	178.3
1985	156.9	59.2	295.5	200.0	144.9	856.5	522.5	334.0
1986	91.7	41.9	294.0	229.3	160.4	817.3	429.3	388.0
1987	94.9	15.9	326.6	286.2	198.4	922.0	364.1	557.9
1988	156.7	82.2	317.4	236.5	116.9	909.7	540.0	369.7
1989	156.9	70.5	305.6	147.9	85.6	766.5	542.4	224.1
1990	118.1	69.7	276.8	171.3	94.1	730.0	489.4	240.6
1991	76.6	25.6	315.5	221.9	151.0	790.6	436.0	354.6
1992	76.5	9.3	370.5	412.4	261.3	1,130.0	327.2	802.8
1993	107.5	17.8	371.0	349.5	151.0	996.7	407.3	589.4
1994	95.5	41.1	297.7	269.8	110.6	814.8	424.6	390.2
1995	90.8	35.2	272.1	235.0	127.8	761.0	399.6	361.3
1996	117.6	66.3	286.8	150.2	84.7	705.6	493.6	212.0
1997	77.0	31.4	260.2	243.3	149.2	761.1	377.1	383.9
1998	113.1	51.3	312.4	271.8	168.8	917.6	453.5	464.1
1999	104.0	49.2	307.1	295.5	143.0	898.8	442.7	456.1
2000	89.1	45.1	283.6	226.1	108.4	752.3	414.8	337.5
2001	68.6	33.9	291.6	327.7	175.4	890.0	367.7	529.6
2002	76.2	40.6	311.9	350.4	202.1	981.2	371.3	609.9
2003	89.4	34.8	331.7	344.7	176.3	976.9	362.1	621.5
2004	91.3	22.5	331.9	341.4	153.1	940.3	317.4	622.9
2005	107.4	37.3	366.1	349.3	175.6	1,035.7	388.5	647.1
2006	107.5	64.9	289.5	216.7	87.9	766.5	454.5	312.0
2007	64.6	18.4	330.2	331.7	196.0	940.9	319.9	621.0
2008	102.0	48.8	320.4	266.6	108.0	845.7	428.6	417.1
2009	76.9	47.3	265.2	206.6	87.8	683.7	395.7	287.9
2010	53.1	36.4	298.5	312.1	162.5	862.6	372.6	490.0
2011	79.6	57.4	277.2	187.7	91.0	692.9	427.7	265.2
2012	57.6	44.3	267.5	193.4	124.2	687.0	384.7	302.3
2013	43.6	42.8	251.0	154.9	96.0	588.6	355.8	232.8
2014	41.5	43.1	230.5	114.5	97.9	527.5	332.2	195.4
2015	27.1	27.6	256.3	239.8	178.8	729.7	325.2	404.5
2016	46.9	31.9	262.6	320.7	208.3	870.3	325.3	545.0
2017	63.0	43.6	305.3	294.0	166.8	872.2	379.2	493.0
2018	69.9	42.0	277.1	244.0	130.4	763.6	370.6	393.0
2019	76.8	40.9	290.7	306.1	225.0	884.6	358.6	526.0
2020	79.1	50.5	236.6	235.2	114.7	716.2	362.4	353.7
2021	56.1	39.8	222.3	235.2	113.7	667.1	326.6	340.5
2022	70.7	56.4	241.7	143.1	92.9	607.2	387.2	219.9
For period of record (1955--2022):								
Median	69.9	22.5	256.3	235.2	118.5	705.6	332.2	383.9
Mean	71.1	25.2	249.6	230.1	125.0	700.4	318.8	381.7
For last ten years (2012--2022):								
Median	57.6	42.8	256.3	235.2	124.2	716.2	358.6	353.7
Mean	57.5	42.1	258.3	225.5	140.8	719.5	355.3	364.2

Data source: USGS Letter Report to Edwards Aquifer Authority files, dated April 3, 2023.

a = As of 2008, no longer includes Kinney County discharge; prior years include 1,900 acre-feet of discharge for Kinney County.

b = Includes reports of Edwards Aquifer irrigators in Atascosa County.

c = Includes reports of Edwards Aquifer industrial and municipal users in Guadalupe County.

Differences in totals may occur due to rounding.

Table 2. Estimated Spring Discharge from the Edwards Aquifer in 2022 (in acre-ft)

Month	Leona Springs and Leona River	San Pedro Springs	San Antonio Springs	Comal Springs	Hueco Springs	San Marcos Springs	Total
Jan	542	158	0	16,800	1,210	9,820	28,500
Feb	521	180	0	15,800	1,850	9,400	27,700
Mar	462	86	0	16,400	1,030	10,400	28,400
Apr	392	2	0	13,200	583	8,730	22,900
May	360	0	0	11,700	309	7,900	20,300
Jun	274	0	0	8,460	124	6,430	15,300
Jul	133	0	0	7,080	7	6,160	13,400
Aug	27	0	0	6,400	2	5,580	12,000
Sep	96	0	0	6,880	446	5,220	12,700
Oct	130	0	0	5,930	195	5,200	11,500
Nov	173	0	0	7,130	511	5,220	13,000
Dec	222	0	0	7,760	515	5,360	13,900
Total	**3,330**	**426**	**0**	**124,000**	**6,790**	**85,400**	**220,000**

Data source: USGS letter report dated April 3, 2023.

Totals may not equal sum of discharge values due to rounding.

Table 3. Discharge Summary for Calendar Year 2022 (in acre-feet)

	Wells – measured			*Wells – not measured*				
County	**Irrigation**	**Municipal**	**Industrial**	**Domestic, Livestock, Limited Pumping†**	**Federal Facilities†**	**Total Well Discharge**	**Total Spring Discharge**	**Total Well and Spring Discharge**
Atascosa	1,869	0	7	0	0	1,876	0	1,876
Bexar	5,491	203,940	17,395	9,392	5,100	241,317	426	241,743
Comal	87	7,496	4,038	700	0	12,322	130,790	143,112
Guadalupe	0	100	229	30	0	359	0	359
Hays	142	5,009	1,073	923	382	7,528	85,400	92,928
Medina	42,044	8,361	4,871	1,168	0	56,444	0	56,444
Uvalde	61,392	3,216	114	2,653	0	67,375	3,330	70,705
Total	**111,024**	**228,122**	**27,727**	**14,866**	**5,482**	**387,221**	**219,946**	**607,167**

†Federal facilities, and domestic and livestock wells are not required to report annual use; these quantities are estimated.

Totals may not equal sum of discharge values due to rounding.

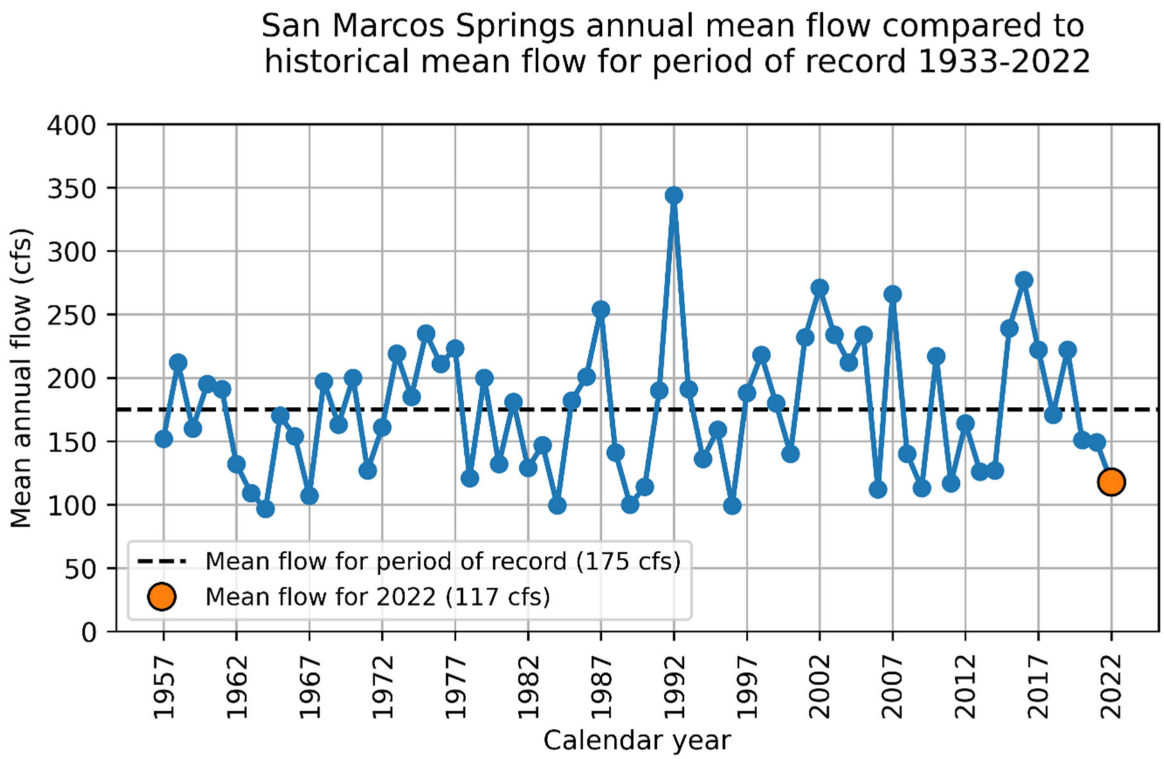

Figure 2. Historical time series of mean annual flow at San Marcos Springs.

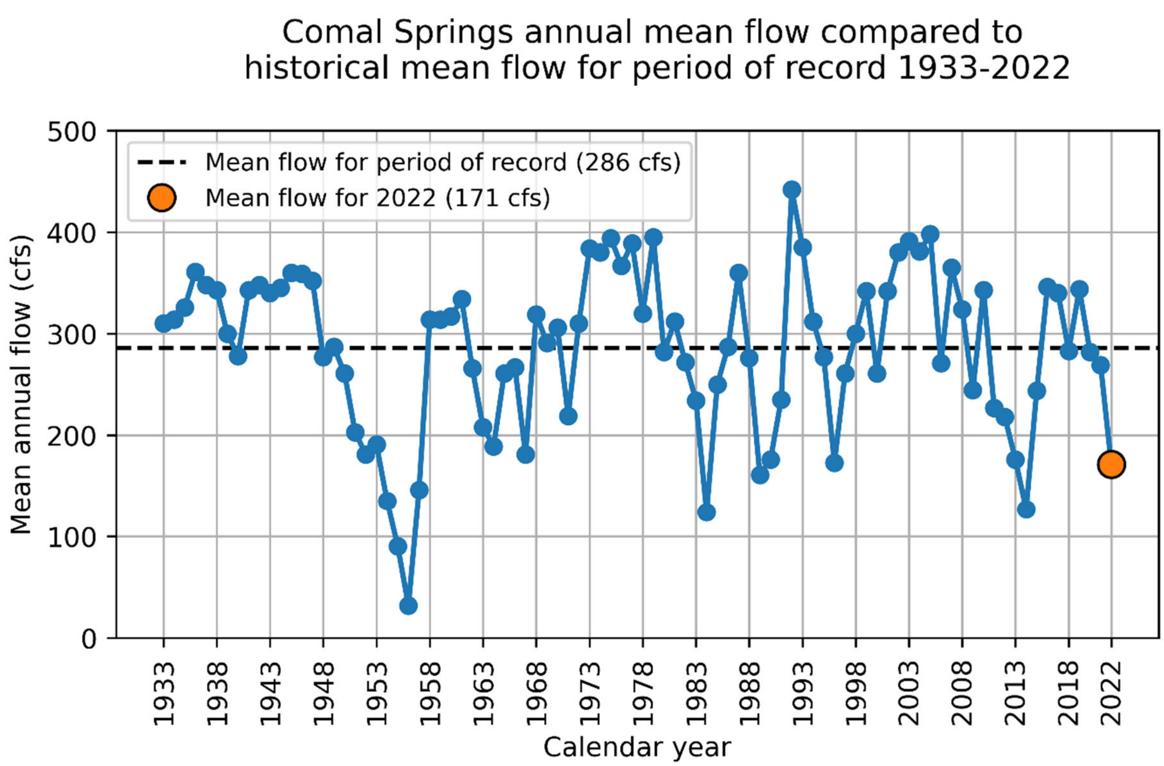

Figure 3. Historical time series of mean annual flow at Comal Springs.

