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2.4.3 **Probable Maximum Flood on Streams and Rivers**

The VCS site is located in the Guadalupe River Basin on the west bank of the Lower Guadalupe River, downstream of its confluence with Coleto Creek near the U.S. Geological Survey (USGS) gage, No. 08177520 near Bloomington, Texas. It is approximately 13 miles (21 km) south of the city of Victoria, Texas, as shown in Figure 2.4.3-1. The natural ground at the site varies in elevation from approximately 60 feet (18.3 meters) to above 80 feet (24.4 meters) in North American Vertical Datum of 1988 (NAVD 88). The minimum finished site grade at the power block is at elevation 95 feet (29.0 meters) NAVD 88. Near the VCS site, the Guadalupe River drains an area of approximately 5816 square miles (15,063 km^2). There are 29 dams upstream of the VCS site on the Guadalupe River and its tributaries, each with storage capacity in excess of 3000 acre-feet (3.7 million cubic meters). The data pertinent to these dams, such as the type, dam height, top-of-dam elevation, storage volume, ownership, and location, is described in Subsections 2.4.1 and 2.4.4.

The most significant dams, in terms of flood storage capacity, are the Canyon Dam at river mile 303 on the Guadalupe River and the Coleto Creek Dam on Coleto Creek, a tributary of the Guadalupe River. The Canyon Dam has a top-of-dam elevation at 974.34 feet (296.98 meters) NAVD 88 and a storage capacity of approximately 1.21 million acre-feet (1492.5 million cubic meters) at that level, as presented in the 2005 Probable Maximum Flood (PMF) Study Report for Canyon Dam by the U.S. Army Corps of Engineers (Reference 2.4.3-1). The Coleto Creek Dam has a top-of-dam elevation at 119.71 feet (36.49 meters) NAVD 88 and a storage capacity of 149,800 acre-feet (184.8 million cubic meters), as given by National Weather Service (NWS) River Forecast System (RFS) for the Guadalupe River Basin down to Bloomington, Texas (Reference 2.4.3-2). See Subsection 2.4.3.3.

Kuy Creek, a small tributary of the Guadalupe River, passes southwest of the VCS site. Because the power block of VCS is located outside of the Kuy Creek Watershed, flooding from Kuy Creek would not affect the power block. Therefore, no flood analysis is performed for Kuy Creek.

Flooding from the San Antonio River is not a concern because the elevations of the drainage divide between the San Antonio and Guadalupe Rivers in the vicinity and upriver of VCS are generally at much higher ground than the river channel elevations. No interbasin flood flow spillage from the San Antonio River Basin to the Guadalupe River Basin causing flooding at the VCS site was recorded or is expected.

Based on air temperature data given in Subsection 2.4.7, the occurrence of snow within the Lower Guadalupe River Basin and its effect on flood-producing phenomena indicates that snowmelt and antecedent snow pack are not critical factors in the production of floods at the VCS site.

In addition, because the drainage area of the Guadalupe River at the VCS site is approximately 5816 square miles (15,063 km^2), it is not expected that any urban developments in the basin would alter significantly the flood runoff characteristics of the watershed or the flood level at the VCS site.

According to the Texas Water Development Board, there are no plans for new dam constructions or dam decommissioning in the Guadalupe River Basin in the next 50 years to 2060 that could affect PMF level at the VCS site (Reference 2.4.3-26).

In this subsection, the effects of the PMF in the Lower Guadalupe River on the power block of VCS are evaluated. The effects of flooding resulting from potential dam failures caused by a PMF in the Guadalupe River Basin are addressed in Subsection 2.4.4.

The following hydrologic and hydraulic studies on the Guadalupe River Basin performed by federal, state, and other local agencies are reviewed to assess the PMF conditions in the Guadalupe River and the potential of flooding of the power block at VCS. These studies/analyses include:

- U.S. Army Corps of Engineers, *Reconnaissance Report, Canyon Lake Modification of Embankment, Guadalupe River, Texas*, Fort Worth District, October 1979 (Reference 2.4.3-4).
- U.S. Army Corps of Engineers, *Canyon Dam Flood Emergency Plan*, Fort Worth District, February 1998 (Reference 2.4.3-7).
- U.S. Army Corps of Engineers, *Dam Assurance Study on Canyon Lake, Guadalupe Basin, Texas*, Fort Worth District, June 2005 (Reference 2.4.3-1).
- U.S. Army Corps of Engineers, *Flood Forecast Model for Guadalupe River Basin, HEC-1 input data file*, updated on August 12, 2004 (Reference 2.4.3-3), with data on the SCS reservoirs updated on February 4, 2008.
- U.S. National Weather Service, *River Forecast System for Guadalupe River Basin, input files*, March 2007 (Reference 2.4.3-2).
- Albert H. Halff Associates, Inc., *Dam Break Analysis for Coleto Creek Dam, for Guadalupe-Blanco River Authority*, March 1989 (Reference 2.4.3-5).
- Albert H. Halff Associates, Inc., *Phase 1 Hydrologic Study, Coleto Creek Dam*, prepared for the Guadalupe-Blanco River Authority, December 1992 (Reference 2.4.3-6).
- URS Corporation, *Bi-Annual Dam Inspection of Coleto Creek Dam*, submitted to Guadalupe-Blanco River Authority, August 21, 2003 (Reference 2.4.3-10).
- Federal Emergency Management Agency, *Flood Insurance Study, Victoria County, Texas, Unincorporated Area*, November 20, 1998 (Reference 2.4.3-8).

- Federal Emergency Management Agency, *Flood Insurance Study, City of Victoria, Texas, Victoria County*, July 21, 1999 (Reference 2.4.3-9).

Among the existing flood study reports and data files listed above, there are two PMF studies performed for the Guadalupe River Basin. The first study was conducted by the U.S. Army Corps of Engineers (USACE) who studied the Canyon Dam in the Upper Guadalupe River for a drainage area of approximately 1425 square miles (3691 km^2) (References 2.4.3-1 and 2.4.3-4). The second study was performed by Albert H. Halff Associates, Inc. for the Coleto Creek Dam on Coleto Creek, with a drainage area of approximately 491 square miles (1272 km^2), for the Guadalupe-Blanco River Authority (Reference 2.4.3-6). As these studies are not directly applicable to the VCS site, an independent PMF model study is performed to evaluate the flooding impact on the power block of VCS.

Besides the two existing PMF studies, there are also two flood forecast models. The first one is the RFS by the U.S. NWS (Reference 2.4.3-2) and the second one is the Flood Forecast Model for Guadalupe River Basin by the USACE (Reference 2.4.3-3). Both models were developed for flood prediction in the Guadalupe River Basin. The PMF study for VCS adopts the basin characteristics from the USACE Flood Forecast Model, including the physical layout of the watershed elements such as subbasin boundary definition, channel reach locations and physical characteristics, and dam/reservoir physical attributes. However, the USACE model includes only the portion of the Guadalupe River Basin down to the USGS gaging station on the Guadalupe River at Victoria, Texas, and it does not include the Coleto Creek Watershed. Coleto Creek is a tributary of the Guadalupe River, and the confluence is located between the USGS gaging station at Victoria and the VCS site. Therefore, the VCS PMF model was expanded to include the watersheds from the USGS gaging station at Victoria, Texas, down to the VCS site.

The VCS PMF model study is conducted using the computer application, HEC-HMS (Hydrologic Modeling System) (Reference 2.4.3-12). The USACE Flood Forecast Model, which was developed in HEC-1 (Reference 2.4.3-11), is first converted to HEC-HMS format. The HEC-HMS model is then expanded to include the Coleto Creek Watershed using model data from the NWS RFS for the Guadalupe River Basin (Reference 2.4.3-2) and Halff Associates' model study for the Coleto Creek Watershed (Reference 2.4.3-6), and records from the USGS stream gaging stations (Reference 2.4.3-13).

As noted above, the first PMF study by the USACE for the Canyon Dam was performed in 1979 (Reference 2.4.3-4). This study was updated in 2005 (Reference 2.4.3-1) using additional PMP data from U.S. NWS HMR 52 (Reference 2.4.3-15) and the USACE Watershed Run-off Computer Model (WRCM) (Reference 2.4.3-20). Review of the 2005 PMF study model parameters indicates that this study is still applicable for flood modeling of the Guadalupe River. The calibrated parameters of the basin runoff model used for the PMF development of the Canyon Dam Watershed are, therefore, applied directly in the VCS PMF model. The calibration of the expanded USACE Flood Forecast Model (in HEC-HMS) for the Guadalupe River down to the VCS site is performed only for the portion of the Guadalupe River Basin downstream of the Canyon Dam.

The HEC-HMS model for the portion of the Guadalupe River Basin between Canyon Dam and the VCS site is calibrated using the observed rainfall and flood hydrograph data from two storms, which occurred in October 1998 and November 2004. According to the flood peak discharge data observed in the USGS gage on the Guadalupe River at Victoria, Texas (Reference 2.4.3-13), these are the largest and fourth largest floods on record from 1935 to 2006. The fourth largest flood on record, the 2004 flood, is selected because the average basin rainfall data for the Guadalupe River Basin for the second largest flood (July 1935) and third largest flood (September 1981) on record are not available.

The calibrated HEC-HMS model for the Guadalupe River Basin downstream of the Canyon Dam to the VCS site is expanded to include the Canyon Dam Watershed using the calibrated basin model parameters of the 2005 USACE PMF Study for that watershed (Reference 2.4.3-1). A verification study is performed to assure that the calibrated WRCM model parameters for the Canyon Dam Watershed are properly transferred to the HEC-HMS model for VCS.

The 72-hour probable maximum precipitation (PMP) estimates for the Guadalupe River near the VCS site are derived following procedures described in NWS Hydrometeorological Reports (HMRs) Nos. 51 and 52 (References 2.4.3-14 and 2.4.3-15, respectively), and using the computer application HEC-HMR 52, developed by the Hydrologic Engineering Center (HEC) of the USACE (Reference 2.4.3-16). Note that the 72-hour storm duration is the maximum given in HMRs 51 and 52.

For the watershed downstream of the Canyon Dam, the precipitation losses for the PMF model are conservatively established from the model calibrations of the 1998 and 2004 floods. For the Canyon Dam watershed, the precipitation losses used by the USACE in the 2005 PMF Study (Reference 2.4.3-1) are adopted as given.

As demonstrated in the following discussions, the Guadalupe River PMF hydrograph at the VCS site is found to have a peak discharge of approximately 1,123,300 cfs (31,808 m^3/s) with a volume of approximately 8,256,300 acre-feet (10,184 million cubic meters). The maximum PMF still water level at the VCS site is estimated to be at elevation 44.6 feet (13.6 meters) NAVD 88 using the computer program HEC-RAS (Reference 2.4.3-18). A 500-year flood event in the San Antonio River is postulated to be occurring coincidentally with the PMF event in the Guadalupe River. The 500-year flood flow from the San Antonio River is estimated to be approximately 180,000 cfs (5097 m^3/s). The river cross sections used in the HEC-RAS analysis are developed from the digital terrain maps. Adding the conservative wind set-up and wave run-up presented in Subsection 2.4.5 derived from the probable maximum hurricane (PMH) wind field, the maximum water level of the Guadalupe River at the VCS site during a PMF event is postulated to be no more than elevation 65.9 feet (20.1 meters) NAVD 88.

Details of the development of the PMP estimates, the basin runoff model calibration, and the determination of the PMF peak discharge and water level at the VCS site are discussed in the following subsections.

2.4.3.1 **Probable Maximum Precipitation**

PMP depths for the Guadalupe River Basin upstream of the VCS site are derived following the procedures described in NWS HMRs Nos. 51 and 52 (References 2.4.3-14 and 2.4.3-15, respectively) and using the computer program HEC-HMR 52 (Reference 2.4.3-16). HMRs Nos. 51 and 52 provide discussions on the developments of the PMP estimates, in terms of precipitation maximization, spatial and temporal distributions, orographic effects, and seasonal effects, for areas east of the 105th Meridian in the United States.

In using HEC-HMR 52, the PMP estimates and the storm orientation for the basin of interest for the various area sizes and durations are required as inputs to the program. They are derived from NWS HMRs Nos. 51 and 52 and are presented in Table 2.4.3-1. HEC-HMR 52 also requires the X and Y coordinates of the boundaries of the river basin and of each of the subbasins as well as the preferred storm orientation, which is 195 degrees, as suggested in NWS HMR No. 52 for this area. The boundaries of the Guadalupe River Basin and its subbasins are shown on Figure 2.4.3-2. The program estimates the hourly PMP values for each of the subbasins, for a particular storm center in the basin and the hourly PMP values are stored in the data storage system (Reference 2.4.3-19) to be recalled for use in flood hydrograph developments.

A special flood study is performed to verify the proper transfer of the calibrated basin runoff parameters from the USACE WRCM Canyon Dam model of the 2005 PMF Study (Reference 2.4.3-1) to the HEC-HMS model above Canyon Dam. It involves the development of the subbasin PMP estimates for the Canyon Dam Watershed using HEC-HMR 52. The input data to HEC-HMR 52 are: watershed PMP estimates (Table 2.4.3-2), a storm center at Longitude 98 degrees 59 minutes and Latitude 29 degrees 59 minutes (equivalent to X=373.82 and Y=2633.54 in the Texas State Plane System with the units given in miles), and a storm area size of 1000 square miles with a storm orientation of 279.5 degrees, as given by the USACE (Reference 2.4.3-1).

In accordance with guidelines suggested by Subsection 9.2.1.1 of ANSI 2.8-1992 (Reference 2.4.3-22), an antecedent storm, equal to 40 percent of the 72-hour PMP, is assumed to end 3 days before the start of the 72-hour PMP.

2.4.3.2 Precipitation Losses

The PMF development requires estimates of infiltration rates to determine the direct runoff hydrograph corresponding to the excess rainfall (i.e., total rainfall minus rainfall loss). Infiltration rates, in terms of initial losses and a constant loss rate, are used in this flood study. For the watershed downstream of Canyon Dam, the adopted initial losses for the subbasins vary from 0.05 inches (1.27 mm) to 1.0 inches (25.4 mm), while the constant loss rates of 0.05 inches per hour (1.27 mm per hour) and 0.1 inches per hour (2.54 mm per hour) are used. These losses are derived primarily from the results of the model calibrations of the 1998 and 2004 floods and adjusted conservatively for use in the PMF developments. For the Canyon Dam Watershed, the values used by the USACE in its 2005 PMF study; an initial loss of 1.0 inch (25.4 mm) and a constant loss of 0.15 inches per hour (3.81 mm per hour), with the losses for the surface of Canyon Lake being zero, are adopted. The loss values for each of the subbasins used in the PMF development are presented in Table 2.4.3-4.

2.4.3.3 Runoff and Stream Course Models

The VCS PMF model adopts the calibrated WRCM model parameters for the Canyon Dam Watershed as given in the 2005 USACE PMF Study and the basin characteristics from the Flood Forecast Model developed by the USACE, Fort Worth District, Texas for the Guadalupe River Basin downstream of Canyon Dam to the USGS gage at Victoria, Texas (Reference 2.4.3-3). The basin characteristics include the physical layout of the watershed elements, such as subbasin boundary definitions, channel reach locations and physical characteristics, and dam/reservoir physical attributes. The USACE Flood Forecast model includes two small agriculture-related reservoirs located in the San Marcos River Basin. They are the SCS No. 3 and SCS No. 5 reservoirs with the top of dam elevations at 647.7 feet (197.47 meters) NAVD 88 and 667.51 feet (203.51 meters) NAVD 88, and maximum storage capacities of approximately 4000 acre-feet (4.93 million cubic meters) and 7000 acre-feet (8.63 million cubic meters), respectively (Reference 2.4.3-3). No reasons were given by the USACE as to why these two small reservoirs were included in the model despite their relatively small storage capacities when compared to other larger reservoirs in the basin. Because their inclusions would not significantly affect the runoff characteristics of the basin, the two SCS reservoirs are included in the VCS PMF simulation.

The USACE model only covers the portion of the basin upstream of the USGS gage at Victoria, Texas. It does not include the drainage area from Coleto Creek, a tributary of the Guadalupe River, which joins the main river downstream of the gage at Victoria but upstream of the VCS site. The Coleto Creek Watershed, together with the Coleto Creek Dam/Reservoir are modeled by including the drainage areas given by the USGS at gaging station No. 08176900 (Reference 2.4.3-13) and by Halff Associates for the Coleto Creek Dam/Reservoir (Reference 2.4.3-6). The drainage area downstream of the Coleto Dam to its confluence with the Guadalupe River, the subbasin boundaries, and the elevation-storage-discharge relationships for the Coleto Creek Dam/Reservoir are those given in the NWS RFS for the Guadalupe River Basin near Bloomington, Texas (Reference 2.4.3-2). The elevation-storage relationships for the Coleto Creek Dam are slightly different from those given in Subsections 2.4.1 and 2.4.4. Since the impact due to these differences is expected to be minor, they are adopted in the VCS PMF model as given in the NWS RFS model.

In the 1979 PMF study for the Canyon Dam (Reference 2.4.3-4), the USACE calibrated the runoff response characteristics of the watershed with the August 1978 flood flows observed at the Johnson Creek gage near Ingram, the North Fork gage near Hunt, and the Guadalupe River gages near Hunt, Comfort, and Spring Branch. USACE updated the model in 2005 (Reference 2.4.3-1) using the WRCM (Reference 2.4.3-20) with the same basin runoff response characteristics, but including additional PMP data from U.S. NWS HMR 52 (Reference 2.4.3-15). The 1978 flood is still the flood of record to-date for the part of the Guadalupe Watershed upstream of the Canyon Dam, which has a drainage area of approximately 1432 square miles (3709 km^2) (Tables 2.4.3-5 and 2.4.3-6). It is, therefore, reasonable to postulate that the runoff parameters established in the USACE PMF model adequately represent the basin response during extreme floods and no new calibration of the Canyon Dam Watershed is necessary. The calibration efforts, therefore, concentrate only on the portion of the Guadalupe Watershed downstream of the Canyon Dam to the VCS site.

The resulting composite watershed and the subbasins, including those for the Canyon Dam Watershed used in the 2005 USACE PMF model, are shown on Figure 2.4.3-2.

2.4.3.3.1 **Runoff Model Calibrations**

The HEC-HMS model developed for the watershed downstream of the Canyon Dam is calibrated using the flood records of October 1998 and November 2004 storms. The storms of October 1998 and November 2004 produced the largest and the fourth-largest floods on record from 1935 to 2006 at the USGS gaging station at Victoria, Texas, as indicated in Table 2.4.3-7. The November 2004 flood is selected because the average subbasin rainfall data for the Guadalupe River Basin for the second-largest (July 1935) and the third-largest (September 1981) floods are not available. The observed hourly rainfall depths for each of the subbasins, from October 13, 1998, to October 30, 1998, and from November 15, 2004, to December 3, 2004, are obtained from the NWS West Gulf Region Forecast Center (WGRFC).

There are a total of 13 USGS stream gaging stations on the Guadalupe River downstream of the Canyon Dam to the VCS site for which flood hydrograph data are available for the 1998 and 2004 floods. The observed 15-minute flood flow hydrographs from these gages are used for the calibration (Reference 2.4.3-21). The gaging stations are:

- USGS No. 08168500 — Guadalupe River above Comal River with a drainage area of 1518 square miles (3932 km^2)

- USGS No. 08173900 — Guadalupe River at Gonzales with a drainage area of 3490 square miles (9039 km^2)
- USGS No. 08175800 — Guadalupe River at Cuero with a drainage area of 4934 square miles (12,779 km^2)
- USGS No. 08176500 — Guadalupe River at Victoria with a drainage area of 5198 square miles (13,463 km^2)
- USGS No. 08171000 — Blanco River at Wimberley with a drainage area of 355 square miles (919 km^2)
- USGS No. 08171300 — Blanco River near Kyle with a drainage area of 412 square miles (1067 km^2)
- USGS No. 08172000 — San Marcos River at Luling with a drainage area of 838 square miles (2170 km^2)
- USGS No. 08172400 — Plum Creek at Lockhart with a drainage area of 112 square miles (290 km^2)
- USGS No. 08173000 — Plum Creek near Luling with a drainage area of 309 square miles (800 km^2)
- USGS No. 08174600 — Peach Creek below Dilworth with a drainage area of 460 square miles (1191 km^2) (2004 Storm Only)
- USGS No. 08175000 — Sandies Creek near Westhoff with a drainage area of 549 square miles (1422 km^2)
- USGS No. 08176900 — Coleto Creek at Arnold Road Crossing near Schroeder with a drainage area of 357 square miles (925 km^2)
- USGS No. 08177500 — Coleto Creek near Victoria with a drainage area of 514 square miles (1331 km^2)

In the calibration of the VCS HEC-HMS model, the 1998 and 2004 observed flood hydrographs of the Guadalupe River at the Sattler, Texas gage (USGS Gage No. 08167800) are used as inflows to the model basin. The Sattler gage is located immediately downstream of the Canyon Dam with a drainage area of 1436 square miles (3719 km^2). The locations of the USGS gaging stations are shown in Figure 2.4.3-3.

The model basin of the USACE Flood Forecast Model is subdivided into 22 subbasins, linked respectively by 16 channel reaches. The two small SCS reservoirs included in the model are located in Subbasins 16 and 17 (Figure 2.4.3-2). The elevation-storage-discharge relationships for these two reservoirs are given in Table 2.4.3-8. The model uses the Muskingum channel routing method for 13 of these 16 channel reaches and the Modified Puls method with prescribed storage-discharge relationship for the remaining three channel reaches. The prescribed storage-discharge relationships for the Modified Puls method for the three channel reaches are given in Table 2.4.3-9. In the calibration process, only the K and X values are adjusted and the storage-discharge relationships remain unchanged as defined by the USACE.

As noted in Subsection 2.4.3.3, the USACE Flood Forecast Model does not include the Coleto Creek Watershed. Thus, the Coleto Creek Watershed and Reservoir are added to the model. The stage-storage and storage-discharge relationships for the Coleto Creek Dam/Reservoir from NWS RFS for Guadalupe River Basin are adopted instead of those from Reference 2.4.3-10 because they are more current (dated March 2007) and are used by the NWS WGRFC in its current flood forecast model for the Guadalupe River Basin. They are presented in Tables 2.4.3-10 and 2.4.3-11, respectively. The runoff model of the Coleto Creek Watershed at its confluence with the Guadalupe River is represented by three subbasins, Subbasins 29, 30, and 31 (See Figure 2.4.3-2), and three channel reaches. The initial K and X values for the Muskingum channel routing method used in the calibration are developed from data given in Reference 2.4.3-6 and are given in Table 2.4.3-12.

The historical observed rainfall data for the 1998 and 2004 floods are obtained from the NWS WGRFC, for the subbasins shown in Figure 2.4.3-4. Comparisons of the individual drainage boundaries of the respective subbasins, as shown in Figures 2.4.3-2 and 2.4.3-4, indicate that there are some minor differences in the subbasin definitions. In some parts of the basin, the USACE definitions are more refined, resulting in more subbasins, and the reverse is true for other areas. In areas where a USACE subbasin consists of more than one NWS subbasin, the area-weighted average of the NWS subbasin rainfall depths is used to approximate the rainfall depth of the corresponding USACE subbasin. In the case where the NWS subbasin encompasses a number of USACE subbasins, the average rainfall depth of that NWS subbasin is assumed to be applicable to all the corresponding USACE subbasins. Table 2.4.3-13 depicts the names of the NWS subbasin rainfall data files used as inputs to the HEC-HMS for the subbasins downstream of Canyon Dam.

