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2.4.11 **Low Water Considerations**

The cooling system design for VCS separates the normal cooling and the emergency cooling systems. Depending on the reactor technology, emergency cooling (safety-related) for VCS is provided by an ultimate heat sink (UHS) consisting of mechanical draft cooling towers and associated water storage basin. Normal plant cooling (nonsafety-related) is provided by the circulating water system using the cooling basin and service water system(s) employing mechanical draft cooling towers for heat dissipation.

Nonsafety-related cooling water is withdrawn from the cooling basin via a circulating water pump intake structure, and heated water is returned to the cooling basin via a circulating water discharge structure. The cooling basin itself functions to transfer heat from the circulating water to the atmosphere. The cooling basin and cooling basin intake and discharge structures are not safety-related.

The raw water makeup (RWMU) system provides makeup water to the cooling basin to compensate for evaporation, seepage, and blowdown losses and water losses from UHS/service water mechanical draft cooling towers (for the applicable reactor technology). The RWMU system is nonsafety-related. The Guadalupe River is the source of the makeup water to the cooling basin. The river water is diverted to the RWMU intake canal immediately upstream of the Lower Guadalupe Saltwater Barrier and Diversion Dam (Figure 2.4.1-10). Makeup water is pumped into the cooling basin, as needed, via the RWMU system intake structure located at the end of the intake canal. Subsection 2.4.1 provides a description of the RWMU system.

The Saltwater Barrier and Diversion Dam on the Guadalupe River is located near Tivoli, Texas downstream of the confluence of the Guadalupe River and San Antonio River. The Saltwater Barrier and Diversion Dam prevents intrusion of downstream brackish water into the upstream fresh water during river low flow periods and creates necessary head on the river for water diversion to the intake canal. Figures 2.4.1-1 and 2.4.1-10 show the location of VCS with respect to the RWMU intake canal system and Saltwater Barrier and Diversion Dam, respectively.

The design water level of the cooling basin is elevation 90.5 feet (27.6 meters) NAVD 88. The cooling basin storage capacity at this elevation is 103,600 acre-feet. The normal maximum operating level of the cooling basin is elevation 91.5 feet (27.9 meters) NAVD 88, which includes an operating range of 1 foot. The storage volume of the cooling basin is about 108,500 acre-feet when the basin water level reaches the normal maximum operating level. Makeup water to the cooling basin is supplied from the Guadalupe River and is pumped into the cooling basin via the RWMU facility. The only natural inflow into the cooling basin is direct rainfall, as the cooling basin has no drainage area other than the reservoir surface. The water level of 73.5 feet (22.4 meters) NAVD 88 allows the operation of the plant under full load condition with an intake water temperature of less than 100°F. At this level, the volume of water remaining in the cooling basin is approximately 21,700 acre-feet. Evaluations of the cooling basin's inventory and thermal performance are described in detail in Subsection 2.4.8.

The live storage capacity of the cooling basin between the design pool level and 73.5 feet (22.4 meters) NAVD 88 is adequate to sustain continuous operation of the plant during extended periods of drought in the Guadalupe River with reduced and infrequent makeup water flow to the cooling basin. The design capacity of the RWMU system is about 267 cubic feet per second (cfs) (120,000 gpm). The RWMU system can supply up to 217 cfs (97,400 gpm) to the VCS cooling basin and an additional 50 cfs (22,400 gpm) of pumping capacity is available for use by another entity or entities in the future. As described in Subsection 2.4.8, the evaluation of the cooling basin storage capacity is based on a maximum annual diversion rate for makeup to the VCS cooling basin of 75,000 acre-feet, subject to run-of-river availability.

2.4.11.1 **Low Flow in Rivers and Streams**

The safety-related cooling functions for VCS, including the UHS, do not rely upon river or stream flow rates or water levels. The low flow characteristics of the rivers that supply makeup water to the nonsafety-related cooling systems are described below.

The major rivers near the VCS site are the Guadalupe River and the San Antonio River. The Guadalupe River, upstream of its confluence with the San Antonio River, passes on the eastern boundary of the site. The Guadalupe River watershed extends from the south central portion of Texas in Kerr County to its mouth in the San Antonio Bay at the Gulf of Mexico in a northwest to south easterly direction. The drainage area for the Guadalupe River is 5953 square miles (Reference 2.4.11-1). The San Antonio River watershed extends from north of San Antonio, Texas to its confluence with the Guadalupe River just upstream from Tivoli, Texas. The San Antonio River watershed is located on the south side of the Guadalupe River watershed and its drainage area is 4180 square miles (Reference 2.4.11-1). The boundaries for both watersheds are shown on Figure 2.4.1-3. The total drainage area for the combined river basins at the stream gage at Tivoli, Texas is 10,128 square miles, which includes the sub-watershed area from the confluence of the two rivers up to the Tivoli gaging station (Reference 2.4.11-2).

