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Appendix 6F

Mercury and Methylmercury

This appendix describes the analysis approach, data, assumptions, and analysis results for the Sites Reservoir Project Environmental Impact Report/Environmental Impact Statement (EIR/EIS) analysis of mercury and methylmercury. This includes a description of the conceptual model for mercury and methylmercury, analytical tools, available data, a qualitative analysis discussion, and quantitative model results for the impact analysis. Appendix 6F1, *Mercury and Methylmercury Supplemental Analysis*, describes the approach, data, assumptions, and analysis results of a supplemental sensitivity analysis for the EIR/EIS analysis of mercury and methylmercury.

This appendix is organized into the following three main sections:

- **Section 1: Methodology – S**ummarizes the methods and tools used to assess and quantify effects of the project alternatives on the environment. A description of the qualitative assessment framework, quantitative analysis approach, and relevant water quality criteria are also presented.

- **Section 2: Data and Assumptions –** Describes available data and key assumptions made for the qualitative and quantitative assessments.

- **Section 3: Analysis Results –** Describes results from the qualitative and quantitative assessments and presents tables and figures summarizing these analyses.

6F.1   Mercury and Methylmercury Assessment Methodology

This section describes the overall analytical framework and qualitative and quantitative evaluation methodologies used to assess mercury and methylmercury concentrations associated with the No Project Alternative and four project alternatives. Note that for this EIR/EIS, the term No Project Alternative describes both the No Project Alternative for CEQA and the No Action Alternative for NEPA purposes. The No Project Alternative is also considered to reasonably represent existing conditions for this analysis (Chapter 2, *Project Description and Alternatives*).

This assessment evaluated the potential for the project to increase mercury and methylmercury concentrations in water and methylmercury concentrations in fish tissue in the following four spatial domains:

- Sites Reservoir Project Footprint

- Colusa Basin Drain

- Yolo Bypass

- Sacramento-San Joaquin Delta (Delta)

To the extent possible, mercury concentrations in water and fish tissue for the four project alternatives were compared with concentrations determined for the No Project Alternative in each spatial domain. Any potential increases in mercury or methylmercury concentrations identified for the alternatives, relative to the No Project Alternative concentrations, were

evaluated relative to identified thresholds of significance for the purposes of making CEQA impact determinations and NEPA effect determinations in Chapter 6, *Surface Water Quality*.

Note that this mercury impact assessment differs from the approach used for trace metals. The organisms most sensitive to aqueous trace metals are typically aquatic invertebrates and fish. Thus, water quality standards for most trace metals are based on aqueous concentrations and are protective against adverse effects over relatively short-term exposures (i.e., hours to days). Mercury exposures and effects differ from those of most trace metals. Mercury bioaccumulates in the aquatic food web and poses the greatest risk to human health and aquatic-dependent wildlife that consume fish. Thus, impairment listings are driven by concentrations in fish tissues rather than concentrations in surface waters. Mercury bioaccumulation occurs over time (e.g., months) and average fish tissue mercury concentrations or average surface water concentrations, rather than maximum surface water concentrations, are appropriate for assessing mercury impacts.

6F.1.1   Objectives

Specific objectives for this assessment were to determine the following for project alternatives, relative to the No Project Alternative.

- Potential for changes in water column mercury and methylmercury concentrations.

- Potential for changes in fish tissue methylmercury concentrations.

- Determine whether alternative-driven increases in water and fish tissue mercury and methylmercury concentrations would cause human health or fish and wildlife adverse effect thresholds to be exceeded more often and by greater magnitudes, relative to threshold exceedances determined for the No Project Alternative.

- Determine whether the frequency and magnitude of fish tissue effect threshold exceedances for the four project alternatives would be sufficiently greater, relative to that determined for the No Project Alternative, that one or more alternative(s) would substantially increase the health risks to wildlife (including fish) or humans consuming fish and other aquatic organisms from the assessment areas.

6F.1.2   Key Components of the Qualitative Assessment

Factors that affect how mercury (including methylmercury) moves through the environment, and subsequent uptake into the aquatic food web, are complex and subject to site-specific conditions. Thus, information learned from one location may not be applicable at another location and local environmental conditions that change over time can result in changes to mercury fate and transport at each site. Quantitative geochemical fate and transport models for mercury and fish tissue uptake models are not widely applicable; although, site-specific fish tissue uptake models have been developed based on local data. The Central Valley Regional Water Quality Control Board mercury model relies upon the relationship between methylmercury concentrations in surface water and in fish tissues of the Sacramento-San Joaquin Delta and Yolo Bypass (Central Valley RWQCB 2010a). Sediment methylmercury concentrations, organic content, and grain size is considered in modeling mercury in fish tissue concentrations in Sierra Nevada streams (Alpers et al. 2016).

This mercury assessment relied upon a conceptual model describing mercury fate and transport to describe how predicted or modeled flows within the receiving waters, and the proposed Sites Reservoir, could affect mercury concentrations in water and fish tissue in each of the spatial domains assessed. A limited quantitative assessment was also conducted for the Delta and Yolo Bypass using the Central Valley RWQCB (2010a) model.

Four project alternatives were considered and compared to the No Project Alternative. The following alternatives have detailed descriptions in Chapter 2, *Project Description and Alternatives*).

- Alternative 1A – Reservoir capacity of 1.5 million acre-feet (MAF) and conveyance through the Dunnigan Pipeline to the Colusa Basin Drain. The inundated area would be 13,200 acres and the maximum reservoir elevation would be 498 feet above mean sea level.

- Alternative 1B (Preferred Alternative) – Reservoir capacity of 1.5 MAF and conveyance through the Dunnigan Pipeline to the Colusa Basin Drain. Bureau of Reclamation funding partner (up to 7%) would allocate 91,000 acre-feet with operational exchanges. The inundated area and the maximum reservoir elevation would be the same as Alternative 1A.

- Alternative 2 – Reservoir capacity of 1.3 MAF and conveyance through the Dunnigan Pipeline to the Sacramento River with partial discharge to the Colusa Basin Drain. The inundated area would be 12,600 acres and the maximum reservoir elevation would be 482 feet above mean sea level.

- Alternative 3 – Reservoir capacity of 1.5 MAF and conveyance through the Dunnigan Pipeline to the Colusa Basin Drain. Bureau of Reclamation funding partner (up to 25%) would allocate 375,000 acre-feet with operational exchanges. The inundated area and the maximum reservoir elevation would be the same as Alternatives 1A and 1B.

6F.1.2.1 Mercury Criteria and Objectives

Elemental mercury and the much more bioavailable methylated form, methylmercury, are of statewide concern in California. Mercury is a neurotoxin that causes a range of effects in people from tingling sensations and the loss of muscle control to birth defects and death. The environmental concentrations of water column mercury and methylmercury are typically below concentrations causing direct acute and chronic effects to aquatic organisms. However, because mercury is bioaccumulative, the primary exposure pathway is through the diet and it poses the greatest risk to wildlife and to human health due to the consumption of fish. Water column and fish tissue-based water quality criteria and objectives been promulgated/adopted but fish tissue methylmercury concentrations are the most relevant indicator of exposure and are more reliable indicators of the potential for adverse effects to humans and wildlife. Mercury is almost entirely present as methylmercury in fish tissues.

Table 6F-1 presents applicable water quality criteria and objectives for mercury and methylmercury. The lowest water quality criteria are based on concentrations protective of human health for direct consumption of mercury in water and for the consumption of mercury in fish or shellfish. Human health fish consumption advisories are often associated with mercury contamination.

The lowest applicable water column criterion for mercury is the 50 ng/L total recoverable mercury CTR criterion. This criterion is intended for the protection of aquatic life but may not be sufficiently protective of human health and wildlife consuming large fish (Central Valley RWQCB 2010a).