The NWS rainfall data indicates that there is a substantial difference in the rainfall amount for the 1998 storm between the upper (VICT2U) and lower (VICT2) parts of Subbasin 28 (Figure 2.4.3-4). It would be difficult to achieve good calibration results if the rainfall depth for the entire Subbasin 28 is assumed to be represented by an average value. Therefore, Subbasin 28 is further subdivided into two sub-subbasins, namely: Subbasins 28A and 28 (Figure 2.4.3-2), according to the subbasin definition given by the NWS in Figure 2.4.3-4 for VICT2U and VICT, respectively. The observed rainfall depths for VICT2U and VICT are used as inputs for Subbasin 28A and 28, respectively.

Consequently, the channel reach through the original Subbasin 28 is divided into two model sub-reaches.

With a given drainage area and rainfall input sequence, the runoff characteristics of a basin are defined by four groups of parameters in the HEC-HMS rainfall-runoff model, namely:

(1) Basin losses

(2) Runoff characteristic of rainfall excess to the conveyance channels

(3) Base flow characteristics

(4) Channel and reservoir flood routing characteristics

For the VCS PMF study, the basin losses are represented by an initial loss and a constant loss rate. The Snyder's lags and peaking coefficients are used to define the runoff characteristics. Base flows are estimated by the recession method, while the Muskingum channel routing and Modified Puls routing techniques are employed for the routing of the flood hydrograph through the channel reaches as described previously. Reservoir hydrograph routing is performed using the defined elevation-storage-discharge functions for each of the reservoirs modeled.

As basin losses vary from storm to storm and are dependent on basin antecedent moisture conditions, the first step in the basin runoff model calibration is to adjust the basin losses. The calibration target is considered to have been achieved when the observed and computed runoff volumes are reasonably reconciled. Then, the Snyder's lags and peaking coefficients and the K and X values of the Muskingum Method are adjusted to fine-tune the timing and the magnitude of the computed flood hydrographs to get their peaks and the shapes to reasonably match the observed hydrographs. Also, the recession coefficients, initial base flow values, and the starting times of the recession flows are varied during the calibration to achieve a reasonable match of the recession limbs of the computed and observed flood hydrographs.

The calibration process to define the basin response parameters starts from the very top of the watershed immediately downstream of the Canyon Dam and proceeds downstream to the USGS gaging station at Victoria, including the Coleto Creek Watershed and the USGS gaging station downstream of the Coleto Creek Dam. The observed and computed peak flows and volumes for the 1998 and 2004 floods at the various USGS gaging stations are presented in Tables 2.4.3-14 and 2.4.3-15, respectively. The plots of the observed and computed flood hydrographs at each of the USGS gaging stations used in the calibration process for the 1998 and 2004 floods are depicted in Figures 2.4.3-5 through 2.4.3-25. The calibrated basin runoff parameters, namely, the basin loss values, the Snyder's lags and peaking coefficients, the base flow recession coefficients, and

Muskingum K and X values for the 1998 and 2004 floods are also presented in Tables 2.4.3-16 through 2.4.3-19.

2.4.3.4 Probable Maximum Flood Flow

The adopted basin runoff parameters for the PMF development for each of the basin elements for the Guadalupe River Basin downstream of the Canyon Dam are shown in Tables 2.4.3-4 and 2.4.3-24. They are developed from the calibrated basin runoff parameters given in Tables 2.4.3-16 through 2.4.3-19 by selecting the more conservative values from the two floods. To account for nonlinearity effects of extreme flood conditions, the calibrated Snyder's lags for the subbasins are reduced by 15 to 20 percent. A lag reduction is typically suggested for PMF development (Reference 2.4.3-17) even though the model is calibrated with the extreme floods of 1998 and 2004.

In the 2005 PMF study for the Canyon Dam (Reference 2.4.3-1), the USACE subdivided the watershed above the dam into 9 subbasins, instead of 24 subbasins in the Flood Forecast Model (Reference 2.4.3-4). The definitions of the subbasins and respective drainage areas in the 2005 study are presented in Table 2.4.3-20. Note that the total drainage area for the Canyon Dam is shown as 1417.85 square miles (3672 km^2), which is slightly less than the drainage area of 1436 square miles (3719 km^2) given by USGS. The subbasin delineation for the Flood Forecast Model is modified for the Canyon Dam Watershed to match those given in the 2005 PMF study for the same area, as shown in Figure 2.4.3-2. These revised subbasin boundaries, including the watershed for the Coleto Creek Basin, are used in the VCS PMF model development.

In the same 2005 study, the unit hydrograph for each of the subbasins was specified by the USACE and is presented in Table 2.4.3-21. A storage-discharge relationship was defined by the USACE for each of the five channel elements for flood routing through the channel reaches in the watershed, as depicted in Table 2.4.3-22. The elevation-storage-discharge relationship for the Canyon Dam and Reservoir is presented in Table 2.4.3-23. The basin runoff routing parameters for each of these subbasins are obtained from the WRCM.

To verify the basin runoff parameters of the subbasins upstream of the Canyon Dam, the calibrated HEC-HMS model was first run using the subbasin PMP estimates developed from HEC-HMR 52 for the Canyon Dam Watershed according to storm area size and storm center developed, and the same infiltration losses established in the 2005 USACE PMF Study. The peak and volume of the inflow PMF hydrograph to the Canyon Lake are approximately 751,200 cfs (21,271.6 m^3/s) and 1,564,200 acre-feet (1929 million cubic meters), respectively, as compared to the values of 748,000 cfs (21,181 m^3/s) and 1,722,000 acre-feet (2214 million cubic meters) from the USACE 2005 PMF Study (Reference 2.4.3-1).

The USACE simulated PMF flood volume is higher because a 96-hour PMP was used as compared to the 72-hour PMP used in this verification run. In addition, in the USACE study, a storm equal to 50 percent of the PMP was assumed to occur 5 days preceding the start of the PMP. This preceding storm increases the volume to the PMF hydrograph.

For the verification run, the maximum outflow from Canyon Dam and the maximum reservoir water level are found to be 614,300 cfs (17,395 m^3/s) and elevation 974.23 feet (296.95 meters) NAVD 88, respectively. These values also compare well with the values of 616,300 cfs (17,452 m^3/s) and elevation 974.32 feet (296.97 meters) NAVD 88, given in the USACE 2005 study. From the comparison of the model results, it is concluded that the HEC-HMS model for the Canyon Dam Watershed is verified.

The hourly PMP estimates for each of the subbasins, with storm centers as depicted in Table 2.4.3-3, are used as input to the calibrated PMF HEC-HMS model with the loss and base flow parameters as given in Table 2.4.3-4.

In accordance with the combined-event criterion stated in Subsection 9.2.1.1 of ANSI 2.8-1992 (Reference 2.4.3-22), an antecedent rainfall equal to 40 percent of the PMP should be simulated as part of the PMF flood level determination. As suggested in Section 5.2.7.1 of ANSI 2.8-1992 (Reference 2.4.3-22), an antecedent storm preceding the PMP by 3 days is selected. Using a 72-hour PMP, this combined-event criterion would require generating a 40 percent PMP sequence and placing it 6 days ahead of the PMP estimates. To simulate this, the HEC-HMS is first run using the 40 percent PMP event. The simulation is re-started for the full PMP event with the starting water levels in the 4 reservoirs, Canyon Lake, SCS Nos. 3 and 5, and the Coleto Creek Reservoir, equal to the predicted reservoir levels at 3 days after the cessation of the 40 percent PMP event, as shown in Table 2.4.3-25. The 2 resulting flood hydrographs near the VCS site, i.e., with a 40 percent PMP and with a full PMP, are shown in Figures 2.4.3-26 and 2.4.3-27, respectively.

The PMF hydrograph is superimposed onto the hydrograph for the 40 percent PMP, with the start of day 1 of the PMF at the start of day 7 of the 40 percent PMF; i.e., the PMF hydrograph lagged 3 full days after the cessation of the 40 percent 72-hour PMP. Note that the PMF at VCS peaks at approximately 06:00 hours on day 5 with a flow rate of approximately 1,123,300 cfs (31,808 m^3/s) (Figure 2.4.3-27). From the 40 percent PMP hydrograph (Figure 2.4.3-26), the flow rate at approximately 06:00 hours in day 11 is estimated to be approximately 40,000 cfs (1133 m^3/s). This indicates that the 40 percent PMP would add less than 4 percent to the PMF peak discharge. Therefore, it is concluded that the antecedent storm of 40 percent PMP would not significantly increase the PMF peak discharge near the project site. It is not necessary to superimpose the two flood hydrographs together to arrive at the PMF peak discharge.

Using the starting reservoir water levels at the four reservoirs resulting from the 40 percent PMP runs, as shown in Table 2.4.3-25, the resulting flood peak discharges of the Guadalupe River at the Canyon Dam, Gonzales, Cuero, and Victoria near the VCS site are depicted in Table 2.4.3-26. The

PMF hydrograph of the Guadalupe River near the VCS site is presented in Figure 2.4.3-27, with the peak discharge of 1,123,300 cfs (31,808 m^3/s), with a volume of 8,256,300 acre-feet (10,184 million cubic meters for the PMP storm centered at the southeast corner of subbasin 13.

2.4.3.5 **Water Level Determinations**

The water surface profile in the Guadalupe River for the postulated PMF condition is estimated using the steady state routing option of the computer program HEC-RAS, Version 3.1.3 (Reference 2.4.3-18). The river channel and cross section geometry of the Guadalupe River from San Antonio Bay to a location upstream of the VCS site are established from the digital terrain map of the area (Reference 2.4.3-23). The Manning's n values are conservatively assumed to be 0.1 for both the channel and overbank areas. Discussions on the selection of this Manning's n value are given in Subsection 2.4.4. The locations of these cross sections are presented in Figure 2.4.3-28. The downstream boundary condition is assumed to be at normal depth with a slope equal to 0.00016. This slope is the average of the bed slopes between the 10-foot to 20-foot contour (equal to 0.00032) and that near the confluence between the Guadalupe and San Antonio Rivers, which is basically flat.

With the San Antonio River joining the Guadalupe River upstream of Tivoli, Texas, at approximately 14 miles (22.5 km) downstream of the VCS site, the flood level at the VCS site could potentially be influenced by the flood flow of the San Antonio River as well. For the PMF level prediction at VCS, a 500-year flood in the San Antonio River Basin is assumed to occur coincidentally with a PMF event in the Guadalupe River Basin.

The USGS gaging station on the San Antonio River closest to its confluence with the Guadalupe River and with a long stream flow record for flood frequency analysis is at Goliad, Texas, (USGS Gage No. 0818850). At this gage, the San Antonio River drains an area of approximately 3921 square miles (10,155 km^2), and has annual peak discharge records of 75 years (Reference 2.4.3-13). A flood frequency analysis is performed using these 75-years of data, assuming the Log-Pearson Type III distribution and following the formulations suggested by Rao and Hamed (Reference 2.4.3-24) and USGS Bulletin 17B (Reference 2.4.3-25). The 500-year flood peak discharge at Goliad is found to be approximately 164,000 cfs (4644 m^3/s).

The San Antonio River drainage area at its confluence with the Guadalupe River is estimated to be approximately 4180 square miles (10,826 km^2). By prorating the peak discharge using a drainage area ratio, the San Antonio River 500-year flood peak discharge at its confluence with the Guadalupe River is determined to be 180,000 cfs (5097 m^3/s). This flow rate is added to the Guadalupe River PMF peak discharge of 1,123,300 cfs (31,808.3 m^3/s), yielding a total flood discharge of approximately 1,303,300 cfs (36,905 m^3/s). The PMF peak discharge value of 1,300,000 cfs (36,812 m^3/s) is used for the cross sections downstream of the confluence of the San Antonio River in the HEC-RAS model in determining the PMF water level at the VCS site. Upstream of that confluence, the PMF peak discharge used in the model is 1,120,000 cfs (31,715 m^3/s). The PMF inflow discharge from Coleto Creek to the Guadalupe River at the time of the PMF peak discharge in the Guadalupe River is estimated to be approximately 20,000 cfs (566 m^3/s) from the HEC-HMS run. Therefore, for the reach of the Guadalupe River upstream of its confluence with Coleto Creek, the PMF peak discharge used in the simulation is approximately 1,100,000 cfs (31,149 m^3/s). The PMF water surface profile along the Guadalupe River from STA 7.247 to STA 66.256 is shown in Table 2.4.3-27. The PMF flooding water level of the Guadalupe River near the VCS site (river mile 29.5984) is found to be approximately 44.6 feet (13.6 meters) NAVD 88.

The PMF HEC-RAS model does not include the railroad bridge, which is located downstream of VCS and between river mile 23.4397 and river mile 25.0028. A sensitivity study that includes the bridge section was performed and it indicates that the bridge section has minimal impact on the flood level at VCS because it will be completely inundated during major flood events such as the PMF or the PMH. In addition, the HEC-RAS model does not include the inflatable Lower Guadalupe Salt Water Barrier and Diversion Dam, a fabridam, located near river mile 11. Since this inflatable dam would rupture when a hydraulic head against the dam exceeds approximately 4.8 feet (1.46 meters), when inflated (Reference 2.4.3-27), it would not have any effect on the PMF level at the VCS site.

2.4.3.6 **Coincident Wind Wave Activity**

For the effect of wind set-up and wave run-up concurrent with a PMF event, ANSI 2.8-1992 (Reference 2.4.3-22) suggests the use of a 2-year wind speed. The wind set-up and wave run-up values are conservatively adopted from the results for the PMH wind field as described in Subsection 2.4.5. As stated in Subsection 2.4.5, the maximum PMH wind was estimated to be 105.5 knots (195.4 km per hour) based on a conservative estimate of still water level of elevation 48.3 feet (14.7 meters) NAVD 88 at the VCS site during a PMH event. Under these conditions, using a fetch distance of 9 miles (14 km) to the river bank at the VCS site, the wind set-up and wave run-up were estimated to be approximately 4 feet (1.2 meters) and 17.3 feet (5.3 meters), respectively. It is assumed conservatively that the wind set-up and wave run-up during the PMH condition are superimposed directly to the PMF water level at the VCS site.

2.4.3.7 **Probable Maximum Flood Water Level**

The maximum PMF still water level of the Guadalupe River at VCS, before wind-wave induced set-up and run-up, is predicted to be at elevation 44.6 feet (8.8 meters) NAVD 88. Adding the conservative wind set-up and maximum wave run-up prediction of approximately 4 feet (1.2 meters) and 17.3 feet (5.3 meters) for the PMH event, the maximum PMF flooding water level at VCS is postulated to be at elevation 65.9 feet (20.1 meters) NAVD 88. This is over 29 feet (8.8 meters) lower than the minimum finished site grade of 95 feet (29.0 meters) NAVD 88 of the power block at VCS. Erosion affecting the power block as a result of the postulated PMF flooding is not expected because the predicted PMF flood level is much lower than the existing natural ground elevation of approximately 80 feet (24.4

meters) NAVD 88 at the power block area. With the relatively gentle grades at the general vicinity of the site, the inundated areas during the PMF event will be a considerable distance away from the power block area. Therefore, the PMF-induced flooding is not expected to impact the safety functions of VCS.

2.4.3.8 References

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Table 2.4.3-1
Average PMP Depths for Guadalupe River Basin above VCS Site (inches)

Area (sq mi)	6-hr PMP	12-hr PMP	24-hr PMP	48-hr PMP	72-hr PMP
10	32.0	38.7	47.1	51.8	55.7
200	24.6	31.2	39.5	44.3	48.8
1,000	18.2	24.9	33.2	37.7	41.3
5,000	10.1	15.0	21.9	26.6	30.7
10,000	7.6	11.8	17.6	22.5	26.5
20,000	5.6	9.2	13.6	18.0	22.0

Table 2.4.3-2
Average PMP Depths for Canyon Dam Watershed (inches)

Area (sq mi)	6-hr PMP	12-hr PMP	24-hr PMP	48-hr PMP	72-hr PMP
10	29.6	36.0	42.4	47.8	50.8
200	22.3	27.9	34.5	38.8	43.0
1,000	16.1	21.5	28.1	32.6	36.3
5,000	9.2	12.8	18.6	22.9	26.6
10,000	7.0	10.2	15.0	19.0	22.5
20,000	5.2	8.0	11.7	15.9	19.1

Source: USACE (Reference 2.4.3-1)

Table 2.4.3-3
X and Y Coordinates of Storm Center and Optimized Orientation for PMP Estimates

Storm Center	X[a]	Y[a]	Optimized Orientation (°)
Southeast Corner of Subbasin 13	459.0	2599.5	155
Centroid of Subbasin 23	461.2	2607.0	155
Centroid of Subbasin 24	469.1	2598.6	155
Centroid of Subbasin 27B	433.7	2608.0	140
Lower end of Subbasin 5	373.82	2633.5	279.5[b]

(a) X and Y coordinates are based on Texas State Plane system, with units in miles
(b) Not optimized; obtained from USACE (Reference 2.4.3-1)

Table 2.4.3-4
PMF Basin Runoff Model Parameters

Model Subbasin[(a)]	Drainage Area (sq mi)	Initial Loss (in)	Constant Loss Rate (in/hr)	Snyder's Lag[(b)] (hr)	Snyder's C_p[(b)]	Base Flow STRTQ[(b)] (cfs/sq mi)	Base Flow QRCSN[(b)]	Base Flow Recession Coefficient[(b)]
1	179.14	1.0	0.15	(c)	(c)	(d)	(d)	(d)
2	102.00	1.0	0.15	(c)	(c)	(d)	(d)	(d)
3	31.69	1.0	0.15	(c)	(c)	(d)	(d)	(d)
4	131.82	1.0	0.15	(c)	(c)	(d)	(d)	(d)
5	382.53	1.0	0.15	(c)	(c)	(d)	(d)	(d)
6	473.43	1.0	0.15	(c)	(c)	(d)	(d)	(d)
8	64.07	1.0	0.15	(c)	(c)	(d)	(d)	(d)
9	32.04	1.0	0.15	(c)	(c)	(d)	(d)	(d)
10	20.14	0.0	0.0	(c)	(c)	(d)	(d)	(d)
11	86	1.0	0.1	2.5	0.6	2	0.05	0.887
12	130	0.5	0.1	4.0	0.625	0.4	0.08	0.887
13	456	0.5	0.1	8.0	0.55	0.3	0.05	0.887
14	355	0.5	0.05	2.0	0.625	6	0.1	0.92
15A	57	1.0	0.05	2.0	0.6	0.3	0.1	0.887
15B	24	1.0	0.05	2.0	0.625	0.3	0.1	0.887
16	48.5	1.0	0.05	2.5	0.6	0.3	0.05	0.788
17	46.5	1.0	0.05	2.5	0.6	0.3	0.05	0.788
18	82	1.0	0.05	3.5	0.6	0.3	0.05	0.788
19	143	1.0	0.05	3.5	0.6	0.3	0.05	0.788
20	82	1.0	0.05	5.5	0.6	0.3	0.05	0.788
21	23	1.0	0.05	2.3	0.6	0.3	0.1	0.887
22A	112	0.5	0.05	4.2	0.6	0.1	0.24	0.788
22B	277	0.5	0.05	5.0	0.6	0.1	0.1	0.788
23	108	0.5	0.05	5.0	0.6	0.1	0.05	0.887
24	69	0.5	0.05	3.5	0.6	0.3	0.05	0.887
25	483	0.5	0.05	22	0.55	0.1	0.6	0.887
26	209	0.5	0.05	12.5	0.55	0.3	0.05	0.887
27A	390	1.0	0.05	37.0	0.75	0.1	0.05	0.75
27B	159	1.0	0.05	37.0	0.75	0.1	0.05	0.75
27C	162	1.0	0.05	34.0	0.75	0.3	0.05	0.75
28A	132.5	0.5	0.05	12.5	0.55	0.1	0.05	0.887
28	132	0.5	0.05	12.5	0.55	0.1	0.05	0.887
29	357	1.0	0.05	4.2	0.52	0.1	0.1	0.75
30	133	1.0	0.05	5.0	0.58	0.1	0.01	0.75
31	148	1.0	0.05	5.0	0.55	0.1	0.01	0.75

(a) Subbasin designation 7 not used.
(b) No base flow is assumed by USACE (Reference 2.4.3-1).
(c) Use unit hydrographs (Table 2.4.3-21).
(d) Definitions are given in HEC-HMS Users Manual (Reference 2.4.3-12).

Table 2.4.3-5
Largest Five Recorded Peak Discharges USGS Gage No. 08167000
Guadalupe River at Comfort, Texas

Water Year	Date	Peak Discharge (cfs)
1978	August 2, 1978	240,000
1987	July 17, 1987	130,000
2002	July 4, 2002	128,000
1960	October 4, 1959	111,000
1944	May 26, 1944	74,200

Source: Reference 2.4.3-13 and the drainage area is 839 square miles.

Table 2.4.3-6
Largest Five Recorded Peak Discharges USGS Gage No. 08167500
Guadalupe River near Spring Branch, Texas

Water Year	Date	Peak Discharge (cfs)
1978	August 3, 1978	160,000
1932	July 3, 1932	121,000
1997	June 2, 1997	116,000
1935	June 15, 1935	114,000
2002	July 5, 2002	94,400

Source: Reference 2.4.3-13 and the drainage area is 1315 square miles.

Table 2.4.3-7
Largest Five Recorded Peak Discharges USGS Gage No. 08176500
Guadalupe River at Victoria, Texas

Water Year	Date	Peak Discharge (cfs)
1999	October 20, 1998	466,000
1936	July 3, 1935	179,000
1981	September 2, 1981	105,000
2005	November 26, 2004	102,000
1987	June 7, 1987	83,400

Source: Reference 2.4.3-13 and the drainage area is 5198 square miles.