Low flow conditions in the Guadalupe River will affect the availability of water for the RWMU system. To assess supply adequacy during a 100-year drought, a low flow frequency analysis was performed to determine the availability of makeup water for nonsafety-related cooling systems. In particular, the 100-year low flow condition was estimated to check for water supply adequacies in accordance with RG 1.206 guidance. The results of this analysis are described below.

The USGS gaging station nearest to the RWMU intake canal is located at Tivoli, Texas, downstream of the confluence of the Guadalupe and San Antonio Rivers (Reference 2.4.11-2). However, the historical stream flow data at the Tivoli gaging station are discontinuous and incomplete and a long-term record is not available. Historical stream flow data were, therefore, estimated by combining the stream flow records from upstream gaging stations. A review of the available USGS stream flow data indicates that the Victoria gaging station on the Guadalupe River (Reference 2.4.11-3) and the Goliad gaging station on the San Antonio River (Reference 2.4.11-4) have the longest period of record and are the closest to the RWMU intake canal. As shown in Figure 2.4.1-6, the Victoria gaging station is on the Guadalupe River upstream of its confluence with the San Antonio River, and the Goliad gaging station is on the San Antonio River upstream of its confluence with the Guadalupe River. Coleto Creek discharges to the Guadalupe River downstream of the Victoria gaging station. However, Coleto Creek flows are regulated by a reservoir supplying cooling water to another power plant, and during low flow periods there is essentially no flow released from the dam (Reference 2.4.11-1). Consequently, the Coleto Creek flows were conservatively assumed to be negligible for the low flow analysis. For this evaluation, the daily average flows recorded at Victoria and Goliad gaging stations were added for the common period of record, to represent the approximate Guadalupe's River stream flow downstream of its confluence with the San Antonio River. The common period of record extends from calendar year 1939–2007.

Using the stream flow record described above, average low flow rates for 7-, 30-, and 60- day durations were calculated and analyzed statistically. Table 2.4.11-1 presents the estimated historical rolling annual minimum 7-day average low flows for the Guadalupe River at the RWMU intake canal for 1939 through 2007. Similarly, Tables 2.4.11-2 and 2.4.11-3 present the estimated rolling annual minimum 30- and 60-day average low flows, respectively, for the same period of record. From these tables, the historical minimum 7-, 30-, and 60-day average low flows are 46.3 cfs, 58.3 cfs, and 84.2 cfs, respectively, which all occurred in August 1956. A statistical evaluation of stream flow data included in Tables 2.4.11-1 through 2.4.11-3 was conducted to determine the 100-year drought flows. This analysis resulted in 7-day, 30-day, and 60-day low flows of 60.2 cfs, 80.1 cfs, and 104.5 cfs, respectively, for the 100-year drought event (Table 2.4.11-4).

Major droughts are the result of several years of consecutive, below normal, rainfall on the Guadalupe River watershed. Table 2.4.11-5 summarizes the annual rainfall recorded at the Victoria Regional Airport meteorological station and the 7-, 30-, and 60-day flows. This data indicates that the historic drought of 1956 was preceded by below normal annual rainfall from 1953 through 1955; while 1956 itself was the second driest year on record.

To determine the storage volume of the cooling basin, a water budget analysis was conducted using 60 years of stream flow data, which included the 1950–1956 drought of record, as described in Subsection 2.4.8. The analysis uses as a basis a maximum annual diversion rate of 75,000 acre-feet per year of makeup water from the Guadalupe River to the cooling basin. This annual diversion rate is primarily based on estimates of the natural and forced evaporation from the cooling basin and an allowance for seepage and blowdown losses from the basin and water losses from UHS/service water mechanical draft cooling towers (for the applicable reactor technology). The RWMU system is capable of providing a maximum of 217 cfs to the cooling basin. Based on these arrangements and estimates, the cooling basin storage capacity was determined to be adequate to allow continuous operation of the plant for the drought of record with infrequent and reduced makeup, which is more severe than the 100-year drought based on the low flow frequency analysis.

Currently there are no downstream dams that could affect the water supply to the makeup water intake and no future dams are contemplated.

