EFFECTS OF THE PROJECT AND RELATED ACTIVITIES ON THE LOSSES OF MARINE-DERIVED NUTRIENTS IN THE TUOLUMNE RIVER STUDY REPORT

LA GRANGE HYDROELECTRIC PROJECT FERC NO. 14581

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
HDR, Inc.

February 2016

Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River
Study Report

TABLE OF CONTENTS

List of Figures

List of Tables

List of Acronyms

ac-ft ....acre-foot
BLM............................Bureau of Land Management
BOR ....Bureau of Reclamation
CCSF...........................City and County of San Francisco
CDFG..........................California Department of Fish and Game, now CDFW
CDFW.........................California Department of Fish and Wildlife
cfs...............................cubic feet per second
CG..............................Conservation Group
Districts.......................Turlock Irrigation District and Modesto Irrigation District
FERC...........................Federal Energy Regulatory Commission
FLA.............................Final License Application
FPA ....Federal Power Act
GIS ....geographic information system
ILP..............................Integrated Licensing Process
ISR ....Initial Study Report
LGDD ....La Grange Diversion Dam
LP...............................Licensing Participant
M&I............................municipal and industrial
MID............................Modesto Irrigation District
NMFS.........................National Marine Fisheries Service
NPS ....National Park Service
O&M..........................operation and maintenance
PAD............................Pre-Application Document
PSP.............................Proposed Study Plan
QA/QC.......................quality assurance/quality control
RM ....river mile
RSP ....Revised Study Plan
SD2 ....Scoping Document 2
SPD ....Study Plan Determination
TAF............................thousand acre-feet
TID.............................Turlock Irrigation District
TM..............................technical memorandum
USFWS ....United States Fish and Wildlife Service
USGS ....United States Geological Survey
USR............................Updated Study Report

1.0 INTRODUCTION

1.1 Background

The Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) own the La Grange Diversion Dam (LGDD) located on the Tuolumne River in Stanislaus County, California (Figures 1.1-1 and 1.1-2). LGDD is 131 feet high and is located at river mile (RM) 52.2 at the exit of a narrow canyon, the walls of which contain the pool formed by the diversion dam. Under normal river flows, the pool formed by the diversion dam extends for approximately one mile upstream. When not in spill mode, the water level upstream of the diversion dam is between elevation 294 feet and 296 feet approximately 90 percent of the time. Within this 2-foot range, the pool storage is estimated to be less than 100 acre-feet of water.

The drainage area of the Tuolumne River upstream of LGDD is approximately 1,550 square miles. Tuolumne River flows upstream of LGDD are regulated by four upstream reservoirs: Hetch Hetchy, Lake Eleanor, Cherry Lake, and Don Pedro. The Don Pedro Hydroelectric Project (Federal Energy Regulatory Commission [the Commission or FERC] No. 2299) is owned jointly by the Districts, and the other three dams are owned by the City and County of San Francisco (CCSF). Inflow to the La Grange pool is the sum of releases from the Don Pedro Project, located 2.3 miles upstream, and very minor contributions from two small intermittent streams downstream of Don Pedro Dam.

LGDD was constructed from 1891 to 1893 displacing Wheaton Dam, which was built by other parties in the early 1870s. LGDD raised the level of the Tuolumne River to permit the diversion and delivery of water by gravity to irrigation systems owned by TID and MID. The Districts' irrigation systems currently provide water to over 200,000 acres of prime Central Valley farmland and drinking water to the City of Modesto. Built in 1924, the La Grange hydroelectric plant is located approximately 0.2 miles downstream of LGDD on the east (left) bank of the Tuolumne River and is owned and operated by TID. The powerhouse has a capacity of slightly less than five megawatts. The La Grange Hydroelectric Project (La Grange Project or Project; FERC No. 14581) operates in a run-of-river mode. The LGDD provides no flood control benefits, and there are no recreation facilities associated with the Project or the La Grange pool.

Figure 1.1-1. La Grange Hydroelectric Project location map.