Table 2.4.3-8
Elevation-Storage-Discharge Relationships
SCS#3 (Subbasin 16) and SCS#5 (Subbasin 17) Reservoirs

SCS #3 Reservoir			SCS #5 Reservoir		
Elevation (ft)	**Storage (AF)**	**Discharge (cfs)**	**Elevation (ft)**	**Storage (AF)**	**Discharge (cfs)**
611	127.000	0.0	616.2	161.00	0.0
611.84	147.09	81.48	616.59	172.14	1.14
612.67	171.55	230.46	616.98	183.29	3.23
613.51	197.08	423.39	617.38	194.43	5.93
614.35	222.60	651.85	617.62	201.29	6.91
616.05	275.55	696.39	617.86	208.14	7.77
617.76	355.75	737.46	618.1	215	8.54
619.47	435.96	776.35	619.14	245.63	113.74
621.17	532.9	813.4	620.17	276.16	303.28
622.88	637.42	848.82	621.21	319.17	547.78
624.59	750.75	882.83	631.07	856.77	704.08
626.29	880.88	915.57	640.94	1,780.1	831.35
628	1,011	947.18	650.8	3,160.6	941.57
629.2	1,127.7	1,915	651.66	3,304.9	1,337.7
630.4	1,244.4	3,884.5	652.52	3,464.9	2,214.4
632.56	1,470.1	9,028.2	654.07	3,771.4	4,624.9
635.20	1,800.8	17,466.9	655.96	4,146	8,761.4
640	2,526	37,634	659.4	4,958	19,119.4
646	3,728	65,754.9	663.7	6,152.6	36,103.1
652	5,321	94,115	668	7,596	54,142.6

Source: USACE Flood Forecast Model for Guadalupe River Basin (Reference 2.4.3-3)
Note: Elevations in Table 2.4.3-8 are given in terms of NGVD 29. To convert to NAVD 88, for SCS #3 and SCS #5 reservoirs, add 0.30 feet and 0.31 feet, respectively, to the values shown in the table.

Table 2.4.3-9
Basin Runoff Model — Channel Elements
Storage-Discharge Relationships for Modified Puls Method

WMBKYE[a]		KYESMR[a]		SCSBLC[a]	
Storage (AF)	**Discharge (cfs)**	**Storage (AF)**	**Discharge (cfs)**	**Storage (AF)**	**Discharge (cfs)**
0	0	0	0	0	0
169	100	273	100	76	100
273	200	353	200	106	200
506	500	548	500	176	500
631	700	666	700	224	700
793	1,000	823	1,000	296	1,000
1,235	2,000	1,295	2,000	480	2,000
1,608	3,000	1,709	3,000	638	3,000
2,251	5,000	2,436	5,000	932	5,000
2,817	7,000	3,101	7,000	1,211	7,000
3,584	10,000	3,994	10,000	1,610	10,000
5,785	20,000	6,540	20,000	2,736	20,000
7,675	30,000	8,758	30,000	3,891	30,000
12,690	60,000	14,541	60,000	6,647	50,000
19,029	100,000	22,042	100,000	10,129	70,000

Source: U.S. Army Corps of Engineers Flood Forecast Model for Guadalupe River Basin (Reference 2.4.3-3)

(a) WMBKYE is the channel reach through Subbasin 15A; KYESMR is that through Subbasin 15B; SCSBLC is that on San Marcos River below the SCS #3 and #5 reservoirs to its confluence with Blanco River.

Table 2.4.3-10
Coleto Creek Dam Reservoir
Elevation-Storage Relationship

Elevation (ft)	Storage (AF)
58.0	0.000
80.0	4,416
90.0	14,620
95.0	23,960
97.0	28,700
98.0	31,280
99.0	34,000
101.0	39,850
104.0	49,950
107.3	63,560
115.0	111,100
120.0	149,800

Source: U.S. National Weather Service River Forecast System for Guadalupe River Basin (Reference 2.4.3-2)

Note: Elevations in Table 2.4.3-10 are given in terms of NGVD 29. To convert to NAVD 88, subtract 0.29 feet from the values shown in the table.

Table 2.4.3-11
Coleto Creek Dam Reservoir
Elevation Storage-Discharge Relationship

Elevation (ft)	Storage (AF)	Discharge (cfs)
58.0	0.00	0.0
98.5	32,640	5
99.5	35,462.5	10,008.81
101.0	39,850	50,044.18
102.5	44,900	80,070.71
104.0	49,950	120,108.02
106.0	58,198.5	124,110.29
107.0	63,560	127,113.48
108.0	67,881.82	130,115.7
115.0	111,100	188,165.56
120.0	149,800	300,267.06

Source: U.S. National Weather Service River Forecast System for Guadalupe River Basin (Reference 2.4.3-2), with storage values interpolated from Table 2.4.3-10.

Note: Elevations in Table 2.4.3-11 are given in terms of NGVD 29. To convert to NAVD 88, subtract 0.29 feet from the values shown in the table.

Table 2.4.3-12
Coleto Creek
Initial Channel Muskingum K & X Values

Model Element[(a)]	K (hrs)	X	No. of Subreaches
Coleto-1	3	0.2	7
Coleto-2	3	0.2	7
Coleto-Vic	1	0.2	1

(a) Coleto-1 is the channel reach through Subbasin 30; Coleto-2 is that through Subbasin 31; Coleto-Vic is that downstream of Subbasin 31 to its confluence with Guadalupe River.

Table 2.4.3-13
Subbasin Drainage Areas and NWS Rainfall Used in Basin Runoff Model Calibration

Model Subbasin	Drainage Area (sq mi)	NWS Subbasin Rainfall File Name[a]
11	86	NBRT2
12	130	GBCT2
13	456	Weighted Average of (SEGT2, GNLT2U, & GNLT2M)[b]
14	355	Weighted Average of (WMBTU & WMBT)[b]
15A	57	KYET2
15B	24	LLGT2U
16	48.5	LLGT2U
17	46.5	LLGT2U
18	82	LLGT2U
19	143	LLG2T
20	82	LLG2T
21	23	GNLT2
22A	112	LULT2U
22B	277	LULT2
23	108	GNLT2
24	69	CUET2U
25	483	DLWT2
26	209	CUET2U
27A	390	Weighted Average of (WHOT & WHOT2U)[b]
27B	159	WHOT2M
27C	162	CUET
28A	132.5	VICTU
28	132	VICT2
29	357	SCDT2
30	133	CKDT2
31	148	DUPT2

(a) NWS subbasin names as defined in Figure 2.4.3-4.
(b) Weighted average is based on drainage areas.

Table 2.4.3-14
Guadalupe River — Downstream of Canyon Dam
Basin Runoff Model Calibration — 1998 Flood
Observed and Computed Peak Discharge and Volumes
at Various USGS Gaging Stations

HEC-HMS Basin Element	USGS Gage No.[a]	USGS Drainage Area (sq mi)	USGS Observed Peak Discharge (cfs)	USGS Observed Volume (AF)	Computed Peak Discharge (cfs)	Computed Volume (AF)
NBRT	08168500	1,518 (1,522)[b]	90,000	97,000	87,900	96,700
Sub14	08171000	355	88,500	78,700	88,500	81,700
KYET	08171300	412	105,000	—	102,900	114,900
LLGT	08172000	838	206,000	322,700	215,300	401,900
Sub 22A	08172400	112	47,200	95,100	48,900	86,000
SMRGNL	08173900	3,490 (3,466)[b]	340,000	—	408,500	1,385,100
Sub 25	08174600	483	—	—	53,500	240,300
WHOT	08175000	549	36,200	158,500	33,500	180,500
SANCUE	08175800	4,934 (4,938)[b]	473,000	1,835,600	483,400	2,030,600
VICT2	08176500	5,198 (5,203)[b]	466,000	1,640,000	486,300	2,102,200
Sub 29	08176900	357	14,400	47,100	14,500	47,300
Coleto Creek Dam Outflow	08177500	514	22,400	68,000	22,300	70,200

(a) Refer to Subsection 2.4.3.3.1 for names of gaging stations.

(b) The bracketed drainage area values shown in Column 3 are those used in the calibration run, which yielded the computed peak discharges and volumes. If no bracketed values are shown, the drainage area values used in the calibration run are the same as given by USGS. This is due to the fact that the USGS gaging stations are not located exactly at the subbasin boundaries.

Table 2.4.3-15
Guadalupe River — Downstream of Canyon Dam
Basin Runoff Model Calibration — 2004 Flood
Observed and Computed Peak Discharge and Volumes
at Various USGS Gaging Stations

HEC-HMS Basin Element	USGS Gage No.[a]	USGS Drainage Area (sq mi)	USGS Observed Peak Discharge (cfs)	USGS Observed Volume (AF)	Computed Peak Discharge (cfs)	Computed Volume (AF)
NBRT	08168500	1,518 (1,522)[b]	17,000	97,500	19,400	93,700
Sub 14	08171000	355	34,000	103,700	33,900	126,400
KYET	08171300	412	29,900	N/A	36,000	143,400
LLGT	08172000	838	84,800	287,700	76,700	324,000
Sub 22A	08172400	112	6,340	28,600	6,800	32,400
SMRGNL	08173900	3,490 (3,466)[b]	101,000	642,800	101,000	786,600
Sub 25	08174600	483	32,200	95,500	31,200	102,900
WHOT	08175000	549	4,630	38,000	4,800	39,700
SANCUE	08175800	4,934 (4,938)[b]	113,000	770,500	119,200	977,100
VICT	08176500	5,198 (5,203)[b]	102,000	964,300	115,900	999,200
Sub 29	08176900	357	20,800	41,400	21,200	45,500
Coleto Creek Dam Outflow	08177500	514	41,700	70,700	40,500	98,800

(a) Refer to Subsection 2.4.3.3.1 for names of gaging stations.

(b) The bracketed drainage area values shown in Column 3 are those used in the calibration run, which yielded the computed peak discharges and volumes. If no bracketed values are shown, the drainage area values used in the calibration run are the same as given by USGS. This is due to the fact that the USGS gaging stations are not located exactly at the subbasin boundaries.

Table 2.4.3-16
Subbasin Runoff Parameters 1998 Flood Calibration Results

Model Subbasin	Initial Loss (in)	Constant Loss Rate (in/hr)	Snyder's Lag[a] (hr)	Snyder's C_p[a]	Base Flow		
					STRTQ[a] (cfs/sq mi)	QRCSN	Recession Coefficient[a]
11	1.5	0.15	3.0	0.6	0.3	0.02	0.887
12	0.5	0.15	5.0	0.625	0.4	0.08	0.887
13	0.5	0.10	10	0.5469	0.3	0.05	0.887
14	1.8	0.45	2.7	0.6	0.05	0.04	0.887
15A	1.0	0.08	2.0	0.6	0.05	0.01	0.887
15B	1.0	0.08	2.0	0.6	0.05	0.1	0.887
16	1.9	0.10	3.0	0.6	0.05	0.01	0.750
17	1.9	0.10	3.0	0.6	0.05	0.01	0.750
18	2.5	0.10	4.0	0.6	0.05	0.01	0.750
19	2.0	0.10	4.0	0.6	0.05	0.01	0.700
20	2.0	0.10	6.0	0.6	0.05	0.01	0.750
21	2.0	0.10	2.5	0.5469	0.05	0.1	0.887
22A	1.65	0.05	5.0	0.6	0.01	0.04	0.788
22B	1.5	0.05	6.0	0.6	0.01	0.04	0.788
23	0.8	0.10	6.0	0.6	0.1	0.05	0.887
24	0.5	0.08	4.0	0.6	0.3	0.05	0.887
25	0.5	0.11	25	0.5	0.1	0.6	0.1
26	0.5	0.05	15	0.5	0.3	0.05	0.887
27A	1.5	0.10	44.0	0.75	0.1	0.001	0.55
27B	1.5	0.10	43.0	0.75	0.1	0.001	0.55
27C	1.5	0.10	40.0	0.75	0.1	0.001	0.55
28A	0.5	0.10	15.0	0.5469	0.1	0.05	0.887
28	0.5	0.10	15.0	0.5469	0.1	0.05	0.887
29	2.5	0.12	14.0	0.55	0.1	0.1	0.75
30	2.0	0.12	6.0	0.55	0.1	0.01	0.75
31	2.0	0.12	6.0	0.55	0.1	0.01	0.75

(a) Definitions are given in HEC-HMS Users Manual (Reference 2.4.3-12).

Table 2.4.3-17
Channel Elements — Muskingum K and X 1998 Flood Calibration Results

Model Channel Elements	Channel Reach Location[(a)]	Muskingum Channel Routing		
		K (hrs)	X	Number of Subreaches
SMCNRB	through Sub 11	3	0.2	3
NBRSMR	through Sub 13	30	0.35	20
WMBKYE	through Sub 15A	(b)	(b)	(b)
KYESMR	through Sub 15B	(b)	(b)	(b)
SCSBLC	(c)	(b)	(b)	(b)
BLCYRK	through Sub 18	6	0.3	5
YRKLLG	through Sub 20	3.3	0.2	2
LLGPLM	through Sub 21	4	0.1	2
LCPSM	through Sub 22B	25	0.3	10
PLMGR	through Sub 23	10	0.3	5
SMRGNL	(d)	2	0.3	1
GNLPCH	through Sub 24	10	0.3	6
PCHSAN	through Sub 26	22	0.3	11
WHOGR	through Sub 27C	20	0.4	7
SANCUE	(e)	2	0.2	1
UPPERVIC	through Sub 28A	4	0.4	9
CUEVIC	through Sub 28	4	0.4	9
Vic-Coleto	(f)	3	0.3	3
Coleto-1	through Sub 30	7	0.25	3
Coleto-2	through Sub 31	7	0.25	3
Coleto-Vic	(g)	1	0.2	1

(a) Refer Figure 2.4.3-2.
(b) Refer to Table 2.4.3-9.
(c) On San Marcos River below SCS #3 and 5 reservoirs to its confluence with Blanco River.
(d) On Guadalupe River below its confluence with San Marcos River to USGS Gage at Gonzales, Texas.
(e) On Guadalupe River below its confluence with Sandies Creek to USGS Gage at Cuero, Texas.
(f) On Guadalupe River below USGS Gage at Victoria, Texas, to a location near VCS Site.
(g) On Coleto Creek below Sub 31 to its confluence with Guadalupe River.

Table 2.4.3-18
Subbasin Parameters 2004 Flood Calibration Results

Model Subbasin	Initial Loss (in)	Constant Loss Rate (in/hr)	Snyder's Lag[a] (hr)	Snyder's C_p[a]	Base Flow STRTQ[a] (cfs/sq mi)	Base Flow QRCSN[a]	Base Flow Recession Coefficient[a]
11	1.3	0.11	4.0	0.6	2	0.05	0.887
12	0.5	0.15	5.0	0.625	0.4	0.08	0.887
13	0.5	0.10	13.0	0.5469	0.3	0.05	0.887
14	0.42	0.09	3.8	0.625	6	0.1	0.92
15A	2.0	0.20	6.0	0.6	0.3	0.1	0.887
15B	1.0	0.08	3.0	0.625	0.3	0.1	0.887
16	1.8	0.05	4.0	0.6	0.3	0.05	0.788
17	1.8	0.05	4.0	0.6	0.3	0.05	0.788
18	2.5	0.05	5.0	0.6	0.3	0.05	0.788
19	2.0	0.05	5.0	0.6	0.3	0.05	0.788
20	2.0	0.05	8.0	0.6	0.3	0.05	0.788
21	1.8	0.08	3.0	0.6	0.3	0.05	0.887
22A	0.5	0.08	5.8	0.35	0.1	0.24	0.600
22B	0.5	0.15	6.0	0.6	0.1	0.1	0.788
23	0.8	0.10	6.0	0.5469	0.1	0.05	0.887
24	0.5	0.08	6.0	0.5469	0.3	0.05	0.887
25	1.5	0.15	20	0.55	0.1	0.6	0.887
26	0.5	0.05	8.0	0.5469	0.3	0.05	0.887
27A	1.55	0.12	43.0	0.6	0.1	0.05	0.75
27B	1.55	0.12	35.0	0.6	0.1	0.05	0.75
27C	1.55	0.12	33.0	0.6	0.3	0.05	0.75
28A	2.5	0.15	8.0	0.5469	0.1	0.05	0.887
28	2.5	0.15	8.0	0.5469	0.1	0.05	0.887
29	1.8	0.09	5.0	0.52	0.1	0.07	0.75
30	1.5	0.10	6.0	0.58	0.1	0.01	0.75
31	1.5	0.10-	6.0	0.55	0.1	0.01	0.75

(a) Definitions are given in HEC-HMS Users Manual (Reference 2.4.3-12).

Table 2.4.3-19
Channel Elements — Muskingum K and X Values 2004 Flood Calibration Results

Model Channel Elements	Channel Reach Location[a]	Muskingum Channel Routing		
		K (hrs)	X	Number of Subreaches
SMCNRB	through Sub 11	4	0.25	3
NBRSMR	through Sub 13	39	0.2	20
WMBKYE	through Sub 15A	(b)	(b)	(b)
KYESMR	through Sub 15B	(b)	(b)	(b)
SCSBLC	(c)	(b)	(b)	(b)
BLCYRK	through Sub 18	8	0.15	5
YRKLLG	through Sub 20	4	0.25	2
LLGPLM	through Sub 21	4	0.1	2
LCPSM	through Sub 22B	20	0.2	10
PLMGR	through Sub 23	15	0.2	5
SMRGNL	(d)	2	0.2	1
GNLPCH	through Sub 24	12	0.2	6
PCHSAN	through Sub 26	22	0.2	11
WHOGR	through Sub 27C	18	0.2	7
SANCUE	(e)	2	0.15	1
UPPERVIC	through Sub 28A	18	0.2	9
CUEVIC	through Sub 28	18	0.2	9
Vic-Coleto	(f)	2	0.2	3
Coleto-1	through Sub 30	3	0.25	3
Coleto-2	through Sub 31	3	0.25	3
Coleto-Vic	(g)	1	0.2	1

(a) Refer to Figure 2.4.3-2.
(b) Refer to Table 2.4.3-9.
(c) On San Marcos River below SCS #3 and 5 reservoirs to its confluence with Blanco River.
(d) On Guadalupe River below its confluence with San Marcos River to USGS Gage at Gonzales, Texas.
(e) On Guadalupe River below its confluence with Sandies Creek to USGS Gage at Cuero, Texas.
(f) On Guadalupe River below USGS Gage at Victoria, Texas, to a location near VCS Site.
(g) On Coleto Creek below Sub 31 to its confluence with Guadalupe River.

Table 2.4.3-20
Canyon Dam Watershed Subbasins

Subbasin	Descriptions	Drainage Area (sq mi)
1	North Fork of Guadalupe River	179.14
2	South Fork of Guadalupe River	102.00
3	Area between N & S Fork of Guadalupe and mouth of Johnson Creek	31.69
4	Johnson Creek	131.82
5	Area between Johnson/Guadalupe confluence to Comfort	382.53
6	Area between Comfort and Head of Canyon Lake	473.43
8	Area adjacent to north side of Canyon Lake	64.07
9	Area adjacent to south side of Canyon Lake	32.04
10	Canyon Lake Surface	20.14
	Total	1417.85

Source: U.S. Army Corps of Engineers Probable Maximum Flood Study for Canyon Dam (Reference 2.4.3-1)
Note: Subbasin designation 7 not used.

Table 2.4.3-21 (Sheet 1 of 2)
Canyon Dam Watershed 1-Hour Unit Hydrographs for Subbasins (in cfs)

Time (hr)	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6	Subbasin 8	Subbasin 9	Subbasin 10
0	45	235	357	300	5	2	19,049	12,120	12,995
1	270	1,215	11,644	1,560	2,275	47	16,463	7,347	12,995
2	1,530.0	2,979	4,522	3,840	13,650	70	4,561	1,076	12,995
3	18,000	20,482	2,321	26,400	60,900	512	1,012	131	12,995
4	27,000	11,917	1,190	15,360	40,950	1,163	208	2	—
5	18,000	8,428	417	10,865	27,300	2,558	44	—	—
6	11,250	6,311	00	8,142	19,474	12,276	8	—	—
7	7,200	4,283	—	5,520	14,788	21,762	—	—	—
8	5,760	2,607	—	3,360	11,830	27,714	—	—	—
9	4,590	931	—	1,200	9,555	30,059	—	—	—
10	3,870	559	—	720	8,008	28,272	—	—	—
11	3,150	470	—	600	6,734	23,622	—	—	—
12	2,700	451	—	576	5,733	17,298	—	—	—
13	2,250	431	—	552	4,823	14,322	—	—	—
14	1,980	412	—	528	4,095	12,276	—	—	—
15	1,710	392	—	504	3,458	10,602	—	—	—
16	1,440	372	—	480	2,821	9,254	—	—	—
17	1,260	353	—	456	2,366	8,277	—	—	—
18	1,080	333	—	432	1,911	7,440	—	—	—
19	900	314	—	408	1,638	6,789	—	—	—
20	720	294	—	384	1,365	6,185	—	—	—
21	540	274	—	360	1,138	5,673	—	—	—
22	360	255	—	336	865	5,208	—	—	—
23	0	235	—	312	637	4,790	—	—	—
24	—	216	—	288	455	4,418	—	—	—
25	—	196	—	264	273	4,092	—	—	—
26	—	176	—	240	182	3,720	—	—	—
27	—	157	—	216	91	3,488	—	—	—
28	—	137	—	192	73	3,302	—	—	—
29	—	118	—	168	55	3,023	—	—	—
30	—	98	—	144	36	2,790	—	—	—
31	—	78	—	120	18	2,604	—	—	—
32	—	59	—	96	0	2,372	—	—	—
33	—	39	—	72	—	2,186	—	—	—
34	—	20	—	48	—	2,000	—	—	—
35	—	—	—	24	—	1,814	—	—	—
36	—	—	—	—	—	1,674	—	—	—
37	—	—	—	—	—	1,535	—	—	—

Table 2.4.3-21 (Sheet 2 of 2)
Canyon Dam Watershed 1-Hour Unit Hydrographs for Subbasins (in cfs)

Time (hr)	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6	Subbasin 8	Subbasin 9	Subbasin 10
38	—	—	—	—	—	1,395	—	—	—
39	—	—	—	—	—	1,256	—	—	—
40	—	—	—	—	—	1,116	—	—	—
41	—	—	—	—	—	977	—	—	—
42	—	—	—	—	—	884	—	—	—
43	—	—	—	—	—	791	—	—	—
44	—	—	—	—	—	698	—	—	—
45	—	—	—	—	—	605	—	—	—
46	—	—	—	—	—	512	—	—	—
47	—	—	—	—	—	419	—	—	—
48	—	—	—	—	—	372	—	—	—
49	—	—	—	—	—	326	—	—	—
50	—	—	—	—	—	279	—	—	—
51	—	—	—	—	—	233	—	—	—
52	—	—	—	—	—	186	—	—	—
53	—	—	—	—	—	140	—	—	—
54	—	—	—	—	—	93	—	—	—
55	—	—	—	—	—	47	—	—	—

Source: U.S. Army Corps of Engineers Probable Maximum Flood Study for Canyon Dam (Reference 2.4.3-1)

Table 2.4.3-22
Canyon Dam Watershed Channel Elements Guadalupe River Storage-Discharge Relationships

Channel Element	Location of Channel Reach	Storage (AF)	Discharge (cfs)
NF Gage	North Guage to North and South Fork Confluence	0	0
		66,112	800,000
HNTJNC	North & South Confluence to confluence with John Creek	0	0
		66,112	800,000
JNCCOM	John Creek-Guadalupe confluence to Comfort	0	0
		264,448	800,000
COMFORT	Comfort to a point d/s of Comfort	0	0
		595,008	800,000
COMFCAN	A point d/s of Comfort to head of Canyon Lake Reservoir	0	0
		330,560	800,000

Source: U.S. Army Corps of Engineers Probable Maximum Flood Study for Canyon Dam (Reference 2.4.3-1)

Table 2.4.3-23
Canyon Dam Elevation-Storage-Discharge Relationship

Elevation (ft)	Storage (AF)	Discharge (cfs)
909	378,899	0.0
910	387,248	0.0
912	404,216	0.0
915	430,423	0.0
918	457,703	0.0
920	476,495	0.0
925	525,719	0.0
930	578,588	0.0
935	635,221	0.0
940	695,624	0.0
943	733,602	0.0
944	746,545	2,500
944.5	753,095	4,750
945	759,645	7,000
946	772,895	14,000
947	786,285	23,000
948	799,820	34,000
949	813,485	47,000
950	827,295	62,000
951	841,265	77,000
952	855,395	95,000
953	869,685	110,000
954	884,135	130,000
958	943,400	210,000
959	958,610	235,000
962	1,005,275	310,000
966	1,070,010	410,000
968	1,103,500	470,000
970	1,137,730	525,000
975	1,226,445	640,000

Source: U.S. Army Corps of Engineers (Reference 2.4.3-1).