Current and/or potential fish tissue methylmercury concentrations in the Colusa Basin Drain and Sites Reservoir Footprint spatial domains were compared to the SWRCB (2017a) sport fish objective of 0.2 mg/kg wet weight, or the 0.05 mg/kg prey fish objective if tissue mercury concentration data were not available from trophic level-4 (TL4) fish. These objectives are applicable to waterbodies outside of the Delta and Yolo Bypass. Tissue concentrations in the Delta and Yolo Bypass were compared to the Central Valley RWQCB methylmercury TMDL tissue concentration goal of 0.24 mg/kg, wet weight, for TL4 fish (Central Valley RWQCB 2010a). The Central Valley RWQCB fish tissue objective is based on fillets normalized to 350-mm total length largemouth bass and is protective of health effects in wildlife and human health when the TL4 objective is met. Mercury tissue concentrations normalized to 350 mm largemouth bass corresponds with the 0.08 mg/kg objective in TL3 fish. Therefore, meeting the TL4 objective is protective of all listed beneficial uses in the Delta (Central Valley RWQCB 2010a). The objective for small TL2 and TL3 fish is protective of wildlife species that consume small fish less than 50 mm in length can be evaluated if no TL3 or TL4 species data are available. It is appropriate to standardize concentrations by length at each location to facilitate comparisons and because of the well-established positive relationship between fish length and age and tissue mercury concentrations (Alpers et al. 2008).

Table 6F-1. Applicable Water Quality Criteria and Objectives for Mercury and Methylmercury.

National Recommended Water Quality Criteria (USEPA 2022)	To protect freshwater species (as dissolved mercury)		CMC = 1.4 µg/l
			CCC = 0.77 µg/l
	To protect saltwater species (as dissolved mercury)		CMC = 1.8 µg/l
			CCC = 0.94 µg/l
	To protect human health [1]		0.3 mg/kg [2]
CTR – California Toxic Rule (USEPA 2000)	To protect human health (as total mercury)	Consumption of water + organism	0.050 µg/l
		Consumption of organism only	0.051 µg/l
Central Valley RWQCB TMDL (2010b)	To protect human health and wildlife	trophic level 4 fish	0.24 mg/kg [2]
		trophic level 3 fish	0.08 mg/kg [2]
	To protect wildlife	whole fish <50 mm in length.	0.03 mg/kg[3]
SWRCB (2017a)	To protect human health and wildlife	Sport fish objective	0.2 mg/kg [2,4]
	To protect wildlife	Prey fish objective	0.05 mg/kg [5]

Notes:

[1] For the consumption of organisms only and based on a total consumption 0.0175 kg fish and shellfish per day.

[2] Methylmercury in edible muscle tissue of fish (wet weight).

[3] Methylmercury in whole fish (wet weight).

[4] 12-month average concentration, measured in trophic level 3 (150-500 mm) or trophic level 4 (200-500 mm) fish and is applicable to the highest tropic level in the waterbody.

[5] Methylmercury in whole fish (wet weight) of any species 50-150 mm total length (applicable if there are no trophic level 4 fish to evaluate the sport fish objective).

6F.1.2.2 *Conceptual Models for Methylmercury Production and Fish Tissue Bioaccumulation*

In this section, conceptual models for methylmercury production, bioaccumulation, and effects are described for each of the spatial domains. Drivers and mechanisms affecting methylmercury production and bioaccumulation are similar among some, but not all of the spatial domains. Therefore, the qualitative analysis of mercury will consider differences in the sources and drivers within each spatial domain. Mercury conceptual models are based on the sequential processes by which mercury fate and transport affect the conversion of mercury to methylmercury and subsequent uptake into the fish tissues. There is a potential to affect human health or aquatic life when all of the following conditions exist.

- Mercury is present in a source(s).

- Mercury becomes methylated in water and/or sediment.

- Mercury bioaccumulates in biota, including fish tissue.

- Humans and/or wildlife may exhibit health effects due to exposure (primarily via diet) above adverse effect threshold levels.

Mercury sources can include historical mercury or gold mining activities, atmospheric deposition, and soils and sediments containing mercury. Runoff from mercury mines contain mercury in the various forms of cinnabar (mercury sulfide; HgS), which is virtually insoluble in water and not readily converted to methylmercury. In contrast, runoff from legacy gold mines in the Sierra Nevada mountains contains elemental mercury used in the extraction of gold, which is much more readily converted to methylmercury. The most transformable form of mercury in a waterbody is from atmospheric deposition directly onto the reservoir surface. This atmospheric deposition contains the highest proportion of reactive mercury $(Hg(II)R)$[1] which is highly susceptible to methylation and is subsequently incorporated into the food web (SWRCB 2017b). The form of mercury is a critical factor determining how much mercury is methylated; although, all of these forms can be converted to methylmercury under the right conditions, or if weathering changes it from one form to another.

Mercury methylation is a process where mercury is converted into an organometallic methylmercury cation (CH_3Hg^+). This form is most easily incorporated into biological tissues. The methylation process is affected by many factors, including the following.

- Physical/chemical factors: temperature, pH, redox potential, organic carbon (amount of and type), dissolved oxygen/redox, salinity, nutrients, sulfate/sulfides, suspended sediment,

[1] This is the most available portion of the oxidized form of total inorganic mercury (Hg^{+2}) (Alpers et al. 2008).

sediment grain size distribution, presence of other ions, mercury speciation, inorganic mercury sources, and demethylation rates.

- Biological factors: microbial communities, electron donor and acceptor abundance for microbial communities.

- Hydrodynamic factors: wetting/drying cycles or reservoir water fluctuations, stratification, turbulence affecting sediment resuspension, residence time, water depth.

Methylation of mercury occurs primarily in anoxic environments. Anaerobic sulfate-reducing bacteria at the sediment-water interface are primarily responsible for mercury methylation in aquatic systems. Iron-reducing bacteria also do this to a lesser degree. Mercury methylation occurs under anoxic conditions in sediments, flooded shoreline soils, and to a lesser degree in the water column (SWRCB 2017b, Alpers et al. 2008). Mercury is tightly bound to insoluble metal oxides under oxic conditions, but under anoxic conditions it is released and forms iron and manganese hydrous oxides. Increased methylmercury is also associated with wetting and drying cycles. This is likely due to oxidation of organic matter and sulfate under dry conditions. The oxidized materials fuel bacterial sulfate reduction once the soils are wetted and anoxia sets in after a few days (SWRCB 2017b).

Sulfate concentrations can also affect methylmercury production because the majority of mercury methylation is a byproduct of metabolic sulfate reduction. The presence of sulfide in anoxic sediments will produce dissolved mercury-sulfides that are easily transported across the cell-membranes of sulfate reducing bacteria. However, too much sulfide will inhibit methylation. If sulfide concentrations are too high they will form polysulfide complexes that are less bioavailable for uptake by bacteria.

Demethylation can also occur as part of biotic or abiotic processes. Microbes can demethylate mercury, and in some cases this mercury is once again available to be methylated. The primary abiotic process is photodemethylation, in which exposure to light causes the mercury to demethylate. Mercury can also volatilize from the water column into the air.

Methylmercury that diffuses into the water column can enter the bottom of the food web via phytoplankton and zooplankton or be exported downstream. Bioaccumulation of mercury in biota is another complex process affected by many factors, including: methylmercury concentrations in water and sediment, species present and trophic level (i.e., their position in the food web), organism size, population abundance, the nature of the local food web, habitat, and exposure. Bioaccumulation refers to the build-up of mercury in the tissues of an organism. This occurs when more mercury is taken in than can be removed (i.e., excreted). Methylmercury concentrations in organisms also increase from simpler to more complex organisms (e.g., from lower to higher trophic levels) in a process called biomagnification. Methylmercury uptake into algae occurs passively through diffusion and concentrations can be 100,000 times higher in algae than in surface water (Gorski et al. 2008, Pickhardt and Fisher 2007, Gorski et al. 2006, Mason et al. 1996). Concentrations again increase by 2 to 5 times in the invertebrates that consume algae and another 2 to 5 times in fish that consume the invertebrates (Central Valley RWQCB 2010a, Stewart et al. 2008, Peterson et al. 2007, Cabana et al. 1994). Bioaccumulation of methylmercury into fish tissues is almost exclusively through the diet (e.g., Hall et al. 1997).