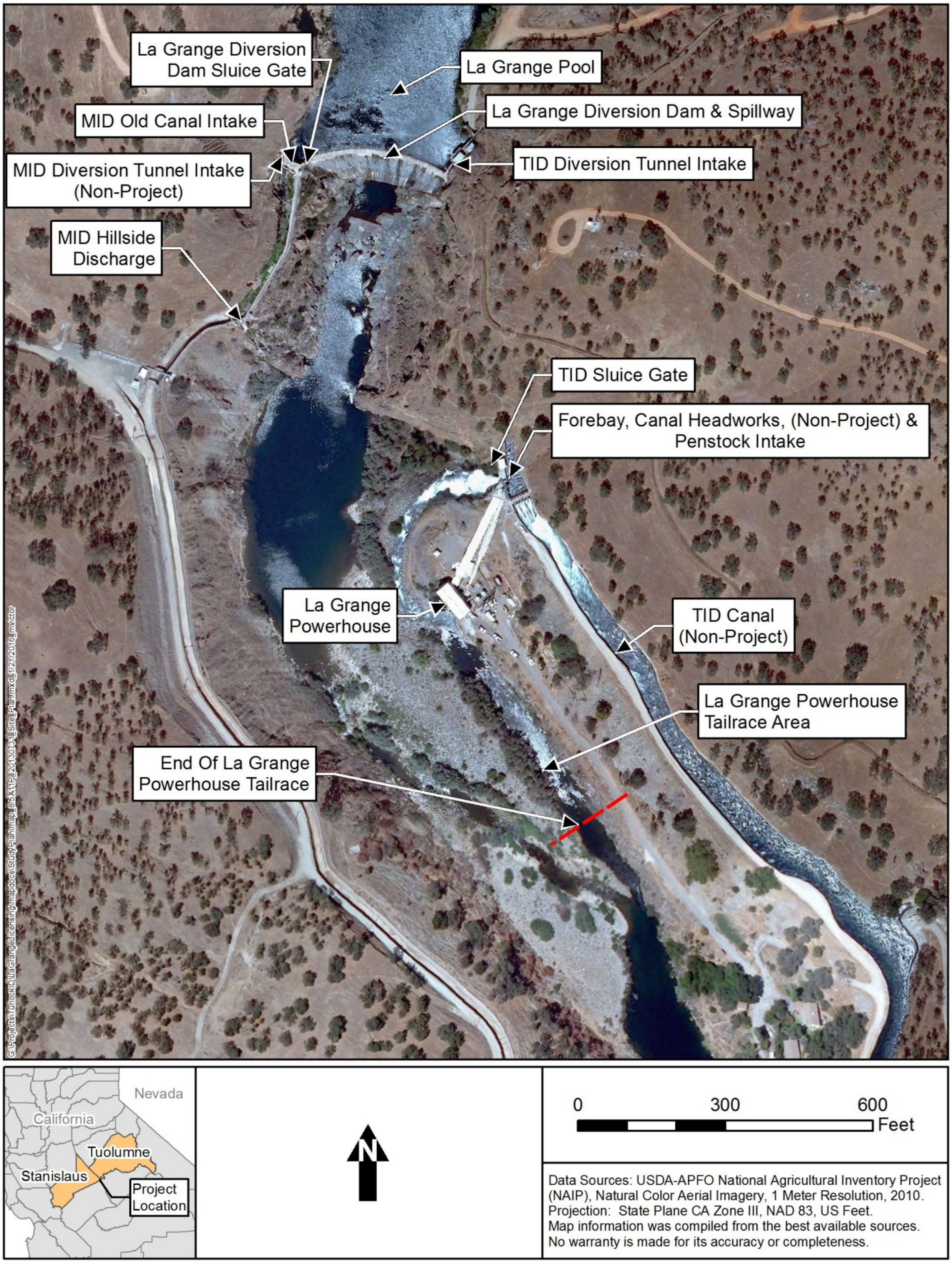

Figure 1.1-2. La Grange Hydroelectric Project site plan.

1.2 Licensing Process

On January 29, 2014, the Districts commenced the pre-filing process for the licensing of the La Grange Project by filing a Pre-Application Document (PAD) with FERC[1]. The Districts' PAD included descriptions of the Project facilities, operations, and lands as well as a summary of existing information available on Project area resources.

On September 5, 2014, the Districts filed their Proposed Study Plan (PSP) to assess Project effects on fish and aquatic resources, recreation, and cultural resources in support of their intent to license the Project. On October 6, 2014, the Districts held a PSP meeting at MID's offices in Modesto, California. Based on discussion at the PSP meeting, the Districts prepared an Updated Study Plan document that went to licensing participants (LP) for review and comment on November 21, 2014. On December 4, 2014, the National Marine Fisheries Service (NMFS), the Conservation Groups (CG), and the California Department of Fish and Wildlife (CDFW) filed comments on the PSP and/or Updated Study Plan.

On January 5, 2015, in response to comments from LPs, the Districts filed their Revised Study Plan (RSP) containing three study plans: (1) Cultural Resources Study Plan; (2) Recreation Access and Safety Assessment Study Plan; and (3) Fish Passage Assessment Study Plan[2]. Comments on the RSP were received from CDFW on January 16, 2015, and from NMFS, the CGs and the City of Modesto on January 20, 2015.

On February 2, 2015, FERC issued the Study Plan Determination (SPD), approving or approving with modifications six studies (Table 1.2-1). Of those six studies, five had been proposed by the Districts in the RSP. The Districts note that although FERC's SPD identified the Fish Passage Barrier Assessment, Fish Passage Facilities Alternatives Assessment, and Fish Habitat and Stranding Assessment below La Grange Diversion Dam as three separate studies, all three assessments are elements of the larger Fish Passage Assessment as described in the RSP. The sixth study approved by FERC, Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River, was requested by NMFS in its July 22, 2014 comment letter. Of the eight studies requested by LPs, FERC approved only the NMFS study noted above.

Although FERC's SPD did not require the Districts to undertake the Upper Tuolumne River Basin Habitat Assessment studies contained in the RSP, the Districts are voluntarily conducting the Upper River Barriers Study and the Water Temperature Monitoring and Modeling Study. Regarding the third component of the Upper Tuolumne River Basin Habitat Assessment, the ongoing upstream habitat characterization work being completed by NMFS, the Districts anticipate the results of this work becoming available for consideration in this licensing proceeding.

[1] On December 19, 2012, Commission staff issued an order finding that the La Grange Hydroelectric Project is required to be licensed under Section 23(b)(1) of the Federal Power Act. Turlock Irrigation District and Modesto Irrigation District, 141 FERC ¶ 62,211 (2012), aff'd Turlock Irrigation District and Modesto Irrigation District, 144 FERC ¶ 61,051 (2013). On May 15, 2015, the U.S. Court of Appeals for the District of Columbia Circuit denied the Districts' appeal and affirmed the Commission's finding that the La Grange Hydroelectric Project requires licensing. Turlock Irrigation District, et al., v. FERC, et al., No. 13-1250 (D.C. Cir. May 15, 2015).

[2] The Fish Passage Assessment Study Plan contained a number of individual, but related, study elements.

Table 1.2-1. Studies approved or approved with modifications in FERC's Study Plan Determination.

No.	Study	Approved by FERC in SPD without Modifications	Approved by FERC in SPD with Modifications
1	Recreation Access and Safety Assessment		X
2	Cultural Resources Study		X
3	Fish Passage Barrier Assessment		X[1]
4	Fish Passage Facilities Alternatives Assessment		X
5	Fish Habitat and Stranding Assessment below La Grange Dam		X
6	Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River	X[2]	

[1] Page A-1 of Appendix A of FERC's SPD states that FERC approved with modifications the Fish Passage Barrier Assessment. However, the Districts found no modifications to this study plan in the SPD and page B-7 of the SPD states that "no modifications to the study plan are recommended."
[2] FERC directed the Districts to conduct the study plan as proposed by NMFS.

In addition to the six studies noted in Table 1.2-1, the SPD required the Districts to develop a plan to monitor anadromous fish movement in the Project's powerhouse draft tubes and to determine the potential for injury or mortality from contact with the turbine runners. Per the SPD, the Districts developed a study plan in consultation with NMFS and other LPs. The Districts filed the Investigation of Fish Attraction to La Grange Powerhouse Draft Tubes study plan with FERC on June 11, 2015, and on August 12, 2015, FERC approved the study plan as filed.

This study report describes the objectives, methods, and results of the Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River being implemented by the Districts in accordance with FERC's February 2, 2015 SPD. Documents relating to the Project licensing are publicly available on the Districts' licensing website at www.lagrange-licensing.com/.

1.3 Study Plan

FERC's February 2, 2015 Study Plan Determination for the La Grange Project stated that FERC approved as filed NMFS' Request for Information or Study #5 - Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River, dated July 22, 2014.