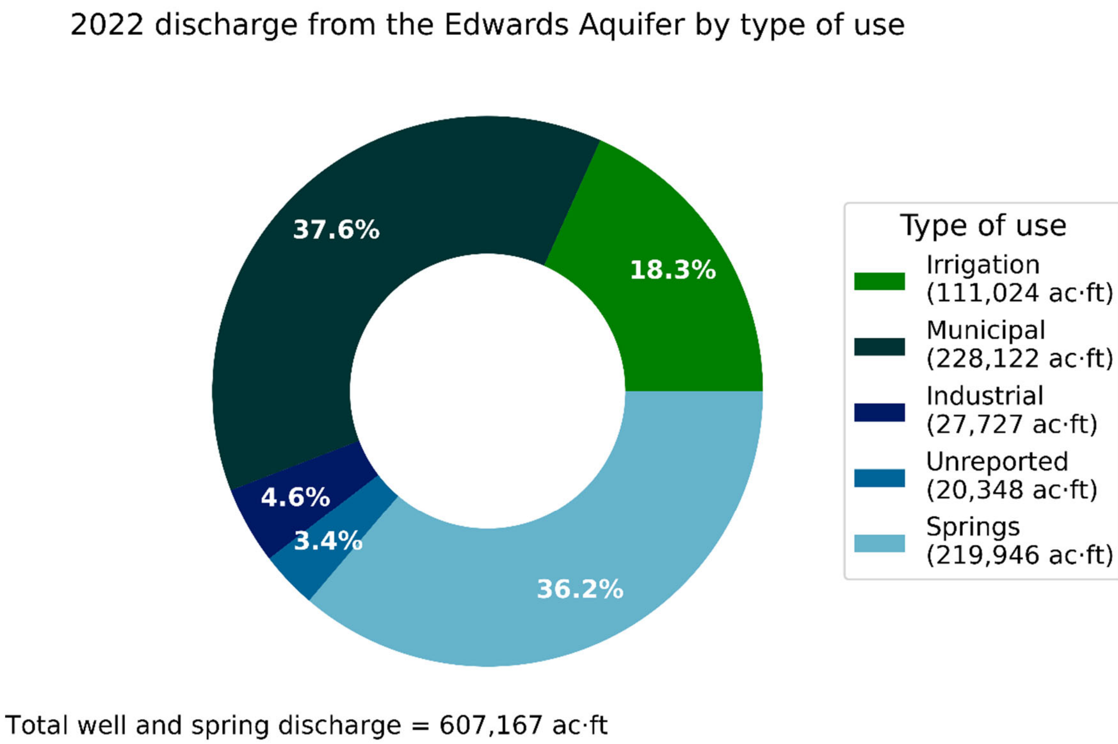

Figure 4. Discharge from the Edwards Aquifer by type of use.

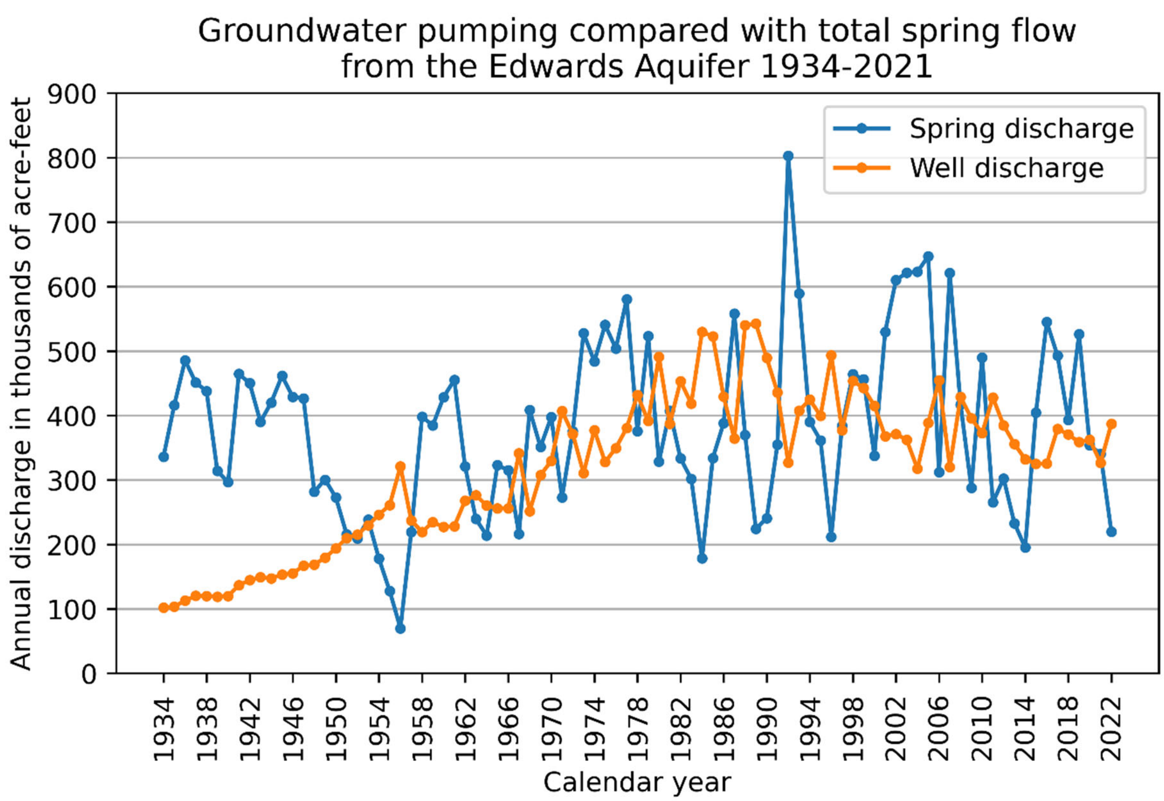

Figure 5. Historical time series of Edwards Aquifer spring discharge compared with groundwater pumping.

Table 4. Annual Estimated Edwards Aquifer Groundwater Discharge by Use, 1955–2021 (in thousands of acre-feet)

Year	Irrigation	Municipal	Domestic/ Stock	Industrial/ Commercial	Springs
1955	85.2	120.5	30.1	25.1	127.8
1956	127.2	138.3	28.9	22.4	69.8
1957	68.8	116.1	29.8	22.6	219.2
1958	47.2	113.7	33.4	25.1	398.2
1959	60.0	118.9	31.5	24.2	384.5
1960	54.9	121.1	31.5	23.3	428.3
1961	52.1	124.5	29.6	22.2	455.3
1962	72.7	143.7	28.8	22.8	321.1
1963	75.4	151.8	27.8	21.8	239.6
1964	72.6	140.2	26.3	21.7	213.8
1965	68.0	138.8	27.0	22.3	322.8
1966	68.2	141.8	23.3	22.6	315.3
1967	119.4	171.0	25.1	25.8	216.1
1968	59.3	146.9	25.5	20.0	408.3
1969	95.2	162.0	29.2	21.1	351.2
1970	110.1	167.5	29.3	22.5	397.7
1971	159.4	196.2	28.6	22.6	272.7
1972	128.8	190.5	30.8	21.1	375.8
1973	82.2	177.1	32.3	18.8	527.6
1974	140.4	174.6	33.5	15.1	483.3
1975	96.4	182.5	33.6	15.3	540.4
1976	118.2	182.1	34.6	14.7	503.9
1977	124.2	205.3	38.1	13.0	580.3
1978	165.8	214.2	40.3	11.5	375.5
1979	126.8	208.9	40.7	15.2	523.0
1980	177.9	256.2	43.3	13.7	328.3
1981	101.8	231.8	40.9	12.6	407.3
1982	130.0	268.6	39.5	15.0	333.3
1983	115.9	249.2	38.8	14.7	301.5
1984	191.2	287.2	36.2	15.2	178.3
1985	203.1	263.7	39.2	16.5	334.0
1986	104.2	266.3	42.0	16.8	388.0
1987	40.9	260.9	43.5	18.7	557.9
1988	193.1	286.2	41.9	18.8	369.7
1989	196.2	285.2	38.2	22.9	224.1
1990	172.9	254.9	37.9	23.7	240.6
1991	88.5	240.5	39.5	67.5	354.6
1992	27.1	236.5	34.8	29.0	802.8
1993	69.3	252.0	49.9	36.1	589.4
1994	104.5	247.0	33.9	39.3	390.2
1995	95.6	255.0	11.6	37.3	361.3
1996	181.3	261.3	12.3	38.8	212.0

Table 4. (Continued)

Year	Irrigation	Municipal	Domestic/ Stock	Industrial/ Commercial	Springs
1997	77.4	253	12.3	34.4	383.9
1998	131.9	266.5	13.4	41.7	464.1
1999	113.6	273.3	13.4	42.4	456.1
2000	106.3	261.3	13.4	33.8	337.5
2001	79	245.9	13.4	29.4	529.4
2002	97.1	228.4	13.6	32.3	609.9
2003	79.6	237.2	13.7	31.7	621.5
2004	55.4	220.3	13.8	28.1	622.9
2005	85.3	255.1	13.8	34.3	647.1
2006	149.1	259.1	13.8	34.5	312
2007	42.5	236	13.8	27.6	620.6
2008	112.7	273.6	13.5	28.8	417.1
2009	108.9	247.5	13.6	25.7	288
2010	72.7	259.9	13.6	26.4	490
2011	124.9	265.5	13.6	23.6	265.2
2012	90.6	257.9	13.7	22.6	302.3
2013	76.3	239.5	13.7	26.3	232.8
2014	75.3	220.1	13.9	22.8	195.4
2015	42.2	247.2	13.9	21.9	404.5
2016	54.7	232.6	14	24	545
2017	74.1	268.3	14	22.8	493
2018	84	250.5	14.1	22.1	393
2019	73.7	241.5	14.1	23.8	526
2020	97.7	223.4	14.6	26.8	353.7
2021	74.3	212	14.5	25.7	340.5
2022	111.0	228.1	14.9	27.7	220.0
For period of record (1955--2022):					
Median	95.4	236.3	28.2	22.9	379.9
Mean	100.9	217.0	25.8	24.9	389.7
For last ten years (2012--2022):					
Median	75.3	239.5	14.0	23.8	353.7
Mean	77.6	238.3	14.1	24.2	364.2

Appendix C2 | **2022 Groundwater Recharge**

2022

GROUNDWATER RECHARGE

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2022 GROUNDWATER RECHARGE

Recharge to the Edwards Aquifer originates as precipitation over the contributing and recharge zones of the aquifer, or as interformational flow from adjacent aquifers. The EAA maintains a joint funding agreement with the U.S. Geological Survey (USGS) to provide surface recharge estimates for eight of the nine major drainage basins with streams that flow on to the Edwards Aquifer recharge zone (Figure 1). Recharge is estimated using a water-balance method that relies on precipitation and streamflow measurements across the region. Based on the USGS methodology, the Guadalupe River Basin does not appear to provide significant recharge to the Edwards Aquifer, so recharge is not estimated for that drainage basin.

Table 1 lists estimated annual recharge by drainage basin for the period of record from 1934 through 2022 based on USGS calculations. Estimates of total annual recharge ranged from 43,700 acre-feet during the drought of record in 1956 to 2,486,000 acre-feet in 1992, as shown in Figure 2. In 2022, total estimated recharge was 156,000 acre-feet, which is below both the mean annual recharge of 689,000 acre-feet and the median annual recharge of 538,000 acre-feet for the period of record.

The EAA currently operates four recharge dams in Medina County on the Edwards Aquifer Recharge Zone (yellow triangles in Figure 1). The total amount of enhanced recharge for each site is estimated using data from stage recorders near these structures. Enhanced recharge refers to the estimated amount of additional recharge attributable to these structures above the amount of recharge that would have occurred naturally in the absence of these structures. Table 2 shows the estimated annual enhanced recharge for each site starting in 2014. Recharge estimates in Table 2 prior to 2014 reflect total annual recharge at each dam site. The total estimated enhanced recharge recorded for these structures in 2022 was 0 acre-feet. Enhanced recharge is generally a small fraction of total recharge and tends to be greater in wet years when natural recharge is also high.

Recharge resulting from interformational flow in adjacent aquifers such as the Trinity Aquifer is not estimated annually. Estimates associated with interformational flow are variable and range from 5,000 to 100,000 acre-feet per year in different publications. Estimated interformational recharge is not included in recharge values provided in this report. Edwards Aquifer Authority is presently conducting an Interformational Flow Study that may help to better quantify the amount of water that may enter the Edwards Aquifer from Trinity Aquifer formations to the north.

Figure 1. Major Drainage Basins and Edwards Aquifer Authority-Operated Recharge Structures in the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer.