Methylmercury concentrations in organisms are regulated by a complex series of interactions. Factors that control methylmercury production rates or the transfer of methylmercury through the

food web will have the greatest influence on fish tissue methylmercury concentrations (SWRCB 2017b). In addition to the list of factors affecting methylmercury production above, primary production (i.e., algae growth and abundance – which is affected by climate and nutrients), secondary production (e.g., zooplankton growth and abundance), the number of trophic levels in a food web, fish species, size, age, and diet affect food web transfer. The highest methylmercury concentrations occur in large, old, piscivorous fish (i.e., the top predators). An example of how mercury uptake is subject to site-specific conditions was documented at Clear Lake, CA. Threadfin shad populations collapsed for over a decade in the 1990s before recovering in 2002. The increased shad population drove young of the year largemouth bass to shift form a primarily planktonic diet to a primarily benthic diet. This shift in the bass diet caused their methylmercury tissue concentrations to nearly double (Eagles-Smith et al. 2008).

These mercury methylation and bioaccumulation processes, and the potential of the project to affect any of these "steps", are discussed further in the following conceptual models for each spatial domain.

Sites Reservoir Project Footprint Conceptual Model

The Sites Reservoir will be filled with water diverted from the Sacramento River during periods of high flow and winter storm events. The project will divert water into the Tehama-Colusa Canal Authority Canal at Red Bluff and the Glenn-Colusa Irrigation District Canal at Hamilton City. The maximum combined diversion rate is expected to be 3,900 cubic feet per second (cfs) and most of the diversions would occur in December through March of Wet and Above Normal water years. This would provide flood control benefits associated with reservoir storage.

One unique feature of the Sites Reservoir is that, as an off-stream storage reservoir, most of the water it will contain will not be from the local watershed, but rather from the Sacramento River watershed. Thus, the extent of influence of local watershed/soils via runoff and infiltration processes may be limited, compared to the much higher volume of water imported to the reservoir from the Sacramento River. There is naturally occurring mercury in nearby soils, due to presence of mercury deposits in the coast range, as well as anthropogenic sources that have contributed to atmospheric releases (i.e., burning of coal) and subsequent deposition in soils worldwide. However, there are no legacy mercury mines in the vicinity of Sites Reservoir that would contribute runoff directly into the project. Furthermore, none of the geologic units in the reservoir footprint, nor in the watershed of the Sites Reservoir, are known to contain mercury and do not have the typical characteristics of mercury-bearing rocks. Mercury is generally associated with veins and fractures near recent hot springs or volcanic activity or associated with organic-rich sedimentary rocks. In California, mercury is associated with the Franciscan Formation, and most of the mercury mines in the state are located in this formation. Because these rock types do not occur in the study area, naturally occurring mercury is not expected to be present in the study area (see Chapter 12, *Geology and Soils*). Local inputs from Stone Coral Creek and Funks Creek are also intermittent. Therefore, the majority of mercury inputs will be from atmospheric deposition onto the reservoir surface and from Sacramento River water.

Mercury and methylmercury cycling and biogeochemistry in lakes and reservoirs is a complex process. Mercury in reservoirs can be present in the underlying soils, in water that enters the reservoir through surface or subsurface flow, or from atmospheric deposition. The forms of mercury and their proportions will affect net methylmercury production, as discussed above.

Physical characteristics of lakes and reservoirs, such as depth and shape, affect water temperature and flow patterns within the waterbody. Sites is a relatively large (15,000 acre surface area), deep (approx. 300 ft), and 'v' shaped reservoir that will thermally stratify during the late spring, summer, and early fall. Water temperatures can be uniform throughout the water column and water mixes from the late fall through early spring. Surface temperatures will increase in late spring/summer and a temperature gradient will be established with cooler water below and warmer water near the surface. Water of different temperatures has different density, which will limit mixing between the warmer upper "epilimnion" layer and the lower, colder "hypolimnion" in a condition called stratification. Oxygen in the hypolimnion is depleted due to respiration and organic carbon decomposition. The resulting anoxic conditions stimulate mercury methylation by bacteria. Due to this stratification, reservoir releases from the epilimnion near the surface during the summer are less likely to have elevated methylmercury concentrations than releases from the deeper hypolimnion. A study of the seasonal hydrology and stratification of a reservoir in Oklahoma found that while there was mercury methylation in the anoxic hypolimnion, there was a net sequestering of mercury, and surface water concentrations of methylmercury in the reservoir were lower than in the inflows (Wildman 2016). This was due to infrequent mixing between the epilimnion and hypolimnion. Subsequently, fish and other aquatic life experienced the greatest exposure to elevated methylmercury during large inflows and seasonal mixing events.

Vertical stratification breaks down in the fall as temperatures cool and there is no longer a temperature gradient between upper and lower water layers. Methylmercury accumulated in the hypolimnion will mix throughout the water column during this fall turnover event and will be available for uptake into the food web. Seasonal increases in zooplankton and fish methylmercury concentrations have coincided with turnover at Davis Creek Reservoir in California (Slotton et al. 1995).

Inflows to Sites Reservoir during the winter would contribute to mixing. Inflows from rivers into reservoirs can have a large influence on circulation, as temperature differences and topography may drive these flows downward within the reservoir, displacing bottom waters, and contributing to horizontal and vertical advective mixing (Wildman 2016).

In addition to occurring under low oxygen environments, methylation in sediment and soils is correlated with higher levels of organic carbon. New reservoir inundation can cause higher net methylmercury production in early years after filling, when organic carbon is relatively abundant, than under long-term average conditions. This initial spike in mercury methylation can increase water column methylmercury 2-3 times long-term average concentrations for up to 10 years (Hall et al. 2005; SWRCB 2017b). Increased methylmercury in surface water is expected to be reflected in fish, albeit with a lag-time as mercury is cycled within the food web. Studies suggest that fish tissue mercury concentrations may peak 3-8 years after filling, with concentrations slowly declining to a lower steady-state after 10-35 years (Azimuth 2012, Bodaly et al. 2007, SWRCB 2017b). Although, it should be noted that this temporal scale is largely based on locations in Canada, where the climate differs and the available organic carbon within the new reservoir may have been higher than is expected in the more arid conditions of central and northern California.

The duration and degree to which there will be an initial spike in mercury methylation depends, in part, on the amount of organic carbon in the underlying soils and well as how much organic

material (e.g., trees and shrubs) is inundated when the reservoir fills. Flooding accelerates the decomposition of organic matter and promotes methylating bacteria. A series of experiments performed in experimental lakes in Canada amid the boreal forest showed that methylmercury in waters exported from newly flooded reservoirs increased for two years after initial flooding (Hall et al. 2005). This increase was correlated with levels of organic carbon in the soil at the time of initial reservoir flooding. The methylmercury pulse began to subside in the third year due to net demethylation processes (though not back to background levels). As labile organic carbon was consumed/degraded, and as mercury was exported in reservoir releases, levels of methylmercury dropped (Hall et al. 2005).

Not all methylmercury produced in new reservoirs is immediately transported to the water column or taken up by aquatic organisms. Mercury in aquatic organisms of newly filled reservoirs was not related to the amount of organic carbon content prior to inundation (Hall et al. 2005). Therefore, some of the methylmercury produced in a reservoir can stay in the sediment and not enter the food web. Reservoirs in the Sierra Nevada mountains and foothills have been found to efficiently trap and sequester methylmercury and inorganic mercury, even though the reservoirs themselves enhanced methylation (Slotton et al. 1997, Alpers 2016). For example, Englebright Lake is a net sink and traps about 40% of total mercury inputs to the reservoir.

Mercury accumulated in reservoir sediments is not a good predictor of fish tissue methylmercury (SWRCB 2017b). Inorganic mercury in sediment influences methylmercury production by bacteria and there are weak relationships between sediment inorganic mercury and water column methylmercury among California reservoirs (SWRCB 2017b). The lack of clear relationships is partly because the majority of mercury in sediment or surface water is in the inorganic form and only a small amount of inorganic mercury in sediment is converted, under the right environmental conditions, into bioavailable methylmercury. The complexity of these relationships is further demonstrated by the fact that only half of California reservoirs with anthropogenic sources of mercury had fish tissue mercury above the sport fish tissue target of 0.2 mg/kg (SWRCB 2017b).

As part of the State Water Resources Control Board Statewide Mercury Control Program for Reservoirs, over 70 environmental factors were assessed to determine statistical relationships with fish methylmercury concentrations among reservoirs throughout California (SWRCB 2017b). No single factor explained fish tissue methylmercury concentrations in California reservoirs. Multiple important factors were identified (i.e., ratio of aqueous methylmercury to chlorophyll-a; sediment total mercury concentration; longitude; watershed soil mercury concentration; annual reservoir water level fluctuation; chlorophyll-a concentration; aqueous total mercury; and reservoir depth) and 85% of the variability in fish tissue concentrations was explained by a combination of: 1) the ratio of aqueous methylmercury to chlorophyll-a, 2) aqueous total mercury concentration, and 3) annual reservoir water level fluctuation.

