4.1.14 Indicators of Hydrologic Alteration Study

4.1.14.1 Project Nexus

Continued Project O&M activities have the potential to affect flow in the Pyramid reach downstream of Pyramid Dam.

4.1.14.2 Existing Information and Need for Additional Information

Existing, relevant, and reasonably available information regarding flow control devices in Pyramid Dam are described in Section 3.2.2.2 of the Licensees' PAD. As a summary, water can flow out of Pyramid Lake into the Pyramid reach through one or more Project structures. These include: (1) a Pyramid Dam gate-controlled spillway; (2) a Pyramid Dam uncontrolled emergency spillway; (3) a Pyramid Dam low-level outlet; and (4) seepage through, under, or around Pyramid Dam. All of the structures deliver water to the Pyramid reach within the first few hundred feet of Piru Creek below Pyramid Dam.

Existing, relevant, and reasonably available information regarding flow in the Pyramid reach immediately downstream of Pyramid Dam is described in Section 3.2.3.5 of the Licensees' PAD. In general, daily average flows are highest in the winter and spring months, with median flows between approximately 10 and 100 cubic feet per second (cfs). Daily average flows are lowest in summer, with median average daily flows of approximately 5 cfs. Median average daily flows have been recorded as high as 8,000 cfs in spring and as high as approximately 80 cfs in summer (see Figure 3.2-17 in PAD).

This *IHA Study* will develop statistics comparing daily average flows in the Pyramid reach under With-Project conditions and Without-Project conditions.

4.1.14.3 Study Goals and Objectives

The goal of this *IHA Study* is to compare various metrics of hydrologic alteration to assess how the Project alters Without-Project flows. The objective of the *IHA Study* is to gather sufficient data necessary to fill recognized gaps in existing information including the development of flow metrics and statistics for analyzing With-Project and Without-Project flows.

4.1.14.4 Study Methods

Study Area

The study area for the *IHA Study* will consist of Pyramid reach shown in Figure 4.1-22. Specifically, flow statistics will be developed for a single location in the Pyramid reach immediately downstream of where the Pyramid Dam spillway enters Pyramid reach. In this way, flows from the Pyramid Dam spillway, low-level outlet, and dam seepage will be collectively accounted for in the study.

General Concepts and Procedures

- Personal safety is the most important consideration of each fieldwork team. Fieldwork will only occur in safely accessible areas and under conditions deemed safe by the field crews. Locations within the study area that cannot be accessed in a safe manner (e.g., locations containing dense vegetation or unsafe slopes) and areas inundated when the surveys are performed, will not be surveyed; these areas will be identified in the data summary and an explanation for survey exclusion will be provided.

- The *IHA Study* will begin after FERC issues its Study Plan Determination.

- The *IHA Study* does not include the development of requirements for the new license, which will be addressed outside the *IHA Study*.

- The *IHA Study* focuses specifically on flow in the Pyramid reach below Pyramid Dam, and the study area *IHA Study* is specific to that resource.

- If required for the performance of the *IHA Study*, the Licensees will make a good faith effort to obtain permission to access private property well in advance of initiating the *IHA Study*. The Licensees will only enter private property if permission has been provided by the landowner.

- The Licensees will acquire all necessary agency permits and approvals prior to beginning fieldwork for the *IHA Study*.

- Field crews may make variances to the *IHA Study* in the field to accommodate actual field conditions and unforeseen problems. Any variances in the *IHA Study* will be noted in the data resulting from the *IHA Study*.

- To prevent the introduction and transmittal of amphibian chytrid fungus and invasive invertebrates (e.g., quagga mussels, zebra mussel, and Asian clams), field crews will be trained on, provided with, and use materials (e.g., Quat) for decontaminating their boots, waders, and other equipment when leaving or traveling between water-based study sites. Field crews will follow DWR's Quagga and Zebra Mussel Rapid Response Plan and CDFW's Aquatic Invasive Species Decontamination Protocol found at the following link: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=43333. All boats used during the study will follow clean protocols, including inspections before and after use. All decontamination requirements in place at Project reservoirs including those of DWR's *Quagga and Zebra Mussel Rapid Response Plan* for the SWP will be strictly followed (DWR 2010).