Note: Elevations in Table 2.4.3-23 are given in terms of NGVD 29.To convert to NAVD 88, add 0.34 feet to the values shown in the table.

Table 2.4.3-24
PMF Basin Runoff Model
Muskingum Channel Routing Coefficients K and X

Model Channel Elements[a]	Muskingum Channel Routing		
	K (hrs)	X	Number of Sub-reaches
NFGage	[b]	[b]	[b]
HNTJNC	[b]	[b]	[b]
GRAJNC	[b]	[b]	[b]
JNCCOM	[b]	[b]	[b]
COMFORT	[b]	[b]	[b]
COMFCAN	[b]	[b]	[b]
SMCNRB	3	0.2	3
NBRSMR	30	0.35	20
WMBKYE	[c]	[c]	[c]
KYESMR	[c]	[c]	[c]
SCSBLC	[c]	[c]	[c]
BLCYRK	6	0.3	5
YRKLLG	3.3	0.2	2
LLGPLM	4	0.1	2
LCPSM	25	0.3	10
PLMGR	10	0.3	5
SMRGNL	2	0.3	1
GNLPCH	10	0.3	6
PCHSAN	22	0.3	11
WHOGR	20	0.4	7
SANCUE	2	0.2	1
UPPERVIC	4	0.4	9
CUEVIC	4	0.4	9
Vic-Coleto	3	0.3	3
Coleto-1	3	0.2	3
Coleto-2	3	0.2	3
Coleto-Vic	1	0.2	1

(a) Refer to Tables 2.4.3-12, 2.4.3-17, 2.4.3-19 and 2.4.3-22 for locations of the channel reaches.
(b) Refer to Table 2.4.3-22.
(c) Refer to Table 2.4.3-9.

Table 2.4.3-25
PMF Development
Starting Reservoir Water Levels

Reservoir	40% PMP Run		Full PMP Run	
	Starting Reservoir Water Level (El, ft)[a]	Starting Reservoir Storage (AF)	Starting Reservoir Water Level (El, ft)[e][a]	Starting Reservoir Storage (AF)
Canyon Dam	909.0[b]	378,899[b]	947.73[b]	796,166[b]
SCS#3	611.0[c]	127[c]	613.3	190.6
SCS#5	616.2[c]	161[c]	632.8	1,023
Coleto Creek Dam	98.5[d]	32,640[d]	98.9	33,863

(a) Elevations in Table 2.4.3-25 are given in terms of NGVD 29. To convert to NAVD 88 for Canyon Dam, SCS #3, and SCS #5, add 0.34 feet, 0.30 feet and 0.31 feet, respectively, to the values shown in the table. For Coleto Creek Dam, subtract 0.29 feet from the values shown in the table.

(b) From USACE 2005 PMF Study for Canyon Dam (Reference 2.4.3-1) and USACE used 50 percent PMP as the preceding storm.

(c) From USACE Flood Forecast Model, updated August 12, 2004 (Reference 2.4.3-3).

(d) From HEC-HMS calibrations of the 1998 and 2004 floods.

(e) These are the water levels at the respective reservoirs 3 days after the cessation of the 72-hr 40 percent PMP, except as noted.

Table 2.4.3-26
Guadalupe PMF Peak Discharge (cfs)
for Various Storm Centers

Storm Center	Canyon Lake Inflow (SMCIN)[a]	Gonzales (SMRGNL)[a]	Cuero (SANCUE)[a]	Victoria (VICT2)[a]	VCS Site (Junction 6)[a]
At SE Corner of Subbasin 13	44,900	770,100	1,092,400	1,103,200	1,123,300
At Centroid of Subbasin 23	56,500	733,800	1,025,800	1,035,900	1,053,100
At Centroid of Subbasin 24	28,900	646,000	949,400	960,300	978,200
At Centroid of Subbasin 27B	254,100	762,700	969,100	973,600	988,500
At lower end of Subbasin 5	751,200	616,800	574,000	573,000	571,300

(a) The bracketed acronyms are the respective element names in the HEC-HMS model.

Table 2.4.3-27
PMF Water Surface Profile along Guadalupe River

STA	Discharge (cfs)	Water Level (ft, NAVD 88)
7.2467	1,300,000	28.87
8.7744	1,300,000	29.97
11.1811	1,300,000	31.50
12.0915	1,300,000	32.30
12.9444	1,300,000	32.76
14.5044	1,120,000	33.01
16.0078	1,120,000	33.22
17.6557	1,120,000	33.69
18.6485	1,120,000	34.83
20.7087	1,120,000	35.92
22.0501	1,120,000	37.12
23.4397	1,120,000	39.22
25.0028	1,120,000	41.58
26.7812	1,120,000	42.95
29.5984	1,120,000	44.64
29.5984	1,120,000	44.64
30.8097	1,120,000	46.02
32.2088	1,120,000	47.73
37.1142	1,120,000	50.78
41.6305	1,100,000	54.25
46.127	1,100,000	59.42
49.2913	1,100,000	63.12
52.1817	1,100,000	66.74
54.702	1,100,000	72.70
56.1333	1,100,000	103.69
60.9682	1,100,000	104.34
63.8964	1,100,000	105.52
66.2563	1,100,000	108.32

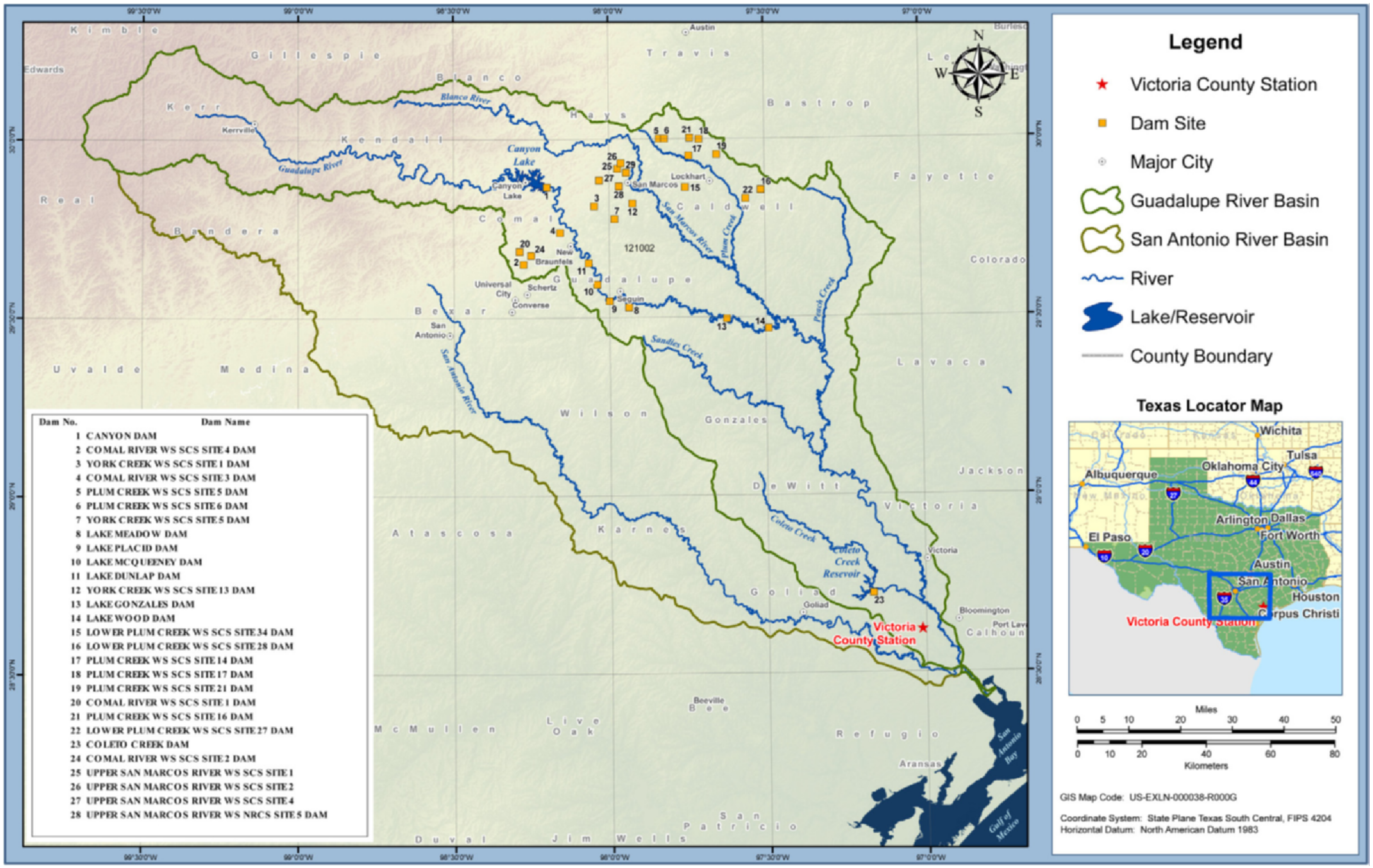


Figure 2.4.3-1 Project and Dam Locations — Guadalupe River Basin

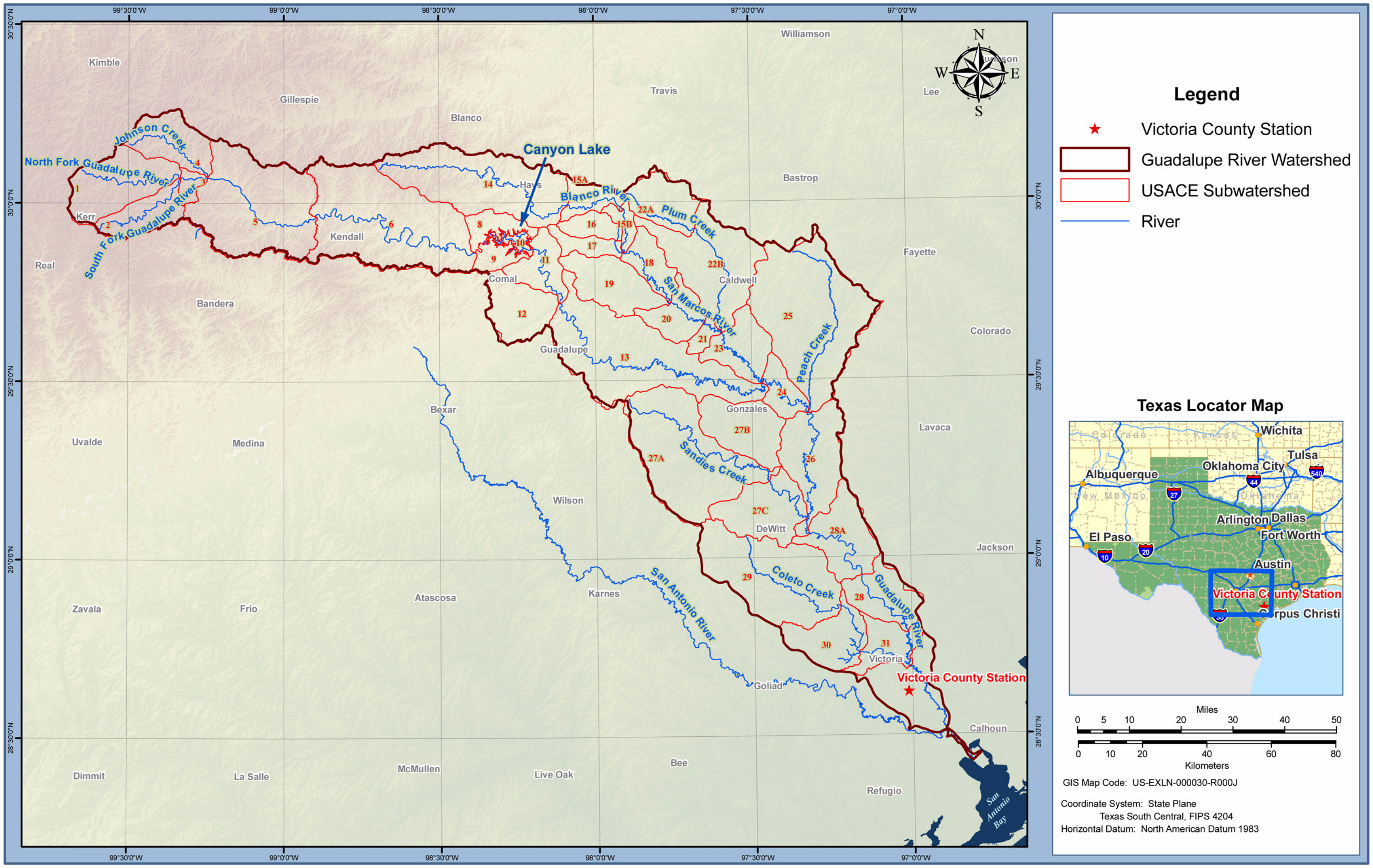


Figure 2.4.3-2 Subbasin Delineation — U.S. Army Corps of Engineers

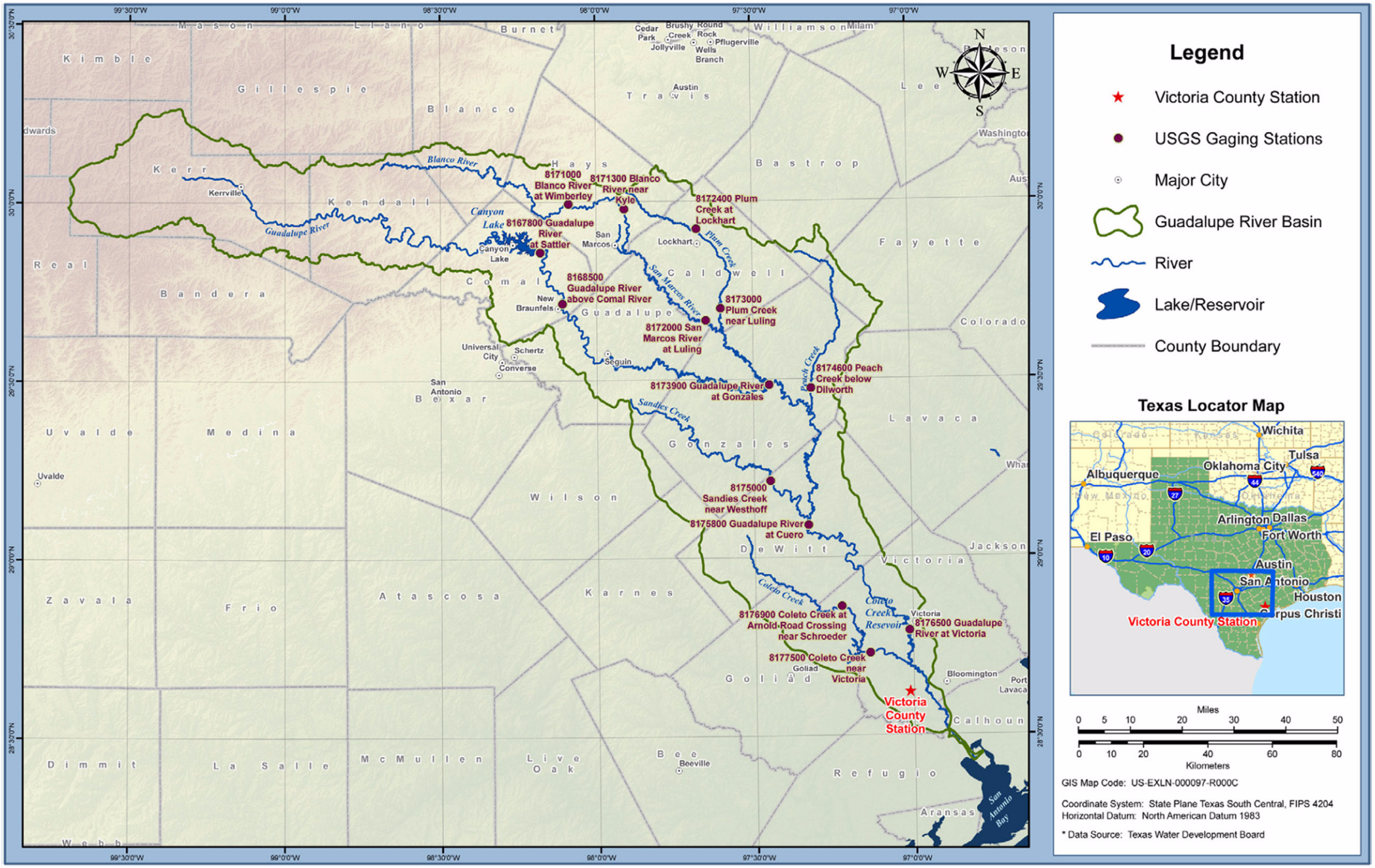


Figure 2.4.3-3 U.S. Geological Survey Gaging Stations used in the HEC-HMS Model Calibration

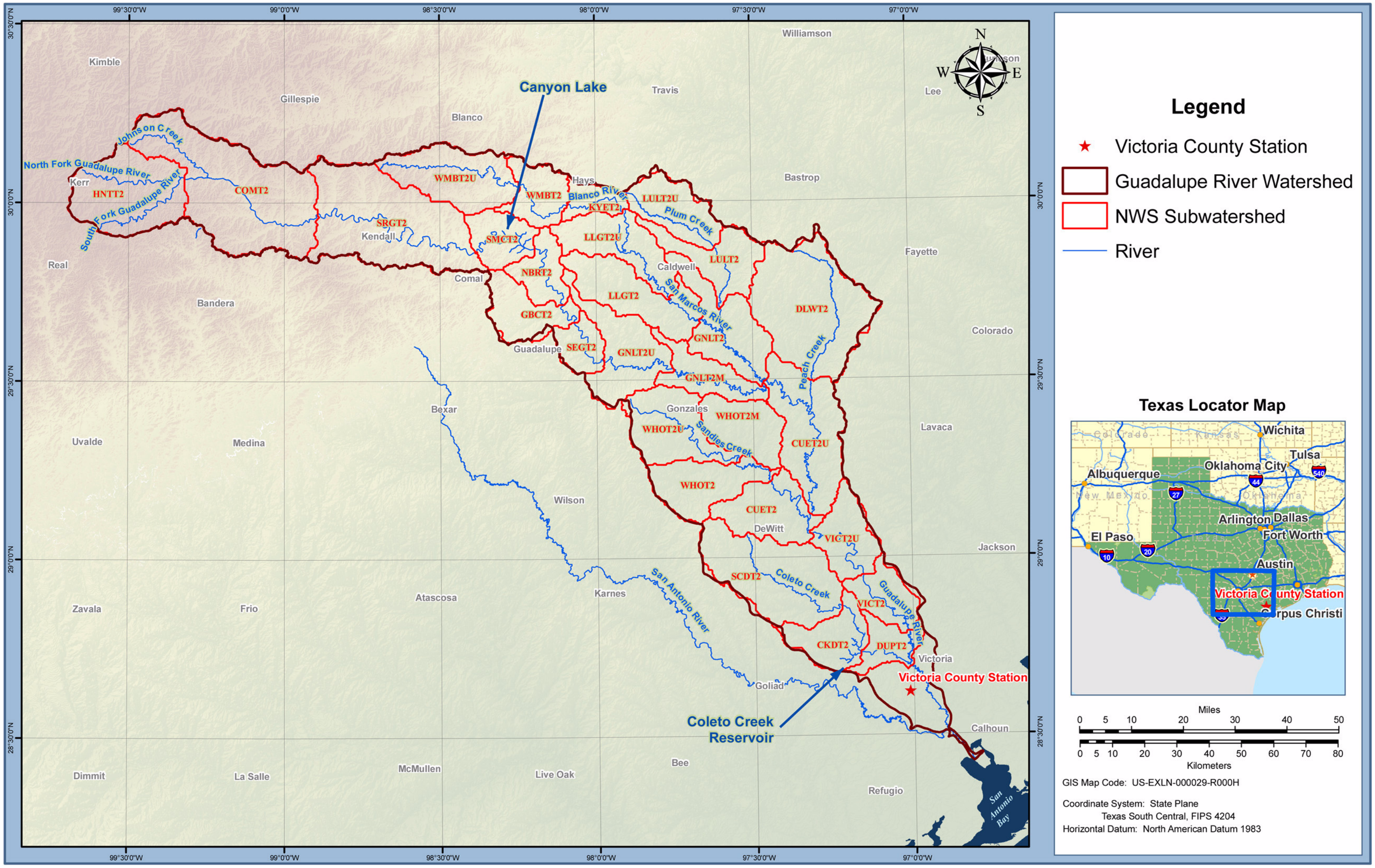


Figure 2.4.3-4 Subbasin Delineation — U.S. National Weather Service

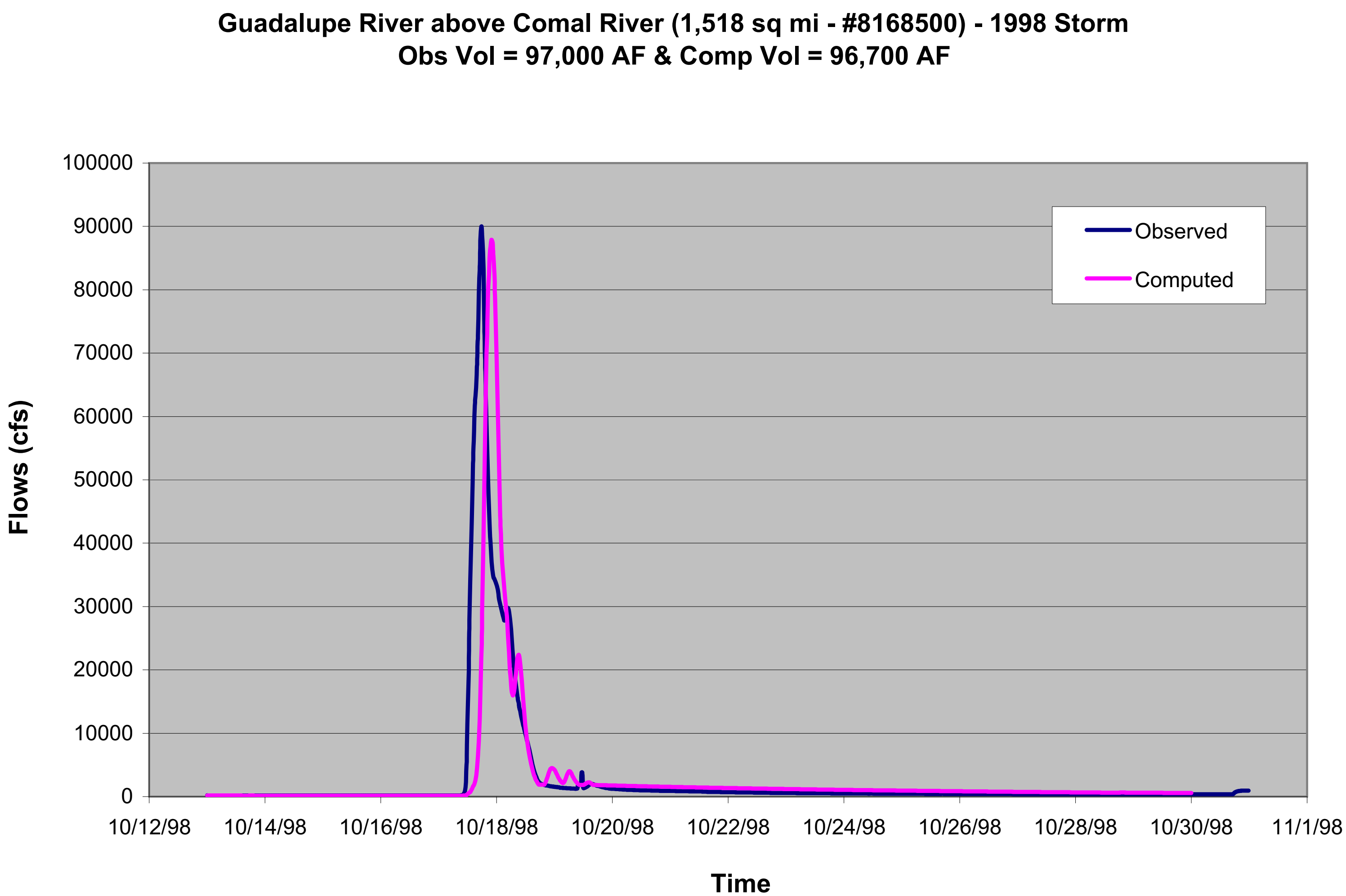


Figure 2.4.3-5 1998 Flood — Observed and Computed Hydrographs, Guadalupe River above Comal River (USGS No. 8168500)