In its information request, NMFS stated that it was presenting an information request and not a specific study methodology (preferred data collection and analysis techniques, or objectively quantified information). The information presented in this report is responsive to the request by NMFS and is consistent with other studies of the same subject prepared for NMFS in other FERC proceedings.

2.0 STUDY GOALS AND OBJECTIVES

The goals and objectives for this study as provided below are taken from NMFS' study request dated July 22, 2014.

The goal or purpose of this study, as cited by NMFS, is to evaluate the potential effects of the Project and Project-related activities on the degree of reduction or loss in nutrient replenishment to the upper and lower Tuolumne River. The nutrients in question are those that are marine-derived, and then transported and deposited in freshwaters by migrating anadromous fishes. The mass of nitrogen (N) is addressed in this study for simplicity, although carbon and phosphorus are also transported and deposited by returning anadromous salmon.

The information to be obtained is:

(1) An estimate of a range of the historical mass of marine-derived N that was transported annually by Chinook salmon (all runs) to the Tuolumne River. For this study, this is considered to be a historical estimate.

(2) An estimate of the historical mass of marine-derived N that was transported annually by spring-run Chinook salmon to the upper Tuolumne River. For this study, this is considered to be a historical estimate.

(3) An estimate of the current annual mass of marine-derived N transported by fall-run Chinook salmon to the Tuolumne River. This is existing information, for comparison with historical conditions.

(4) An estimate of annual losses, from historical to current levels, of marine-derived N transported by fall-run Chinook salmon to the Tuolumne River. This compares existing conditions with historical conditions.

(5) An estimate of the annual loss, from historical to current levels, of marine-derived N to the upper Tuolumne River. This compares historical conditions with existing conditions (extirpated spring-run Chinook population).

3.0 STUDY AREA

Based on NMFS' study request (July 22, 2014), the study area includes the upper and lower Tuolumne River. Some components of the study request address estimated historical Chinook salmon escapement to the lower Tuolumne River, while some components address estimated historical Chinook salmon escapement to the upper Tuolumne River, or the combined upper and lower Tuolumne River. According to Yoshiyama et al. (2001), the historical natural upstream limit of anadromous fish is likely to have been Preston Falls on the mainstem Tuolumne River, approximately one mile above the mouth on the North Fork Tuolumne River, while the Middle Fork and South Fork Tuolumne rivers were presumably not used by salmon. Therefore, these are assumed to be the upstream limits of the study area for the purposes of this study. The lower limit of the study area is the confluence of the Tuolumne and San Joaquin rivers.

4.0 METHODOLOGY

4.1 NMFS Request Element #1: Estimate a range of the historical mass of marine-derived N transported annually by Chinook salmon (all runs) to the Tuolumne River

Element #1 of the study requires derivation of three primary variables: (1) estimated historical total annual escapement of all runs of Chinook salmon (i.e., fall-run and spring-run) to the Tuolumne River; (2) estimate of average mass of individual adult Chinook salmon; and (3) estimated average N content per individual fish.

4.1.1 Historical Total Annual Escapement of All Runs of Chinook Salmon (i.e., Fall-run and Spring-run) to the Tuolumne River

In its study request, NMFS (2014) acknowledges that information is not available regarding the actual, pre-European settlement, historical escapement ranges for Chinook salmon in the Tuolumne River.

NMFS (2014) provided references and quotes from some historical accounts for use in the development of this study. Empirical data of historical annual escapement estimates are not available; therefore, some anecdotal accounts must be used to approximate roughly historical quantities. To augment the information provided by NMFS (2014), a literature review was conducted to locate potential historical escapement estimates for spring-run Chinook salmon, as well as for fall-run Chinook salmon and total Chinook salmon escapement to the Tuolumne River. Based on the information provided by NMFS (2014) and this literature review, neither of which identified actual counts, the following methods were developed to provide a rough approximation of historical spring-run Chinook salmon, fall-run Chinook salmon and total Chinook salmon escapement to the upper Tuolumne River watershed.

4.1.1.1 Estimation of Potential Historical Spring-run Chinook Salmon Escapement to the upper Tuolumne River

Review of available literature did not reveal any readily available estimates of historical escapement of spring-run Chinook salmon specific to the Tuolumne River. Three anecdotal accounts of spring-run Chinook salmon escapement to the Tuolumne River were identified through the literature review. Each of these anecdotal accounts is addressed below in three different approaches to develop rough approximations of historical spring-run Chinook salmon escapement to the Tuolumne River.

First Approach

NMFS (2014) provided the following information.

> *"The former spring salmon run of the San Joaquin River has been described as one of the largest Chinook salmon runs anywhere on the Pacific Coast, possibly in the range of 200,000 to 500,000 spawners annually (CDFG 1990, in Yoshiyama et al. 2001, p. 91). It*

> *is not clear what proportion of this estimated run was contributed by the Tuolumne River, the largest San Joaquin tributary."*

The proportional distribution of reported historical habitat used by spring-run Chinook salmon in the upper San Joaquin River and the major tributaries to the San Joaquin River (Stanislaus, Merced and Tuolumne rivers) was used in an effort to allocate the above-referenced total annual spring-run Chinook salmon escapement among the San Joaquin River and its tributaries, including the Tuolumne River. Yoshiyama et al. (2001) provides information regarding the potential upstream extent of salmon passage and habitat utilization in the various rivers, but little information regarding the downstream extent. Given that spring-run Chinook salmon historically ascended their natal streams into the upper portions to hold and spawn, for this study it is generally assumed that the lower boundary of historical spawning habitat was located in the reaches above existing impassible dams.

Yoshiyama et al. (2001) reports that spring-run Chinook salmon in the mainstem Tuolumne River historically were most likely restricted to below Preston Falls, located four miles above Early Intake near the boundary of Yosemite National Park (about 50 miles upstream of the existing Don Pedro Dam). Steep reaches and natural impediments in the Clavey River and the South and Middle forks of the Tuolumne River just above their mouths most likely prevented passage of adult Chinook salmon, suggesting that spring-run Chinook salmon did not utilize the South or Middle forks of the Tuolumne River (T. Ford, personal communication, as cited in Yoshiyama et al. 2001), nor the Clavey River. In the North Fork Tuolumne River, a 12-foot waterfall approximately one mile upstream of the mouth reportedly also likely limited upstream access to salmonids (Yoshiyama et al. 2001). Therefore, it is assumed that access by spring-run Chinook salmon to the upper Tuolumne River Basin was primarily limited to approximately 50 miles of the mainstem Tuolumne River upstream of the existing Don Pedro Dam, and approximately one mile of the North Fork Tuolumne River. Overall, Yoshiyama et al. (2001) estimates that a total of about 52 miles of the historically available 104 miles remain available to Chinook salmon in the Tuolumne River.