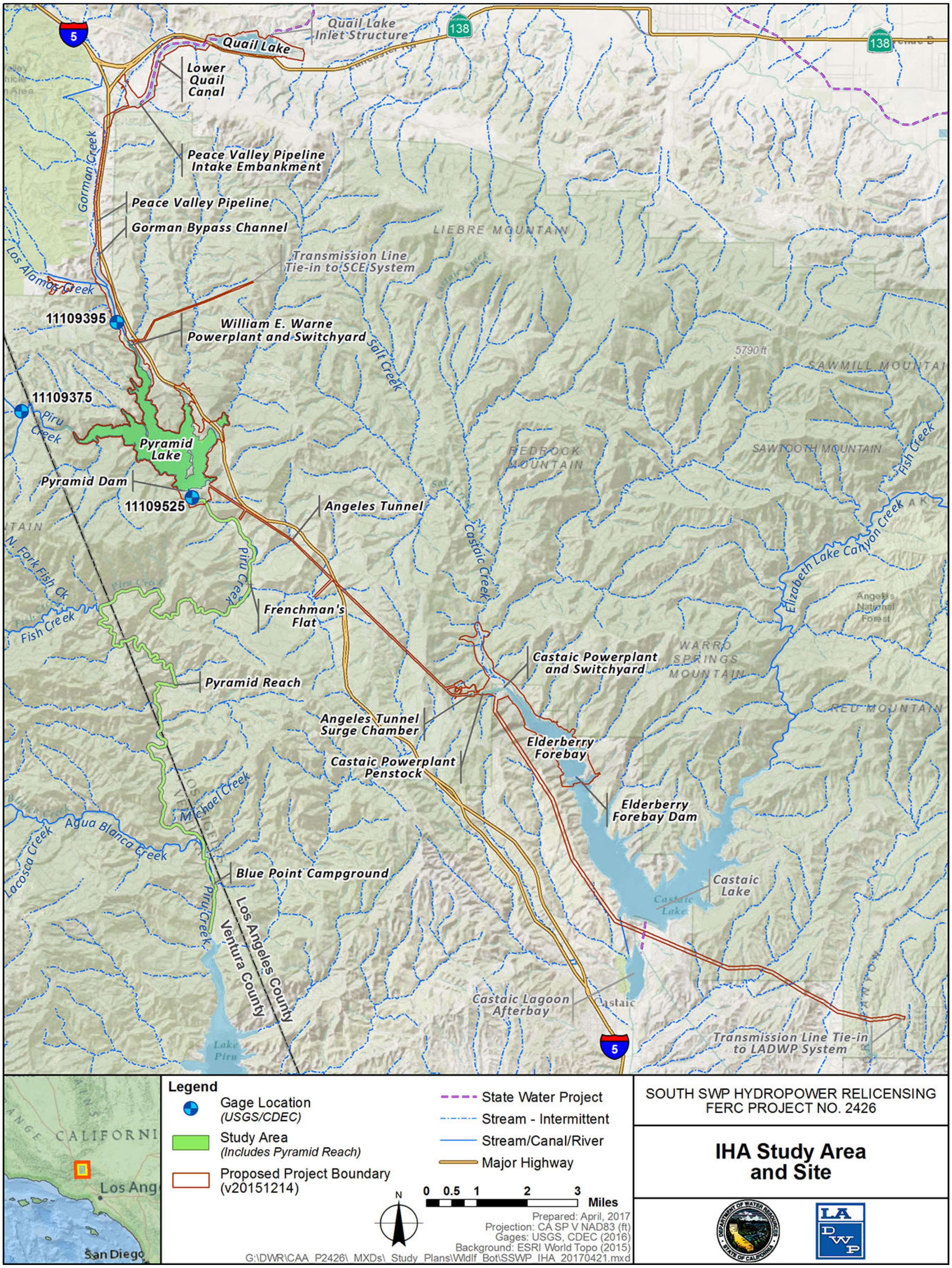

Figure 4.1-22. IHA Study Area and Site

Methods

This *IHA Study* will consist of three steps: (1) develop With-Project and Without-Project hydrology records; (2) conduct the ramping rate analysis; and (3) conduct the IHA analysis. These steps are described below.