Given the above, effects of the Sites Reservoir Footprint on mercury and methylmercury would result from one or more of the following pathways.

1. Mobilization of mercury in native soil into water, or import of mercury from Sacramento River inflows, and subsequent methylation in the water column, followed by:

    a. export in water to areas downstream, and/or

    b. uptake by pelagic organisms, and/or

c. binding to suspended sediment, followed by settling.

2. Methylation of mercury in native soil or settled suspended sediment to form methylmercury in the sediment, and

   a. subsequent release to the water column (via partitioning and/or resuspension), where it could follow any of 1a, 1b, or 1c, above, or

   b. uptake into benthic organisms, or

   c. degradation/demethylation due to biotic or abiotic factors (which then may be followed by 1a, 1b, or 1c, above).

3. Following 1b or 2b, bioaccumulation and biomagnification within the reservoir can occur primarily through uptake into plankton and then into higher trophic level organisms from their diet.

Colusa Basin Drain Conceptual Model

Releases from Sites Reservoir into the Tehama-Colusa Canal and Glenn-Colusa Canal would occur to a greater degree during periods of relatively low flows (i.e., primarily in dry and critical water years) to address water supply reliability and could assist the CVP and SWP in meeting regulatory flow obligations through exchanges. Discharges may also be to the terminus of Tehama-Colusa Canal at Dunnigan for delivery to the Dunnigan pipeline and subsequently directly to the Sacramento River (Alternative 2), or to the Sacramento River or Yolo Bypass and Delta via the Colusa Basin Drain (Alternatives 1 and 3). Releases intended for the south Delta pumping facilities through the Dunnigan Pipeline would occur primarily during the transfer window (July through November). Increased flows may reduce residence time in the canal and increase water levels in the Colusa Basin Drain, Tehama-Colusa Canal, and the Glenn-Colusa Canal. These increased late summer-fall flows to provide irrigation water will not occur during flood flows and will be contained in the canals.

The Colusa Basin Drain is an unlined engineered drainage canal that drains the majority of Colusa County, both during the irrigation and non-irrigation seasons. Studies have shown that mercury and methylmercury concentration of water in the Colusa Basin Drain are similar to those of the Sacramento River from 1997 to 2003 (Central Valley RWQCB 2010a). The total mercury load from the Colusa Basin drain to the Delta between 1984 and 2003 has been estimated as 2-4% of the total load (Central Valley RWQCB 2010a). Thus, mercury concentrations into, and exports from, the Colusa Basin drain have been considered a minor component of the mercury budgets of its receiving basins (Gray and Pasternack 2016).

Although fish do utilize the Colusa Basin Drain, their abundance is low. Events have occurred in which chinook salmon were observed in large numbers in the Colusa Basin Drain, but this was infrequent. Species present in the Colusa Basin Drain at Knights Landing include the benthic feeding common carp (TL3) and Sacramento Sucker (TL3), and the piscivorous channel catfish (TL4) and crappie (TL4).

Yolo Bypass Conceptual Model

The Yolo Bypass is a flood bypass to divert Sacramento River flow out of the main channel during winter and spring flood events. The Fremont Weir and Sacramento Weir are located on the Sacramento River and can be opened to relieve over 500,000 cfs from the Sacramento River,

protecting property, levees, and other structures from damage. Cache Creek, which flows from Clear Lake, drains through the bypass year-round and in all years. Cache Creek is high in mercury due to historic mercury mining and contamination in the Clear Lake and Cache Creek watershed. The Yolo Bypass receives high levels of mercury from Cache Creek, from legacy mercury mines in the coastal range draining into the Sacramento River, and from the American River where mercury was used as part of the gold mining process in the Sierra Nevada mountains (Alpers et al. 2013).

Land use in the bypass is primarily managed wetlands, both agricultural rice growing and nonagricultural wetlands (of which some are permanently and others seasonally inundated). Seasonal inundation increases methylation rates, as organic matter in recently oxidized soils is correlated with higher methylation rates. The water is relatively shallow, which facilitates temperature increases (and decreases), and the residence time can be high, leading to conditions conducive to methylation. The ratio of the rate of methylation to the rate of demethylation in shallow sediments is higher in warm temperatures than in cooler temperature (SWRCB 2017b).

Studies conducted by the U.S. Geological Survey (USGS) in 2007-2014 investigated mercury and methylmercury in surface water, sediment, pore water, plants, and biota in the Yolo Bypass (Alpers et al. 2013). They made conclusions regarding concentrations and biogeochemical processes in the wetland surface waters, exports of mercury and methylmercury, sediments, and photodegradation. One of the primary findings of this work was the extremely high concentrations of methylmercury in water that was drained from agricultural rice fields.

Both permanently and seasonally inundated floodplains provide excellent habitat value, particularly for rearing juvenile salmon. The Yolo Bypass is also along The Pacific Flyway and hosts numerous special-status wildlife such as giant garter snake, bald eagles, and Swainson's hawks, among others. Studies have shown that juvenile chinook salmon in the Yolo Bypass grow faster than those in the Sacramento River, but also accumulate more methylmercury than fish in the river. Although, fish accumulate less methylmercury in wet years when flow in the Bypass is dominated by Sacramento River water than in most years when Cache Creek is the primary source of flow (Henery et al. 2010).

Delta Conceptual Model

Legacy mining in the headwaters of the Sacramento River watershed is the primary source of mercury to the Delta and Suisun Bay. Over 80% of total mercury flux to the Delta can be attributed to the Sacramento River and Yolo Bypass (Central Valley RWQCB 2010a). The Sacramento River is the primary tributary source of mercury to the Delta in dry years and the proportion of mercury loading from the Yolo Bypass increases in wet years to the extent that it is comparable to that of the Sacramento River.

A conceptual model for mercury transformation and bioaccumulation in the Delta was developed by Alpers et al. (2008). This Delta conceptual model includes linkages between mercury sources, mercury transformation, mercury bioaccumulation, and subsequent exposure and health effects. Transformation refers to the conversion of various mercury species, including elemental mercury, into the most reactive portion, which is mercury in the oxidized form (Hg(II)R), and subsequently to methylmercury, and the corresponding reverse transformations. Methylmercury is transferred between the water-column and bed sediment hydrodynamically and between dissolved and particle-bound phases via physical-chemical partitioning. Some fraction of

methylmercury is taken up into the base of the food web and is then biomagnified up the food web, resulting in the highest concentrations at the top of the food web, generally in piscivorous fish, reptiles, mammals, or birds (Scudder et al. 2009). The single largest increase of methylmercury in the Delta food web occurs between aqueous methylmercury and phytoplankton; although, the rate of bioaccumulation in algae consumers is complicated by the variability in algae community structure and abundance (Alpers et al. 2008). There is an inverse relationship between algae abundance and methylmercury concentrations in zooplankton and fish because the available methylmercury is diluted in algae blooms.

Numerous factors affect the multiple linkages contained within the model, which are common to most if not all aquatic environments. Water and sediment properties that affect virtually all parts of the model include: oxidation-reduction conditions, salinity, nutrients, suspended sediment, major ions and especially levels of sulfate, trace metals, mineralogy, grain size, microbial community, organic carbon, and dissolved oxygen. Factors that affect uptake into the food-web and subsequent bioaccumulation and biomagnification include: species composition, growth rate, density, food web complexity, trophic transfer efficiency, exposure time, food availability and quality, predation, fecundity, habitat/vegetation, and hydrodynamics. Methylmercury photodegradation is also a significant process affecting the mass balance of methylmercury in shallows of the Delta; although, the rates at which this occurs are uncertain (Alpers et al. 2008).

Despite the complexity and numerous factors contributing to mercury methylation in the Delta, the project is not expected to have a substantial effect on many of these factors in this spatial domain. Detectable changes in organic carbon, dissolved oxygen, redox, pH, salinity, and nutrients in the Delta are not expected due to the relatively small proportion of Delta water volume that would be comprised of releases from Sites Reservoir and the distance between Sites and the Delta over which these properties can change. Local habitat within the Delta, such as floodplains, tidal or freshwater marshes, are also not expected to change under each of the project alternatives relative to the No Project Alternative.