2.4.11.2 **Low Water Resulting from Surges, Seiches, or Tsunamis**

Any safety-related cooling systems for VCS, including a UHS, will not rely upon river or stream flow rates or water levels for performance of their safety-related functions and are not affected by low water resulting from surges, seiches, or tsunamis. The effects of these phenomena on the supply of makeup water to the nonsafety-related cooling systems are described below.

Low water in the Guadalupe River resulting from surges, seiches, or tsunamis will not affect the ability of the RWMU system to pump water to the cooling basin because low water level in the Guadalupe River at the RWMU intake canal is maintained by the Saltwater Barrier and Diversion Dam. As described in Subsection 2.4.5, floods resulting from surges, seiches, or tsunamis can affect the Guadalupe River water levels and the operation of the RWMU system, but these phenomena would have no effect on the performance of the nonsafety-related cooling basin. The cooling basin storage capacity permits an extended period of reduced and infrequent makeup flow supply without interruption to the operation of VCS.

Ice formation or ice jams causing low flow conditions are not expected, as described in Subsection 2.4.7.

2.4.11.3 **Historical Low Water**

Stream flow gaging data collected in the Guadalupe and San Antonio watersheds since the 1930s indicate that there have been major droughts in almost every decade since gaging began. During the 30-year period from 1941–1970, there were three major statewide droughts: the first from 1947–1948, the second from 1950–1957, and the third from 1960–1967. The most severe of these droughts occurred from 1950–1957. Recent less severe droughts in the South Central Texas Region have also occurred from 1983–1984, 1987–1990, and in 1996, 1999, and 2006 (Reference 2.4.11-5). The most recent regional drought occurred from 2007 to 2009 (Reference 2.4.11-6).

From annual 7-day and 60-day low flow data plotted in Figure 2.4.11-1, the Guadalupe River has experienced a drought every 7–10 years in the 69 years prior to 2007. The historical low flows and estimated 100-year low flows are described in Subsection 2.4.11.1. Since the drought of record that occurred in the 1950s, many small dams and reservoirs have been built on the Guadalupe and San

Antonio Rivers contributing to the increase in the river base flows in the past two decades. There are 29 storage reservoirs in the Guadalupe River basin and 34 storage reservoirs in the San Antonio River basin with storage capacities of at least 3000 acre-feet, as described in Subsection 2.4.1. In addition, small water discharges by various municipalities have also contributed to this base flow as well. As a result of these changes within the Guadalupe River watershed, the characteristics of river base flows have been affected (increased). Consequently, the 100-year low flows reported in Table 2.4.11-4 are conservatively estimated.

2.4.11.4 **Future Controls**

Any safety-related functions for VCS, including a UHS, will not rely upon river or stream flow rates or water levels and are not affected by future uses or controls. The effects of future uses on flow rate, duration, and levels for drought conditions on the nonsafety-related cooling systems are described below.

The Guadalupe River is used to supply water to the cooling basin via the RWMU system at a maximum annual diversion rate of 75,000 acre-feet. As demonstrated by the water budget analysis, described in Subsection 2.4.8, the storage capacity of the cooling basin is adequate to allow continuous plant operation through a drought event equivalent to the drought of record as is described in Subsection 2.4.11.1. The future uses of the Guadalupe River will be through securing water rights obtained during the COL application stage.

2.4.11.5 **Plant Requirements**

The capability of the nonsafety-related cooling basin to maintain a sufficient water level during periods of drought in the Guadalupe River is described in Subsection 2.4.11.1. In addition, cooling basin level will be closely monitored and the cooling basin filled to the design pool level of elevation 90.5 feet (27.6 meters) NAVD 88 whenever possible, using maximum pumping capacity, to ensure sufficient inventory in the cooling basin is provided. The circulating water pump intake structure and discharge structure on the cooling basin are designed based on a minimum water level in the basin of 71.5 feet NAVD 88.

Subsection 2.4.1.2.7 describes surface water users in the Guadalupe River and San Antonio River basins. The Texas Commission on Environmental Quality maintains records of surface water withdrawals for the state of Texas. Tables 2.4.1-8 through 2.4.1-10 identify the surface water users for the Lower Guadalupe and Lower San Antonio River basins and locations of the surface water users are shown in Figure 2.4.1-11. The sizing of the cooling basin has considered the effect of full utilization of water rights on the water availability.