In the upper San Joaquin River, Yoshiyama et al. (2001) reports that spring-run Chinook salmon historically ascended past the present site of Kerckhoff Power House to upstream spawning grounds (CFGC 1921b, as cited in Yoshiyama et al. 2001). Although a natural barrier shortly upstream of Willow Creek near present-day Redinger Lake may have obstructed passage of Chinook salmon (E. Vestal, personal communication, as cited in Yoshiyama et al. 2001), there is reportedly evidence that Chinook salmon traveled much further upstream at least to the vicinity of present-day Mammoth Pool Reservoir. Although Yoshiyama et al. (2001) estimate that a total of 173 miles were historically available to spring-run Chinook salmon in the upper San Joaquin River, based on accounts of historical spring-run Chinook salmon adult holding and spawning in the San Joaquin River (Yoshiyama et al. 2001), spring-run Chinook salmon appear to have primarily utilized the Friant area and areas upstream for holding and spawning. Therefore, for the purposes of this analysis, it is assumed that approximately 55 miles were historically available to spring-run Chinook salmon spawning in the upper San Joaquin River (i.e., RM 267 (Friant Dam) upstream to RM 322 (Mammoth Pool Reservoir)).

Yoshiyama et al. (2001) provides additional information on the potential historical distribution of spring-run Chinook salmon in the Stanislaus and Merced rivers. One ethnographic account stated that on the Middle Fork Stanislaus River, salmon went upstream as far as a waterfall at Baker's Bridge (Barrett and Gifford 1933 in Yoshiyama et al. (2001)), located about two miles below present-day Beardsley Reservoir. The practical upstream limit of historical salmon distribution on the North Fork Stanislaus River is McKay's Point (about eight miles above the confluence with the Middle Fork). Yoshiyama et al. (2001) found no suggestions of salmon having occurred in the South Fork Stanislaus River, and do not include it as a former salmon stream. Overall, Yoshiyama et al. (2001) estimates that a total of about 66 miles of the historically available 124 miles remain available to Chinook salmon in the Stanislaus River. Yoshiyama et al. (2001) also estimates that a total of about 56 miles of the historically available 107 miles remain available to Chinook salmon in the Merced River.

A rough approximation of spring-run Chinook salmon escapement to the upper Tuolumne River can be made assuming that: (1) the San Joaquin river system, including the upper San Joaquin, Stanislaus, Merced and Tuolumne rivers, may have produced from 200,000 to 500,000 spring-run Chinook salmon annually; (2) historical densities of spawning spring-run Chinook salmon were proportionally distributed among the upper San Joaquin River and major tributaries to the lower San Joaquin River; and (3) spring-run Chinook salmon spawning habitat generally was located in the reaches above existing impassible dams. Based on Yoshiyama et al. (2001), approximately 55, 66, 56 and 52 miles were historically available to Chinook salmon in the upper portions of the upper San Joaquin, Stanislaus, Merced and Tuolumne rivers. Applying these lengths of habitat as proportions of the total length (229 miles) of habitat in the upper portions of these rivers, the Tuolumne River could have experienced historical maximum annual returns ranging from about 45,000 to 114,000 spring-run Chinook salmon.

Second Approach

Regarding spring-run Chinook salmon historical escapement, NMFS (2014) stated that Moyle (2002) suggested that spring-run Chinook salmon in the upper San Joaquin River probably exceeded 200,000 fish at times, and further stated that "*it is likely that an equal number of fish were once produced by the combined spring runs in Merced, Tuolumne, and Stanislaus Rivers. However, early historical population levels were never measured*." (p. 260).

Based on Moyle's (2002) statement, for this study we used a historical estimate of 200,000 spring-run Chinook salmon as a combined annual run to the Stanislaus, Merced and Tuolumne rivers. Using the same methodology employed in the first approach, a rough approximation of spring-run Chinook salmon escapement to the upper Tuolumne River can be made. Based on Yoshiyama et al. (2001), approximately 66, 56 and 52 miles were historically available to Chinook salmon in the upper portions of the Stanislaus, Merced and Tuolumne rivers, respectively. Applying these lengths of habitat as proportions of the total length (174 miles) of habitat in the upper portions of these rivers, the Tuolumne River might have potentially experienced historical maximum annual returns approximating 60,000 spring-run Chinook salmon.

Third Approach

According to Reynolds et al. (1993), large runs of salmon in the San Joaquin River near Fresno during the 1940s were predominantly spring-run Chinook salmon. They stated that Chinook salmon total production (ocean harvest plus spawning escapement) in the San Joaquin River drainage historically approached 300,000 adults but probably averaged nearer 150,000 adults. Although no direct reference to spawning escapement was specifically made by Reynolds et al. (1993), a rough approximation of escapement contribution to total production can be made using information presented in the Final Restoration Plan for the Anadromous Fish Restoration Program (AFRP) (USFWS 2001). Information provided in USFWS (2001) for the major tributaries of the San Joaquin River indicated that for the doubling goal baseline period (1967-1991), spawning escapement in the Stanislaus, Merced and Tuolumne rivers averaged 4,800, 4,500 and 8,900 adult fall-run Chinook salmon. For this same period, total production in the Stanislaus, Merced and Tuolumne rivers averaged 11,000, 9,900 and 19,000 adult fall-run Chinook salmon. The percentage of escapement to total production averaged 44 percent, 46 percent and 47 percent, respectively, for a combined average of about 46 percent. Given the absence of information regarding spring-run Chinook salmon, and the lack of applicable data prior to the AFRP doubling goal baseline period, as a surrogate for this study we applied this average percentage of escapement to total production for fall-run to the major tributaries of the San Joaquin River.

Based on Reynolds et al. (1993) statement, for this approach we used a historical approximation of 69,000 (150,000 x 46 percent) to 138,000 (300,000 x 46 percent) of spring-run Chinook salmon as a combined annual run to the San Joaquin river system, including the upper San Joaquin, Stanislaus, Merced and Tuolumne rivers. Using the same methodology employed in the previous approaches, approximately 55, 66, 56 and 52 miles were historically available to Chinook salmon in the upper portions of the upper San Joaquin, Stanislaus, Merced and Tuolumne rivers. respectively. Applying these lengths of habitat as proportions of the total length (229 miles) of habitat in the upper portions of these rivers, the Tuolumne River could have experienced historical maximum annual returns approximating 16,000 to 31,000 spring-run Chinook salmon.