6F.1.3 Qualitative Assessment Approach

The qualitative assessment considered the primary factors that could increase or decrease mercury and methylmercury concentrations in each spatial domain due to the project alternatives, relative to the No Project Alternative. CALSIM II modeling results were also reviewed to determine the magnitude and timing of reservoir end-of-month storage and releases and flow conditions under project alternatives. The conceptual model discussion described the mechanisms by which these factors can affect mercury and methylmercury, and the qualitative assessment determined if they are expected to cause a relative increase in mercury or methylmercury in surface waters or fish tissues in each of the spatial domains. If so, the analysis further determined if elevated mercury concentrations projected for the alternatives would be expected to result in increases in fish tissue mercury concentrations of sufficient frequency and magnitude to cause a substantial increase in health risks to humans and wildlife (including fish) consuming fish and other aquatic life from the areas assessed. More specific information about the qualitative assessments for each spatial domain is discussed below.

6F.1.3.1 Sites Reservoir Project Footprint

To the extent possible, this qualitative assessment of Sites Reservoir focused on: 1) the ratio of aqueous methylmercury to chlorophyll-a, 2) aqueous total mercury concentration, and 3) annual

reservoir water level fluctuation as the primary factors driving fish methylmercury concentrations in reservoirs identified by the SWRCB (2017b). Levels of mercury and methylmercury anticipated to be present in the reservoir were estimated, based on similar reservoirs in California and known or suspected sources of mercury to the Sites Reservoir.

This assessment cataloged mercury data and other information from reservoirs in California to compare with the Sites Reservoir in terms of location, size (e.g., surface area and volume), expected reservoir surface elevation fluctuations, mercury sources, and fish species present. Though there is no perfect analog that can be used to model expected project conditions, some inferences can be reasonably drawn based on nearby reservoirs with similar physical characteristics. Expected mercury concentrations were determined for the alternatives based on this analysis but cannot be compared with a No Project Alternative within the reservoir footprint because the Sites Reservoir does not currently exist.

6F.1.3.2   Colusa Basin

The primary ways in which mercury concentrations could become elevated in the Colusa Basin Drain, Tehama-Colusa Canal, or Glenn-Colusa Canal due to the project alternatives are:

1) increased flows at certain times, and

2) potentially increased mercury or methylmercury concentrations from the Sites Reservoir deliveries.

These factors were qualitatively assessed, along with potential mercury and methylmercury inputs from Sites Reservoir deliveries, to determine the potential for changes to mercury and methylmercury concentrations from project alternatives relative to the No Project Alternative.

6F.1.3.3   Yolo Bypass

The primary ways in which mercury and methylmercury concentrations could become elevated in the Yolo Bypass due to the project alternatives are:

1) changes in the timing and magnitude of flows through the Yolo Bypass, and

2) concentrations of mercury and methylmercury in the Sacramento River when it enters the Yolo Bypass that would be available for methylation and/or bioaccumulation.

If the Yolo Bypass were to be used more or less frequently as a flood bypass due to the proposed project or its alternatives, this could affect the loading of mercury and methylation, as well as the exposure of fish to methylmercury within the Yolo Bypass.

To qualitatively assess potential changes in mercury and methylmercury concentrations in the Yolo Bypass due to the alternatives, relative to the No Project Alternative, results of assessments in upstream spatial domains were considered for their potential to elevate mercury and methylmercury concentrations entering the bypass. For example, if increased methylmercury production was expected in an upstream domain, the potential for these increased concentrations to persist downstream to the Yolo Bypass (considering dilution, degradation, etc.) was assessed.

6F.1.3.4   Delta

Primary factors affecting mercury and methylmercury concentrations in the Delta that could change due to the proposed project or its alternatives include:

1) changes in the timing and magnitude of flows in the Sacramento River and through the Yolo Bypass, and

2) concentrations of mercury and methylmercury in Sacramento River and Yolo Bypass flows as they enter the Delta.

To assess changes in the timing and magnitude of flows for each alternative, relative to the No Project Alternative, CALSIM II modeling output of flows for each alternative in the Sacramento River at Freeport and in the Yolo Bypass were analyzed to determine the magnitude and timing of changes. These flows were considered together with historical and/or projected mercury and methylmercury concentrations within the Sacramento River and Yolo Bypass to determine how loading of mercury and methylmercury to the Delta would be expected to change.

To qualitatively assess potential changes in mercury and methylmercury concentrations due to the alternatives, relative to the No Project Alternative, results of assessments in upstream spatial domains were considered for their potential to elevate mercury and methylmercury concentrations entering the Delta. For example, if increased methylmercury production was expected in an upstream domain, the potential for these increased concentrations to persist downstream to the Delta (considering dilution, degradation, etc.) was assessed.

Additional quantitative analysis modeled surface water and fish tissue methylmercury concentrations that could occur in the Delta due to the project alternatives for comparison with the No Project Alternative. These modeling methods are described below.

6F.1.4   Quantitative Assessment Approach

Changes in water column methylmercury concentrations that could contribute to fish tissue concentrations above tissue-based criteria were assessed quantitatively for the Delta using the Central Valley RWQCB (2010a) Total Maximum Daily Load (TMDL) model (RWQCB model).

6F.1.4.1   Regional Board Fish Tissue Model

The RWQCB model is an empirical non-liner tissue concentration model that predicts mercury (assumed to be primarily methylmercury) concentration in 350-millimeter normalized largemouth bass fillet tissue from unfiltered methylmercury concentrations in water (Central Valley RWQCB 2010a). The RWQCB model was based on measured mercury concentrations in water from March to October 2000 and largemouth bass fillet mercury concentrations collected in September/October 2000. The relationship between tissue mercury concentrations averaged over large areas of the Delta (rather than specific locations) compared to average methylmercury concentrations in water for those same areas and time periods (Central Valley RWQCB 2010a) is described by Equation 1:

Fish methylmercury (milligrams/kilogram, wet weight) = 20.365× (methylmercury in water, ng/L)$^{1.6374}$

(where r^2=0.91, and P<0.05)

Largemouth bass are excellent indicators of mercury contamination because they are abundant and distributed throughout the Delta, are a popular sport fish, are a TL4 predatory species (i.e., are piscivorous and so bioaccumulate relatively high level of mercury compared to other species), they live for several years, and tend to stay in the same area (i.e., they exhibit high site fidelity). Consequently, largemouth bass are indicators of long-term average mercury exposure and reflect spatial patterns of tissue mercury concentrations (Central Valley RWQCB 2010a). Modeled fish tissue concentrations provide an estimated mean tissue concentration as would be expected by location and alternative.

6F.1.4.2   Quantitative Analysis for Methylmercury

For this assessment, the Central Valley RWQCB model was used to estimate tissue methylmercury concentrations in 350 mm largemouth bass based on potential water column methylmercury concentrations from the project alternatives. This Delta-specific quantitative model-based analysis determined methylmercury concentrations in 350 mm largemouth bass based on potential methylmercury concentrations discharged from the project, as they would affect methylmercury concentrations in the Sacramento River at Freeport and the Yolo Bypass. The RWQCB Delta model is not applicable to the Site Reservoir Footprint or Colusa Basin Drain spatial domains because mercury uptake is governed by site-specific conditions and this model has not been validated for other spatial domains.

Additional calculations were made, as a sensitivity analysis, to identify the concentrations of water column methylmercury that would need to be discharged from the project to cause a given change (e.g., a 5% increase in water column methylmercury concentrations in the Sacramento River at Freeport). Calculations were based on the proportional flows from the project in the Sacramento River at Freeport and are applicable to the Delta and Yolo Bypass, as determined by CALSIM II. Source water concentrations (i.e., inputs from all sources affecting concentrations at Freeport except for Sites Reservoir) were held constant for the sensitivity analysis. The geometric mean of measured historical water column methylmercury concentrations in the Sacramento River at Freeport (**Table 6F-6**) was used to represent concentrations entering the Delta and Yolo Bypass for the No Project Alternative in this analysis. Varying the potential methylmercury concentrations from the proposed project determined how much change in water column mercury concentration at Freeport would need to be driven by Sites Reservoir discharge to result in specified percent increases in Delta fish tissue mercury concentrations.