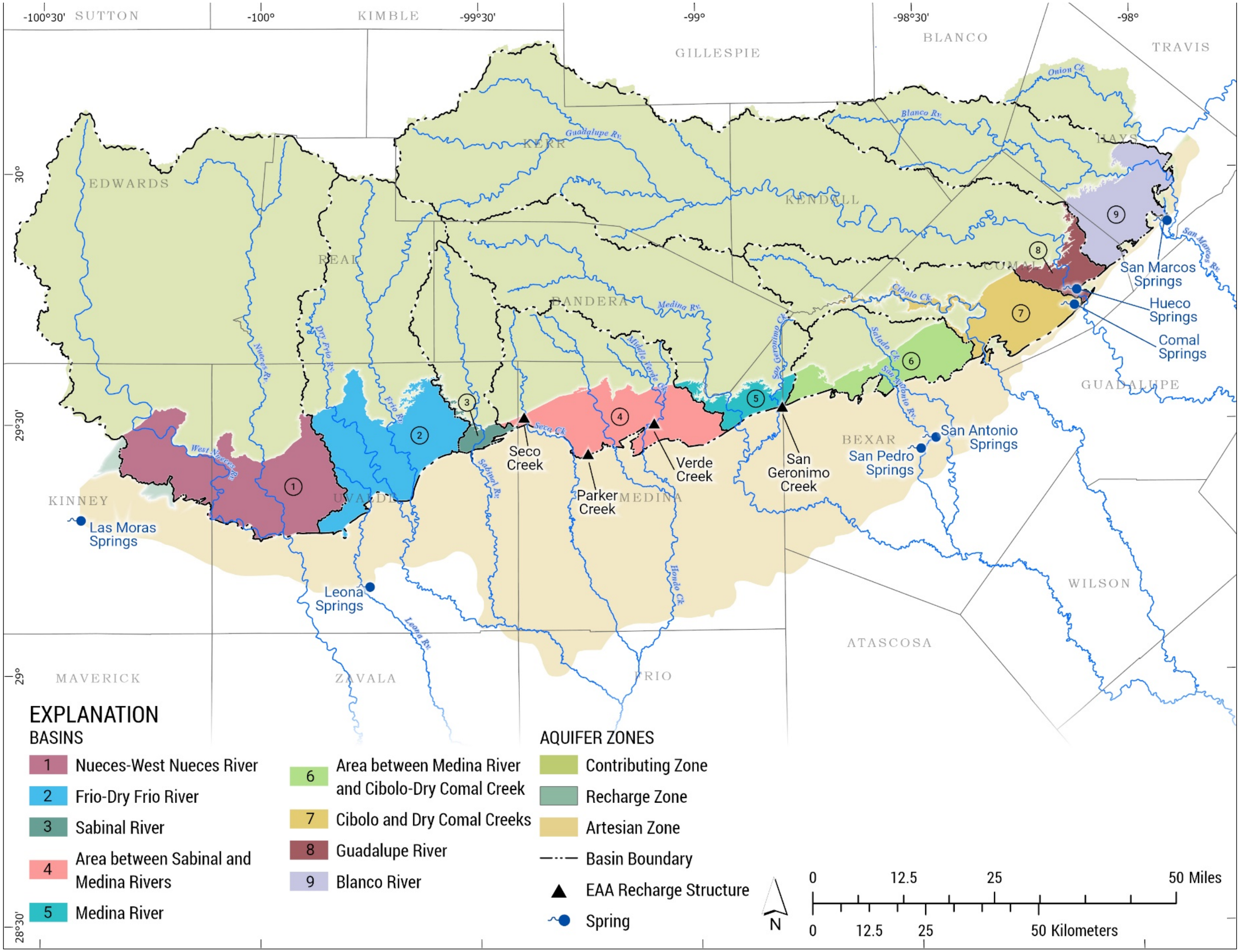

Table 1. Estimated Annual Groundwater Recharge to the San Antonio Segment of the Edwards Aquifer by Drainage Basin, 1934–2022 (in thousands of acre-feet)

Year	Nueces River/ West Nueces River Basin	Frio River/ Dry Frio River Basin	Sabinal River Basin	Area between Sabinal River and Medina River Basins	Medina River Basin	Area between Medina River and Cibolo Creek/ Dry Comal Creek Basins	Cibolo Creek/Dry Comal Creek Basin	Blanco River Basin	Total†
1934	8.6	27.9	7.5	19.9	46.5	21.0	28.4	19.8	179.6
1935	411.3	192.3	56.6	166.2	71.1	138.2	182.7	39.8	1,258.2
1936	176.5	157.4	43.5	142.9	91.6	108.9	146.1	42.7	909.6
1937	28.8	75.7	21.5	61.3	80.5	47.8	63.9	21.2	400.7
1938	63.5	69.3	20.9	54.1	65.5	46.2	76.8	36.4	432.7
1939	227.0	49.5	17.0	33.1	42.4	9.3	9.6	11.1	399.0
1940	50.4	60.3	23.8	56.6	38.8	29.3	30.8	18.8	308.8
1941	89.9	151.8	50.6	139.0	54.1	116.3	191.2	57.8	850.7
1942	103.5	95.1	34.0	84.4	51.7	66.9	93.6	28.6	557.8
1943	36.5	42.3	11.1	33.8	41.5	29.5	58.3	20.1	273.1
1944	64.1	76.0	24.8	74.3	50.5	72.5	152.5	46.2	560.9
1945	47.3	71.1	30.8	78.6	54.8	79.6	129.9	35.7	527.8
1946	80.9	54.2	16.5	52.0	51.4	105.1	155.3	40.7	556.1
1947	72.4	77.7	16.7	45.2	44.0	55.5	79.5	31.6	422.6
1948	41.1	25.6	26.0	20.2	14.8	17.5	19.9	13.2	178.3
1949	166.0	86.1	31.5	70.3	33.0	41.8	55.9	23.5	508.1
1950	41.5	35.5	13.3	27.0	23.6	17.3	24.6	17.4	200.2
1951	18.3	28.4	7.3	26.4	21.1	15.3	12.5	10.6	139.9
1952	27.9	15.7	3.2	30.2	25.4	50.1	102.3	20.7	275.5
1953	21.4	15.1	3.2	4.4	36.2	20.1	42.3	24.9	167.6
1954	61.3	31.6	7.1	11.9	25.3	4.2	10.0	10.7	162.1
1955	128.0	22.1	0.6	7.7	16.5	4.3	3.3	9.5	192.0
1956	15.6	4.2	1.6	3.6	6.3	2.0	2.2	8.2	43.7
1957	108.6	133.6	65.4	129.5	55.6	175.6	397.9	76.4	1,142.6
1958	266.7	300.0	223.8	294.9	95.5	190.9	268.7	70.7	1,711.2
1959	109.6	158.9	61.6	96.7	94.7	57.4	77.9	33.6	690.4
1960	88.7	128.1	64.9	127.0	104.0	89.7	160.0	62.4	824.8
1961	85.2	151.3	57.4	105.4	88.3	69.3	110.8	49.4	717.1
1962	47.4	46.6	4.3	23.5	57.3	16.7	24.7	18.9	239.4
1963	39.7	27.0	5.0	10.3	41.9	9.3	21.3	16.2	170.7
1964	126.1	57.1	16.3	61.3	43.3	35.8	51.1	22.2	413.2
1965	97.9	83.0	23.2	104.0	54.6	78.8	115.3	66.7	623.5
1966	169.2	134.0	37.7	78.2	50.5	44.5	66.5	34.6	615.2
1967	82.2	137.9	30.4	64.8	44.7	30.2	57.3	19.0	466.5
1968	130.8	176.0	66.4	198.7	59.9	83.1	120.5	49.3	884.7
1969	119.7	113.8	30.7	84.2	55.4	60.2	99.9	46.6	610.5
1970	112.6	141.9	35.4	81.6	68.0	68.8	113.8	39.5	661.6
1971	263.4	212.4	39.2	155.6	68.7	81.4	82.4	22.2	925.3
1972	108.4	144.6	49.0	154.6	87.9	74.3	104.2	33.4	756.4
1973	190.6	256.9	123.9	286.4	97.6	237.2	211.7	82.2	1,486.5

(Table 1. continued)

Year	Nueces River/ West Nueces River Basin	Frio River/ Dry Frio River Basin	Sabinal River Basin	Area between Sabinal River and Medina River Basins	Medina River Basin	Area between Medina River and Cibolo Creek/ Dry Comal Creek Basins	Cibolo Creek/Dry Comal Creek Basin	Blanco River Basin	Total†
1974	91.1	135.7	36.1	115.3	96.2	68.1	76.9	39.1	658.5
1975	71.8	143.6	47.9	195.9	93.4	138.8	195.7	85.9	973.0
1976	150.7	238.6	68.2	182.0	94.5	47.9	54.3	57.9	894.1
1977	102.9	193.0	62.7	159.5	77.7	97.9	191.6	66.7	952.0
1978	69.8	73.1	30.9	103.7	76.7	49.6	72.4	26.3	502.5
1979	128.4	201.4	68.6	203.1	89.4	85.4	266.3	75.2	1,117.8
1980	58.6	85.6	42.6	25.3	88.3	18.8	55.4	31.8	406.4
1981	205.0	365.2	105.6	252.1	91.3	165.0	196.8	67.3	1,448.4
1982	19.4	123.4	21.0	90.9	76.8	22.6	44.8	23.5	422.4
1983	79.2	85.9	20.1	42.9	74.4	31.9	62.5	23.2	420.1
1984	32.4	40.4	8.8	18.1	43.9	11.3	16.9	25.9	197.7
1985	105.9	186.9	50.7	148.5	64.7	136.7	259.2	50.7	1,003.3
1986	188.4	192.8	42.2	173.6	74.7	170.2	267.4	44.5	1,153.7
1987	308.5	473.3	110.7	405.5	90.4	229.3	270.9	114.9	2,003.6
1988	59.2	117.9	17.0	24.9	69.9	12.6	28.5	25.5	355.5
1989	52.6	52.6	8.4	13.5	46.9	4.6	12.3	23.6	214.4
1990	479.3	255.0	54.6	131.2	54.0	35.9	71.8	41.3	1,123.2
1991	325.2	421.0	103.1	315.2	52.8	84.5	109.7	96.9	1,508.4
1992	234.1	586.9	201.1	566.1	91.4	290.6	286.6	226.9	2,485.7
1993	32.6	78.5	29.6	60.8	78.5	38.9	90.9	37.8	447.6
1994	124.6	151.5	29.5	45.1	61.1	34.1	55.6	36.6	538.1
1995	107.1	147.6	34.7	62.4	61.7	36.2	51.1	30.6	531.3
1996	130.0	92.0	11.4	9.4	42.3	10.6	14.7	13.9	324.3
1997	176.9	209.1	57.0	208.4	63.3	193.4	144.2	82.3	1,134.6
1998	141.5	214.8	72.5	201.4	80.3	86.2	240.9	104.7	1,142.3
1999	101.4	136.8	30.8	57.2	77.1	21.2	27.9	21.0	473.5
2000	238.4	123.0	33.1	55.2	53.4	28.6	48.6	34.1	614.5
2001	297.5	126.7	66.2	124.1	90.0	101.5	173.7	89.7	1,069.4
2002	83.6	207.3	70.6	345.2	93.7	175.5	447.8	150.0	1,573.7
2003	149.8	112.2	31.7	67.4	86.6	56.2	105.0	59.9	669.0
2004	481.9	424.5	116.0	343.9	95.5	213.4	315.0	185.8	2,176.1
2005	105.5	147.2	50.1	79.1	82.8	84.8	140.4	74.1	764.0
2006	45.5	60.2	9.0	5.0	47.7	5.1	11.2	17.9	201.6
2007	471.8	474.4	104.0	406.4	75.2	227.6	306.1	96.9	2,162.3
2008	48.2	44.5	5.9	9.8	53.6	9.6	22.8	18.5	212.9
2009	58.5	30.3	1.8	13.5	45.6	7.3	26.4	27.5	210.9
2010	135.4	104.9	31.5	186.3	68.2	81.4	148.2	57.5	813.5
2011	15.3	13.7	1.0	2.0	43.3	3.0	15.3	18.3	112.0
2012	78.3	82.6	8.9	14.4	41.6	3.9	32.2	51.6	313.5
2013	67.7	26.7	0.5	2.8	10.8	3.3	28.7	42.1	182.6
2014	19.8	32.8	4.9	14.4	8.9	0.4	9.5	16.5	107.2
2015	343.8	281.9	42.2	218.4	54.6	131.6	177.3	108.3	1,358.1

(Table 1. continued)

Year	Nueces River/ West Nueces River Basin	Frio River/ Dry Frio River Basin	Sabinal River Basin	Area between Sabinal River and Medina River Basins	Medina River Basin	Area between Medina River and Cibolo Creek/ Dry Comal Creek Basins	Cibolo Creek/Dry Comal Creek Basin	Blanco River Basin	Total†
2016	275.7	247.8	52.4	184.1	77.5	110.9	186.4	86.3	1,221
2017	122.0	95.4	17.0	30.4	72.6	25.0	68.8	55.0	487
2018	360	316	57.3	168	66.8	22.8	71.1	42.9	1,100
2019	90.6	91.8	27.2	40.6	86.8	35.2	81.0	39.1	492
2020	32.0	24.7	3.74	4.49	54.5	4.57	27.4	32.9	184
2021	51.2	35.2	2.54	5.59	46.6	10.9	55.4	39.3	247
2022	78.3	15.6	0.27	1.96	37.3	0.86	5.25	16.6	156
Recharge statistics for the period of record 1934–2022:									
Median	97.9	112	30.8	70.3	59.9	47.8	76.8	36.6	538
Mean	128	135	39.4	106	61.3	67.1	106	46.8	689
Recharge for the period of record 2013–2022 (last ten years):									
Median	84.4	62.3	11.0	22.4	54.6	16.9	62.1	40.7	366
Mean	144	116	20.8	67.1	51.6	34.6	71.1	47.9	553

Data source: USGS letter report (April 3, 2023).