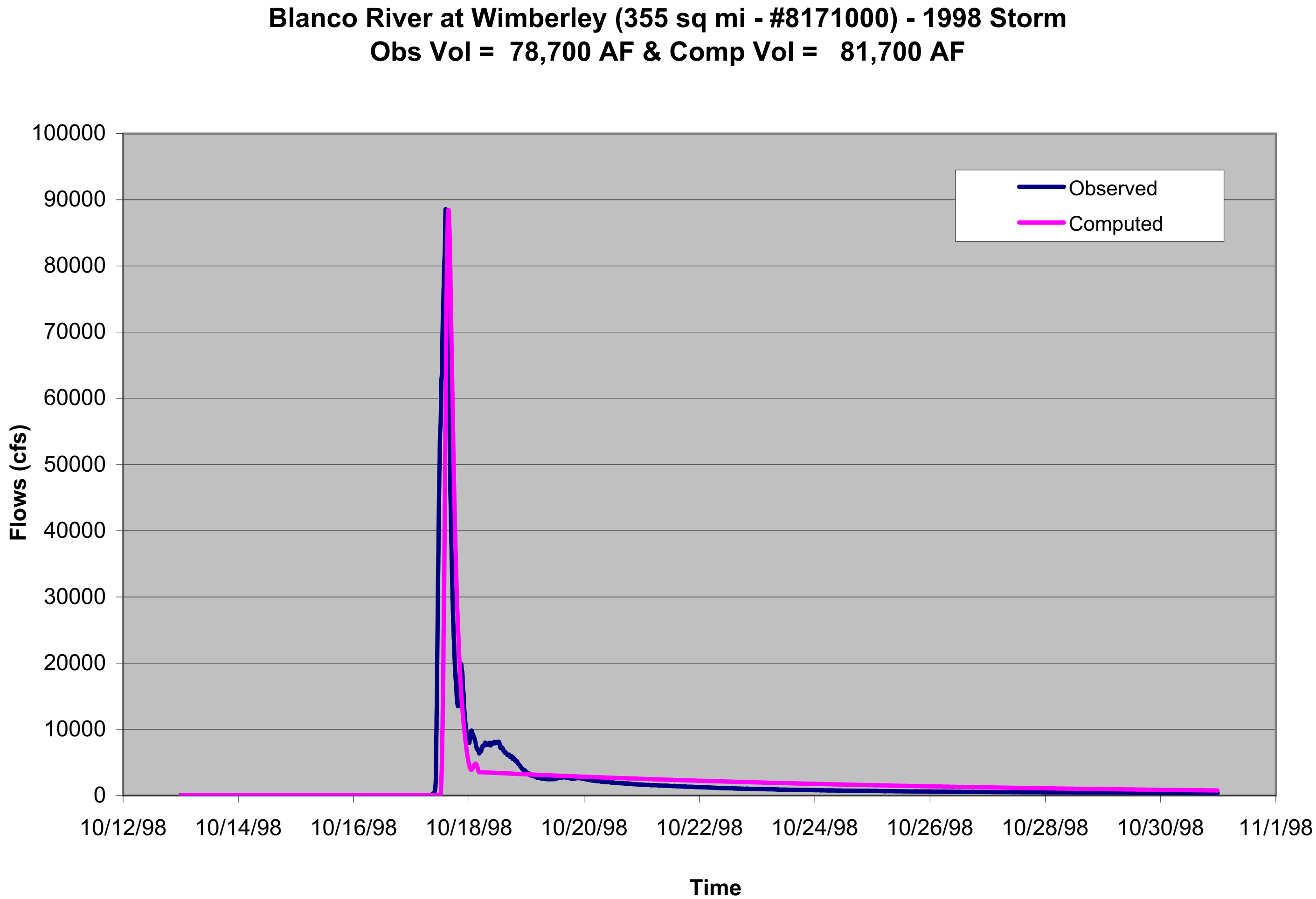


Figure 2.4.3-6 1998 Flood — Observed and Computed Hydrographs, Blanco River at Wimberley (USGS No. 8171000)

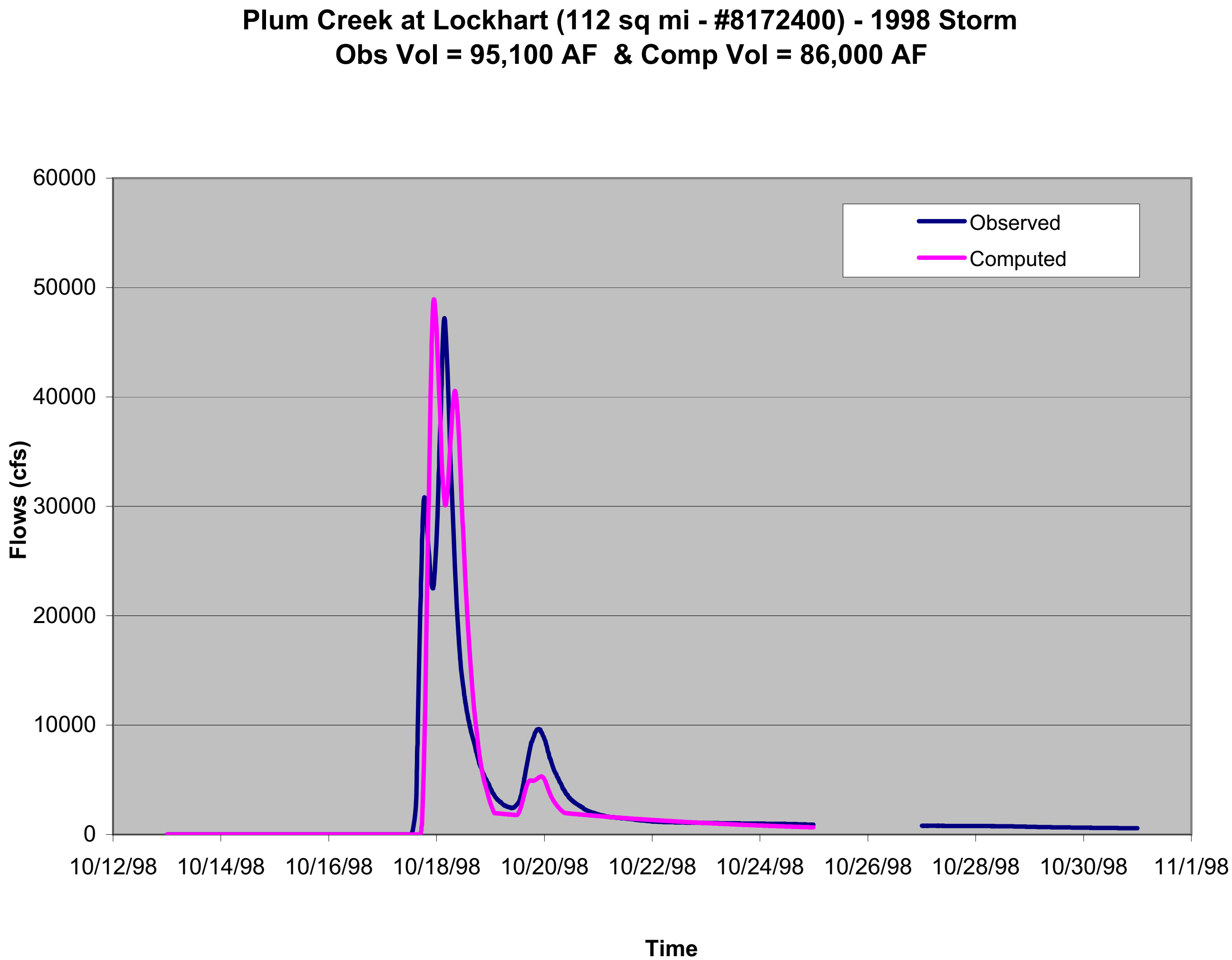


Figure 2.4.3-7 1998 Flood — Observed and Computed Hydrographs, Plum Creek at Lockhart (USGS No. 8172400)

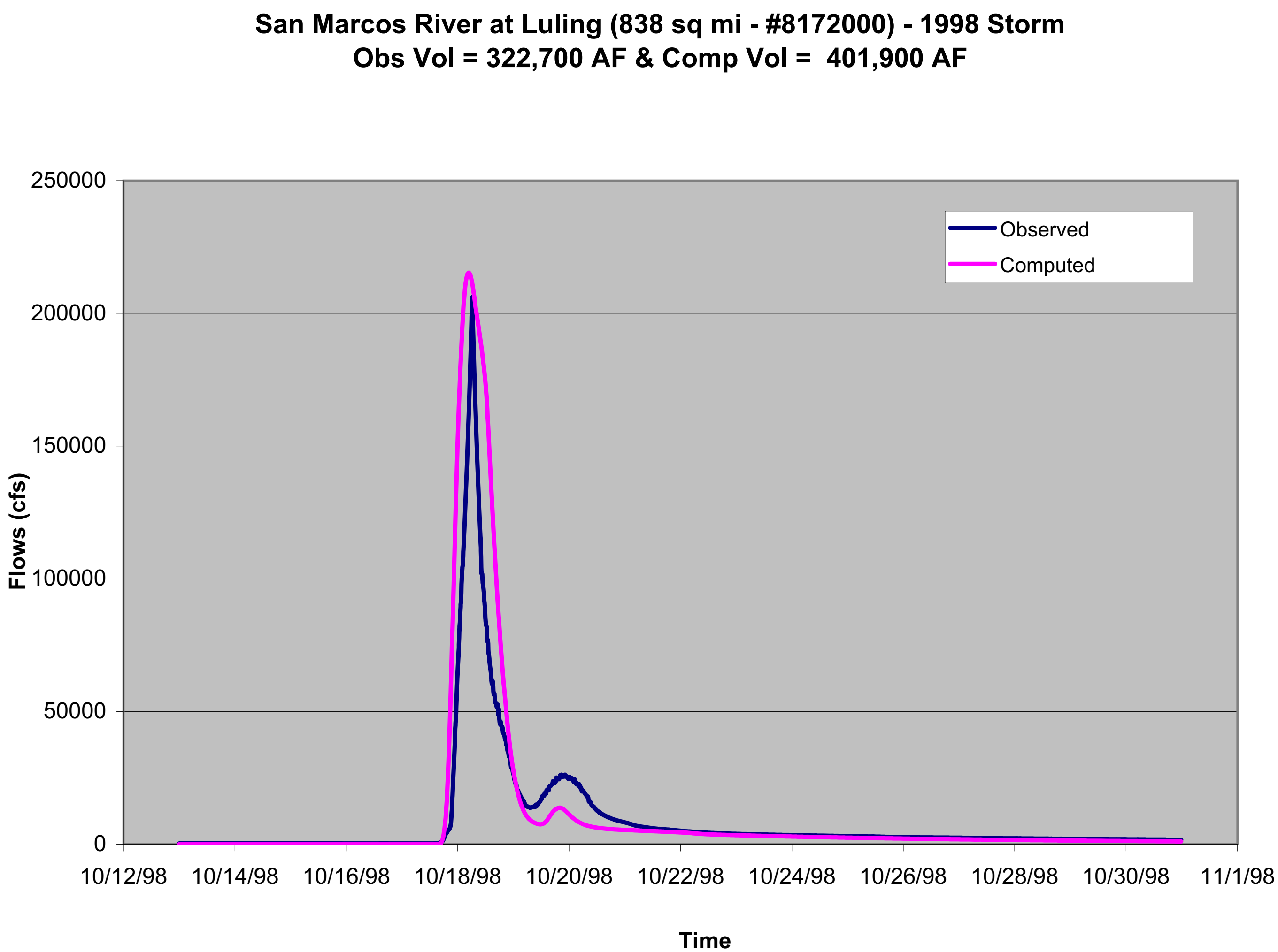


Figure 2.4.3-8 1998 Flood — Observed and Computed Hydrographs, San Marcos River at Luling (USGS No. 8172000)

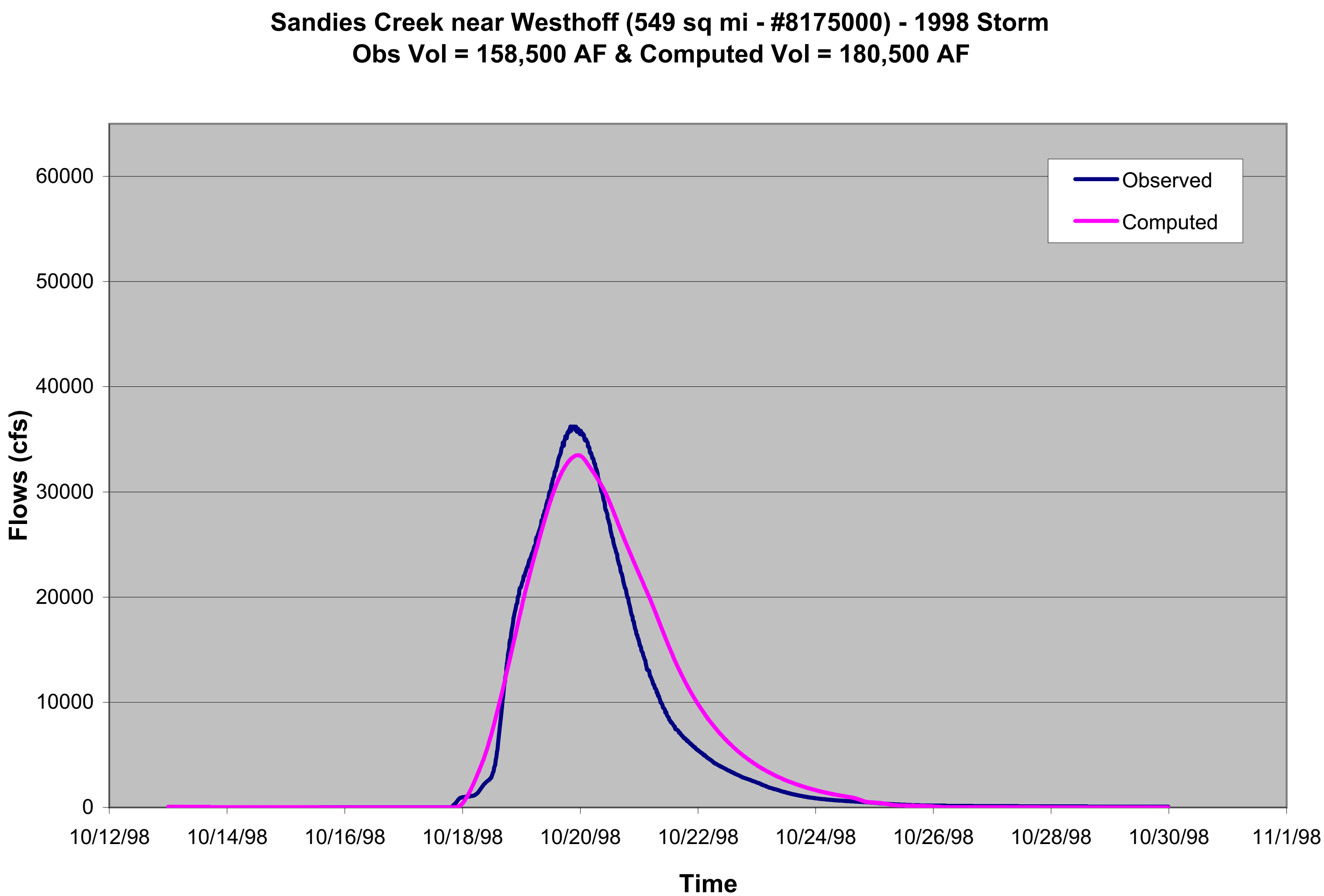


Figure 2.4.3-9 1998 Flood — Observed and Computed Hydrographs, Sandies Creek near Westhoff (USGS No. 8175000)

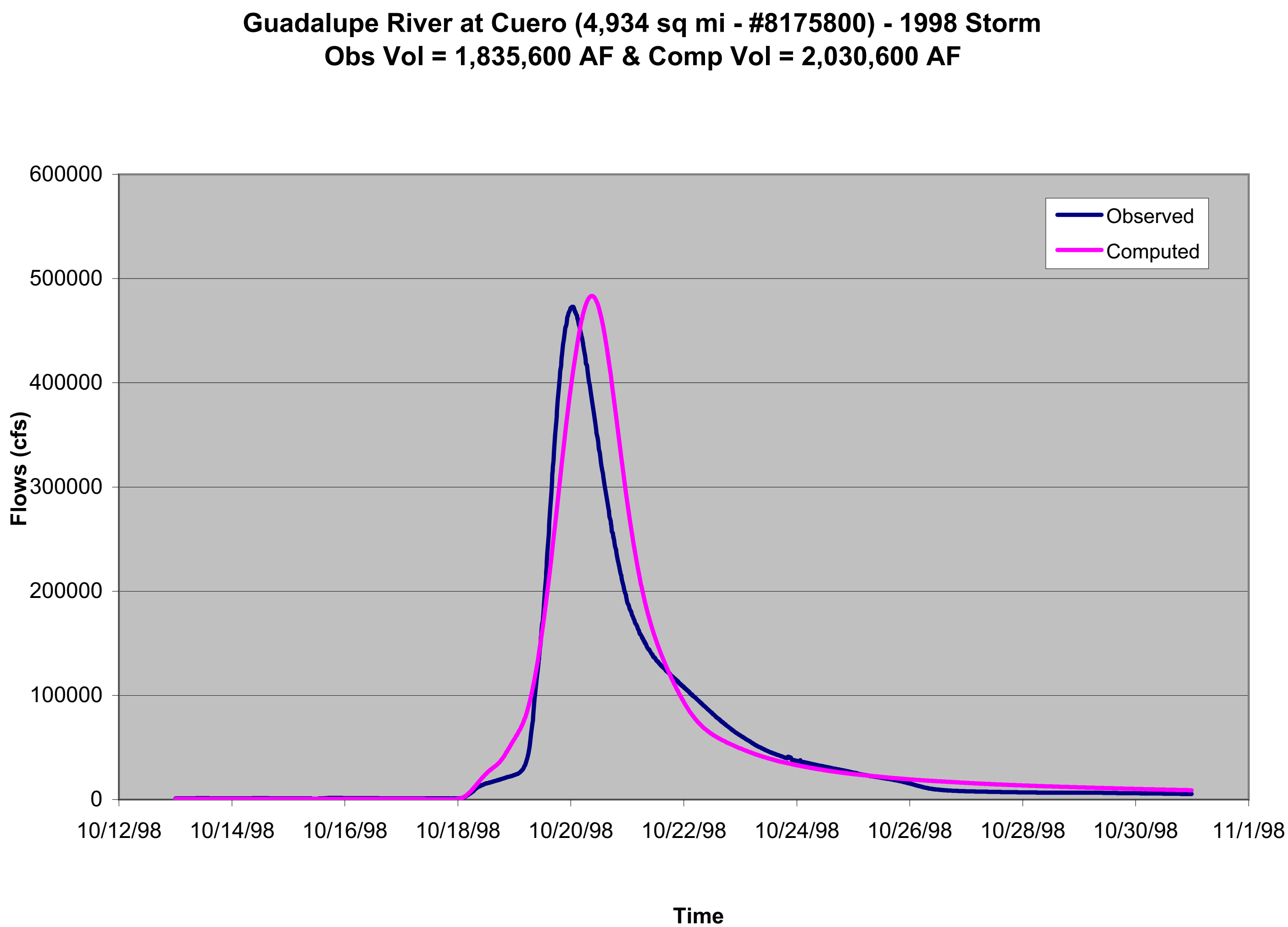


Figure 2.4.3-10 1998 Flood — Observed and Computed Hydrographs, Guadalupe River at Cureo (USGS No. 8175800)