This approach used Freeport as an assessment location because the Central Valley RWQCB model is applicable in the Delta. Freeport, located at the northern end of the Delta, would exhibit the net Sacramento River change in methylmercury concentrations due to the project alternatives. At locations further downstream in the Delta, source waters other than the Sacramento River water mix and would lessen any incremental effects from increased concentrations of methylmercury due to the project alternatives. Thus, project effects would be less at other Delta locations further downstream. This approach also allows use of CALSIM II flow data and historical methylmercury concentration data.

For the sensitivity analysis, a mass balance equation considering the mixing of Sites Reservoir water with water from other sources was developed, which is Equation 2:

$$C_P = \frac{Q_S C_S + Q_E C_E}{Q_S + Q_E}$$

where Q_S and Q_E are the flows from Sites and the flows from all other sources at Freeport except Sites, respectively; C_S is the concentration of methylmercury from Sites discharge; C_E is the historical methylmercury concentration at Freeport (which is due to all other sources besides Sites); and C_P is the estimated concentration at Freeport under the project condition. Solving Equation 2 for C_S produces Equation 3:

$$C_S = \frac{C_P(Q_S + Q_E) - Q_E C_E}{Q_S}$$

The RWQCB model can further be applied using C_S at Freeport to estimate fish tissue methylmercury concentration (see next section for details).

This sensitivity analysis quantitatively addressed the following assessment questions.

- What concentrations of methylmercury (i.e., C_S) would need to be discharged from Sites Reservoir to cause a 5% increase in surface water methylmercury in the Sacramento River at Freeport (i.e., 1.05 times C_E)? How much would this change in surface water concentrations affect fish tissue mercury concentrations at Freeport?

This analysis approach represents a simplified model that assumes that fate and transport of methylmercury from Sites Reservoir is conservative – that is, that there is no loss or generation of methylmercury between Sites and Freeport. This is not entirely realistic. Methylmercury can become particulate associated and settle prior to reaching Freeport, it can be incorporated into the food web before reaching Freeport, some may be degraded by light or microbially, and mercury present in Sites Reservoir discharge may be subject to methylation in transit. Whether or not these processes result in more or less methylmercury in surface water at Freeport is unknown but the assumptions allow a reasonable estimate. Therefore, the modeling is not meant to be taken as predictive but to provide insight as to the relative magnitude and direction of changes that may be expected at in the Delta.

6F.2 Data and Assumptions

6F.2.1 Water Column Mercury and Methylmercury Concentrations

Total and dissolved water column mercury concentrations from waterbodies in the assessment area are presented in **Table 6F-4** and **Table 6F-5**, respectively. Total methylmercury from various waterbodies in the assessment area are presented in **Table 6F-6**. Mercury and methylmercury concentrations in reservoirs near the assessment area are presented in **Table 6F-7** and **Table 6F-8**.

6F.2.2 Fish Tissue Methylmercury Concentrations

Fish tissue methylmercury concentrations reported from waterbodies within the assessment area are summarized in **Table 6F-9**. The Central Valley RWQCB (2010a) model uses 350 mm largemouth bass as an indicator species because it represents a predatory fish (TL4) with a high potential for bioaccumulation and this length is in the middle of the typical size distribution caught for mercury analysis at most California reservoirs (Alpers et al. 2008, Central Valley

RWQCB 2010a, SWRCB 2017b). This standardized fish size allows a relative basis for comparing fish tissue mercury concentrations among locations and is relevant to the protection of wildlife and human health. **Table 6F-10** presents methylmercury concentrations in largemouth bass tissues normalized to 350 mm length for reservoirs and lakes in northern California near the proposed project.

Physical characteristics of these reservoirs and lakes are provided in **Table 6F-11**. Reservoirs in the Sierra Nevada mountains or foothills were generally excluded because their influence from elemental mercury in runoff from legacy gold mining is not representative of the conditions for the proposed Sites Reservoir. Although, New Bullards Bar Reservoir and Lake Oroville were included in these descriptions for context. Likewise, Clear Lake has a decommissioned mercury mine on its eastern shore, and is not representative of the conditions expected for Sites. Black Butte Reservoir, Stony Gorge Reservoir, East Park Reservoir, and Indian Valley Reservoir are located on the eastern side of the Coastal Range, west of Sites, and are closest in location and physical environments to the proposed project.

6F.2.3 CALSIM

CALSIM II modeled the flows for each alternative as well as the No Project Alternative. Monthly operations of the SWP/CVP system, approximate changes in storage reservoirs, river flows, and exports from the Delta were simulated in CALSIM II. Inputs describe assumptions of hydrology at projected levels of land and water use, existing and Project facilities, and riverine and Delta regulatory conditions. The model and assumptions are described in Appendix 5A, *Surface Water Resources Modeling of Alternatives*, and Appendix 5B, *Water Resources System Modeling*.

Differences in the magnitude and duration of changes in flows between the alternatives and the No Project Alternative were compared based on output data from CALSIM II.

6F.3 Analysis Results and Discussion

This section discusses the results of analysis and interpretation for making impact determinations / effect determinations in each spatial domain.

6F.3.1 Sites Reservoir Project Footprint

The project itself does not alter the net mercury discharge to the environment. Although, inundation of previously dry soils that may contain mercury, and/or the change in hydrology and hydraulics that the project entails, may alter how much mercury or methylmercury is present as a source within the reservoir or to downstream waterways, and the timing of these discharges.

Water that would enter Sites Reservoir from the Sacramento River at Red Bluff and Hamilton City has geometric mean total mercury concentrations of 1.2 and 1.8 ng/L, respectively, and the 75th percentile concentrations are 1.6 and 2.5 ng/L (Table 6F-4). Mean methylmercury concentrations in the Sacramento River are 0.037 ng/L and 0.061 ng/L at Red Bluff and Hamilton City, respectively, and the 75th percentile concentrations are 0.053 and 0.078 ng/L (Table 6F-6). The primary source of diversion to the Sites Reservoir would be from the Sacramento River at Red Bluff with up to 2,100 cfs, plus losses. Diversions from the Sacramento

River at Hamilton City would be up to 1,800 cfs, plus losses. Considering such losses, CALSIM modeled data indicate that 73% of flow to Sites Reservoir would originate from Sacramento River diversions at Red Bluff and 27% from Hamilton City on an annual average basis. Based on these considerations, reasonable estimates of concentrations expected to enter the Sites Reservoir are from 1.4 to 1.8 ng/L total mercury and from 0.04 to 0.06 ng/L methylmercury based on the mean and 75th percentile source water concentrations.

Additional inputs from local tributaries are expected to be relatively small in comparison to Sacramento River diversions. Funks Creek and Stone Coral Creek, in which flows are intermittent, are expected to contribute negligible mercury loads to Sites Reservoir. The few samples collected in Stone Coral Creek by DWR in 2007 indicate a mean total mercury concentration of 0.85 ng/L and a maximum of 2.3 ng/L. Two samples from Funks Creek in 2006 and 2007 had an average total mercury concentration of 0.35 ng/L and a maximum of 1.2 ng/L.

Because reservoirs are known to be areas in which mercury methylation potential is high, it is anticipated that Sites Reservoir will result in net methylation of mercury – that is, more methylmercury will be generated within the reservoir than will be degraded or lost due to discharges and uptake into biota, at least in the early years after initial inundation. Thus, it is reasonable to conclude that the concentrations of methylmercury within Sites Reservoir will be at least as high as those entering Sites Reservoir from the Sacramento River, and will likely be somewhat higher due to in-reservoir mercury methylation. Comparisons with other nearby reservoirs and lakes can provide insight into the expected mercury concentrations that would occur at Sites Reservoir.

Concentrations of mercury and methylmercury in nearby reservoirs in Northern California are shown in Table 6F-7 and Table 6F-8, respectively. With the exception of Clear Lake, on which the Sulphur Bank Mercury Mine Superfund site is located, mean concentrations of total mercury were not greater than 4.42 ng/L. A maximum concentration of 149 ng/L was reported in 2000 from Indian Valley Reservoir (Slotton et al. 2004). This outlier was one of 13 samples collected approximately monthly in 2000 and 2001 and was nine times higher than the next highest measured concentration (16.7 ng/L); thus, it does not characterize long-term concentrations within this reservoir. None of almost 500 other samples from nearby reservoirs exceeded the 50 ng/L total mercury CTR criterion.

