Flood-Control Effects of Truckee River Basin Reservoirs, December 31, 1996, Through January 4, 1997, California and Nevada

USGS

U.S. Department of the Interior—U.S. Geological Survey

The New Year's Flood of 1997

Devastating floods throughout northern California and western Nevada occurred January 1-3, 1997. In Nevada alone, about $500 million in projected damages and two deaths were attributed to floodwaters along the Truckee, Carson, and Walker Rivers (fig. 1) (Nevada Appeal, 1997). Flooding was extensive in downtown Reno (fig. 2), at the Reno/Tahoe International Airport, and in the industrial area of Sparks, Nev. (fig. 3).

In late December 1996, snowstorms built up a large (more than 180 percent of normal) snowpack in the higher elevations of the Sierra Nevada, as well as in the valleys along the eastern Sierra Nevada front. A subtropical storm system originating in the central Pacific Ocean near the Hawaiian Islands subsequently brought heavy, unseasonably warm rain to the Sierra Nevada on December 30, 1996, through January 3, 1997. During this period, the Natural Resource Conservation Service recorded 27.7 inches (provisional data) of precipitation at Squaw Valley, Calif., elevation 8,200 feet above sea level, and the National Weather Service recorded 1.9 inches at Reno/Tahoe International Airport, Reno, Nev., elevation 4,400 feet above sea level. Rain falling below an elevation of about 10,000 feet depleted some of the high-elevation snowpack and melted almost all of the snowpack below about 7,000 feet.

Streamflow at *Truckee River at Farad, Calif.* (USGS gaging station 10346000), peaked at about 14,800 ft^3/s (cubic feet per second) at a stage[1] of 13.17 feet (5,166.38 feet above sea level) on January 2 at 0445 hours. This peak streamflow at Farad is well below the record of 17,500 ft^3/s at a stage of 14.50 feet set in 1950.

Streamflow at *Truckee River at Reno, Nev.* (USGS gaging station 10348000), at the U.S. Highway 395 bridge, peaked at about 18,200 ft^3/s at a new river-stage record of 14.94 feet (4,446.91 feet above sea level) on January 2 at 1015 hours. Although the January 1997 peak streamflow was below the record of 20,800 ft^3/s set in December 1955, the 1997 peak stage was higher than the previous peak stage

[1]Stage refers to the height of a water surface above some established reference point (not the river bottom) at a given location.

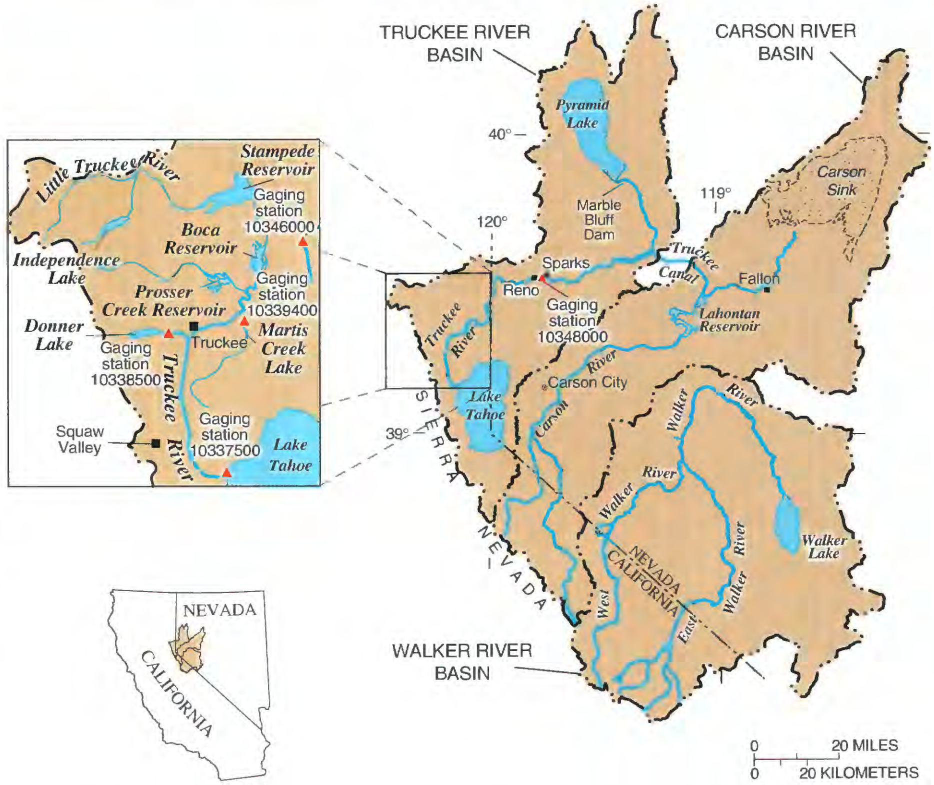

Figure 1. Geographic and hydrologic features of the Truckee River, Carson River, and Walker River Basins.