2.4.11.6 Heat Sink Dependability Requirements

The circulating water system is not a safety-related system. The safety-related emergency cooling system for VCS would depend on the reactor technology selected. Some reactors use passive cooling systems as their UHS and other reactors require mechanical draft UHS cooling towers and water storage facilities with sufficient water inventory to maintain the plant in a safe shutdown mode for 30 days with no makeup water supply. The safety-related UHS cooling towers would use the cooling basin for makeup water and blowdown, but would not depend on the cooling basin to provide emergency cooling for safe shutdown.

2.4.11.7 References

2.4.11-1 U.S. Geological Survey (USGS), *USGS Data; Coleto Creek near Victoria Gaging Station*. Available at http://waterdata.usgs.gov/nwis/dv?cb_00060=on&cb_00065 =on &format=rdb&begin_date=1930-01-01&end_date=2008-05-14&site_ no=08177500&referred_module=sw, accessed May 15, 2008.

2.4.11-2 U.S. Geological Survey (USGS), *USGS Data; Tivoli Gaging Station*. Available at http://waterdata.usgs.gov/nwis/ dv?cb_00060=on&format=rdb&begin_date=1900-03-26&end_date=2008-03-25& site_no=08188800&referred_module=sw, accessed March 25, 2008.

2.4.11-3 U.S. Geological Survey (USGS), *USGS Data; Victoria Station*. Available at http:// waterdata.usgs.gov/nwis/ |dv?cb_00060=on&format=rdb&begin_date=1924-07-01&end_date=2008-03-25& site_no=08176500&referred_module=sw, accessed March 25, 2008.

2.4.11-4 U.S. Geological Survey (USGS), *USGS Data; Goliad Station*. Available at http:// waterdata.usgs.gov/nwis/ dv?cb_00060=on&format=rdb&begin_date=1856-02-17&end_date=2008-03-25& site_no=08188500&referred_module=sw, accessed March 25, 2008.

2.4.11-5 Texas Water Development Board, *Water for Texas 2007*, Vol. II, Document No. GP-8-1, January 2007.

2.4.11-6 Guadalupe-Blanco River Authority, Basin Briefing, November 2009, available at http://www.gbra.org/Library/BasinBriefingNov2009.aspx, accessed February 22, 2010.

Table 2.4.11-1
Guadalupe River Annual Minimum 7-Day Flows

Date	Annual Min flow (cfs)	Date	Annual Min flow (cfs)
10/1939	460	08/1974	973
09/1940	525	11/1975	1,233
09/1941	1,168	04/1976	1,069
06/1942	931	10/1977	1,234
08/1943	792	07/1978	741
08/1944	927	11/1979	1,162
09/1945	736	08/1980	630
08/1946	743	01/1981	1,127
10/1947	766	09/1982	668
08/1948	426	09/1983	701
01/1949	559	09/1984	210
11/1950	419	09/1985	907
08/1951	243	08/1986	854
09/1952	189	12/1987	1,465
08/1953	212	11/1988	710
08/1954	129	10/1989	226
05/1955	152	07/1990	404
08/1956	46	08/1991	885
01/1957	207	10/1992	1,829
09/1958	824	10/1993	1,042
09/1959	830	08/1994	689
06/1960	707	10/1995	750
06/1961	1,062	08/1996	136
08/1962	394	02/1997	801
08/1963	199	08/1998	535
08/1964	245	11/1999	687
01/1965	683	08/2000	374
08/1966	751	08/2001	711
08/1967	147	06/2002	906
11/1968	1,055	08/2003	1,318
08/1969	757	06/2004	1,472
09/1970	863	11/2005	985
07/1971	243	09/2006	349
04/1972	912	03/2007	853
01/1973	1,219	–	–

Table 2.4.11-2
Guadalupe River Annual Minimum 30-Day Flows

Date	Annual Min flow (cfs)	Date	Annual Min flow (cfs)
10/1939	513	08/1974	1,059
10/1940	582	12/1975	1,248
12/1941	1,248	03/1976	1,203
04/1942	994	10/1977	1,335
09/1943	861	07/1978	818
01/1944	1,015	11/1979	1,248
09/1945	860	08/1980	693
08/1946	831	01/1981	1,154
10/1947	797	09/1982	726
08/1948	480	09/1983	783
01/1949	582	08/1984	247
11/1950	447	09/1985	1,001
09/1951	271	09/1986	911
09/1952	215	12/1987	1,810
08/1953	283	12/1988	737
09/1954	153	10/1989	275
11/1955	166	07/1990	555
08/1956	58	01/2001	848
02/1957	225	11/1992	1,895
09/1958	896	10/1993	1,088
10/1959	939	08/1994	838
06/1960	932	11/1995	829
06/1961	1,223	08/1996	233
08/1962	435	01/1997	902
09/1963	216	08/1998	644
08/1964	294	10/1999	713
01/1965	714	09/2000	397
12/1966	778	08/2001	753
07/1967	264	06/2002	1,037
11/1968	1,094	09/2003	1,469
08/1969	817	01/2004	1,541
12/1970	895	11/2005	1,067
08/1971	342	09/2006	411
04/1972	1,077	01/2007	840
01/1973	1,229	–	–