†Totals may not exactly equal sum of all basins due to rounding. USGS began rounding all values to three significant digits in 2017.

Figure 2. Estimated Annual Recharge for the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer, 1934–2022.

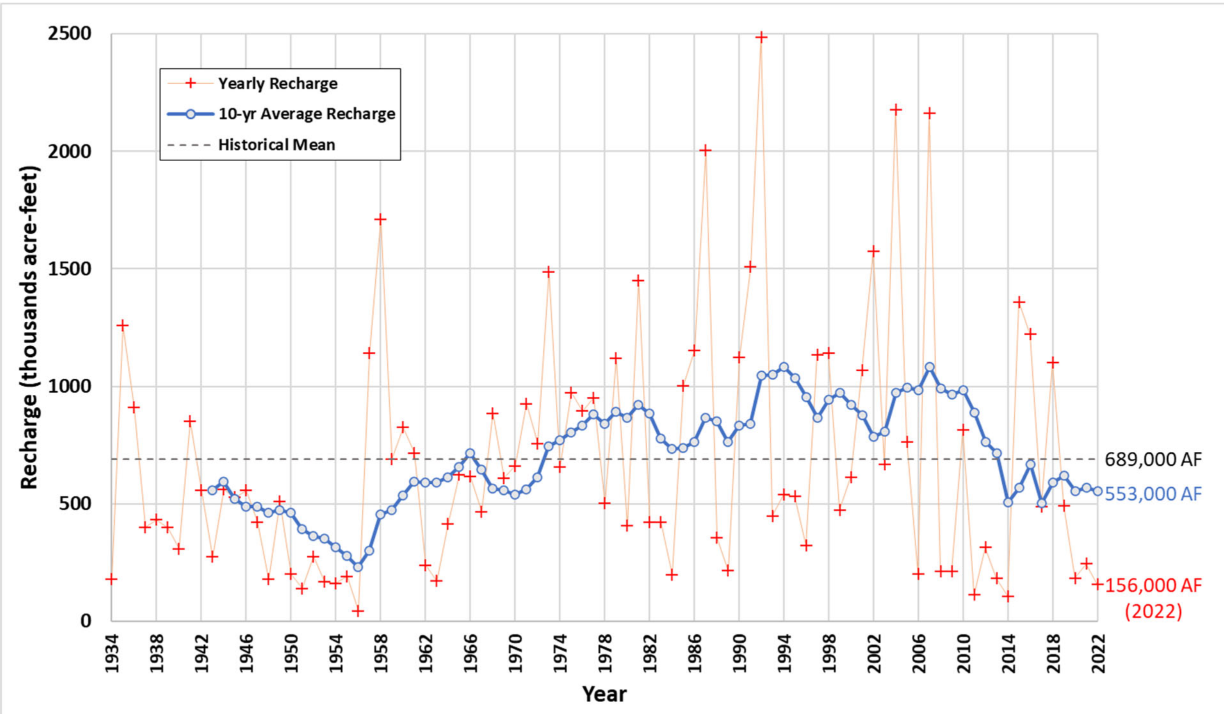

Table 2. Estimated Annual Enhanced Recharge from Edwards Aquifer Authority-Operated Recharge Structures from 1974 to 2022 (measured in acre-feet)

Year	Parker (April 1974)	Middle Verde (April 1978)	San Geronimo (November 1979)	Seco (October 1982)	Annual Total
1974	160	---	---	---	160
1975	620	---	---	---	620
1976	2,018	---	---	---	2,018
1977	6	---	---	---	6
1978	98	150	---	---	248
1979	2,315	1,725	0	---	4,040
1980	0	371	903	---	1,274
1981	772	1,923	1,407	---	4,102
1982	3	112	91	0	206
1983	0	254	0	0	254
1984	251	246	0	143	640
1985	232	440	1,097	643	2,412
1986	217	889	963	1,580	3,649
1987	2,104	4,141	1,176	12,915	20,336
1988	0	0	0	0	0
1989	0	0	0	0	0
1990	49	176	41	479	745
1991	647	966	1,647	2,160	5,420
1992	723	2,775	2,874	14,631	21,003
1993	0	0	334	508	842
1994	159	0	0	5	164
1995	18	79	51	880	1,028
1996	0	0	0	0	0
1997	2,941[a]	2,154[b]	1,579[b]	7,515[b]	14,189[b]
1998	1,469[a/b]	1,160[b]	872[b]	3,796b	7,297[b]
1999	0[b]	0[b]	0[b]	50[c]	50[b/c]
2000	901[b]	1,371[b]	1,023[b]	4,606[b]	7,901[b]
2001	526[b]	657[b/d]	1,085[b/d]	2,154[b/d]	4,422[b/d]
2002	1,811	1,511	4,350	18,872	26,544
2003	665	184	0	465	1,314
2004	2,363	170	4,778	14,682	21,993
2005	795	0	0	58	853
2006	0	0	0	0	0
2007	5,998	2,091	7,268	10,645	26,002
2008	2.6	2.5	0	0	5
2009	630	31	0.1	28	688
2010	1,356	1,324	4,375	6,171	13,226
2011	10	4.5	1.0	0	16
2012	1.0	51	0	98	150
2013	0.6	0	0	0.4	1.0
2014	759	38.0	0	319	1,116
2015	419	816	1,163	4,682	7,079
2016	2,257	747	1,776	4,018	8,799
2017	35	0	0	0	0
2018	756	1,333	4,056	5,838	11,983
2019	0	0	14.7	76.2	90.9
2020	0	0	0	0	0
2021	50.9	6.5	199.3	0	256.7
2022	0	0	0	0	0

Data source: Unpublished Edwards Aquifer Authority files (2023).

a = Written communication from USGS, San Antonio Subdistrict Office.

b = Determined by linear-regression analysis using rainfall data and historical recharge data.

c = Linear-regression analysis indicates zero recharge; however, one recharge event was observed that was estimated to have recharged 50 acre-feet.

d = Part of 2001 recharge estimate provided by HDR Engineering, Inc. (unpublished report).

--- = Years prior to construction of recharge structure.

Appendix C3 | **2022 Estimated Annual Recharge and Spring Discharge**

UNITED STATES DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
5563 De Zavala Rd., Suite 290
San Antonio, TX 78249

Apr 3rd, 2023

To: Paul Bertetti, Director of Aquifer Science, Edwards Aquifer Authority

From: Richard Slattery, Hydrologic Technician, USGS, San Antonio, TX

Thru: Douglas Schnoebelen, South Texas Branch Office Chief, USGS, San Antonio, TX

Subject: Estimated annual recharge to, and spring discharge from, the Edwards aquifer, 2022

Attached are two tables, the first table contains the estimated annual recharge in thousands of acre-feet by stream basin to the Edwards aquifer in the San Antonio area for the period 1934 through 2022. The area had persistent, dry conditions in 2022. Total recharge in 2022 was estimated to be 156 thousand acre-feet, which is lower than the estimated annual (1934-2022 years) average of 689 thousand acre-feet (table 1).

The second table contains the monthly spring discharge from the Edwards aquifer in acre-feet per month by spring for 2022. The accounted for total spring discharge from the Edwards aquifer in 2022 was estimated to be 220 thousand acre-feet (table 2).

To view the USGS recharge information sheet, see the ScienceBase (https://www.sciencebase.gov) web page titled, *Estimated Annual Recharge to the Edwards Aquifer in the San Antonio Area, by Stream Basin or Ungaged Area, 1934–2022*, at: https://doi.org/10.5066/P9OC5CQ7.

U.S. GEOLOGICAL SURVEY
SOUTH TEXAS WATER SCIENCE CENTER
5563 De Zavala Rd., Suite 290
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Table 1. Estimated annual recharge to the Edwards aquifer in the San Antonio area, by stream basin or ungaged area, 1934–2022. [thousands of acre-feet]

Calendar Year	Nueces-West Nueces River Basin	Frio-Dry Frio River Basin [1]	Sabinal River Basin [1]	Area Between Sabinal River and Medina River Basin [1]	Medina River Basin[2]	Area between Medina River Basin and Cibolo-Dry Comal Creek Basins[1]	Cibolo Creek and Dry Comal Creek Basin	Blanco River Basin[1]	Total[3]
1934	8.6	27.9	7.5	19.9	46.5	21	28.4	19.8	179.6
1935	411.3	192.3	56.6	166.2	71.1	138.2	182.7	39.8	1,258.2
1936	176.5	157.4	43.5	142.9	91.6	108.9	146.1	42.7	909.6
1937	28.8	75.7	21.5	61.3	80.5	47.8	63.9	21.2	400.7
1938	63.5	69.3	20.9	54.1	65.5	46.2	76.8	36.4	432.7
1939	227	49.5	17	33.1	42.4	9.3	9.6	11.1	399
1940	50.4	60.3	23.8	56.6	38.8	29.3	30.8	18.8	308.8
1941	89.9	151.8	50.6	139	54.1	116.3	191.2	57.8	850.7
1942	103.5	95.1	34	84.4	51.7	66.9	93.6	28.6	557.8
1943	36.5	42.3	11.1	33.8	41.5	29.5	58.3	20.1	273.1
1944	64.1	76	24.8	74.3	50.5	72.5	152.5	46.2	560.9
1945	47.3	71.1	30.8	78.6	54.8	79.6	129.9	35.7	527.8
1946	80.9	54.2	16.5	52	51.4	105.1	155.3	40.7	556.1
1947	72.4	77.7	16.7	45.2	44	55.5	79.5	31.6	422.6
1948	41.1	25.6	26	20.2	14.8	17.5	19.9	13.2	178.3
1949	166	86.1	31.5	70.3	33	41.8	55.9	23.5	508.1
1950	41.5	35.5	13.3	27	23.6	17.3	24.6	17.4	200.2
1951	18.3	28.4	7.3	26.4	21.1	15.3	12.5	10.6	139.9
1952	27.9	15.7	3.2	30.2	25.4	50.1	102.3	20.7	275.5
1953	21.4	15.1	3.2	4.4	36.2	20.1	42.3	24.9	167.6
1954	61.3	31.6	7.1	11.9	25.3	4.2	10	10.7	162.1
1955	128	22.1	0.6	7.7	16.5	4.3	3.3	9.5	192
1956	15.6	4.2	1.6	3.6	6.3	2	2.2	8.2	43.7
1957	108.6	133.6	65.4	129.5	55.6	175.6	397.9	76.4	1,142.6
1958	266.7	300	223.8	294.9	95.5	190.9	268.7	70.7	1,711.2
1959	109.6	158.9	61.6	96.7	94.7	57.4	77.9	33.6	690.4
1960	88.7	128.1	64.9	127	104	89.7	160	62.4	824.8
1961	85.2	151.3	57.4	105.4	88.3	69.3	110.8	49.4	717.1
1962	47.4	46.6	4.3	23.5	57.3	16.7	24.7	18.9	239.4
1963	39.7	27	5	10.3	41.9	9.3	21.3	16.2	170.7
1964	126.1	57.1	16.3	61.3	43.3	35.8	51.1	22.2	413.2
1965	97.9	83	23.2	104	54.6	78.8	115.3	66.7	623.5
1966	169.2	134	37.7	78.2	50.5	44.5	66.5	34.6	615.2
1967	82.2	137.9	30.4	64.8	44.7	30.2	57.3	19	466.5
1968	130.8	176	66.4	198.7	59.9	83.1	120.5	49.3	884.7
1969	119.7	113.8	30.7	84.2	55.4	60.2	99.9	46.6	610.5
1970	112.6	141.9	35.4	81.6	68	68.8	113.8	39.5	661.6
1971	263.4	212.4	39.2	155.6	68.7	81.4	82.4	22.2	925.3
1972	108.4	144.6	49	154.6	87.9	74.3	104.2	33.4	756.4
1973	190.6	256.9	123.9	286.4	97.6	237.2	211.7	82.2	1,486.5
1974	91.1	135.7	36.1	115.3	96.2	68.1	76.9	39.1	658.5
1975	71.8	143.6	47.9	195.9	93.4	138.8	195.7	85.9	973
1976	150.7	238.6	68.2	182	94.5	47.9	54.3	57.9	894.1
1977	102.9	193	62.7	159.5	77.7	97.9	191.6	66.7	952
1978	69.8	73.1	30.9	103.7	76.7	49.6	72.4	26.3	502.5
1979	128.4	201.4	68.6	203.1	89.4	85.4	266.3	75.2	1,117.8
1980	58.6	85.6	42.6	25.3	88.3	18.8	55.4	31.8	406.4
1981	205	365.2	105.6	252.1	91.3	165	196.8	67.3	1,448.4
1982	19.4	123.4	21	90.9	76.8	22.6	44.8	23.5	422.4
1983	79.2	85.9	20.1	42.9	74.4	31.9	62.5	23.2	420.1
1984	32.4	40.4	8.8	18.1	43.9	11.3	16.9	25.9	197.9
1985	105.9	186.9	50.7	148.5	64.7	136.7	259.2	50.7	1,003.3
1986	188.4	192.8	42.2	173.6	74.7	170.2	267.4	44.5	1,153.7
1987	308.5	473.3	110.7	405.5	90.4	229.3	270.9	114.9	2,003.6