Figure 2. Flooded downtown Reno, Nev., as seen from a Nevada Army National Guard helicopter on January 2, 1997 (photograph by Marilyn Newton, Reno Gazette-Journal).

Figure 3. Flooded industrial area, Sparks, Nev., as seen from a helicopter on January 3, 1997. Trees line banks of normal Truckee River channel at bottom and right of photo (photograph by Patrick A. Glancy, U.S. Geological Survey).

recorded at this site. The previous river-stage record of 13.83 feet, was recorded during a peak streamflow of 19,900 ft^3/s in November 1950 (U.S. Geological Survey, 1954). A stage of 13.63 feet was recorded during the record streamflow of December 1955 (Wells, 1958). The higher river stage associated with a smaller peak streamflow for the flood of 1997 compared to the floods of 1950 and 1955 could have resulted from channel modifications or urban encroachment within the floodplain that have occurred since the fifties.

The frequency or probability of a flood usually is described by assigning a recurrence interval to the flood at each gaging station. This is accomplished by statistically evaluating long-term annual peak streamflows at a station. Standard techniques and procedures used to determine the station flood-frequency relations are described by the U.S. Water Resources Council (1982). For example, a 100-year flood-recurrence interval means that, in any given year, a flood of a specified streamflow magnitude has a 1-in-100 chance of happening. The recurrence intervals of January 1997 Truckee River streamflow peaks at the Farad and Reno gaging stations were slightly less than 50 years (1-in-50 chance). Recurrence intervals typically were higher (close to 100 years) in the adjacent Carson River Basin above Lahontan Reservoir, and the Walker River Basin than those in the Truckee River Basin. This difference is due to minimal upstream storage capacity of the upper Carson River and the Walker River Basins.

Although the hydrologic conditions and streamflow in the Truckee River were fairly severe at Truckee, Calif., catastrophic flooding farther downstream in Reno and Sparks was reduced because of upstream regulation at Prosser Creek Reservoir, Martis Creek Lake, Stampede Reservoir, and Boca Reservoir. An extensive real-time data-collection network helped managers regulate water storage behind the dams at the reservoirs and lake. The data-collection network is maintained by the USGS, the U.S. Army Corps of Engineers, and the District Court Federal Water Master.

River-system managers have estimated that streamflow for the Truckee River would have been from 45,000 to 47,000 ft^3/s at Reno without the flood-protection reservoirs upstream (Reno Gazette-Journal, 1997). This fact sheet summarizes how upstream Truckee River Basin reservoirs reduced the streamflow at Reno during the New Year's flood of 1997. This analysis was accomplished by using a physically-based, hourly streamflow model developed by the Truckee-Carson Program of the U.S. Geological Survey.

Flow-Routing Model of the Truckee-Carson Program

The Truckee-Carson Program was established in 1992 to assist the Department of the Interior in implementing Public Law 101-618, the Truckee-Carson-Pyramid Lake Water Rights Settlement Act of 1990. A primary objective of the Truckee-Carson Program is to construct, calibrate, test, and apply interbasin hydrologic computer models to support efficient water-resources planning, management, and allocation. The modeling system under development is based on the Hydrological Simulation Program—Fortran (HSPF) (Bicknell and others, 1993). HSPF can simulate storage, streamflow, and quality of waters in the system in addition to analyzing alternative water-management scenarios for reservoir and river operations.

The HSPF flow-routing model requires a linked network of river channels, lakes, and reservoirs divided into segments, called reaches, that have relatively uniform hydraulic properties. Streamflow is routed through the reach network by a "modified kinematic-wave algorithm," wherein a water budget is determined for each reach by accounting for water entering a reach, water stored in the reach, and water leaving the reach during a given time interval.

The benefits of the aforementioned reservoirs during the January 1997 flood were examined using an HSPF flow-routing model constructed by Berris (1996). This flow-routing model included the entire Truckee River mainstem from the outlet below Lake Tahoe to Marble Bluff Dam, just upstream from the river's terminus at Pyramid Lake. Berris constructed and tested the original model using hydraulic data derived from 215 field-surveyed cross-sections, and inflow/outflow data for more than 60 gaging stations. The model was modified to simulate Truckee River streamflow at hourly time steps with and without the reservoirs.

Routing simulations using an hourly time step characterize the timing and magnitude of the peak streamflow and duration of the flood more accurately than methods that simply add peak streamflows intercepted by the reservoirs to the peak streamflow observed farther downstream. The estimated peak streamflow of 45,000 to 47,000 ft^3/s at Reno without flood-protection reservoirs (Reno Gazette-Journal, 1997) was made by river-system managers by assuming that all peak streamflows in the Upper Truckee River Basin could be added directly to the peak streamflow at Reno with no adjustment for the timing of peak streamflows. In contrast, the Truckee River simulation model takes into account travel times and the attenuation of the peak streamflow.