Table 2.4.11-3
Guadalupe River Annual Minimum 60-Day Low Flows

Date	Annual Min flow (cfs)	Date	Annual Min flow (cfs)
10/1939	546	08/1974	1,418
01/1940	591	12/1975	1,428
12/1941	1,386	04/1976	1,241
04/1942	1,057	10/1977	1,587
11/1943	932	04/1978	1,431
01/1944	996	12/1979	1,263
09/1945	904	09/1980	940
08/1946	967	01/1981	1,236
11/1947	816	10/1982	760
12/1948	574	09/1983	939
01/1949	579	09/1984	265
12/1950	471	09/1985	1,181
09/1951	314	09/1986	1,133
09/1952	400	12/1987	1,882
08/1953	368	12/1988	747
09/1954	161	10/1989	310
11/1955	178	02/1990	698
08/1956	84	01/1991	911
02/1957	282	11/1992	1,972
09/1958	1,086	10/1993	1,133
10/1959	1,001	09/1994	845
01/1960	1,554	12/1995	893
06/1961	1,472	08/1996	297
09/1962	510	01/1997	806
09/1963	233	08/1998	748
08/1964	530	11/1999	738
01/1965	768	09/2000	438
12/1966	820	08/2001	882
08/1967	302	06/2002	1,152
11/1968	1,132	12/2003	1,694
08/1969	937	01/2004	1,612
12/1970	914	12/2005	1,125
08/1971	494	09/2006	464
04/1972	1,276	01/2007	765
01/1973	1,274	–	–

Table 2.4.11-4
Estimated 100-Year Frequency Low Flows for Guadalupe River Near Tivoli, Texas

Return Period (years)	Minimum Low Flows in (cfs) from Log-Pearson Type 3 Analysis		
	7-Day Low Flow	30-Day Low Flow	60-Day Low Flow
100	60.2	80.1	104.5

Table 2.4.11-5
Total Annual Rainfall of Victoria vs. Annual Minimum Low Flows of The Guadalupe River at Tivoli

Calendar Year	Annual Rainfall (in)	Low Flow (cfs)			Calendar Year	Annual Rainfall (in)	Low Flow (cfs)		
		7-Day	30-Day	60-Day			7-Day	30-Day	60-Day
1947	34.6	766	797	816	1977	39.2	1234	1335	1587
1948	25.8	426	480	574	1978	45.0	741	818	1431
1949	39.5	559	582	579	1979	49.3	1162	1248	1263
1950	18.1	419	447	471	1980	32.5	630	693	940
1951	29.8	243	271	314	1981	45.1	1127	1154	1236
1952	34.9	189	215	400	1982	32.5	668	726	760
1953	23.0	212	283	368	1983	42.4	701	783	939
1954	19.9	129	153	161	1984	33.9	210	247	265
1955	24.9	152	166	178	1985	36.7	907	1001	1181
1956	18.0	46	58	84	1986	39.2	854	911	1133
1957	47.6	207	225	282	1987	43.1	1465	1810	1882
1958	41.0	824	896	1086	1988	15.9	710	737	747
1959	35.2	830	939	1001	1989	25.8	226	275	310
1960	50.3	707	932	1554	1990	35.8	404	555	698
1961	36.1	1062	1223	1472	1991	56.7	885	848	911
1962	25.9	394	435	510	1992	51.4	1829	1895	1972
1963	22.1	199	216	233	1993	51.4	1042	1088	1133
1964	33.3	245	294	530	1994	43.7	689	838	845
1965	30.9	683	714	768	1995	33.5	750	829	893
1966	35.4	751	778	820	1996	25.8	136	233	297
1967	33.9	147	264	302	1997	67.2	801	902	806
1968	49.3	1055	1094	1132	1998	46.4	535	644	748
1969	44.6	757	817	937	1999	27.0	687	713	738
1970	39.8	863	895	914	2000	36.8	374	397	438
1971	36.1	243	342	494	2001	42.8	711	753	882
1972	42.4	912	1077	1276	2002	39.1	906	1037	1152
1973	45.7	1219	1229	1274	2003	38.7	1318	1469	1694
1974	43.3	973	1059	1418	2004	73.5	1472	1541	1612
1975	37.0	1233	1248	1428	2005	34.9	985	1067	1125
1976	43.3	1069	1203	1241	2006	39.4	349	411	464