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Calendar Year	Nueces-West Nueces River Basin	Frio-Dry Frio River Basin [1]	Sabinal River Basin [1]	Area Between Sabinal River and Medina River Basin [1]	Medina River Basin[2]	Area between Medina River Basin and Cibolo-Dry Comal Creek Basins[1]	Cibolo Creek and Dry Comal Creek Basin	Blanco River Basin[1]	Total[3]
1988	59.2	117.9	17	24.9	69.9	12.6	28.5	25.5	355.5
1989	52.6	52.6	8.4	13.5	46.9	4.6	12.3	23.6	214.4
1990	479.3	255	54.6	131.2	54	35.9	71.8	41.3	1,123.2
1991	325.2	421	103.1	315.2	52.8	84.5	109.7	96.9	1,508.4
1992	234.1	586.9	201.1	566.1	91.4	290.6	286.6	228.9	2,485.7
1993	32.6	78.5	29.6	60.8	78.5	38.9	90.9	37.8	447.6
1994	124.6	151.5	29.5	45.1	61.1	34.1	55.6	36.6	538.1
1995	107.1	147.6	34.7	62.4	61.7	36.2	51.1	30.6	531.3
1996	130	92	11.4	9.4	42.3	10.6	14.7	13.9	324.3
1997	176.9	209.1	57	208.4	63.3	193.4	144.2	82.3	1,134.6
1998	141.5	214.8	72.5	201.4	80.3	86.2	240.9	104.7	1,142.3
1999	101.4	136.8	30.8	57.2	77.1	21.2	27.9	21	473.5
2000	238.4	123	33.1	55.2	53.4	28.6	48.6	34.1	614.5
2001	297.5	126.7	66.2	124.1	90	101.5	173.7	89.7	1,069.4
2002	83.6	207.3	70.6	345.2	93.7	175.5	447.8	150	1,573.7
2003	149.8	112.2	31.7	67.4	86.8	56.2	105.0	59.9	669.0
2004	481.9	424.5	116.0	343.9	95.5	213.4	315.0	185.8	2,176.1
2005	105.5	147.2	50.1	79.1	82.8	84.8	140.4	74.1	764.0
2006	45.5	60.2	9.0	5.0	47.7	5.1	11.2	17.9	201.6
2007	471.8	474.4	104.0	406.4	75.2	227.6	306.1	96.9	2,162.3
2008	48.2	44.5	5.9	9.8	53.6	9.6	22.8	18.5	212.9
2009	58.5	30.3	1.8	13.5	45.6	7.3	26.4	27.5	211.0
2010	135.4	104.9	31.5	186.3	68.2	81.4	148.2	57.5	813.5
2011	15.3	13.7	1.0	2.0	43.3	3.0	15.3	18.3	112.0
2012	78.3	82.6	8.9	14.4	41.6	3.9	32.2	51.6	313.5
2013	67.7	26.7	0.5	2.8	10.8	3.3	28.7	42.1	182.7
2014	19.8	32.8	4.9	14.4	8.9	0.4	9.5	16.5	107.2
2015	343.8	281.9	42.2	218.4	54.6	131.8	177.3	108.3	1,358.3
2016	275.7	247.8	52.4	184.1	77.5	110.9	186.4	86.3	1,221.1
2017	122	95.4	17.0	30.4	72.6	25.0	68.8	55.0	487
2018	360	316	57.3	168	66.8	22.8	71.1	42.9	1,100
2019	90.6	91.8	27.2	40.6	86.8	35.2	81.0	39.1	492
2020	32.0	24.7	3.74	4.49	54.5	4.57	27.4	32.9	184
2021	51.2	31.8[4]	2.54	5.76[4]	46.6	10.9	55.4	39.3	244[4]
2022	**78.3**	**15.6**	**0.27**	**1.96**	**37.3**	**0.86**	**5.25**	**16.6**	**156**
Average	**128**	**135**	**39.4**	**106**	**61.3**	**67.1**	**106**	**46.8**	**689**

[1] Includes recharge from ungaged areas.

[2] Recharge to Edwards aquifer from the Medina River Basin consists entirely of losses from the Medina/Diversion Lake System (Puente, 1978, p. 23).

[3] Totals might not equal sum of basin values because of rounding. Beginning in 2017, reported values are rounded to three significant figures.

[4] Reported values revised from previous year.

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Table 2. Summary of spring discharge in acre-feet per month, January–December 2022.

	Leona Springs and Underflow nr Uvalde, Tx (08204000)	San Pedro Springs at San Antonio, Tx (08178090)	San Antonio Springs at San Antonio, Tx (08177818)	Comal Springs at New Braunfels, Tx (08168710)	Hueco Springs nr New Braunfels Tx (08168000)	San Marcos Springs at San Marcos, Tx (08170000)	Total Discharge[1]
Jan	542	158	0.00	16,800	1,210	9,820	28,500
Feb	521	180	0.00	15,800	1,850	9,400	27,700
Mar	462	85.5	0.00	16,400	1,030	10,400	28,400
Apr	392	2.32	0.00	13,200	583	8,730	22,900
May	360	0.00	0.00	11,700	309	7,900	20,300
Jun	274	0.00	0.00	8,460	124	6,430	15,300
Jul	133	0.00	0.00	7,080	6.76	6,160	13,400
Aug	26.8	0.00	0.00	6,400	2.34	5,580	12,000
Sep	95.8	0.00	0.00	6,880	446	5,220	12,700
Oct	130	0.00	0.00	5,930	195	5,200	11,500
Nov	173	0.00	0.00	7,130	511	5,220	13,000
Dec	222	0.00	0.00	7,760	515	5,360	13,900
Total Annual Discharge in acre-feet per year[1]:							
	3,330	**426**	**0.00**	**124,000**	**6,790**	**85,400**	**220,000**

[1] Totals might not equal sum of discharge values because of rounding.

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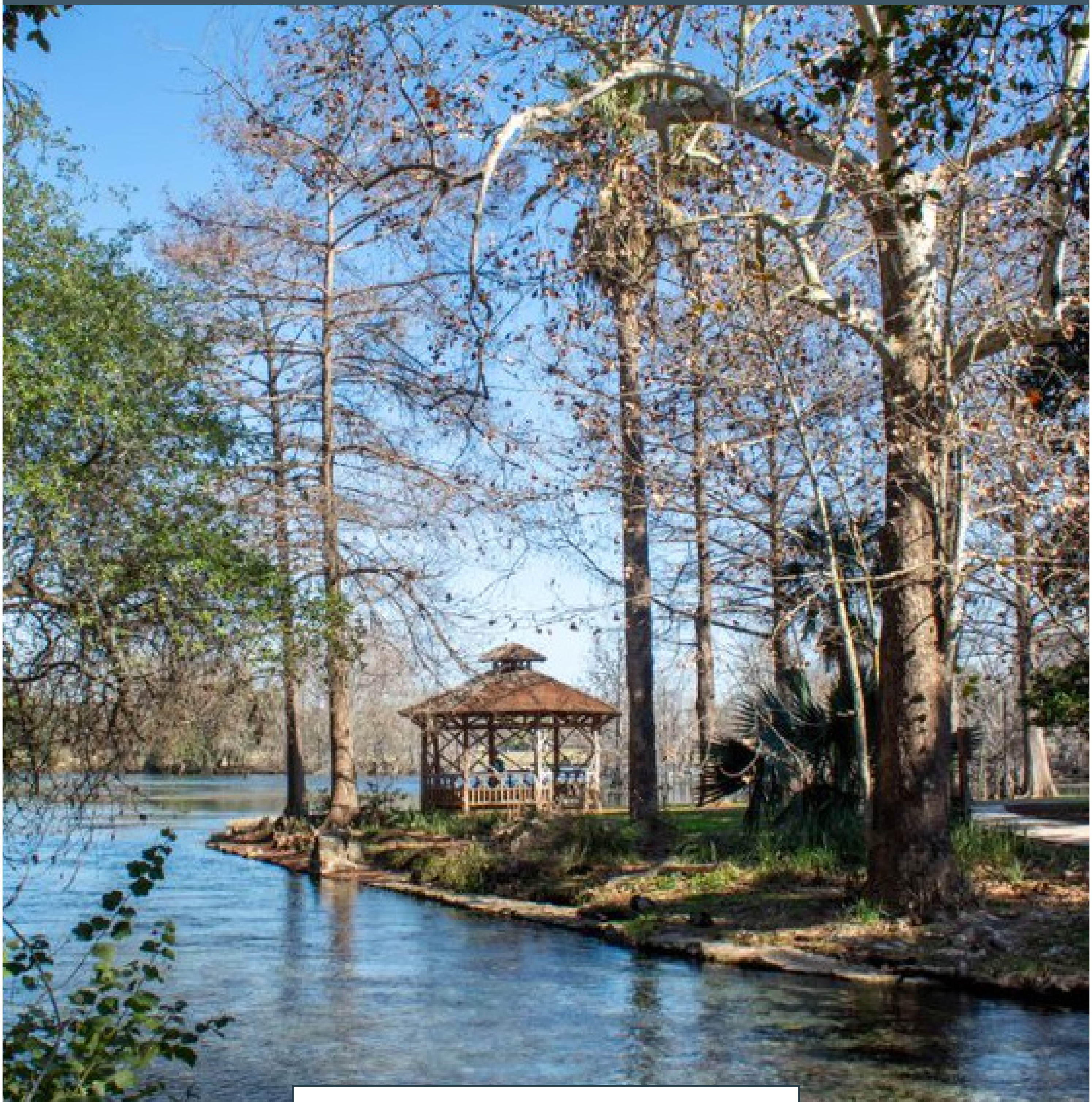
Appendix C4 | **2022 Water Quality Summary**

WATER QUALITY SUMMARY 2022



EDWARDS AQUIFER AUTHORITY

Background

The Edwards Aquifer Authority (EAA) monitors the quality of water in the Edwards Aquifer (Aquifer) by sampling streams, wells, and springs across the region.

The Aquifer is a karst groundwater system formed by the dissolution of limestone bedrock. Dissolution occurs as rainwater or groundwater chemically reacts with limestone. The process significantly enhances the permeability of the Edwards Aquifer by creating caves, sinkholes, and other features through which water moves. The Aquifer can be divided into three main hydrologic zones, each with distinct characteristics: perennial and intermittent streams in the Contributing Zone, rapid recharge and fast groundwater velocities in the Recharge Zone, and highly productive wells and large spring systems in the Artesian Zone.

Water quality in the Contributing Zone is affected by both rainfall and evaporation and may change rapidly in response to storm events. Similarly, water quality in the Recharge Zone can change quickly and vary significantly because of stream infiltration from the Contributing Zone, direct infiltration of rainfall, and rapid groundwater velocities. However, water quality in the deep Artesian Zone is generally more stable because of slower groundwater velocities and larger volumes of water available for dilution.

How We Monitor

The Aquifer is a unique and vulnerable asset. Therefore, the EAA established a comprehensive monitoring program to assess the quality of water throughout the Aquifer system. Water quality sampling consists of *grab* samples taken from streams, wells, and springs at specific times throughout the year. Grab samples are small discrete volumes of water that represent the composition of water present at a particular site and time.

Streams are generally sampled over the Contributing and Recharge zones. The resulting data is used to monitor the quality of water entering the Aquifer. Wells located throughout the Recharge and Artesian zones are sampled to assess the quality of groundwater within the Aquifer. Samples collected at springs provide composite data on water quality across the entire Aquifer system, reflecting contributions from recharge, groundwater, and surface water. Map 1 shows sample locations and boundaries of each hydrologic zone.