Hourly time-step simulations also can provide a continuous hydrograph trace (graphical plot of flow over time) of streamflow from the beginning to the end of a flood as shown in figures 4 and 5. The shape of the hydrographs give information about the effects of flood-protection reservoirs such as:

- Volume of the flood—determined from the area underneath the hydrograph.
- Duration of streamflows—determined from the width of the hydrograph at a specified streamflow rate.
- Rate of increasing or decreasing streamflows—determined from the slope of the rising or falling limb of the hydrograph.

Modeling Assumptions and Set-Up

The flood in Reno without flood protection provided by Prosser Creek Reservoir, Martis Creek Lake, Boca Reservoir, and Stampede Reservoir (fig. 1) was simulated by removing dams at these reservoirs from the original flow-routing model of Berris (1996). During the period December 31, 1996, through January 4, 1997, inflows of approximately 136,000, 7,600, and 2,700 acre-feet were stored in Lake Tahoe, Donner Lake, and Independence Lake, respectively, behind the dam outlet works above the natural sills. Effects of storage in these three lakes were not removed in the "no-reservoir" simulation because the unregulated outflows from these lakes would be constrained by the hydraulic properties (shape, size, and roughness) of the natural sill outlets. Unlike the man-made reservoirs, where valley outflows would not be limited in the absence of the dam, some storage of floodwater would still occur even without the dam outlet works. Therefore, the no-reservoir simulation assumed that the "natural" outflows from these three lakes would be approximately equal to the releases actually made. As a result of this assumption, the simulated flood-control benefits provided by the reservoirs may be underestimated.

The downstream model boundary for simulations was the gaging station at Reno. Farther downstream at Sparks, floodwaters from the Truckee River and water from local tributary flooding ponded in large overbank storage areas that persisted for several days. These backwater conditions (obstructions to streamflow) and the complex flow distribution associated with these large areas of overbank storage could not be accurately simulated using a one-dimensional flow-routing model such as HSPF.

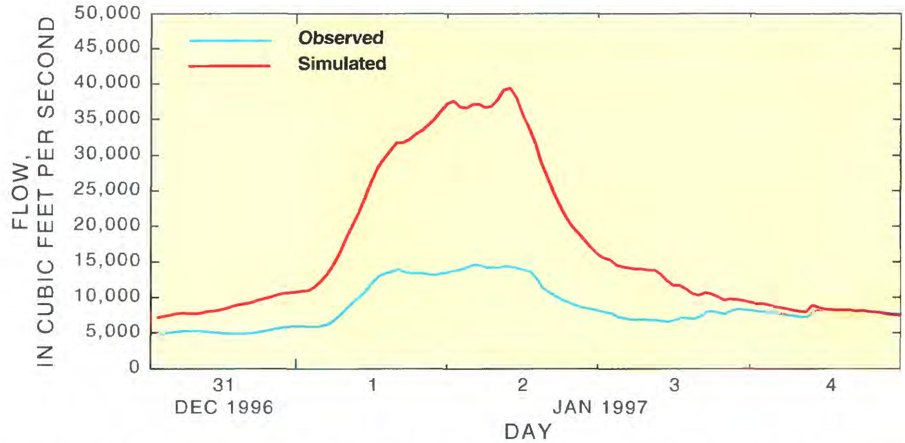

Figure 4. Observed and simulated hourly streamflows, *Truckee River at Farad, Calif.* (station 10346000). Simulated streamflow is without upstream reservoir storage.

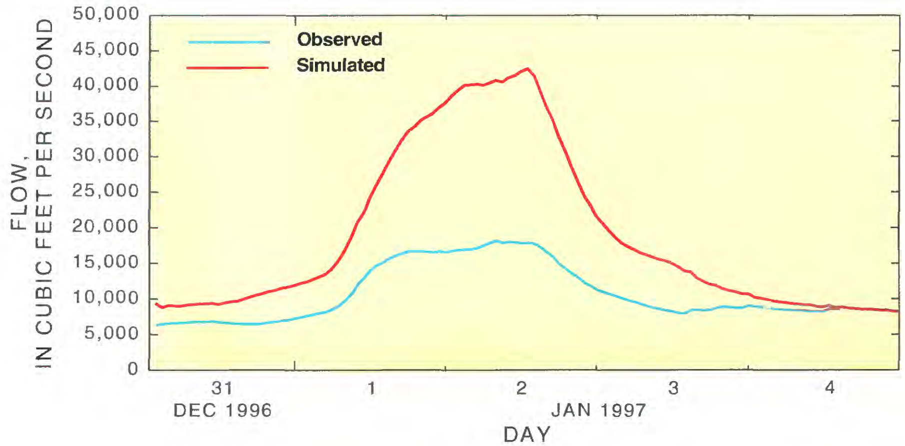

Figure 5. Observed and simulated hourly streamflows, *Truckee River at Reno, Nev.* (station 10348000). Simulated streamflow is without upstream reservoir storage.