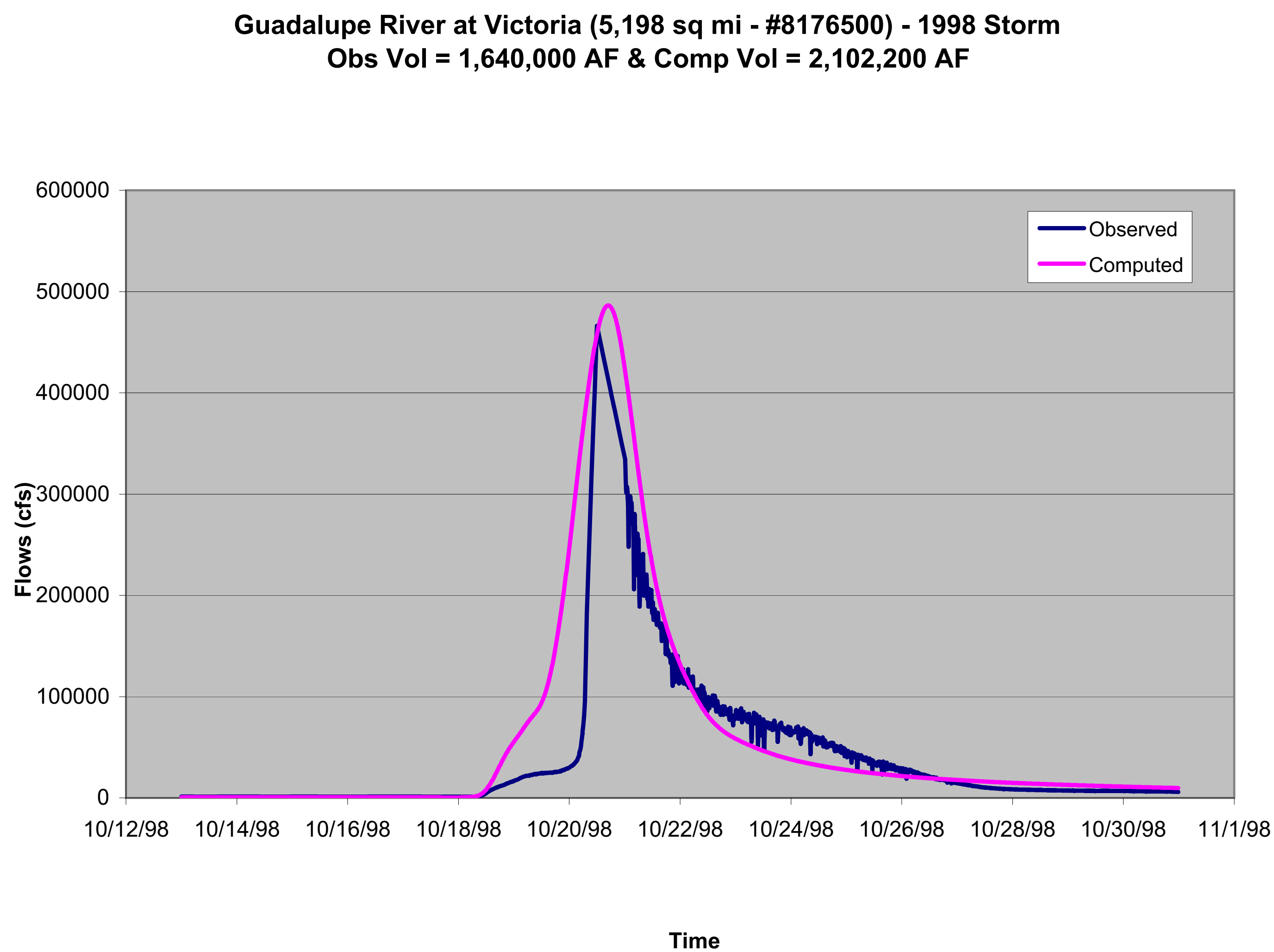


Figure 2.4.3-11 1998 Flood — Observed and Computed Hydrographs, Guadalupe River at Victoria (USGS No. 8176500)

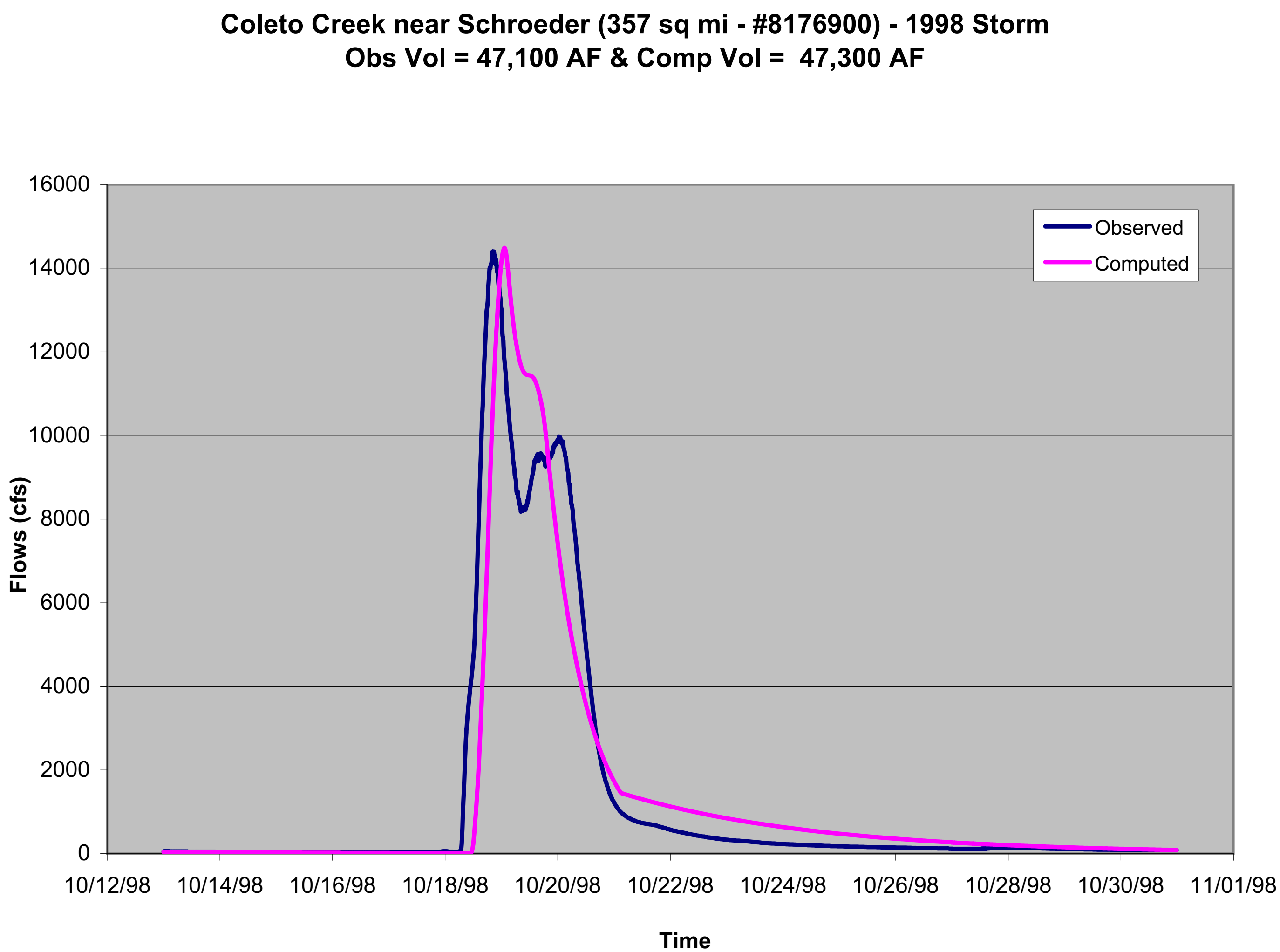


Figure 2.4.3-12 1998 Flood — Observed and Computed Hydrographs, Coleto Creek at Road Crossing near Schroeder (USGS No. 8176900)

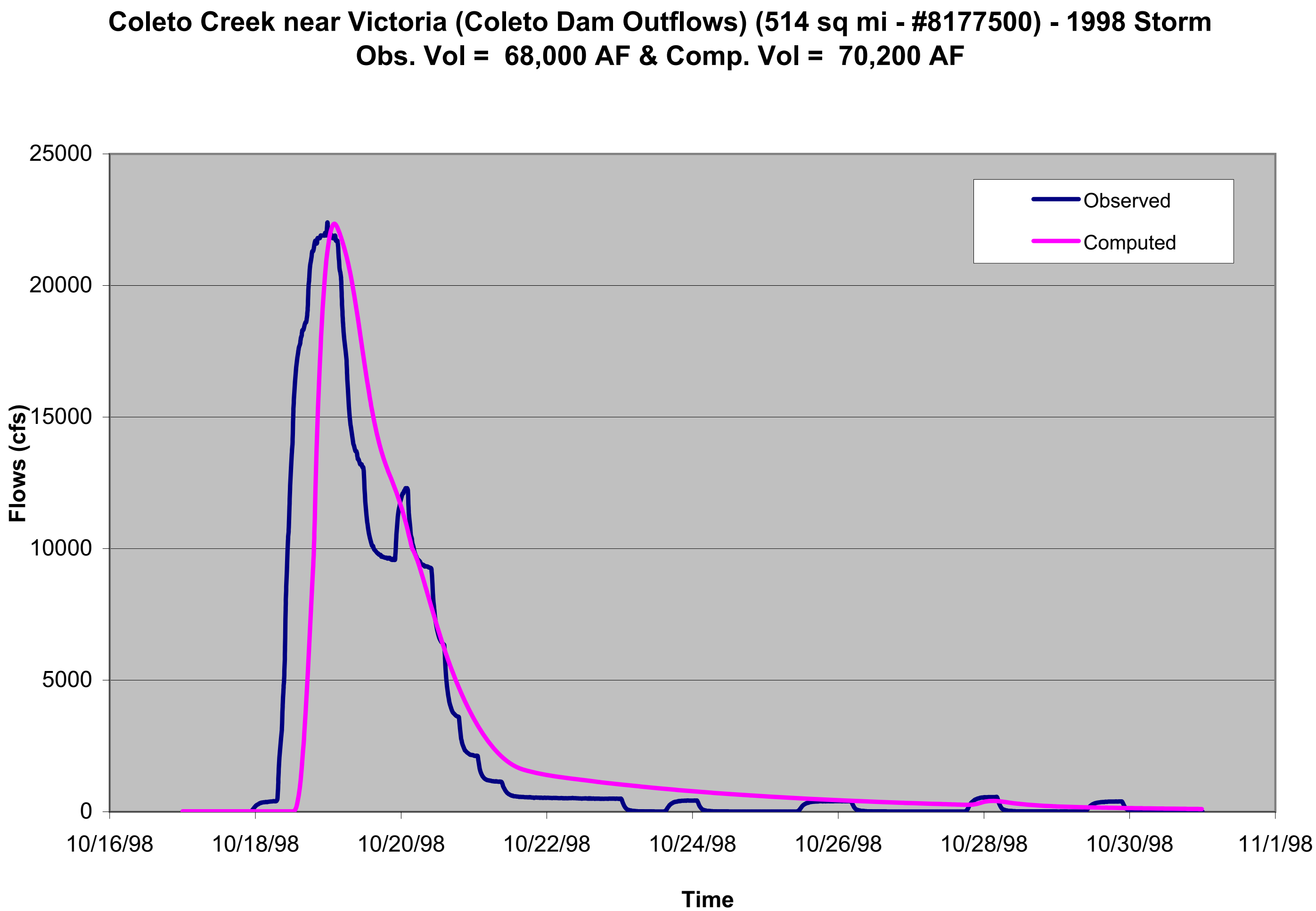


Figure 2.4.3-13 1998 Flood — Observed and Computed Hydrographs, Coleto Creek near Victoria (USGS No. 8177500)

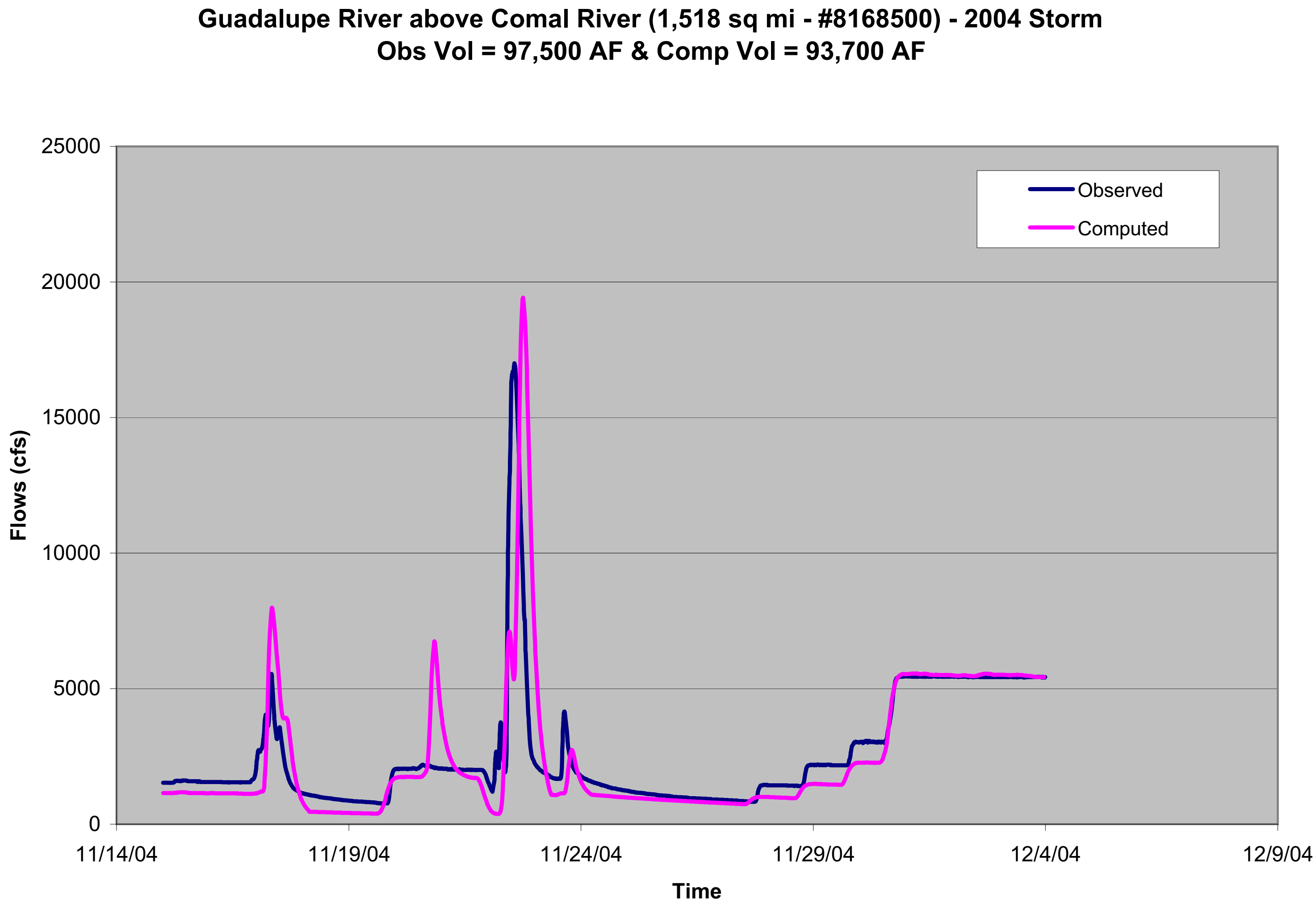


Figure 2.4.3-14 2004 Flood — Observed and Computed Hydrographs, Guadalupe River above Comal River (USGS No. 8168500)

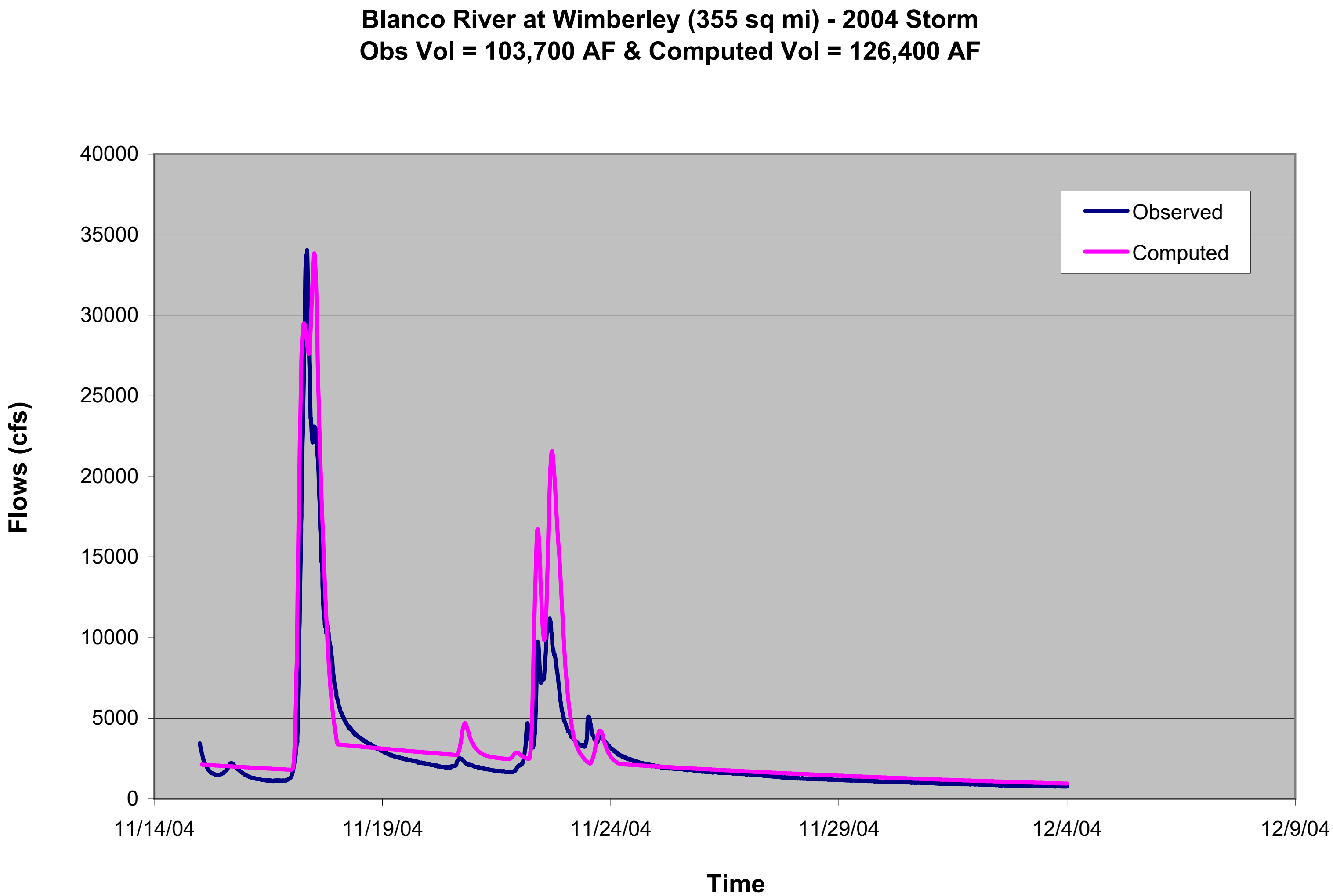


Figure 2.4.3-15 2004 Flood — Observed and Computed Hydrographs, Blanco River at Wimberley (USGS No. 8171000)

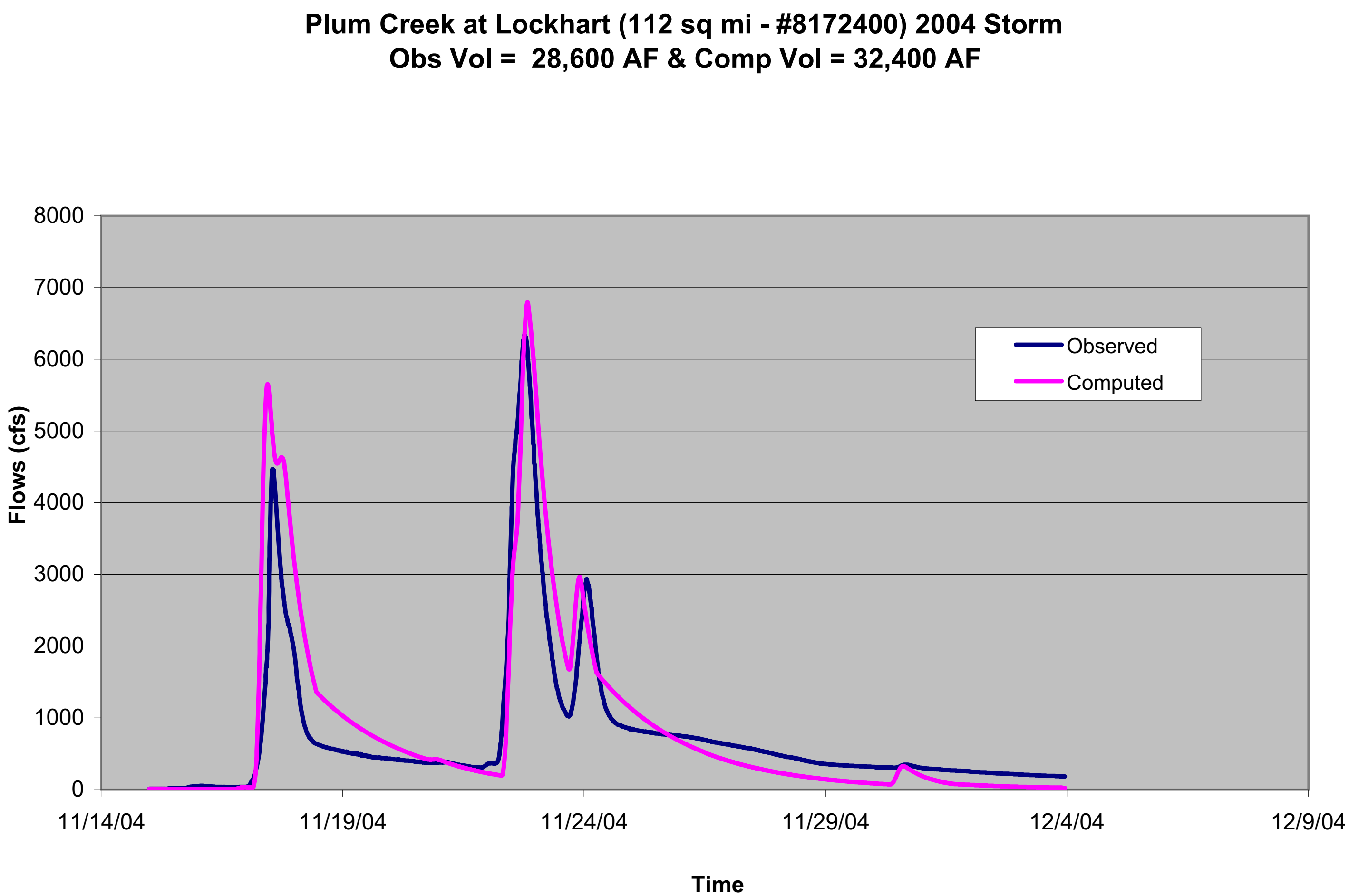


Figure 2.4.3-16 2004 Flood — Observed and Computed Hydrographs, Plum Creek at Lockhart (USGS No. 8172400)