Step 1 – Develop With-Project and Without-Project Hydrology Records. The Licensees will develop With-Project and Without-Project daily average flow hydrology from Water Year (WY) 2006 through WY 2017. The Licensees selected this period because the Licensees began operating to the Article 52 "natural hydrology" beginning in April of 2005 with the first full year of natural hydrology being 2006.

The With-Project hydrology record will be developed from USGS gage 11109525 (Piru Creek below Pyramid Lake, near Gorman, CA), which reports the releases from Pyramid Dam (Figure 4.1-22). The gage record of daily average flows extends from March 1972 through the present, and 15-minute and hourly flow data are available for the last seven years of the record. If any average daily flows are missing from the gaged record from the WYs 2006 through 2017, the Licensees will complete the record for those data using standard hydrology techniques, for example:

- Use historical flows for the same gage from another period that had similar conditions as the one with the missing data;
- Scale historical flows from a nearby gage for the same period of record by the ratio of contributing watershed sizes;
- Interpolate between available data for the gage with missing data.

The Without-Project hydrology record will be developed using the following gages:

- USGS gage 11109375 (Piru Creek below Buck Creek, near Pyramid Lake, CA), which is located in Piru Creek upstream of the NMWSE of Pyramid Lake (Figure 4.1-22). The gage record of daily average flows extends from October 1976 through the present, and 15-minute or hourly flow data are available for the last seven years of the record.
- USGS gage 11109395 (Cañada de Los Alamos above Pyramid Lake, CA), which is located on Gorman Creek upstream of the NMWSE of Pyramid Lake and the Warne Powerplant (Figure 4.1-22). The gage record of daily average flows extends from October 1976 through the present, and 15-minute or hourly flow data are available for the last seven years of the record.

If any daily average flow data are missing from the above record, the Licensees will complete the records for those data using the standard hydrology techniques described above.

The Licensee will also include documentation of the process used to develop the With- and Without-Project hydrologic records, along with the methodology for determining the contribution from the ungaged portion of the watershed.

Step 2 – Conduct Ramping Rate Analysis. The Licensees will select up to 10 events from the WYs 2006 through year 2017, when the Licensees were making releases into Pyramid reach in an effort to reflect representative changes in flows into Pyramid reach. The selection of these 10 events will be contingent upon the Licensees having 15-minute or hourly flow data at USGS gage 11109525, USGS gage 11109375 and USGS gage 11109395 for the events selected. For each event, the Licensees will plot the 15-minute or hourly flow changes at both gages on one figure. For the 10 events, 24-hour hydrographs with any available descriptions of event conditions will be provided. A minimum of three of the examined events will occur when the Licensees released SWP water to be delivered to the UWCD.

Step 3 – Conduct the IHA Analysis. The Licensees will use IHA Version 7.1, a software package developed by Totten Software Design and Smythe Scientific Software (The Nature Conservancy, 2007) to calculate the above IHA statistics. The statistics will be computed for the entire WY 2006 through WY 2017 period for both Without-Project and With-Project conditions.

In order to compare the With-Project and Without-Project hydrologic records, using daily average flow data from WY 2006 through WY 2017 as described above, the flow characteristics identified by Richter et al. (1996) will be computed using the available software described below, for With-Project and Without-Project flows, and the Licensees will prepare comparison tables to show the differences between the With-Project and Without-Project flows for each statistical group. As recommended by Richter, all data will be presented as non-parametric (percentile) statistics due to the highly skewed nature of hydrologic data sets. In general, the median flow will be used as a measure of central tendency. The spread between the 25th percentiles and the 75th percentile divided by the median will be used to measure dispersion called the "coefficient of dispersion" (CD). The median and CD correspond to the mean and standard deviation in parametric statistics, which is typically used for data sets that are not so highly skewed. To express the difference between the Without-Project and With-Project statistics, Richter's deviation factors will be calculated for both medians and CDs. The deviation factor will be presented as an absolute value and calculated by the With-Project median or CD value minus the Without-Project median or CD value divided by the Without-Project median or CD value. The five groups recommended by Richter et al. (1996) will be:

- Group #1: Magnitude of monthly water conditions. This group includes 12 parameters, including monthly median flow values and associated statistics, and associated CDs and deviation factors.