Based on the approximations of potential historical spring-run Chinook salmon annual escapement to the Tuolumne River discussed above, the Tuolumne River may have experienced maximum annual runs associated with the three different approximation approaches as follows:

- 45,000 to 114,000
- 60,000
- 16,000 to 31,000

4.1.1.2 Estimation of Historical Fall-run Chinook Salmon Escapement to the Tuolumne River

Review of available literature did not reveal any available estimates of historical escapement of fall-run Chinook salmon to the Tuolumne River prior to about 1940. As reported by Yoshiyama et al. (2001), historical fall-run Chinook salmon spawning escapements in the Tuolumne River during some years were larger than in any other Central Valley streams except for the mainstem Sacramento River, reaching as high as 122,000 spawners in 1940 and 130,000 in 1944 (CDFG 1946; Fry 1961, both as cited in Yoshiyama et al. 2001). According to NMFS (2014), Reynolds et al. (1993) stated that the Tuolumne River historically supported up to 12 percent of the total fall-run Chinook salmon spawning escapement in the Central Valley. Fisher (1994) developed historical (i.e., pre-1900) maximum Chinook salmon run-specific estimates for the Central Valley, including up to approximately 900,000 fall-run Chinook salmon. If it is assumed that maximum historical fall-run Chinook salmon escapement to the Central Valley was 900,000, and the Tuolumne River supported 12 percent of this escapement, then up to a maximum of approximately 108,000 fall-run Chinook salmon may have historically returned to the Tuolumne River. Based on this approximation, as well as the peak estimates reported for 1940 and 1944, for the purposes of this study, up to approximately 108,000 to 130,000 fall-run Chinook salmon may have historically returned annually to the Tuolumne River.

4.1.1.3 Estimation of Historical Chinook Salmon (all runs) Escapement to the Tuolumne River

Based on the approximations of potential maximum historical spring-run and fall-run Chinook salmon annual escapement to the Tuolumne River discussed above, the Tuolumne River may have experienced maximum annual Chinook salmon runs (spring- and fall-run combined) associated with the three different approximation approaches as follows:

- 153,000 to 244,000
- 168,000 to 190,000
- 124,000 to 160,000

Hence, in order to address study Request Element #1 (Estimate a range of the <u>historical</u> mass of marine-derived N transported annually by Chinook salmon (all runs) to the Tuolumne River), a range of historical annual escapement from about 124,000 to 244,000 will be used in the calculations.

4.1.2 Average Mass and Nitrogen (N) Content of Individual Adult Chinook Salmon

NMFS (2014) stated that a 10 kilogram (kg) (22 lbs) average mass for adult Chinook salmon and a 5.62 percent average N content per fish should be applied to the calculation method provided in Merz and Moyle (2006), which is described as follows.

Transport of N = *nut%t* x *SW* x *SP*

where *nut%* is the average percentage of N, *SW* is the average mass of an adult Chinook salmon, and *SP* is Chinook salmon escapement.

4.1.2.1 Average Mass of Individual Adult Chinook Salmon

Presumably, NMFS obtained the average Chinook salmon mass of 10 kg (22 lbs) from Merz and Moyle (2006), who also calculated estimates of marine-derived nutrients using this mass. Merz and Moyle (2006) include Moyle (2002) as a citation for the use of 10 kg (22 lbs) as an average mass for adult Chinook salmon in California. Moyle (2002) generally states that spawning Chinook salmon have a mass of 9-10 kg (19.8-22 lbs). However, Moyle (2002) also states that late fall-run Chinook salmon are the largest run of salmon in California, commonly with a mass of 9-10 kg (19.8-22 lbs). Moyle (2002) does not provide a mass specifically for fall-run or spring-run Chinook salmon. Therefore, a mass of 19.8-22 lbs potentially could be somewhat high for fall-run Chinook salmon.

The use of 10 kg (22 lbs) for an average adult Chinook salmon returning to the Tuolumne River may be an overestimation, particularly if the focus of this analysis is on marine-derived nutrients associated with historical Chinook salmon escapement. Review of Yoshiyama et al. (1998) indicates that Chinook salmon commercially caught in the Central Valley and San Francisco Bay during the mid- to late-1800s were variously reported to average 12-23 lbs (i.e., 5.4-10.4 kg), with an average weight of approximately 16 lbs (i.e., 7.3 kg).

In order to address study Request Element #1 (Estimate a range of the historical mass of marine-derived N transported annually by Chinook salmon (all runs) to the Tuolumne River), a range of the average mass of an adult Chinook salmon from 12 lbs (5.4 kg) to 23 lbs (10.4 kg) will be used in the calculations.

4.1.2.2 Average Nitrogen (N) Content Per Individual Fish

NMFS (2014) appears to have obtained the 5.62 percent average N content per fish from Merz and Moyle (2006), who reported that the average N content of Mokelumne River Chinook salmon carcasses and eggs that they sampled was 5.62 percent. This percentage of N was based on 26 Chinook salmon eggs collected from a spawning bed in the Mokelumne River and only nine Chinook salmon adults, including one hatchery-origin adult captured by angling in the Mokelumne River, and four post-spawned Chinook salmon collected from the Mokelumne River Fish Hatchery. It was not noted whether a difference in N content would occur between hatchery-origin and naturally produced Chinook salmon.

The 5.62 percent average N content per fish may be somewhat high, based on a review of additional sources, which indicates that percentage N of adult Pacific salmonids may be more in the range of approximately 2.5-3.0 percent. For example, Larkin and Slaney (1997) reported average N content of Pacific salmon carcasses, which included Chinook, coho, pink, sockeye and chum salmon, of 3.04 percent N. However, Merz and Moyle (2006) point out that species such as sockeye (*0. nerka*) have different dietary requirements than those of Chinook salmon, and that trophic level can have a significant effect on the distribution of N isotopes in animals. Nonetheless, Stansby and Hall (1965, as cited in Ashley and Slaney 1997) reported that salmon carcasses are approximately 3.0 percent N (wet weight), although species-specific composition was not referenced. Greene (1926) reported that wet muscle percentage N content of Chinook salmon was found to be 2.50 percent at sea, 2.70 percent at the “tide water” prior to the spawning run, and 2.30 percent while adults were on the spawning grounds. Kohler et al. (2013) applied the percent wet mass contents of 3.04 percent N reported by Larkin and Slaney (1997) to adult Chinook salmon in Idaho. Kohler et al. (2013) acknowledged potential spatial and temporal variation in the proximal composition of N in Chinook salmon adult populations, but stated that the values used in their analyses (e.g., 3.04 percent N) accurately represent Chinook salmon N concentrations in general.