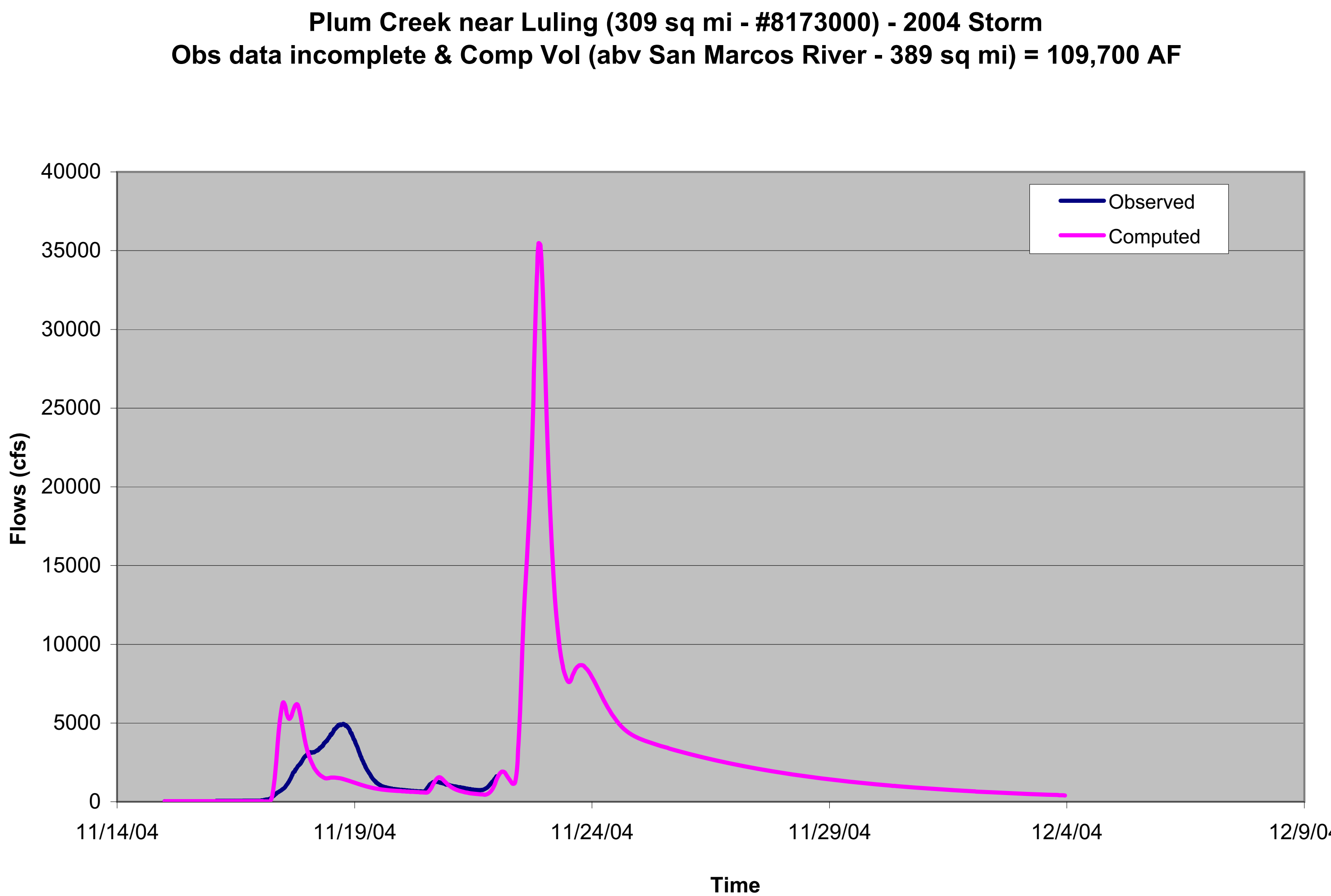


Figure 2.4.3-17 2004 Flood — Observed and Computed Hydrographs, Plum Creek near Luling (USGS No. 8173000)

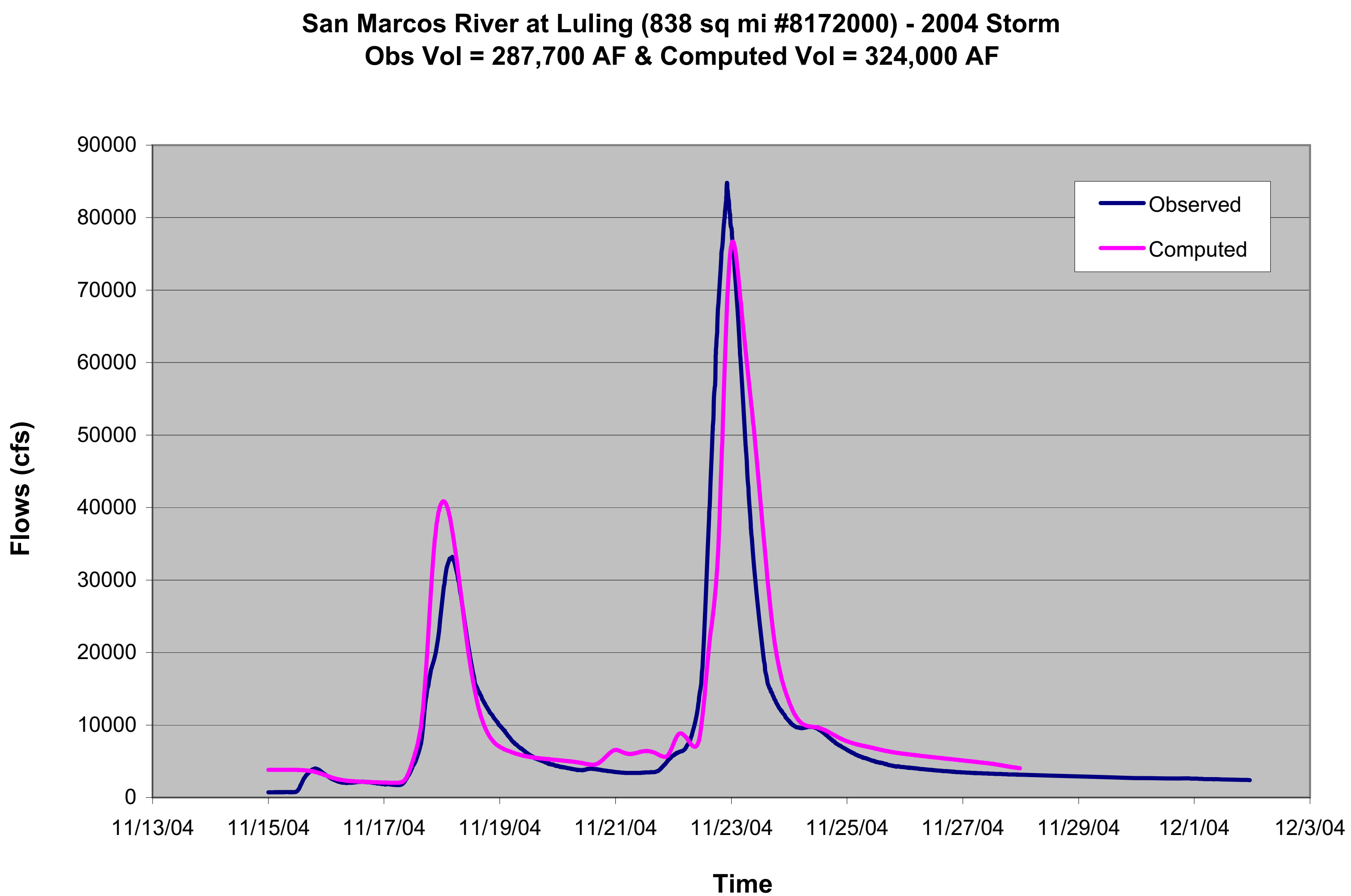


Figure 2.4.3-18 2004 Flood — Observed and Computed Hydrographs, San Marcos River at Luling (USGS No. 8172000)

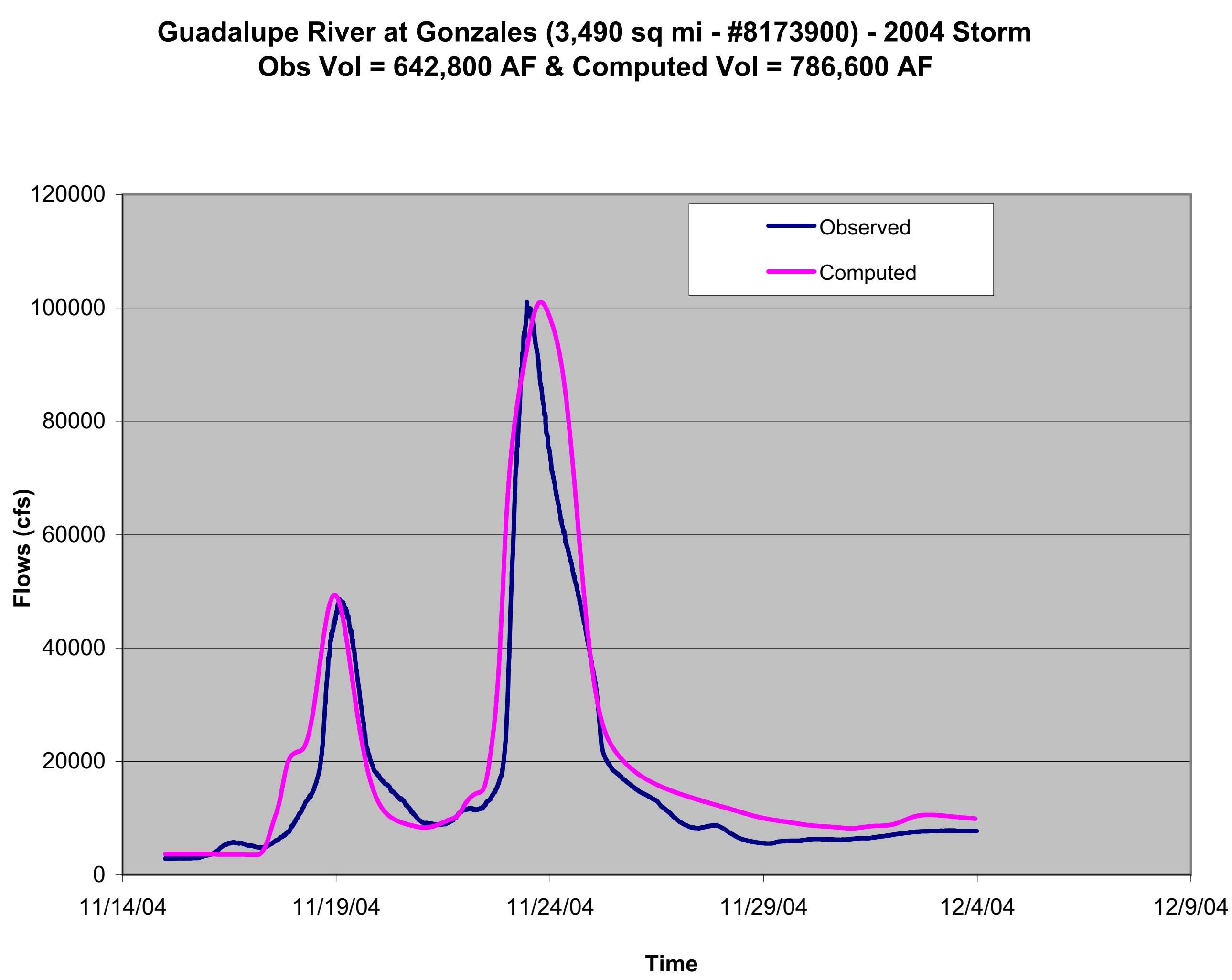


Figure 2.4.3-19 2004 Flood — Observed and Computed Hydrographs, Guadalupe River at Gonzales (USGS No. 8173900)

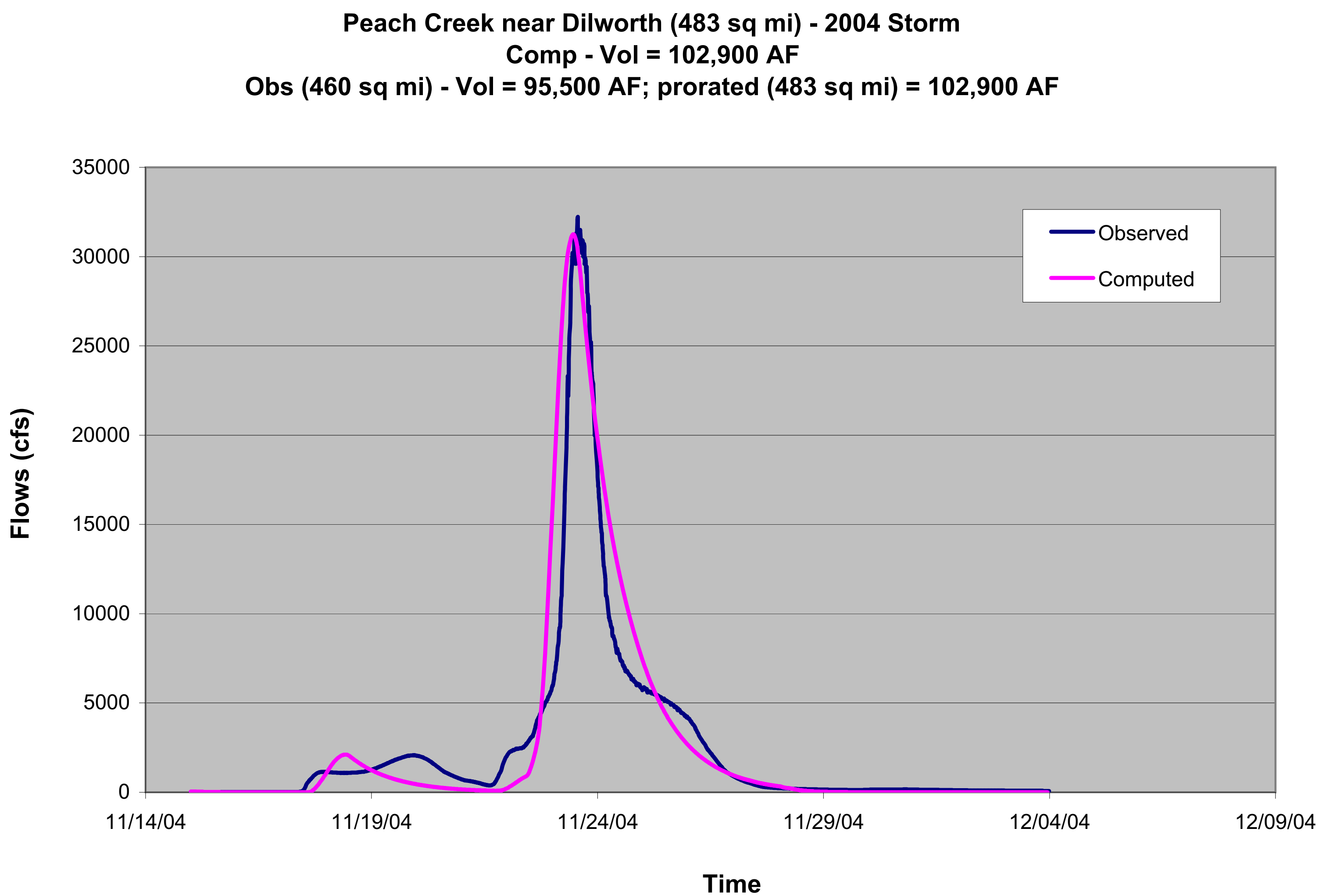


Figure 2.4.3-20 2004 Flood — Observed and Computed Hydrographs, Peach Creek at Dilworth (USGS No. 8174600)

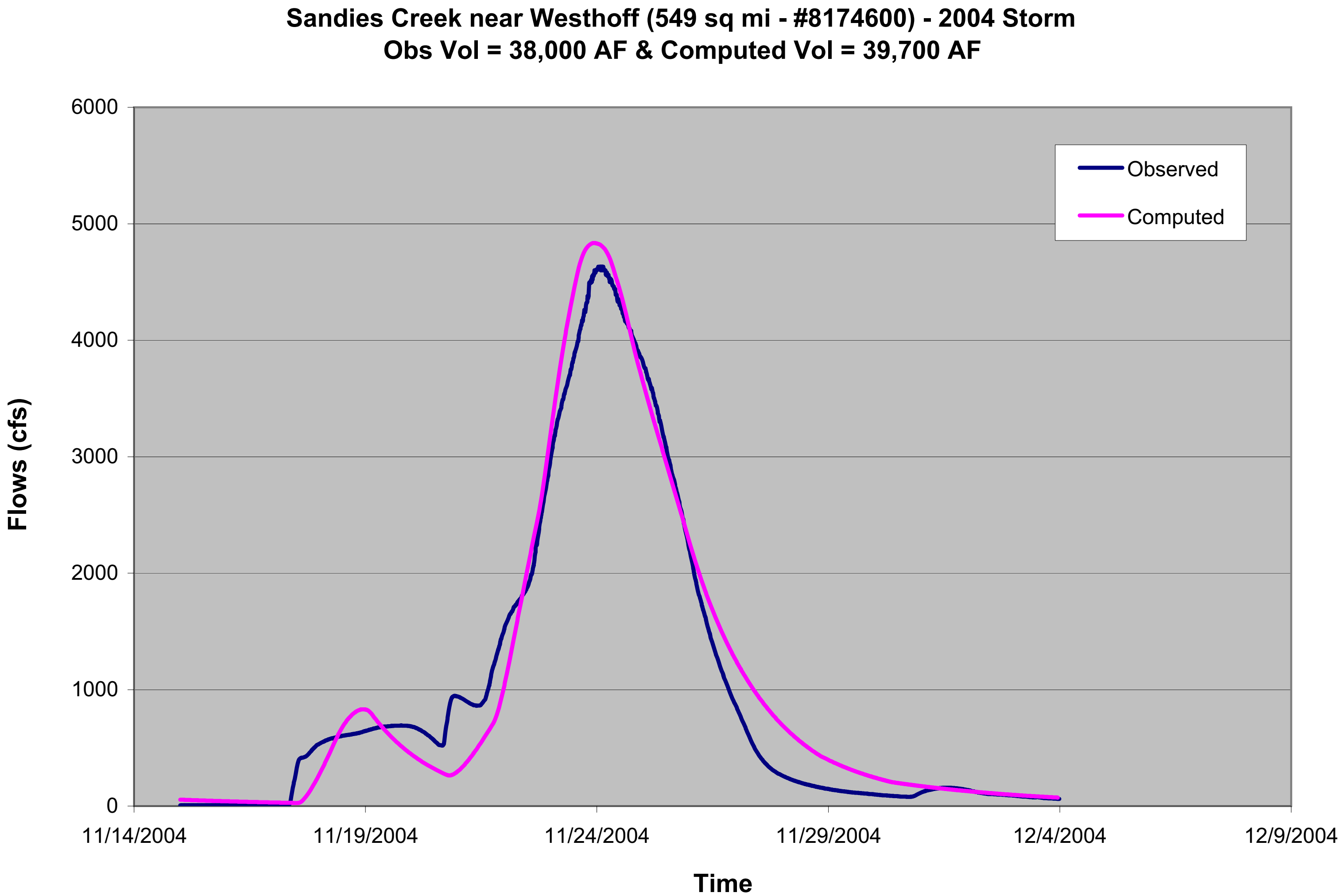


Figure 2.4.3-21 2004 Flood — Observed and Computed Hydrographs, Sandies Creek near Westhoff (USGS No. 8175000)

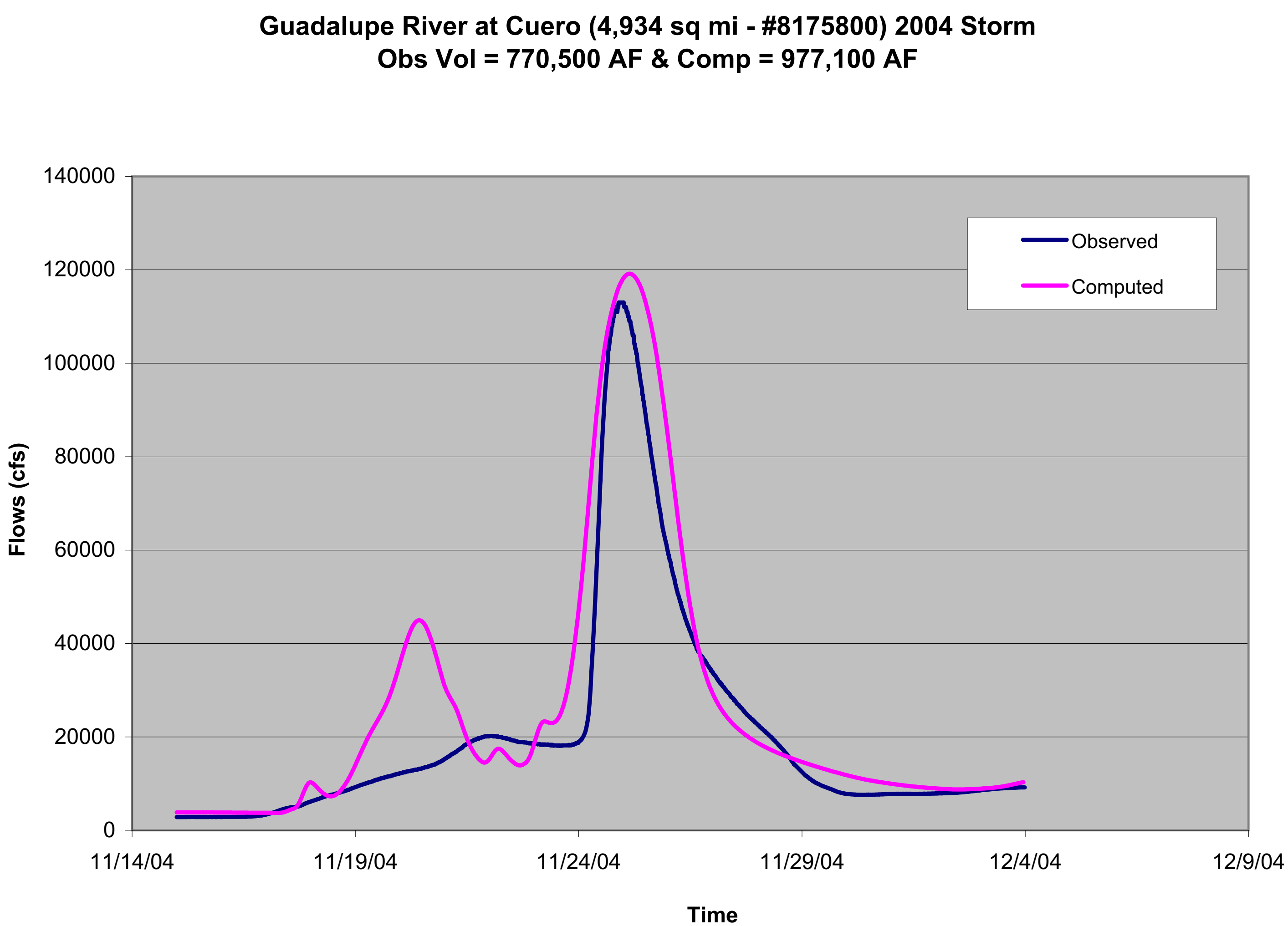


Figure 2.4.3-22 2004 Flood — Observed and Computed Hydrographs, Guadalupe River at Cuero (USGS No. 8175800)