- Group #2: Magnitude and duration of annual extreme water conditions. This group includes 11 parameters that measure the magnitude of extreme (minimum and maximum) annual water conditions or various duration periods ranging from one day to seasonal. The five duration periods for which statistics will be calculated include 1-day, 3-day, 7-day (week), 30-day (month), and 90-day (season) for each year. The number of zero-flow days will be computed. The median, CDs and deviation factors for each value will be shown. For any given year, the 1-day maximum (or minimum) value will be represented by the highest (or lowest) single median daily value occurring during that year. For any given year, the multi-day maximum (or minimum) value will be represented by the highest (or lowest) average of median daily values over that multi-day period occurring in that year.

- Group #3: Timing of annual extreme water conditions. This group compares the timing of With-Project and Without-Project extreme flow conditions. The two parameters include the median of the Julian date when the 1-day minimum water condition occurred, and the median of the Julian date when the 1-day maximum water condition occurred. Associated CDs and deviation factors will be calculated.

- Group #4: Frequency and duration of high and low flow pulses. This group expresses the frequency of high and low flow pulses as well as the duration of each for the With-Project and Without-Project conditions. Four parameters will be measured in this group: two parameters measure the number of annual occurrences (frequency) during which the magnitude of the water condition exceeds an upper threshold or remain below a lower threshold, respectively, and; two parameters measure the number of days (duration) of such high and low pulses. Pulses will be defined as those periods within a year in which the daily median water condition rise above the 75^{th} percentile (high pulse) or drops below the 25^{th} percentile of all daily values for the Without-Project condition.

- Group #5: Rate and frequency of change in water conditions. This group is a comparison of rate and frequency of annual hydrograph changes for the Without-Project and With-Project conditions. Three parameters will be measured in this group: two parameters measure the median of positive and negative differences between consecutive daily values (rate), and one parameter measures the median number of hydrologic reversals (frequency) based on median daily flows. Associated CDs and deviation factors will be calculated.

<u>Step 4 – Conduct a Flood Frequency Analysis.</u> DWR will develop flood frequency curves utilizing annual peak daily flow data and the with- and without-project condition flows developed in Step 1. These curves will be generated using PeakFQ, a software package developed by the United States Geological Survey which provides estimates of instantaneous annual-maximum peak flows for a range of recurrence intervals using a Pearson Type III (logarithmic) frequency distribution (Flynn et al. 2006). The parameters of the Pearson Type III frequency curve are estimated by the logarithmic sample moments (i.e., mean, standard deviation, and coefficient of skewness) with adjustments for low outliers, high outliers, historic peaks, and generalized skew. As sample size warrants at each streamflow gage, standard recurrence interval flows will be reported including 1.5, 2, 2.33, 5, 10, 25, 50, 100, 200, and 500 years.

Quality Assurance and Quality Control

All data, including both input data and output data, will be developed and analyzed in a manner that promotes high quality results and will be subject to appropriate QA/QC procedures. Data will be entered and organized in both Microsoft Excel and Hydrologic Engineering Center Data Storage System formats, where applicable. IHA data will be presented in its standard IHA output format.

Analysis

The Licensees will compare the changes in ramping rates and compare IHA statistics between the With-Project and Without-Project conditions. If any significant differences occur, the Licensees will review operations logs to determine the reason for the differences. If the reason is related to one of the qualifying conditions in Article 52 of the existing license, the Licensees will so indicate. For clarity, the qualifying conditions, as stated in Article 52, are as follows:

- Natural inflow to Pyramid Lake will be released into Piru Creek at a rate of up to about 18,000 cfs, which is the maximum safe, designed release from Pyramid Dam. The exact maximum safe release depends on the lake surface water elevation at the time of the release.