To address study Request Element #1 (Estimate a range of the historical mass of marine-derived N transported annually by Chinook salmon (all runs) to the Tuolumne River), a range of the average N content of an adult Chinook salmon from 2.30 percent to 5.62 percent will be used in the calculations.

4.2 NMFS Request Element #2: Estimate the historical mass of marine-derived N transported annually by spring-run Chinook salmon to the upper Tuolumne River

In order to address study Request Element #2 (Estimate the historical mass of marine-derived N transported annually by spring-run Chinook salmon to the upper Tuolumne River), a range in the maximum annual runs associated with the three different escapement estimation approximation approaches discussed above will be used in the calculations. These ranges are:

- 45,000 to 114,000
- 60,000
- 16,000 to 31,000

A range of the average mass of an adult Chinook salmon from 12 lbs (5.4 kg) to 23 lbs (10.4 kg) will be used in the calculations.

A range of the average N content of an adult Chinook salmon from 2.30 percent to 5.62 percent will be used in the calculations.

The calculations will use the formula:

Transport of N = nut% x SW x SP

where nut% is the average percentage of N, SW is the average mass of an adult Chinook salmon, and SP is Chinook salmon escapement.

4.3 NMFS Request Element #3: Estimate the current annual mass of marine-derived N transported by fall-run Chinook salmon to the Tuolumne River

NMFS (2014) requested that the current annual escapement of fall-run Chinook salmon be used to estimate the current annual mass of marine-derived N transported to the Tuolumne River. NMFS requested that current annual escapement be characterized by the recent peak and 10-year

(2001-2010) average Tuolumne River fall-run Chinook salmon escapement estimates. However, CDFW has updated escapement estimates as of April 15, 2015 with estimates extending through 2014. Thus, a more recent 10-year period of fall-run Chinook salmon escapement to the Tuolumne River extends from 2005 through 2014. Consequently, to comply with NMFS' (2014) request, current annual escapement characterized by the recent peak and 10-year average for both time periods (2001-2010 and 2005-2014) will be used in the calculation of transport of marine-derived N.

As shown in Table 4.3-1, the peak escapement over the 2001-2010 period was 8,782 (in 2001), and the average 10-year escapement was 2,261 fall-run Chinook salmon. By contrast, if the more recent 10-year average of fall-run Chinook salmon escapement is used (i.e., 2005-2014), peak and average escapement are both considerably lower (1,926 and 655, respectively).

In order to address study Request Element #3 (Estimate the current annual mass of marine-derived N transported by fall-run Chinook salmon to the Tuolumne River), four different escapement values will be utilized in the calculations. These values are:

- 8,782 (peak 2001-2010)
- 2,261 (avg. 2001-2010)
- 1,926 (peak 2005-2014)
- 655 (avg. 2005-2014)

Table 4.3-1. Tuolumne River fall-run Chinook salmon escapement during 2001-2010 and during 2005-2014.

2001 - 2010		2005 - 2014	
Year	**Escapement**	**Year**	**Escapement**
2001	8,782	2005	668
2002	7,173	2006	562
2003	2,163	2007	224
2004	1,984	2008	388
2005	668	[2009]	124
2006	562	[2010]	540
2007	224	[2011]	893
2008	388	[2012]	783
[2009]	124	[2013]	1,926
[2010]	540	[2014]	438
Average	**2,261**	**Average**	**655**

Data reported for 2009 through 2014 are preliminary estimates.
Source: CDFW 2015.

A range of the average mass of an adult Chinook salmon from 12 lbs (5.4 kg) to 23 lbs (10.4 kg) will be used in the calculations.

A range of the average N content of an adult Chinook salmon from 2.30 percent to 5.62 percent will be used in the calculations.

The calculations will use the formula:

Transport of N = nut% x SW x SP

where nut% is the average percentage of N, SW is the average mass of an adult Chinook salmon, and SP is current fall-run Chinook salmon escapement.

4.4 NMFS Request Element #4: Estimate the annual losses, from historical to current levels, of marine-derived N transported by fall-run Chinook salmon to the Tuolumne River

Study Request Element #4 involves the subtraction of estimates of marine-derived N transported to the Tuolumne River by fall-run Chinook salmon under recent conditions, from estimates of historically transported marine-derived N.

As described in Section 4.1.1.2, for the purposes of this study, up to approximately 108,000 to 130,000 fall-run Chinook salmon may have historically returned annually to the Tuolumne River. Thus, these two values represent a range in the maximum annual runs of fall-run Chinook salmon historically returning to the Tuolumne River and will be used in the calculations. As described in Section 4.3, four different escapement values will be utilized in the calculations to characterize estimates of marine-derived N transported to the Tuolumne River by fall-run Chinook salmon under recent conditions.

The range in values used to characterize both historical and current escapements of fall-run Chinook salmon to the Tuolumne River will be used in the calculations, along with a range in the average mass of an adult Chinook salmon (12 to 23 lbs) and a range of the average N content of an adult Chinook salmon (2.30 percent to 5.62 percent).

Each calculation will use the formula:

Transport of N = nut% x SW x SP

where nut% is the average percentage of N, SW is the average mass of an adult Chinook salmon, and SP is historical and current fall-run Chinook salmon escapement.

For each of the resultant permutations, estimates of existing marine-derived N transported to the Tuolumne River by fall-run Chinook salmon will be subtracted from estimates of historically transported marine-derived N.

In addition, although not presented as a request element, in its study request NMFS stated that the information to be obtained included an estimate of the annual loss, from historical to current levels, of marine-derived N to the upper Tuolumne River. This equates to the results of Request Element #2. This compares historical conditions with existing conditions (extirpated spring-run Chinook population).

5.0 RESULTS

Results of this study are provided below by study element, as described in NMFS' July 22, 2014 study request, consistent with FERC's February 2, 2015 Study Plan Determination for the La Grange Project.

5.1 NMFS Request Element #1: Estimate a range of the historical mass of marine-derived N transported annually by Chinook salmon (all runs) to the Tuolumne River

Consistent with the methodology and NMFS' (2014) study request, the transport of N is estimated using the calculation method provided in Merz and Moyle (2006), which is described as follows.