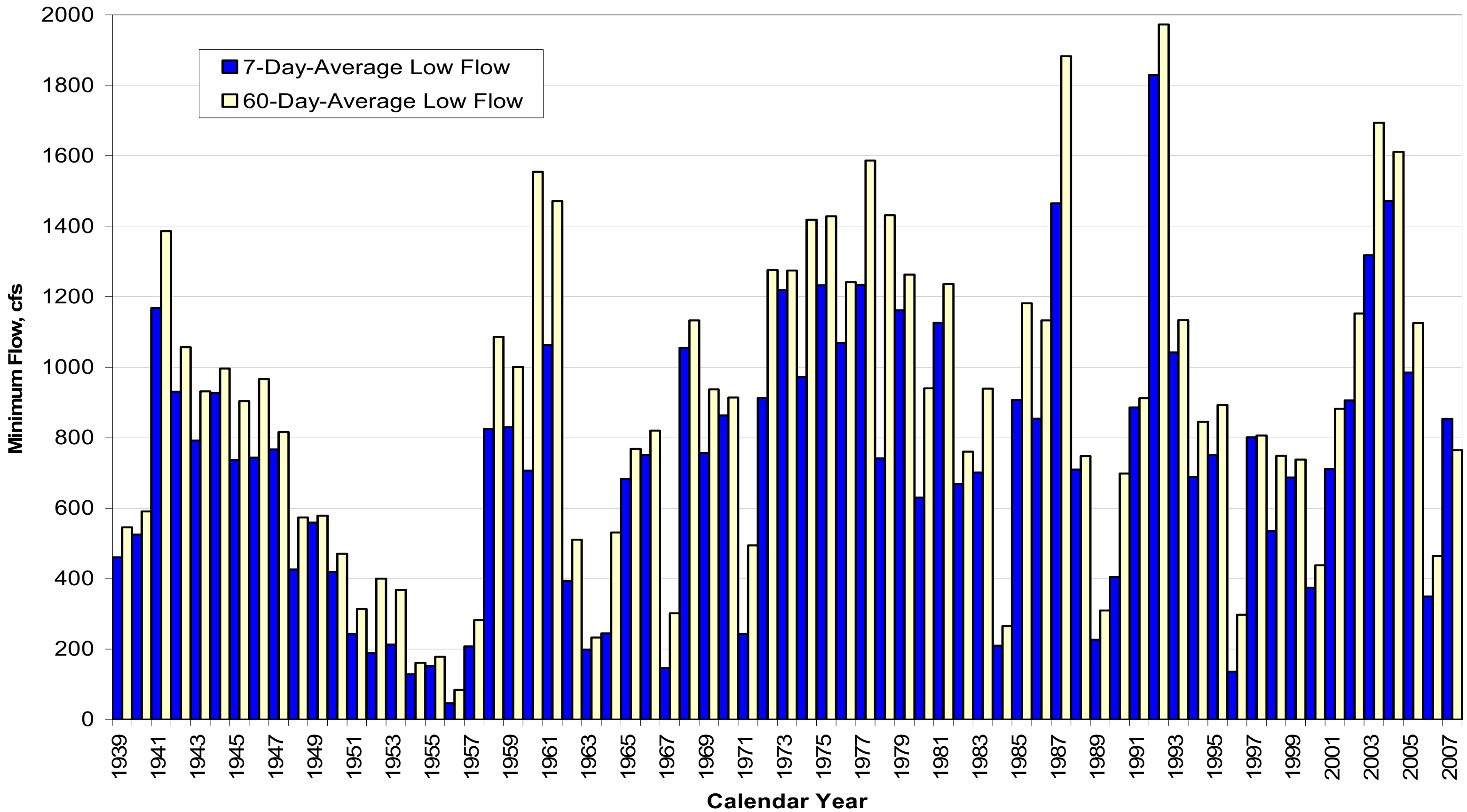

Figure 2.4.11-1 Historic Minimum Low Flows for Guadalupe River near Tivoli, Texas