Sampling in 2022

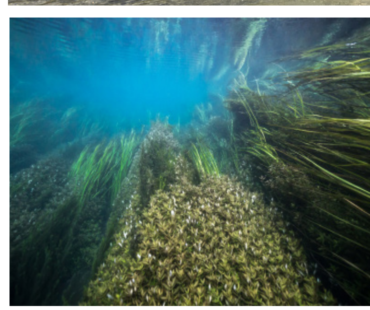
EAA staff collected grab samples from six streams, 25 wells, and six springs in three spring groups between March and October 2022 (Map 1). Water quality information for previous years can be accessed online at https://www.edwardsaquifer.org/science-maps/research-scientific-reports/hydrologic-data-reports/.

The results of laboratory analysis show that high-quality water enters and is produced by the Aquifer, making it suitable for a wide range of uses, such as municipal, agricultural, and livestock. Although most samples in 2022 contained no detectable contaminants, compounds of concerns that were detected typically had concentrations less than their maximum contaminant levels (MCLs) established by the US Environmental Protection Agency (US EPA).

Understanding Results

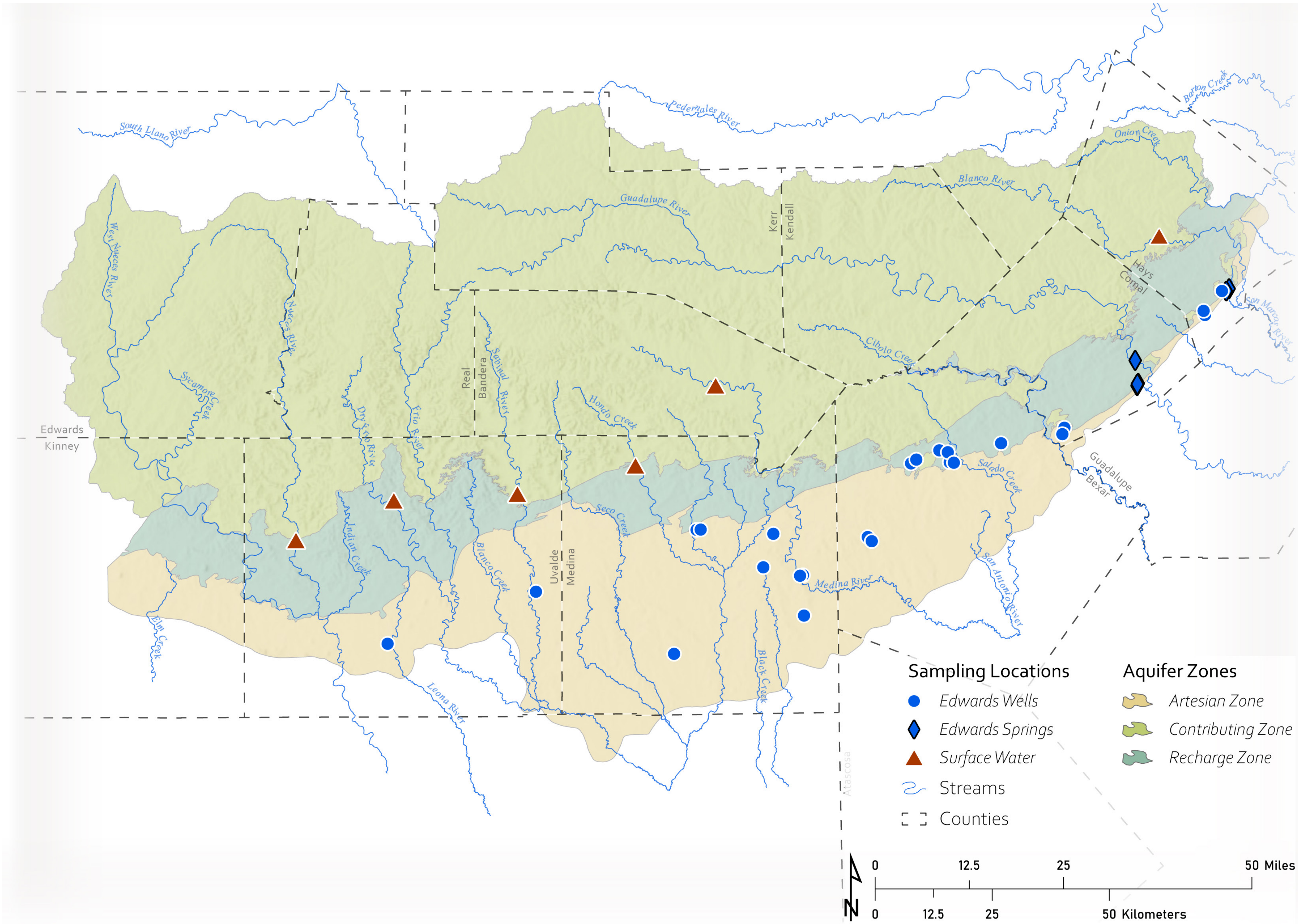
Water quality samples were analyzed for bacterial (E. coli), nutrient, dissolved metal, volatile organic compound (VOC), semivolatile organic compound (SVOC), pesticide, herbicide, and polychlorinated biphenyl compound (PCB) content.

Concentrations of individual chemical compounds (analytes) are reported in micrograms per liter of sampled water (µg/L). This unit is equivalent to parts per billion (ppb). Bacterial content is reported in units of most probable number per 100 milliliters of water (MPN/100 mL), a statistically informed value produced by laboratory analysis. This unit estimates the E. coli population per 100 mL of sampled water.



Above: Seco Creek, a major stream that recharges the Edwards Aquifer. Lower right: Outcrop in the Hill Country, Texas. Lower left: Restored channel of the springfed San Marcos River.

On the cover: Ongoing successful restoration at Comal Springs. Native trees stabilize the soil over Edwards Limestone rock outcrops, while replanted native grasses support birds, insects, and other organisms. These conservation efforts and others ensure the longterm quality and supply of Edwards Aquifer water.



Map 1. The map shows the locations for water quality samples collected by EAA staff in 2022. The samples represent six streams, 25 wells, and three spring groups. Samples were obtained from the Contributing, Recharge, and Artesian zones of the Edwards Aquifer.

Disclaimer: This map was created for demonstrative use by the Edwards Aquifer Authority (EAA) and not intended for other purposes. This map is to be used as an informational tool only.

Streams

Streams play an important role in the recharge of the Aquifer. Discharge from gravity-fed springs and runoff from precipitation accumulates as Hill Country streams in the Contributing Zone of the Aquifer. These streams flow south across the Recharge Zone, where the porous Edwards Limestone is exposed at the surface. As the streams cross this hydrologic zone, they lose all or most of their baseflow as recharge infiltrating though the base of the streams and into the Aquifer. To help assess the quality of this resource, the EAA samples stream water at six sites within the Contributing and Recharge zones. The sample locations are shown below in Map 2. These data provide water quality insights for a major component of overall recharge to the Aquifer system.

The Nueces River (Nueces) is the westernmost stream that drains the Edwards Plateau, originating at two spring-fed forks in Real County and terminating at Corpus Christi Bay. Along its upper reach, baseflow from the Nueces descends into its abundant gravels and reappears as gravity fed springs. The Dry Frio and Frio rivers also arise in Real County, flowing together near the town of Knippa. Garner State Park has provided access to the cool water of Frio River for decades. Near the town of Three Rivers, the Frio River flows into the Nueces.

The Sabinal River arises from springs near Lost Maples State Natural Area, Bandera County, and joins with the Frio River. Seco Creek similarly arises from springs in Bandera County and flows into Hondo Creek. A portion of Seco Creek's high flow enters the Seco Creek Sinkhole, directly recharging the Aquifer. Hondo Creek arises from springs in Bandera County, near Seco Creek, and flows into the Frio River near the town of Pearsall. The Medina River arises from springs in Bandera County and flows into San Antonio River, south of San Antonio. Along its length, it is dammed to form Medina Lake. The Blanco River arises from headsprings in northeastern Kendall County, flowing eastward into the San Marcos River.

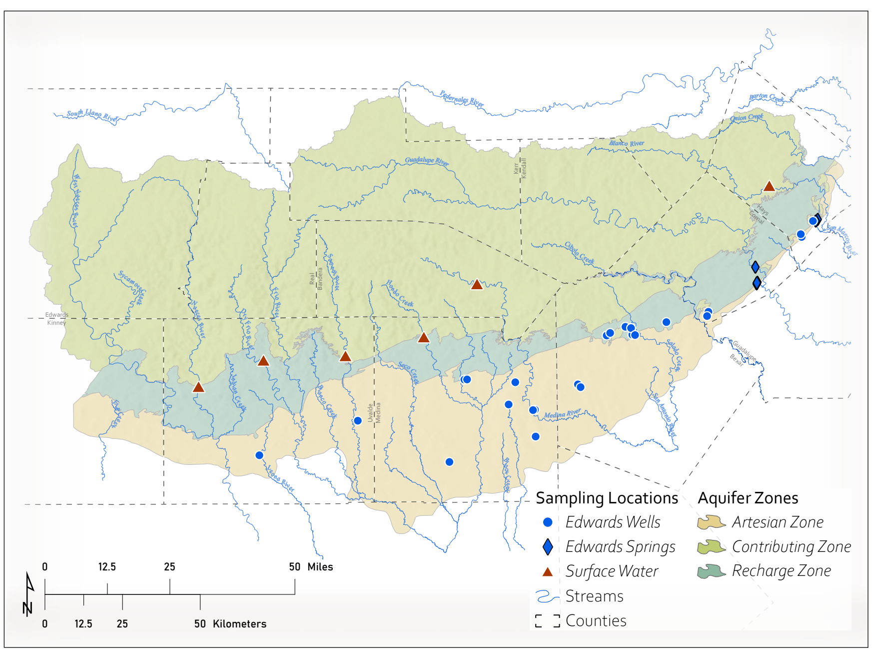
Streams sampling

Six water quality samples were collected by EAA staff in 2022, one each from the Nueces River, Dry Frio River, Sabinal River, Hondo Creek, Medina River, and Blanco River. Frio River and Seco Creek were not flowing at the time of this sampling event because of ongoing drought conditions. Samples were generally collected at or near US Geological Survey (USGS) gauging stations located near the Recharge Zone. These samples were analyzed for bacteria, dissolved metal, nutrient, SVOC, pesticide, herbicide, and PCB concentrations.

Results of streams sampling

Table 1 summarizes the analyses of six stream water samples for concentrations of bacteria, nutrient, SVOC, pesticide, herbicide, and PCB compounds. Since uses of stream water are generally limited to contact recreation, such as paddling and wading, bacterial content analyses are compared to Texas Commission on Environmental Quality's (TCEQ) Contact Recreation Standard (CRS). One sample was found to exceed the CRS for bacteria.

Figure 1 provides additional detail for individual analytes that were detected in stream water samples. Bacteria, nutrient, and dissolved metals that were detected at trace and measurable concentrations have been included. E. coli was detected in one sample above the CRS of 126 MPN/100mL. The presence of E. coli indicates that water may be contaminated by human or animal wastes. Elevated bacterial levels in surface water can be caused by a variety of events, such as high rainfall and runoff. Nitrate was present at trace concentrations in all six samples. Many dissolved metals occur naturally in the Aquifer groundwater, originating from minerals that comprise the host rock. The dissolved metals aluminum, antimony, barium, boron, magnesium, silicon, strontium, and vanadium were detected at concentrations ranging from trace to measurable.



Map 2. Locations of six sampling sites on major streams that cross the Contributing Zone and enter the Recharge Zone. The streams sampled in 2022 are, from west to east: the Nueces River, Dry Frio River, Sabinal River,Seco Creek, Hondo Creek, Medina River, and Blanco River.

STREAM WATER QUALITY SUMMARY, CALENDAR YEAR 2022

Water Quality Parameter Group	Number of Samples Collected	Number of Detections Exceeding MCL
Bacteria (E. coli)	6	1
Metals	6	0
Nutrients	6	0
Volatile Organic Compounds (VOCs)	6	0
Semivolatile Organic Compounds (SVOCs)	6	0
Pesticide and Herbicide Compounds	6	0
Polychlorinated Biphenyl Compounds (PCBs)	6	0

Table 1. Summary of water sampling and concentrations of analytes in seven water quality parameter groups. Results are compared to primary and secondary drinking water standards established by the US EPA and adopted by the State of Texas in Title 30 of the Texas Administrative Code, Chapter 290, Subchapter F, available online at www.sos.state.tx.us/tac/index.shtml. The complete set of water quality data used in the 2022 Water Quality Summary is available via an open records request through the EAA's Contact Us webpage www.edwardsaquifer.org/eaa/contact-us.