> Transport of N = *nut%* x *SW* x *SP*
>
> where *nut%* is the average percentage of N, *SW* is the average mass (lbs) of an adult Chinook salmon, and *SP* is Chinook salmon escapement.

As specified in the methodology (above), ranges of various parameters will be used in the calculations including:

- A range of historical annual escapement of Chinook salmon (all runs) to the Tuolumne River from 124,000 to 244,000 fish.
- A range of the average mass of an adult Chinook salmon from 12 lbs (5.4 kg) to 23 lbs (10.4 kg).
- A range of the average N content of an adult Chinook salmon from 2.30 percent to 5.62 percent.

Application of the calculation method results in the estimated historical mass of marine-derived N transported annually by Chinook salmon (all runs) to the Tuolumne River ranging from 34,000 to 315,000 lbs.

5.2 NMFS Request Element #2: Estimate the historical mass of marine-derived N transported annually by spring-run Chinook salmon to the upper Tuolumne River

As specified in the methodology (above) the estimated historical annual escapement of spring-run Chinook salmon to the upper Tuolumne River ranged from 16,000 to 114,000 fish.

Using the ranges of the average mass of an adult Chinook salmon and the average N content of an adult Chinook salmon specified above, application of the calculation formula results in the estimated historical mass of marine-derived N transported annually by spring-run Chinook salmon to the upper Tuolumne River ranging from 4,400 to 147,000 lbs.

Although not presented as a Request Element, NMFS stated in its study request that the information to be obtained included an estimate of the annual loss, from historical to current levels, of marine-derived N to the upper Tuolumne River. This equates to the results of Request Element #2. This compares historical conditions with existing conditions (extirpated spring-run Chinook population).

5.3 NMFS Request Element #3: Estimate the current annual mass of marine-derived N transported by fall-run Chinook salmon to the Tuolumne River

As specified in the methodology (above), there are four different values used in the calculations to estimate current annual escapement of fall-run Chinook salmon to the Tuolumne River. The estimated historical mass of marine-derived N transported annually by fall-run Chinook salmon to the Tuolumne River, associated with these four different values and using the ranges of the average mass of an adult Chinook salmon and the average nitrogen (N) content of an adult Chinook salmon specified above, are presented below.

Estimated Escapement	Low Value of Mass (12 lbs) and N Content (2.30 percent)	High Value of Mass (23 lbs) and N Content (5.62 percent)
▪ 8,782 (peak 2001-2010)	2,400	11,400
▪ 2,261 (avg. 2001-2010)	600	2,900
▪ 1,926 (peak 2005-2014)	500	2,500
▪ 655 (avg. 2005-2014)	200	800

The current annual mass of marine-derived N transported by fall-run Chinook salmon to the Tuolumne River across the estimated escapements above ranges from 200 to 11,400 lbs.

5.4 NMFS Request Element #4: Estimate the annual losses, from historical to current levels, of marine-derived N transported by fall-run Chinook salmon to the Tuolumne River

Request Element #4 involves the subtraction of estimates of marine-derived N transported to the Tuolumne River by fall-run Chinook salmon under recent conditions, from estimates of historically transported marine-derived N.

As described Section 4.1.1.2, an estimated range of 108,000 to 130,000 maximum annual runs of fall-run Chinook salmon may have historically returned annually to the Tuolumne River, and are used in the calculations. Also, as described in Request Element #3, four different values (see above) are utilized in the calculations. This results in 16 different combinations (Table 5.4-1). The estimated range of differences in mass of marine-derived N transported annually by fall-run Chinook salmon to the Tuolumne River, for all combinations from historical to current escapement levels, are presented below.

Table 5.4-1. The estimated range of differences in mass of marine-derived N transported annually by fall-run Chinook salmon to the Tuolumne River, for all combinations from historical to current escapement levels. The specific differences result from the highlighted cells. Low value of N is defined as calculations using a mass of 12 lbs and N content of 2.30 percent. High value of N is defined as calculations using a mass of 23 lbs and a N content of 5.62 percent.

Historical Conditions		Current Conditions		Historical - Current Difference
Low Value of N (lbs)	High Value of N (lbs)	Low Value of N (lbs)	High Value of N (lbs)	Value of N (lbs)
29,800	168,000	2,400 (peak 2001-2010)	11,400 (peak 2001-2010)	27,400
29,800	168,000	600 (avg. 2001-2010)	2,900 (avg. 2001-2010)	29,200
29,800	168,000	500 (peak 2005-2014)	2,500 (peak 2005-2014)	29,300
29,800	168,000	200 (avg. 2005-2014)	800 (avg. 2005-2014)	29,600
29,800	168,000	2,400 (peak 2001-2010)	11,400 (peak 2001-2010)	18,400
29,800	168,000	600 (avg. 2001-2010)	2,900 (avg. 2001-2010)	26,900
29,800	168,000	500 (peak 2005-2014)	2,500 (peak 2005-2014)	27,300
29,800	168,000	200 (avg. 2005-2014)	800 (avg. 2005-2014)	29,000
29,800	168,000	2,400 (peak 2001-2010)	11,400 (peak 2001-2010)	165,600
29,800	168,000	600 (avg. 2001-2010)	2,900 (avg. 2001-2010)	167,400
29,800	168,000	500 (peak 2005-2014)	2,500 (peak 2005-2014)	167,500
29,800	168,000	200 (avg. 2005-2014)	800 (avg. 2005-2014)	167,800
29,800	168,000	2,400 (peak 2001-2010)	11,400 (peak 2001-2010)	156,600
29,800	168,000	600 (avg. 2001-2010)	2,900 (avg. 2001-2010)	165,100
29,800	168,000	500 (peak 2005-2014)	2,500 (peak 2005-2014)	165,500
29,800	168,000	200 (avg. 2005-2014)	800 (avg. 2005-2014)	167,200

The difference from historical to current escapement levels in the annual mass of marine-derived N transported by fall-run Chinook salmon to the Tuolumne River is estimated to range from 18,400 to 167,800 lbs.

6.0 DISCUSSION AND FINDINGS

The goal or purpose of this study request from NMFS dated July 22, 2014 is to evaluate the degree of reduction or loss in marine-derived nutrient replenishment to the upper and lower Tuolumne River. Although carbon and phosphorus are transported and deposited by returning anadromous salmon, the study request only addressed the mass of N. This study report met the goal or purpose of the NMFS study request, and provided all of the information that NMFS requested be obtained in the conduct of this study.