- Storm releases from Pyramid Dam into Piru Creek may be held back at less than 18,000 cfs if higher releases are deemed a threat to life, safety, or property at Pyramid Dam or downstream of the dam.

- The Licensees may elect to appropriate inflow to Pyramid Lake above the safe release flows under the provisions of its existing water rights.

- Up to 3,150 acre-feet of SWP water would be delivered to UWCD via the Pyramid reach (from Pyramid Dam) between November 1 and the end of February of each water year. During this period, water deliveries may be made over a period of a few days, ramping flows up and down to simulate the hydrograph of a typical storm event, or they may be released more gradually over a longer period.

- Releases from Pyramid Dam could be increased by up to 50 cfs for short periods to exercise the Pyramid Dam radial gate and stream release valves; test emergency power sources; conduct tests mandated by the Commission; or meet other short-term operational or maintenance requirements. No such testing would take place between March 15 and June 15. Testing would also be avoided to the extent possible between June 16 and July 31. Tests may be conducted at any time between August 1 and March 14, provided that flows do not increase by more than 50 cfs above current base flows during the event and that the event does not last longer than 15 minutes. Scheduled tests requiring larger releases or lasting longer than 15 minutes would require prior notification to the USFWS. Unscheduled releases due to equipment failure or emergency situations must be reported to the USFWS no later than three business days after the event.

- The gaging station on upper Piru Creek (located north of Pyramid Lake) provides 24-hour averages; therefore, instantaneous peak stream releases may be attenuated. Unlike the natural inflow hydrograph, which typically peaks sharply, the stream release hydrograph of Pyramid reach may be attenuated.
- A multiplier is used to account for those portions of Pyramid Lake watershed that are not tributaries of upper Piru Creek and Cañada de Los Alamos upstream of their respective gaging stations. This may result in some deviations for individual storm events due to localized variations in storm water intensity.
- Because of operational constraints, the stream release hydrograph of Pyramid reach would typically gage measured inflow. The valves at Pyramid Dam can be adjusted for release flows of less than 3 cfs; however, the precise measurement of released flows less than 3 cfs may not be possible due to operational constraints of the dam's gaging instrumentation.

Reporting

The *IHA Study* methods and results will be prepared and included, to the extent completed and ready for inclusion, in the Licensees' ISR, USR, DLA, and FLA.

4.1.14.5 Consistency of Methodology with Generally Accepted Scientific Practices

The *IHA Study* methods are generally consistent with the methods used for recent FERC hydropower relicensing efforts in California, including the Yuba River Development Project (FERC Project No. 2246). Further, IHA is a widely used hydrologic assessment tool and is endorsed by several State and federal agencies.

4.1.14.6 Schedule

The *IHA Study* will begin after FERC issues its Study Plan Determination. The Licensees anticipate the schedule below will be followed to complete the *IHA Study*:

Develop Hydrology	July 2017 – May 2018
Data QA/QC	June 2018
Conduct Analysis	July 2018 – September 2018
Data Analysis and Reporting	October 2018 – December 2018

4.1.14.7 Level of Effort and Cost

Based on the work effort described above, the Licensees estimate the current cost to complete this *IHA Study* will range between $22,000 and $37,000.

4.1.14.8 References

DWR. 2010. The Quagga and Zebra Mussel Rapid Response Plan for the State Water Project. 93 pp. CONFIDENTIAL/PRIVILEGED – Not for Public Distribution.

Flynn, K.M., W.H. Kirby, and P.R. Hummel. 2006. User's Manual for Program PeakFQ, Annual Flood-Frequency Analysis Using Bulletin 17B Guidelines. Online document: http://pubs.usgs.gov/tm/2006/tm4b4/tm4b4.pdf.

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. Conservation Biology 10:1163-1174.

The Nature Conservancy (in collaboration with Totten Software Design and Smythe Scientific Software). 2007. Indicators of Hydrologic Alteration – Version 7 User's Manual. Online document.