DETECTED ANALYTE CONCENTRATIONS IN STREAM WATER

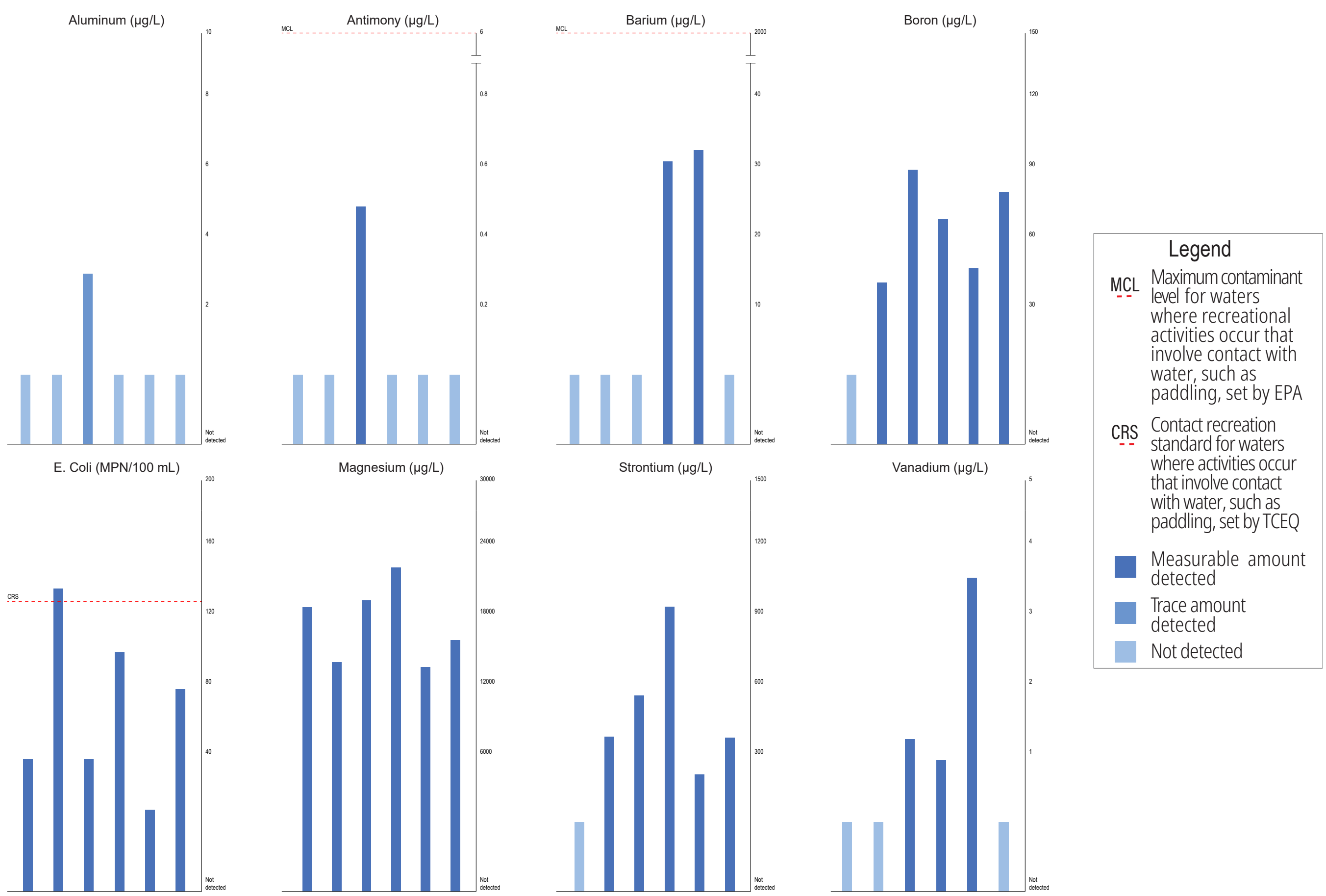


Figure 1. Barcharts of concentrations for individual analytes that had trace or measurable detections from one or more samples.

Wells

Thousands of wells throughout south central Texas pump water from the Aquifer to support municipal, agricultural, and livestock uses. The Aquifer is well known for yielding large volumes of high quality water. To monitor water quality trends within these wells and across the Aquifer's system, a selection of wells were sampled for laboratory analyses. In 2022, 25 wells were sampled across the Recharge and Artesian zones of the Aquifer

Wells sampling

The EAA regularly participates in two interagency sampling efforts, in addition to providing sampling in support of locally focused projects. The National Water Quality Assessment (NAWQA), a program of the USGS, was established by the US Congress in 1991 to measure national water quality and track changes over time. In Bexar County, 30 wells were constructed in the northwestern part of the county and are regularly sampled by both the USGS and EAA staff. The EAA also participates in the Texas Water Development Board's (TWDB) groundwater quality sampling program. Like NAWQA, TWDB's sampling program monitors the quality of water in Texas aquifers through time. In 2022, 10 wells in Bexar, Comal, Hays, Medina, and Uvalde counties were sampled for TWDB.

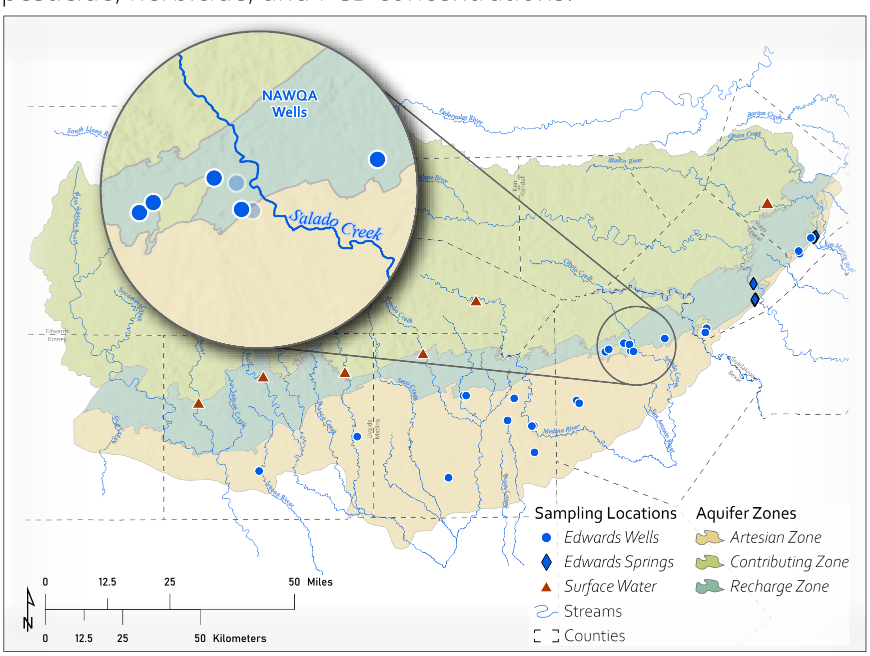
Additionally, the EAA collected water quality samples from wells throughout its jurisdiction that have been historically sampled. The overall selection of wells reflects a snapshot of the Aquifer water used throughout the region. Sampled well locations are shown below in Map 3. Samples were analyzed for bacteria, dissolved metal, nutrient, VOC, SVOC, pesticide, herbicide, and PCB concentrations.

Results of wells sampling

Since Aquifer well water is used for a variety of purposes, including household drinking water, sample results are compared to limits established in the Safe Drinking Water Act by the US EPA, which are incorporated into the Texas Administrative Code. Maximum contaminant levels are legal limits one the concentration of specific chemical compounds and are intended to protect public health. The US EPA also established secondary maximum concentration limits (SMCLs), that are intended as guidelines for aesthetic properties such as taste and smell. Unlike MCLs, SMCLs are not binding and do not indicate health risk.

Table 2 indicates the number of samples that were taken from wells and analyzed for levels of particular parameter groups. For Aquifer wells that were sampled, most dissolved metals were not detected at concentrations above their respective MCLs.

Figure 2 provides additional detail for individual analytes that were detected in well water samples. Chemicals, nutrient, and dissolved metals that were detected at trace and measurable concentrations have been included. Where applicable, maximum concentration limits are indicated for comparison. The VOC chloroform was detected in a single sample. Nitrate was detected in all samples at measurable concentrations below its MCL. Many dissolved metals occur naturally in Aquifer groundwater originating from minerals that comprise the host rock. The dissolved metals arsenic, barium, boron, chromium, copper, iron, lithium, manganese, silicon, strontium, vanadium, and zinc were at concentrations ranging from trace to measurable.



Map 3. Locations of 25 Edwards wells sampled in 2022 for water quality analysis. NAWQA wells are located in Bexar County, on the Recharge and Contributing zones. Wells sampled for TWDB are located in Bexar, Comal, Hays, Medina, and Uvalde counties.

WELL WATER QUALITY SUMMARY, CALENDAR YEAR 2022

Water Quality Parameter Group	Number of Samples Collected	Number of Detections Exceeding MCL
Bacteria (E. coli)	23	0
Metals	25	0
Nutrients	25	0
Volatile Organic Compounds (VOCs)	18	0
Semivolatile Organic Compounds (SVOCs)	17	0
Pesticide and Herbicide Compounds	18	0
Polychlorinated Biphenyl Compounds (PCBs)	3	0

Table 2. Summary of water sampling and concentrations of analytes in seven water quality parameter groups. Results are compared to primary and secondary drinking water standards established by the US EPA and adopted by the State of Texas in Title 30 of the Texas Administrative Code, Chapter 290, Subchapter F, available online at https://www.sos.state.tx.us/tac/index.shtml. The complete set of water quality data used in the 2022 Water Quality Summary is available via an open records request through the EAA's Contact Us webpage at http://www.edwardsaquifer.org/eaa/contact-us/.

DETECTED ANALYTE CONCENTRATIONS IN WELLS

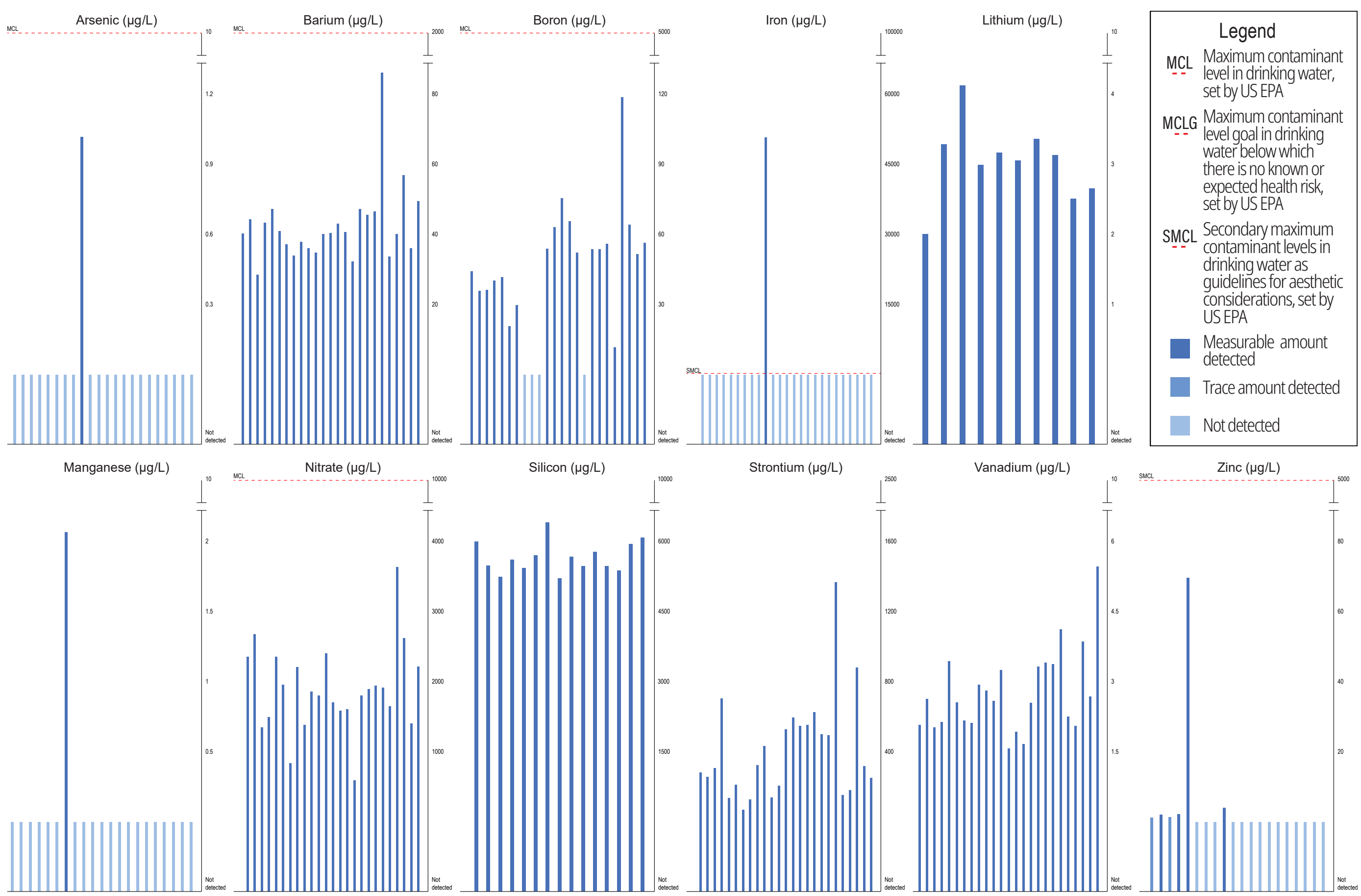


Figure 2. Barcharts of concentrations for individual analytes that had measurable detections from one or more samples.