Mean total methylmercury in nearby reservoirs, with the exception of Clear Lake, ranged from 0.011 ng/L in Lake Oroville to 0.093 ng/L in Indian Valley Reservoir, while maximum concentrations are typically in the range of 0.024 in Shasta Lake to 0.31 ng/L in Englebright Lake, with a maximum measured value of 1.41 ng/L in the Thermalito Afterbay (Table 6F-8). Indian Valley Reservoir is the nearest reservoir for which methylmercury data were available and is located approximately 10 miles southwest of Sites Reservoir. This reservoir is 303(d) listed as having impaired water quality due to mercury but is not directly affected by legacy mercury mining (SWRCB 2017b). Although, mercury is enriched in the Cache Creek watershed (Central Valley RWQCB 2004), which includes Indian Valley Reservoir, and concentrations of methylmercury in Indian Valley Reservoir are higher than most others in the dataset (mean 0.093 ng/L, 75th percentile 0.15 ng/L).

Atmospheric deposition will also contribute mercury that would be available for methylation. The potential atmospheric deposition of mercury to Sites Reservoir can be extrapolated from that in nearby reservoirs. Black Butte, East Park, Indian Valley, and Stony Gorge Reservoirs are

located in the coastal range to the immediate west of the project. These reservoirs are not affected by legacy mercury mines and the primary anthropogenic source of mercury to these reservoirs is from direct atmospheric deposition, ranging from 11.7 to 22.4 g/km^2/year (39th to 97th percentiles among 74 California reservoirs) based on REMSAD model estimates (SWRCB 2017b). The relative influence of atmospheric mercury is incorporated into this assessment by making comparisons with reservoirs and lakes of similar size and in the vicinity of the proposed project. Although, these nearby waterbodies and/or their watersheds are affected by atmospheric deposition to a greater degree than Sites Reservoir would, because they are located closer to geothermal power plants (i.e., at the Geysers) representing a hot-spot for atmospheric mercury deposition (SWRCB 2017a). Whereas the Sites Reservoir would be located in an area with relatively lower atmospheric mercury deposition (12 g /km^2/year) based on REMSAD model outputs (SWRCB 2017b). These nearby waterbodies are also not perfectly analogous with the Sites Reservoir morphology. They are all smaller in surface area and maximum storage (Table 6F-11), and surface area to volume ratios are either the same (i.e., Indian Valley Reservoir) or greater than Sites Reservoir (all others). Watershed runoff sources would also differ for the Sites Reservoir which would receive water inputs from the Sacramento River. These differences mean that mercury loads to Sites Reservoir from atmospheric deposition and runoff would be less than in nearby reservoirs, and methylmercury generation in Sites Reservoir would likely be diluted to a greater degree than that in nearby reservoirs; thus, comparisons are conservative.

Inflows to Sites with different temperature and density than reservoir surface water will determine how the inflows are mixed within the reservoir. These relative differences between these waters will change seasonally as temperature and dissolved and suspended solids varies. A typical northern California reservoir is relatively well mixed during the winter and early spring, then becomes stratified in late spring, summer, and early fall and will turnover (i.e., complete vertical mixing) in late fall when temperatures become uniform throughout the vertical water column. The dominance of inflows to Sites during the winter and spring runoff will bring relatively cool and oxygenated surface water that will encourage mixing and reduce mercury methylation. However, it is expected that the reservoir will still thermally stratify in summer through the fall, leading to water at depth that may become depleted of oxygen, which would then be prone to mercury methylation. Due to this stratification, reservoir releases from the epilimnion near the surface during the summer and into fall would be less likely to have elevated methylmercury concentrations than releases from the deeper hypolimnion.

Reservoir fluctuations also contribute to mercury methylation. CALSIM data were used to calculate the annual average fluctuation in reservoir water surface elevation, which was calculated as the maximum water year surface elevation minus the minimum water year surface elevation, for each water year in the CALSIM modeled data set. This was the same approach used by the State Water Resources Control Board Staff in developing data that was used in the statistical analysis of reservoirs for the Statewide Mercury Control Program for Reservoirs (SWRCB 2017b). The CALSIM modeled reservoir elevations for each alternative are shown in

Figure 6F-1. The annual average fluctuations are lowest for Alternative 1A (36 feet) and greatest for Alternative 3 (46 feet). The resulting average annual fluctuation for each alternative was compared to the same parameter for 65 other reservoirs presented in Appendix B of the Statewide Mercury Control Program for Reservoirs, which range from 3.8 ft to 158 ft (median 25 feet). Sites Reservoir annual average fluctuation would range from the 62nd percentile for Alternative 1A and Alternative 2 to the 71st percentile for Alternative 3 (**Table 6F-2**). No

reservoir exists under the No Project Alternative and these fluctuations cannot be compared to a baseline condition. However, comparison to existing reservoirs in California indicates that expected fluctuations are within the ranges reported by other reservoirs and greater than median fluctuations. This suggests that Sites reservoir water level fluctuations will be more favorable to mercury methylation than the typical condition among other California reservoirs.

Table 6F-2. Modeled Mean Annual Long-term Average Minimum and Maximum Surface Water Elevations at Sites Reservoir.

Parameter	Alternative 1A	Alternative 1B	Alternative 2	Alternative 3
Annual Average Maximum Elevation (feet)	458	454	445	446
Annual Average Minimum Elevation (feet)	423	415	408	400
Annual Average Elevation Fluctuation (feet)	36	39	37	46
Annual Average Fluctuation Compared to other Reservoirs (percentile)	62	64	62	71

Estimated Long-term Reservoir Mercury Concentrations

An estimate of the long-term expected average methylmercury concentrations in Sites Reservoir was calculated by doubling the estimated methylmercury concentration determined for average imports from the Sacramento River (i.e., 0.04 ng/L). This estimate of 0.08 ng/L accounts for methylmercury generation within the reservoir and is consistent with the range of methylmercury concentration among nearby reservoirs. With the exception of Clear Lake, this value is slightly less than the maximum long-term average water column methylmercury concentration among nearby reservoirs, which is 0.093 ng/L from Indian Valley Reservoir in 2011 (Table 6F-8). This estimate is also consistent with the existing literature. In assessing the impacts of increasing the size of Muskrat Falls Reservoir in the eastern shield region of Canada, methylmercury fate and transport modeling was conducted that estimated that concentrations in the reservoir would increase about two times baseline concentrations, 10 years after flooding (Harris 2018).

An estimate of the reasonable worst-case long-term methylmercury concentration, determined by doubling the 75th percentile of inflow concentrations, is 0.12 ng/L. The term "reasonable worst-case" is not necessarily the maximum concentration that could occur at Sites. Rather, it refers to an estimated upper bound of the expected average concentration based on the published literature and site-specific conditions. There is inherent uncertainty associated with these estimated concentrations and they may be conservative. For example, Indian Valley Reservoir mean and maximum methylmercury concentrations, to which the estimated long-term average expected and worst-case methylmercury concentrations for Sites are comparable, is within a watershed naturally enriched with mercury while the Sites Reservoir is not as enriched and water entering Sites will be primarily from the Sacramento River instead of from the area surrounding the reservoir.

Total mercury concentrations in Sites Reservoir over the long-term are expected to range between the mean and 75th percentile concentrations entering the reservoir from Sacramento River diversions. Thus, the expected long-term average total mercury concentration is 1.4 ng/L and a reasonable worst-case total mercury concentration is 1.8 ng/L (**Table 6F-3**).

Estimated Short-term Reservoir Mercury Concentrations

Initial mercury and methylmercury concentrations after filling are expected to be higher than average concentrations in the long-term. The magnitude and the duration of this effect will depend on the amount of organic carbon in the underlying soils and how much organic material is inundated when the reservoir fills. Mercury accumulated in the soil from atmospheric deposition is also a source for total mercury in new reservoirs that is released into the water column after the reservoir is inundated, in addition to being a source for methylmercury generation.