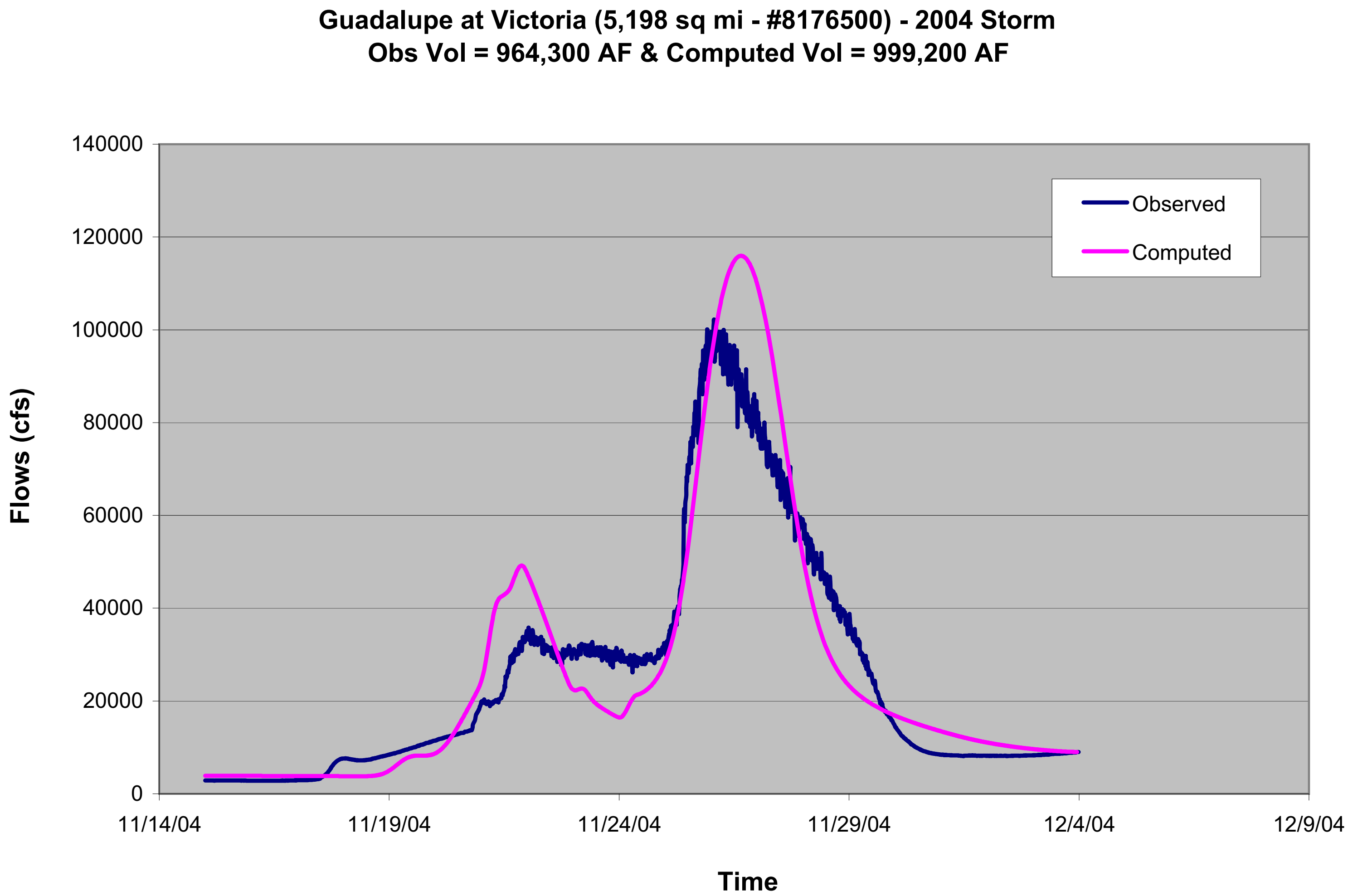


Figure 2.4.3-23 2004 Flood — Observed and Computed Hydrographs, Guadalupe River at Victoria (USGS No. 8176500)

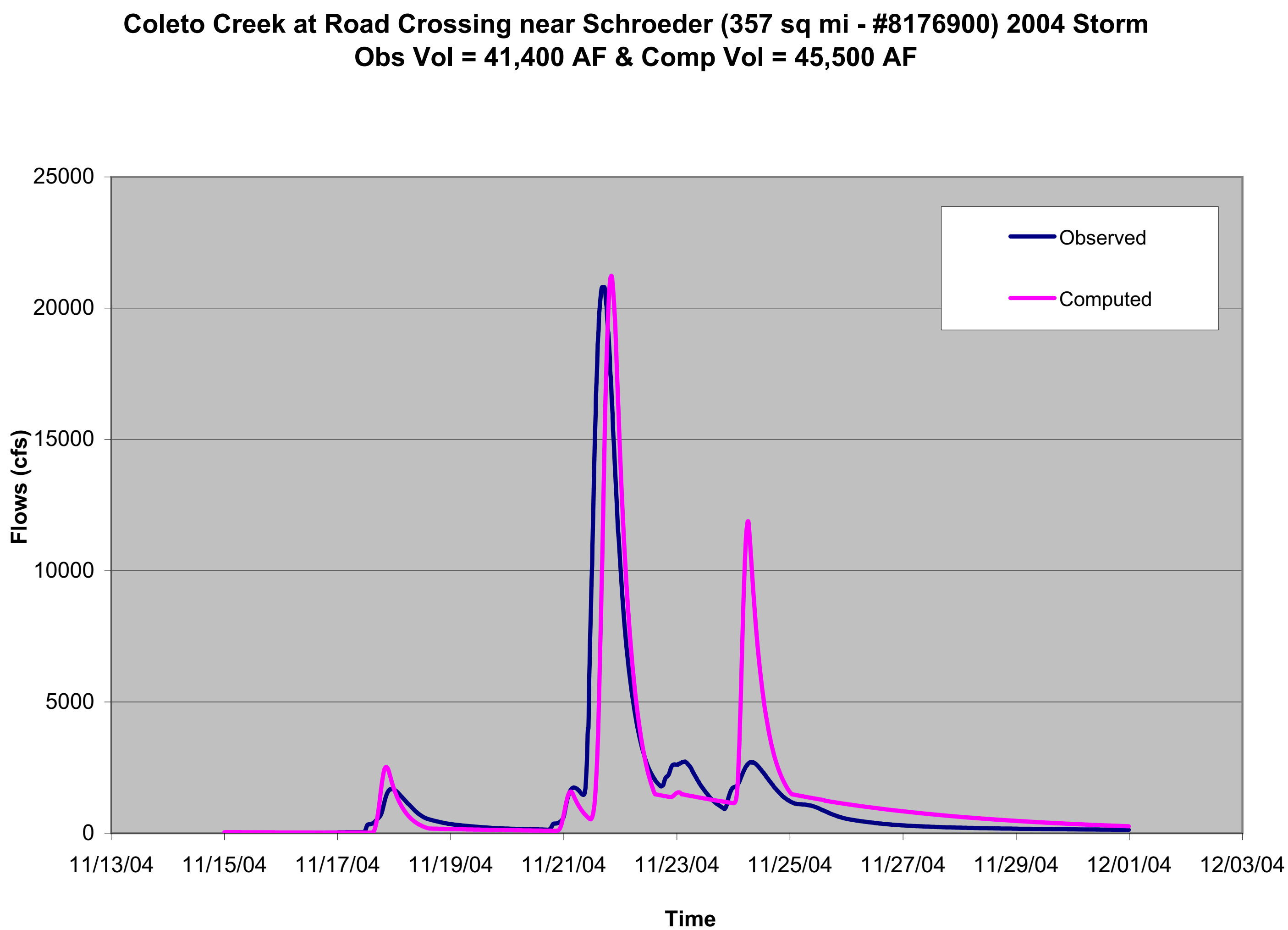


Figure 2.4.3-24 2004 Flood — Observed and Computed Hydrographs, Coleto Creek at Road Crossing near Schroeder (USGS No. 8176900)

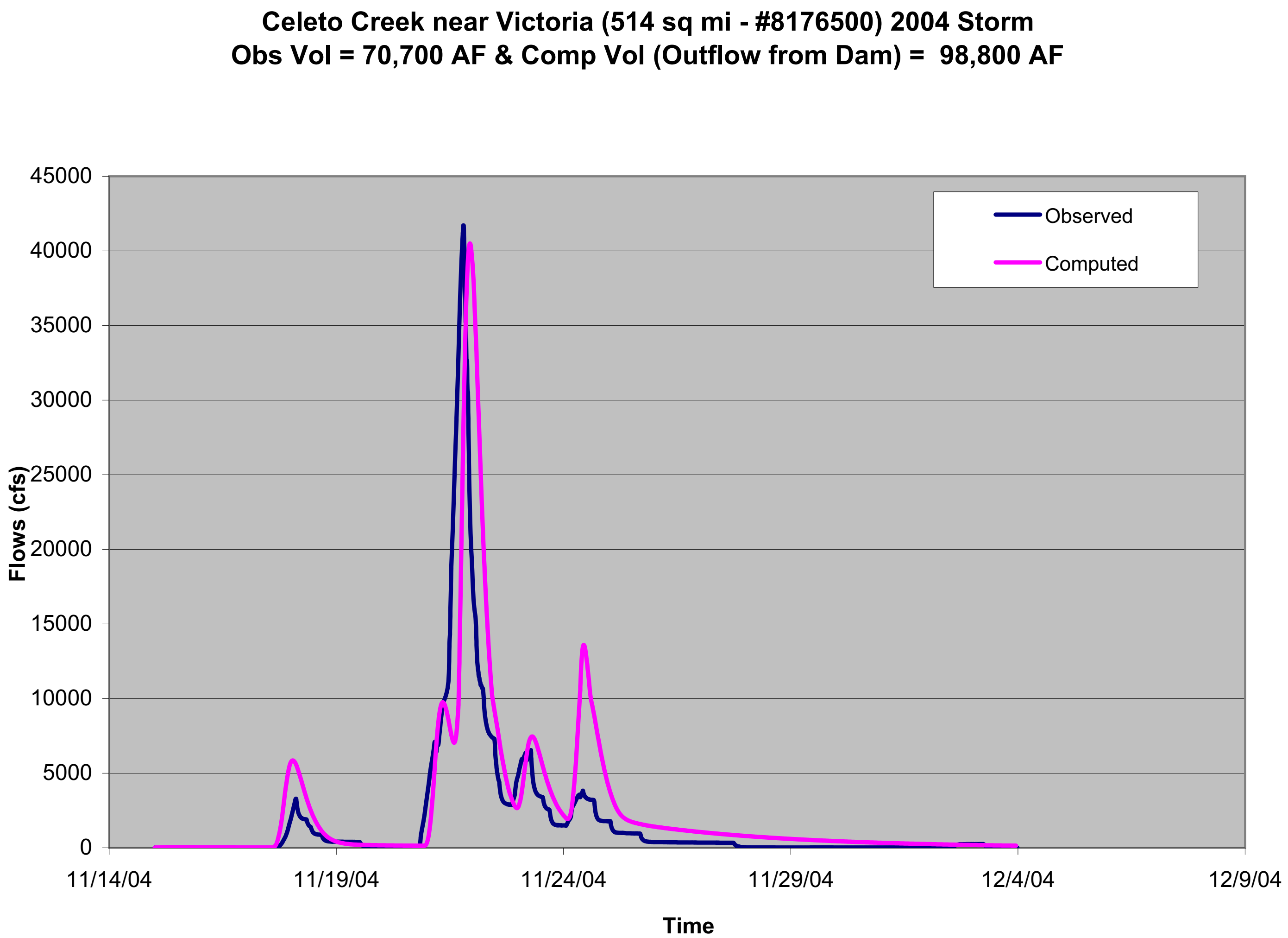
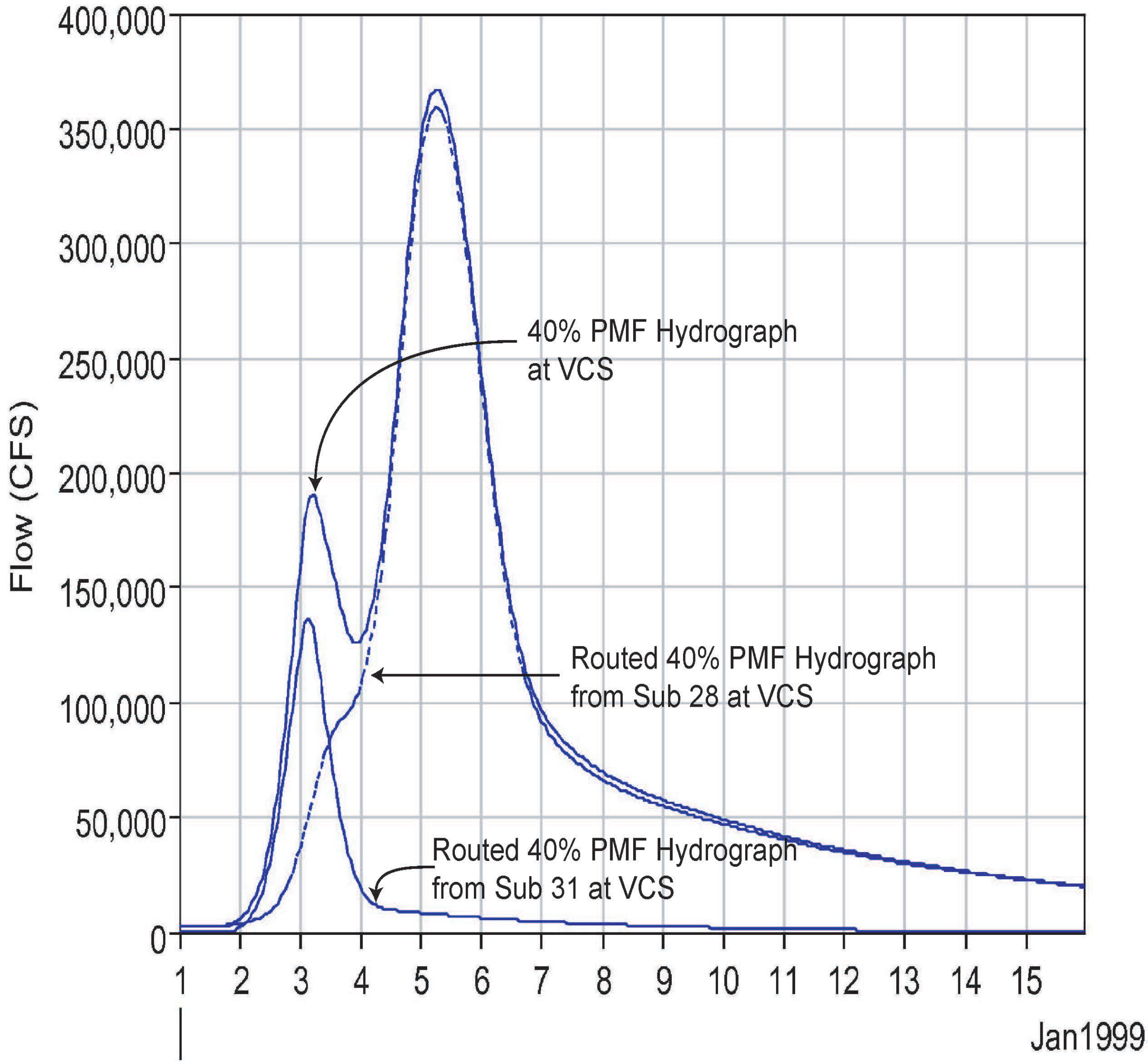
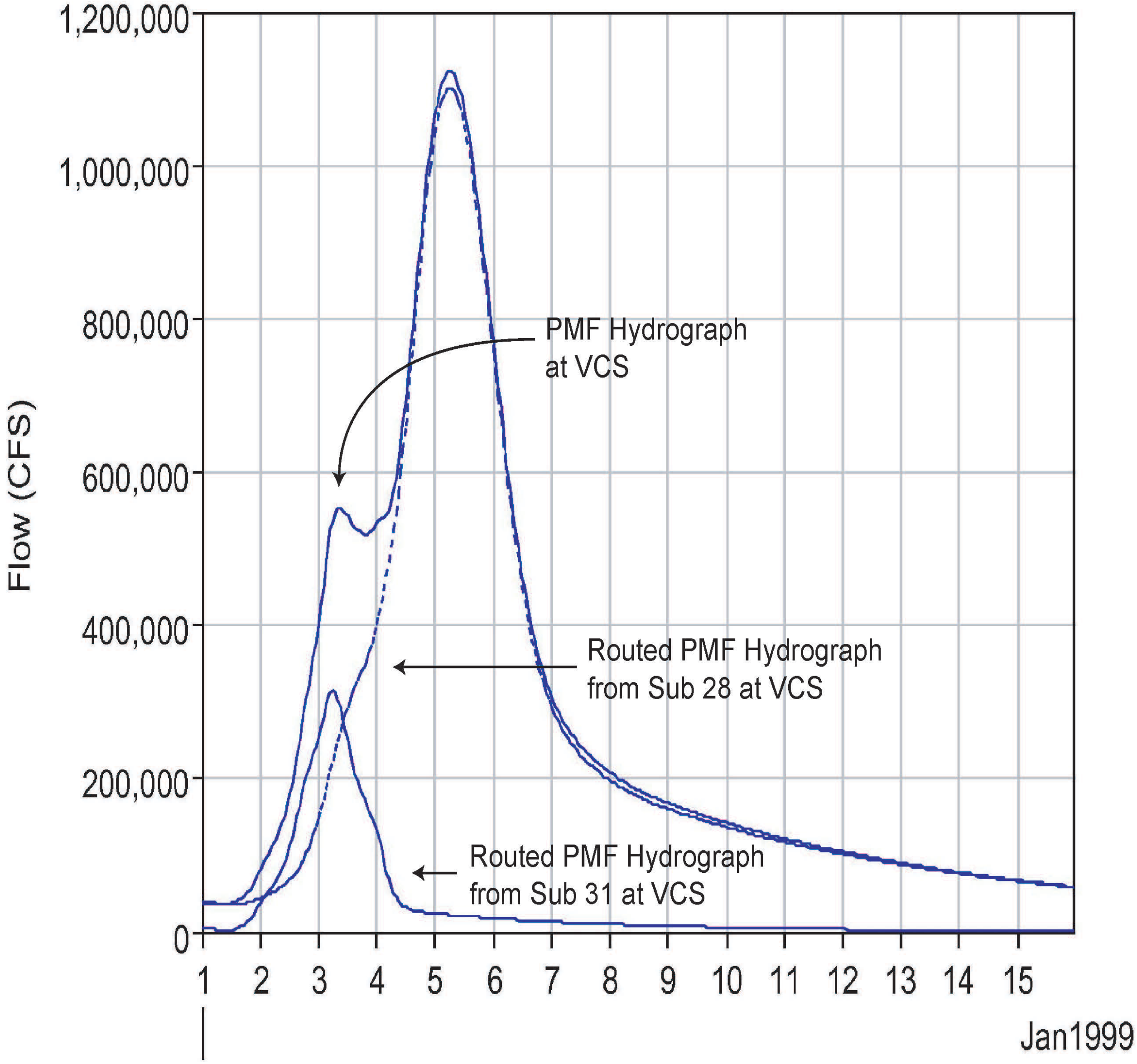


Figure 2.4.3-25 2004 Flood — Observed and Computed Hydrographs, Coleto Creek near Victoria (USGS No. 8176500)



Note: January 1, 1999, is the arbitrary start date of the model storm event.

Figure 2.4.3-26 40 Percent Guadalupe River PMP Flood Hydrograph



Note: January 1, 1999, is the arbitrary start date of the model storm event.

Figure 2.4.3-27 Guadalupe River PMF Flood Hydrograph

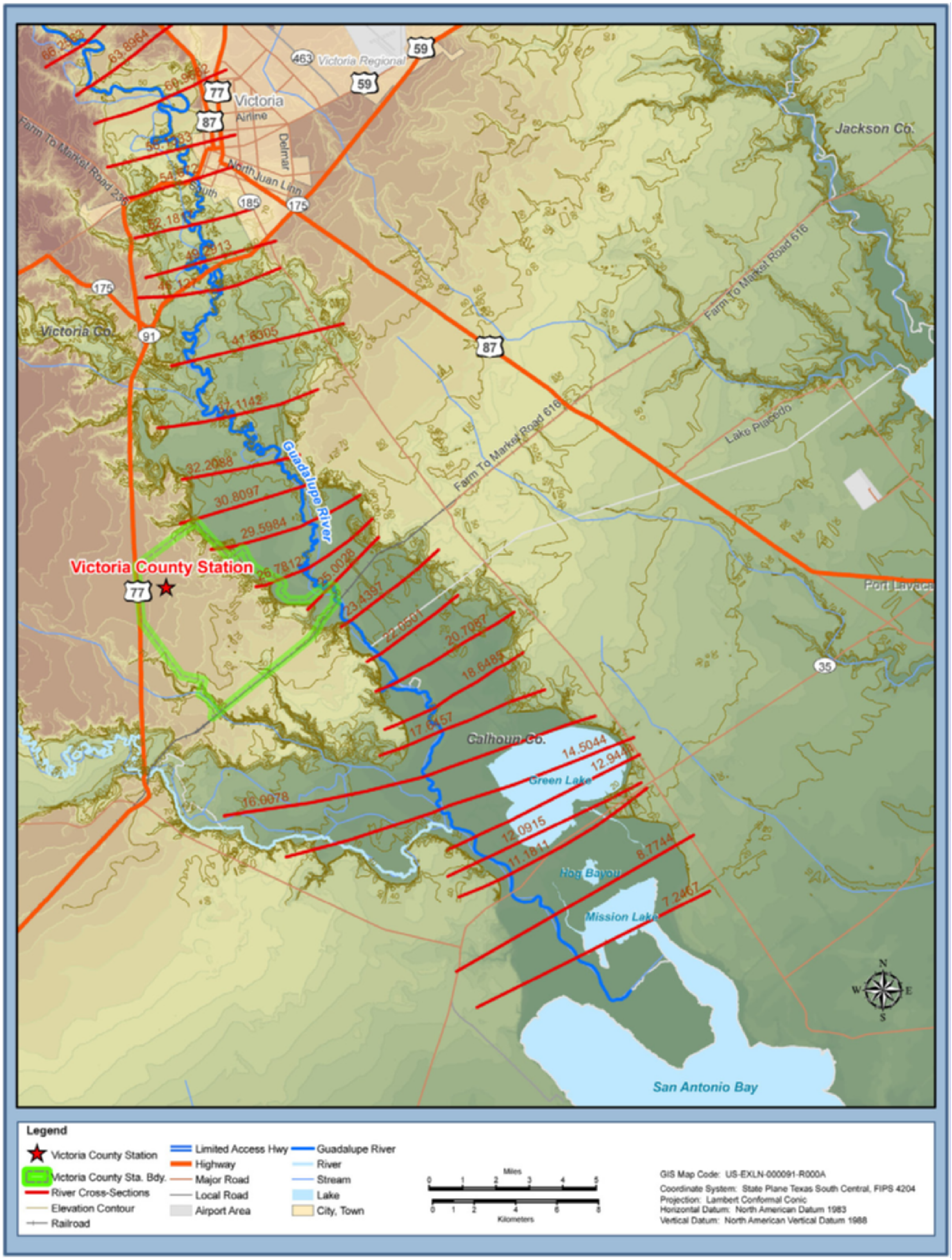


Figure 2.4.3-28   HEC-RAS Cross Section Locations