Springs

Water that flows overland via the streams and rivers of the Contributing Zone and enters the Aquifer in the Recharge Zone emerges as numerous springs. These springs host diverse, endemic plant and animal species and have anchored human settlements for hundreds of years. Water that is discharged at these springs is a composite of the many contributions to the Aquifer. Three major spring groups that were monitored by the EAA for water quality are shown below in Map 4.

Seven federally listed endangered species and threatened species depend on the Comal and San Marcos spring complexes, including Texas wild rice (Zizania texana) and the San Marcos salamander (Eurycea nana). To protect these species, the Edwards Aquifer Habitat Conservation Plan (EAHCP) implements habitat protection, springflow protection, and supporting measures in partnership with local and federal stakeholders. More on the EAHCP is available online at http://www.edwardsaquifer.org/habitat-conservation-plan/. Hueco springs is located on the banks of the Guadalupe River, near Comal springs. All three spring systems emerge in outcrops of the Edwards Limestone.

The San Antonio River headwaters are formed by the San Antonio springs, the best known of which is the Blue Hole (San Antonio spring), located on the University of the Incarnate Word campus. The Blue Hole spring only flows when the Aquifer level is above 665 feet above sea level; and thus it is frequently dry during the summer and early fall. Aquifer levels were below 665 feet above sea level and the Blue Hole Spring was not sampled in 2022. The nearby San Pedro spring forms the headwaters of San Pedro Creek, located on the grounds of San Pedro Park. The San Pedro spring only flows when the Aquifer levels are above 655 feet above sea level and the spring is often dry during the summer and early fall. Aquifer levels were below 655 feet above sea level and San Pedro spring was not sampled in 2022. Both San Antonio and San Pedro spring systems emerge in outcrops of Austin Chalk in the Artesian Zone.

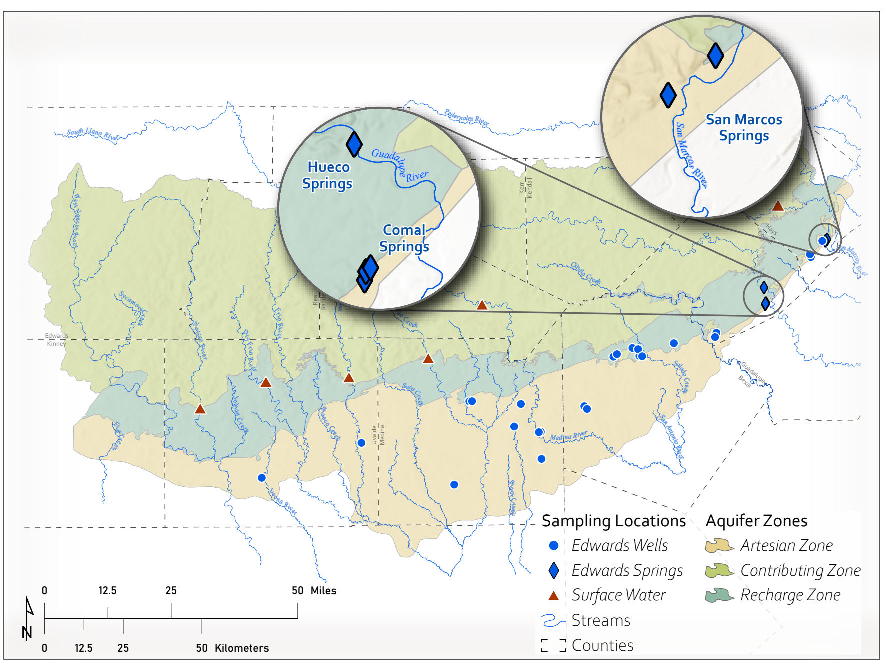
Springs sampling

The Comal, San Marcos, and Hueco spring systems were sampled twice in 2022, once each in March and September. A total of eight samples were analyzed for bacteria, and 11 samples were analyzed for nutrient, dissolved metal, VOC, SVOC, herbicide, pesticide, and PCB concentrations.

Results of springs sampling

Table 3 indicates the number of samples that were taken from springs and analyzed for levels of particular parameter groups. Bacterial detections did not exceed the CRS. No VOCs, SVOCs, pesticides, herbicides, nor PCBs were detected in spring water samples.

Figure 3 provides additional detail for individual analytes that were detected in spring water samples. Bacteria, nutrient, and dissolved metals that were detected at trace and measurable concentrations have been included. While E. coli was detected in three samples, none exceeded the water CRS of 126 MPN/100 mL. The presence of E. coli indicates water may be contaminated by human or animal wastes. Measurable but low concentrations of nitrate were found in all 11 samples. The dissolved metals arsenic, barium, boron, magnesium, selenium, silicon, strontium, vanadium, and zinc were detected at concentrations ranging from trace to measurable. These metals frequently originate from minerals in the limestone host rock.



Map 4. San Antonio Spring (Blue Hole) is located at the headwaters of the San Antonio River, while San Pedro Springs provide flow for San Pedro Creek. Comal Springs feed the Comal River, that winds through New Braunfels' Landa Park into the Guadalupe River. Nearby Hueco Springs also flow into the Comal River. The San Marcos River flows through Texas State University and San Marcos City Park.

SPRING WATER QUALITY SUMMARY, CALENDAR YEAR 2022

Water Quality Parameter Group	Number of Samples Collected	Number of Detections Exceeding MCL
Bacteria (E. coli)	8	0
Metals	11	0
Nutrients	11	0
Volatile Organic Compounds (VOCs)	11	0
Semivolatile Organic Compounds (SVOCs)	11	0
Pesticide and Herbicide Compounds	11	0
Polychlorinated Biphenyl Compounds (PCBs)	11	0

Table 3. Summary of springs sampling and concentrations of analytes in seven water quality parameter groups. Bacterial samples are compared with contact recreation standards as published in Texas Surface Water Quality Standards (Title 30, Chapter 307 of the Texas Administrative Code), available online at https://www.tceq.texas.gov/waterquality/standards/2014standards.html. The complete set of water quality data used in the 2022 Water Quality Summary is available via an open records request through the EAA's Contact Us webpage at http://www.edwardsaquifer.org/eaa/contact-us/.

DETECTED ANALYTE CONCENTRATIONS IN SPRINGS

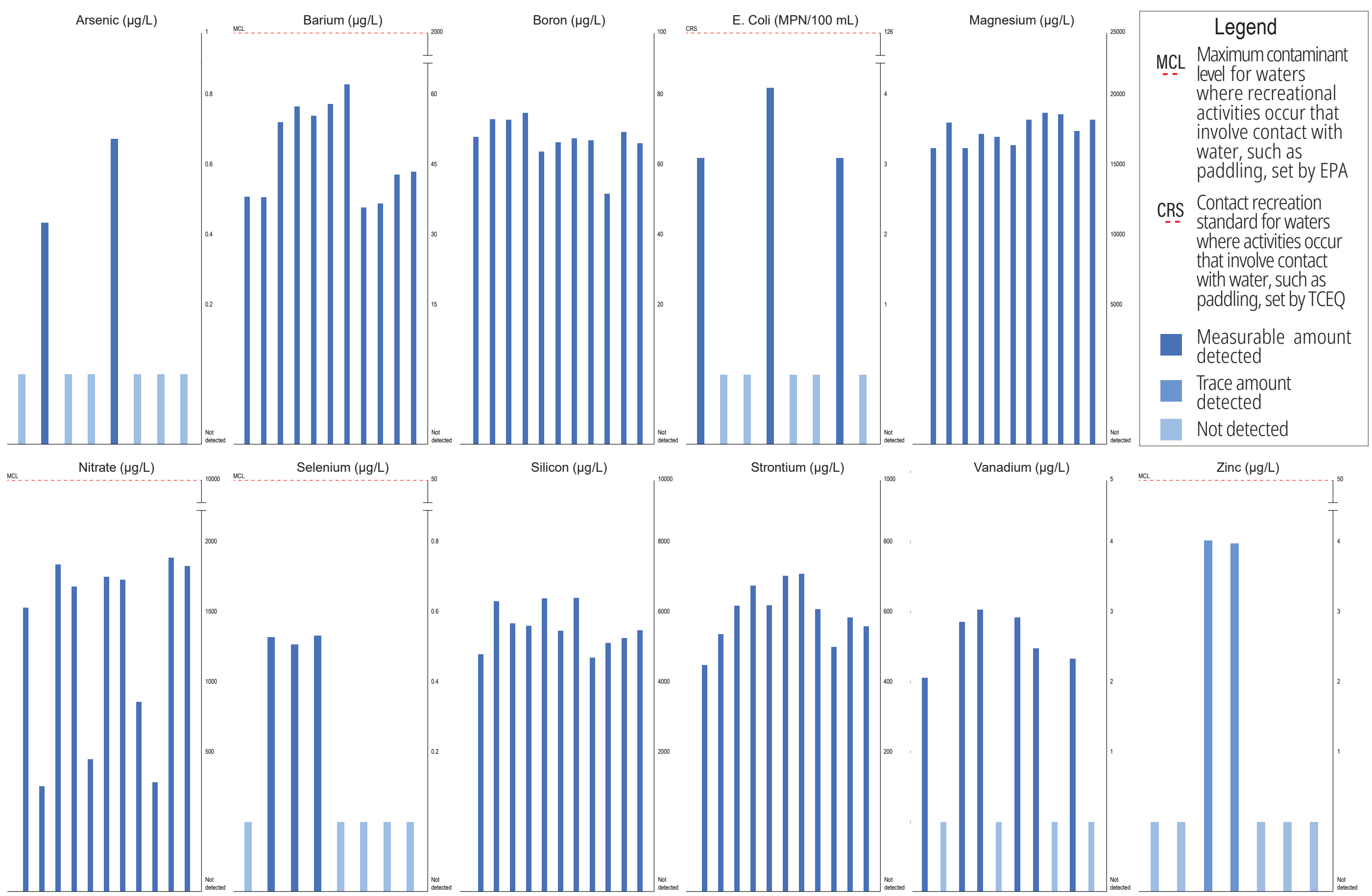


Figure 3. Barcharts of concentrations for individual analytes that had trace or measurable detections from one or more samples.

Summary

The EAA's sampling program provides data about the quality of water entering the Aquifer from surface streams, groundwater moving through the Aquifer, and the composite water that emerges at springs. The results of laboratory analyses for concentrations of bacteria, nutrient, dissolved metal, VOC, SVOC, pesticide, herbicide, and PCB compounds reveal that high quality water is present throughout the Edwards Aquifer system. Most water sampled from streams, wells, and springs did not have detectable levels of contaminants. Concentrations of dissolved metals were generally low and are attributed to natural sources. In streams and springs, bacterial detections were likely caused by contamination from stormwater runoff and non-point sources.

Overall, the Edwards Aquifer produces some of the highest quality groundwater in the State of Texas. The EAA will continue to monitor water quality of the Contributing, Recharge, and Artesian zones in its mission to manage, enhance, and protect the Edwards Aquifer.

Resources

Edwards Aquifer Habit Conservation Plan: https://www.edwardsaquifer.org/habitat-conservation-plan/

Edwards Aquifer Hydrologic Reports: https://www.edwardsaquifer.org/science-maps/research-scientific-reports/hydrologic-data-reports/

Edwards Aquifer Open Records Request: https://www.edwardsaquifer.org/eaa/contact-us/

EPA Drinking Water Standards: https://www.epa.gov/dwreginfo/drinking-water-regulations/

National Water-Quality Assessment (USGS): https://www.usgs.gov/mission-areas/water-resources/science/national-water-quality-assessment-nawqa/

TCEQ Contact Recreation Standards: https://www.tceq.texas.gov/waterquality/standards/2014standards.html/

Texas Administrative Code: https://www.sos.state.tx.us/tac/index.shtml/

Texas Water Development Board groundwater quality sampling program: http://www.twdb.texas.gov/groundwater/data/index.asp/

Clockwise from top left: Clear, cool water at Comal Springs. Butterfly at Field Research Park. Fish swimming in San Marcos Springs. Water cascading down rock formations. San Marcos Springs. Clear, cool water at Comal Springs. The Pedernelas River. Comal Springs and Landa Park. View of the Field Research Park, Contributing Zone.

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Appendix C5 | **2023 Reference Well Conditions**

Historical Daily High Water Elevation for Uvalde and Bexar Index Wells

Provisional measurements (P) are subject to revision

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Provisional measurements (P) are subject to revision