Input data for the flow-routing simulation with reservoir storage were from provisional outflow data for Lake Tahoe, Donner Lake, and Martis Creek Lake obtained from USGS gaging stations. These gaging stations are *Truckee River at Tahoe City, Calif.* (USGS gaging station 10337500), *Donner Creek at Donner Lake, near Truckee, Calif.* (USGS gaging station 10338500), and *Martis Creek near Truckee, Calif.* (USGS gaging station 10339400) (fig. 1). Outflow data for Prosser Creek and Boca Reservoirs were obtained from the U.S. Army Corps of Engineers. Ungaged inflows were estimated by routing measured streamflows along the Truckee River and computing the difference between the observed and simulated hydrographs at selected mainstem gaging stations.

For the simulation of streamflow without reservoir storage, the same outflow data from Lake Tahoe and Donner Lake were used as in the simulation with reservoirs. Unregulated streamflows at the Prosser Creek Reservoir, Martis Creek Lake, Stampede Reservoir, and Boca Reservoir locations were estimated by David Overvold and Gerhard Krueger (Bureau of Reclamation and U.S. Army Corps of Engineers, respectively, written commun., 1997). These estimates were made from hourly outflow and change in storage data obtained from the District Court Federal Water Master or the U.S. Army Corps of Engineers. The no-reservoir simulation then was run using the same estimates for tributary inflows as developed for the model calibration for the observed regulated conditions.

Results

Hydrographs of observed and simulated streamflow for the Truckee River are shown in figure 4 at Farad gage and figure 5 at Reno gage. These hydrographs show streamflow with (observed) and without (simulated) flood-protection reservoirs. Figure 4 illustrates that a peak streamflow of 39,600 ft^3/s would have occurred at Farad without reservoirs and 14,800 ft^3/s occurred with reservoirs, a significant reduction of 24,800 ft^3/s. Figure 5 illustrates that a peak streamflow of 42,500 ft^3/s would have occurred at Reno without reservoirs and 18,200 ft^3/s occurred with reservoirs, a significant reduction of 24,300 ft^3/s.

The water-surface elevation at the Reno gaging station would have been approximately 9 ft higher (4,456 feet above sea level) than the observed elevation, using a straight-line extension of the current stage-discharge relation, had the reservoirs not been in place. This estimate is pertinent only to the Reno gaging station and may not be applicable to locations upstream or downstream. Also, the difference between the observed and simulated hydrographs in figure 5 indicates that an additional 81,500 acre-feet of water would have flowed through Reno from December 31, 1996, through January 4, 1997, in the absence of reservoirs.

Table 1 shows additional duration and volume information that can be obtained from the modeled hydrographs. For example, during the actual flood, a peak streamflow of 18,000 ft^3/s at the Reno gaging station was exceeded for only about 3 hours with reservoirs. But streamflows would have exceeded 18,000 ft^3/s for about 43 hours without reservoirs. During these extra hours an additional 52,600 acre-feet of water would have flowed through Reno.

Truckee River Basin reservoirs serve Nevada in two important ways: (1) to conserve water for later use during times of low streamflow, and (2) to store excess streamflow to reduce downstream flood-waters. While Nevada has long recognized and appreciated the conservation of water for the dry, hot summers, this analysis emphasizes the importance of reservoir management in reducing downstream flood damage.

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Table 1. Summary of observed and simulated hydrograph data for *Truckee River at Reno, Nev.* (USGS gaging station 10348000), December 31, 1996, through January 4, 1997

[Symbol: >, greater than]

Flow (cubic feet per second)	Water-surface elevation		Hydrograph duration		Volume of water above indicated flow	
	above gage datum (feet)	above sea level (feet)	Observed, with reservoirs (hours)	Simulated, without reservoirs (hours)	Observed, with reservoirs (acre-feet)	Simulated, without reservoirs (acre-feet)
6,000	8.6	4,440.6	>119[1]	>119[1]	>46,400[1]	>127,900[1]
8,000	9.8	4,441.8	>93[1]	>119[1]	>29,400[1]	>108,200[1]
10,000	10.9	4,442.9	44	83	19,400	91,300
18,000	14.9	4,446.9	3	43	21	52,600
30,000	19.8	4,451.8	0	28	0	18,100
40,000	23.2	4,455.2	0	12	0	990

[1]Value would be greater if the simulation period were extended after January 4, 1997.

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