The information that NMFS requested included estimates of the historical mass of marine-derived N that was transported annually by Chinook salmon (all runs) to the Tuolumne River, as well as that which was transported by spring-run Chinook salmon to the upper Tuolumne River. That information was requested in order to try to estimate annual losses, from historical to current levels, of marine-derived N transported by fall-run Chinook salmon to the Tuolumne River, in addition to losses to the upper Tuolumne River transported by spring-run Chinook salmon.

The goal of the study request, as well as the specific information requested by NMFS, is dependent upon estimates of annual escapement of historical populations of spring-run and fall-run Chinook salmon to the Tuolumne River. However, in its study request, NMFS acknowledges that actual counts of salmon runs are not available regarding the historical escapement ranges for Chinook salmon in the Tuolumne River for pre-European settlement. Although NMFS provided references and quotes from some historical accounts, empirical data of historical annual escapement estimates are not available. Consequently, historical annual escapement estimates, and resultant estimates of marine-derived N, are highly speculative. The speculative nature of the estimates and necessary assumptions in the estimation methodology are reflected in the extremely broad range of the results.

In addition to the speculative nature of historical annual escapement estimates, current escapement estimates of fall-run Chinook salmon to the Tuolumne River are influenced by numerous non-Project related factors. A few of these include ocean conditions (e.g., annual variability in coastal upwelling and food availability), Bay-Delta conditions, harvest practices (e.g., commercial and sport fishing), historical and current industrial development, downstream water uses, habitat impacts, invasive species and predation by non-native fish. Consequently, differences between historical and current escapement estimates, and associated estimates of marine-derived N, cannot be completely attributed to the Project. Because of the speculative nature of historical annual escapement estimates and the influence of numerous non-project-related factors, use of the information provided in this study report should be undertaken in a very cautious manner.

7.0 STUDY VARIANCES AND MODIFICATIONS

The February 2, 2015 FERC Determination (pg. 2) states that…."*Of the eight requested studies by relicensing* [sic] *participants, one is approved as filed and seven are not required*". That one study request, filed by NMFS, was Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River. FERC recommended that "*the Districts conduct this NMFS study as recommended*" (B-17). Although FERC determined that the study request was approved as filed, and that the study be conducted as recommended by NMFS, FERC's Determination included an additional study item titled "*compare the difference of marine-derived nitrogen incorporated into periphyton and aquatic benthic macroinvertebrates collected in the upper and lower Tuolumne River*" that was not included in NMFS' July 22, 2014 study request. Because this study item is not included in NMFS' July 22, 2014 study request, and because FERC recommended that the study be conducted as recommended by NMFS, this item is not addressed in this study.

There were no variances or modifications in the implementation of this study. However, this study report provides the information requested by NMFS, with some additional detail in terms of identifying ranges of transported marine-derived N. The February 2, 2015 FERC Determination (pg. 2) states that "… *the Districts may choose to conduct any study, or portion of a study, not specifically required herein that they feel would add pertinent information to the record*." Thus, the additional detail provided in this study report estimating ranges of nutrient transport, adding to that requested by NMFS, is appropriate.

8.0 REFERENCES

Ashley, K.I. and P.A. Slaney. 1997. Accelerating recovery of stream, river and pond productivity by low-level nutrient replacement. Chapter 13 in P.A. Slaney and D. Zaldokas [editors] Fish Habitat Rehabilitation Procedures. Province of B.C., Ministry of Environment, Land and Parks, and Ministry of Forests. Watershed Restoration Technical Circular No. 9.

Barrett, S.A. and E.W. Giifford. 1933. Miwok material culture. Bull Milwaukee Public Mus 2(4):125–277.

California Department of Fish and Game (CDFG). 1946. Division of Fish and Game thirty-ninth biennial report for 1944–1946. Sacramento (CA): California Department of Fish and Game.

_____. 1990. Status and management of spring-run Chinook salmon. Report by Inland Fisheries Division to California Fish and Game Commission. Sacramento (CA): California Department of Fish and Game. 33 p.

California Department of Fish and Wildlife (CDFW). California Central Valley Chinook Population Report (Grandtab). Compiled April 2015.

Fisher, F.W. 1994. Past and present status of Central Valley Chinook Salmon. Conservation Biology, Vol. 8, No. 3. pp. 870-873.

Fry D.H., Jr. 1961. King salmon spawning stocks of the California Central Valley, 1940–1959. California Fish and Game 47(1):55–71.

Greene, C. W. 1926. The physiology of the spawning migration. Physiological Reviews 6: 201-241.

Kohler, A.E., P. C. Kusnierz, T. Copeland, D. A. Venditti, L. Denny, J. Gable, B. A. Lewis, R. Kinzer, B. Barnett, and M. S. Wipfli. 2013. Salmon-mediated nutrient flux in selected streams of the Columbia River Basin, USA. Canadian Journal of Fisheries and Aquatic Sciences 70: 502–512.

Larkin, G.A. and P.A. Slaney. 1997. Implications of trends in marine-derived nutrient influx to south coastal British Columbia salmonid production. Fisheries: 22 (11).

Merz, J.E. and P.B. Moyle. 2006. Salmon, wildlife, and wine: marine-derived nutrients in human-dominated ecosystems of central California. Ecological Applications 16(3):999¬1009.

Moyle, P.B. 2002. Inland fishes of California, revised and expanded. University of California Press, Berkley, California.

National Marine Fisheries Service (NMFS). 2014. NOAA's National Marine Fisheries Service's comments on the Applicant's preliminary application document, comments on the Commission's scoping document 1, and requests for information or study, La Grange Hydroelectric Project, P-14581-000. July 22, 2014.

Reynolds, F.L., T. J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley streams: a plan for action. California Department of Fish and Game.

Stansby, M.E. and A.S. Hall. 1965. Chemical composition of commercially important fish of the United States. Fishery Industrial Research 3: 29-46.

United States Fish and Wildlife Service (USFWS). 2001. Final restoration plan for the Anadromous Fish Restoration Program. Prepared for the Secretary of the Interior by the United States Fish and Wildlife Service with assistance from the Anadromous Fish Restoration Program Core Group under authority of the Central Valley Project Improvement Act.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical abundance and decline of Chinook salmon in the Central Valley Region of California. North American Journal of Fisheries Management 18: 487-521.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2001. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179, Volume 1.