In assessing impacts associated with construction of the Site C Reservoir in British Columbia, Canada, methylmercury fate and transport models predicted that methylmercury concentrations would "roughly double" on an annual average basis during the peak period, which was within the first 10 years after flooding (Azimuth 2012). Another study of mercury biogeochemical cycling in three newly inundated reservoirs in the northern boreal forest reported surface water methylmercury outputs ranging from 1.4 to 3.5 times (average of 2.8 times) input concentrations in the first 3 years after flooding of a low carbon reservoir (Hall et al. 2005). Comparisons between total mercury inputs and outputs by Hall et al. (2005) also found total mercury increased 1.3 to 2.4 times (average of 1.7 times) in their low carbon reservoir. It should be noted that the surface area to volume ratios of reservoirs in the study by Hall et al. (2005) were over 30 times greater than the ratio for the Sites Reservoir; thus, initial stores of soil carbon and mercury associated with atmospheric deposition would be diluted to a much greater degree in the Sites Reservoir. Flooded soils of the Hall et al. (2005) low carbon reservoir, where trees and brush were not removed prior to inundation, also had organic carbon ranging from 2.5% to 30% (Calder et al. 2016). This is more carbon than would be in the Sites Reservoir. The Sites Reservoir footprint is located in an area where soil organic carbon is less than 2.5% (U.S. Department of Agriculture 2016). These differences suggest that methylmercury generation in Sites Reservoir would be less than in reservoirs from these studies and using these data to extrapolate conditions that could occur at Sites Reservoir may be conservative. In addition, brush and tree removal prior to Sites Reservoir filling would further minimize internal sources of organic carbon to the reservoir and reduce the potential for methylmercury generation in reservoir sediments. Changes in aqueous total mercury and methylmercury concentrations were also reported to be positively correlated in California reservoirs (SWRCB 2017b).

There are many factors that will affect mercury and methylmercury fate and transport in the Sites Reservoir. However, based on data associated with new reservoirs, a reasonable estimate of expected concentrations in the short-term after filling (i.e., within 1-10 years) is that they will be twice the long-term average expected concentrations (Azimuth 2012; Hall et al. 2005). Estimates of the mercury and methylmercury concentrations in Sacramento River water entering Sites Reservoir serve as the reasonable and worst-case long-term expected concentrations. Thus, 2.8 ng/L is an expected short-term mercury concentration (2 times 1.4 ng/L) and 3.6 ng/L is an estimated short-term reasonable worst-case concentration for total mercury (2 times 1.8 ng/L). Likewise, the short-term methylmercury concentration is expected to be around 0.16 ng/L and the reasonable worst-case short-term concentration is approximately 0.24 ng/L. A summary of estimated mercury and methylmercury concentrations in Sites Reservoir following filling is provided in Table 6F-3.

However, the Berryessa watershed contains what were among the most productive legacy mercury mines in northern California (SWRCB 2017b). Table 6F-10 presents fish tissue concentrations of methylmercury normalized to 350 mm largemouth bass in northern California reservoirs in the vicinity of the proposed project. Fish tissue concentrations in

Lake Berryessa of 0.55 mg/kg ww are roughly in the middle of the reported range (0.16-0.88 mg/kg ww). Table 6F-3. Estimated Concentrations of Total Mercury and Methylmercury in Sites Reservoir.

Estimated Concentration	Short-Term (1-10 years after filling) (ng/L)	Long-Term Average (>10 years after filling) (ng/L)
Expected Total Mercury	2.8	1.4
Reasonable Worst-case Total Mercury	3.6	1.8
Expected Methylmercury	0.16	0.08
Reasonable Worst-case Methylmercury	0.24	0.12

Fish Tissue Methylmercury

Fish tissue methylmercury concentrations within the project will be dependent on many factors, and appropriate reservoir management options to minimize methylmercury accumulation in fish tissues could lead to tissue concentrations comparable with those in existing nearby reservoirs. Table 6F-10 presents fish tissue concentrations of methylmercury normalized to 350 mm largemouth bass in northern California reservoirs in the vicinity of the proposed project. Nearby reservoir fish tissue mercury concentrations range from 0.32 mg/kg ww in the Stony Gorge Reservoir to 0.88 mg/kg ww in Indian Valley Reservoir based on 350 mm normalized largemouth bass (SWRCB 2017b). East Park Reservoir, with a normalized fish tissue mercury concentration of 0.47 mg/kg ww, also falls within this range. Fish tissues collected from East Park and Stony Gorge Reservoirs in 2000-2001 also provide relevant data to forecast conditions at the proposed project (DWR 2007). Largemouth bass from both reservoirs exceeded the 0.2 mg/kg ww sport fish objective (Table 6F-10).

Fish tissue concentrations in Lake Berryessa of 0.55 mg/kg ww are roughly in the middle of the reported range (0.16-0.88 mg/kg ww). Lake Berryessa may represent the closest physical analog to Sites – with a similar surface area, depth, and storage, and located approximately 40 miles south of Sites (Table 6F-11). However, the Berryessa watershed contains what were among the most productive legacy mercury mines in northern California (SWRCB 2017b).

Potential fish species to be stocked into the Sites Reservoir are:

- rainbow trout (*Oncorhynchus mykiss*)
- brown trout (*Salmo trutta*)
- Kokanee salmon (*Oncorhynchus nerka*)
- smallmouth bass (*Micropterus dolomieu*)
- largemouth bass (*Micropterus salmoides*)
- bluegill (*Lepomis macrochirus*)
- green sunfish (*Lepomis cyanellus*)
- channel catfish (*Ictalurus punctatus*)
- brown bullhead (*Ameiurus nebulosus*)

The structure of the food web in Sites Reservoir can be manipulated by fisheries management to minimize mercury bioaccumulation. Actions, such as adjusting predator and prey fish stocking rates, the size of fish stocked, and the species of fish stocked, can potentially lower methylmercury concentrations in fish tissues if based on an understanding of the underlying mechanisms (SWRCB 2017b). Lower trophic level fish (e.g., planktivores and invertivores) and

those that do not grow very big or very old will tend to bioaccumulate less mercury than higher trophic level fish (i.e., piscivores) that are big and live many years. Rainbow trout, brown trout, catfish, bullhead, sunfish, and carp all bioaccumulate less mercury than black bass. Rainbow trout are generally lowest (SWRCB 2017b). The algae community that could develop in Sites Reservoir is not known. Therefore, we can assume algae and other aquatic microorganisms will be similar to those in nearby reservoirs and will contribute to a comparable food web.

Normalized fish tissue methylmercury concentrations among nearby reservoirs are relatively consistent despite their differences in the size, depth, and surrounding mercury sources. Assuming similar fish species and comparable food web structures with these counterparts, a reasonable expected average fish tissue concentration (normalized to 350 mm largemouth bass, ww) is approximately 0.47 mg/kg. This is the median value among reservoirs shown in Table 6F-10 and similar to the mean fish tissue mercury concentration from East Park Reservoir in 2008. A reasonable worst-case fish tissue concentration is the 99th percentile value among these reservoirs of 0.85 mg/kg, which is similar to the mean fish tissue mercury concentrations from nearby Indian Valley Reservoir in 2008. In either case, concentrations would exceed the California sport fish objective of 0.2 mg/kg ww.

Other Reservoirs

Project alternatives could affect storage in Folsom, Shasta, Oroville, or other reservoirs besides Sites, through operational exchanges. Therefore, storage in these other reservoirs was examined to determine if, as an indirect effect of the project, storage changes might result in differing patterns of fluctuations that could increase methylmercury generation in these other reservoirs. Folsom, Shasta, Oroville, as well as other reservoirs evaluated showed no substantial changes in end of month storage for the alternatives relative to the No Project Alternative in all water year types. Thus, mercury and methylmercury dynamics in these reservoirs, as affected by storage levels, are not expected to be affected by the project.

Assessment Summary for the Sites Reservoir Footprint

- Surface water concentrations of total mercury in the Sites Reservoir under each of the project alternatives are expected be similar to source water concentrations of 1.4 to 1.8 ng/L over the long-term (i.e., >10 years), and up to twice as high in the short-term (i.e., up to 3.6 ng/L in the first 10 years). None of these concentrations exceed the CTR criterion of 50 ng/L and they would be within the ranges of mean total mercury concentrations found at other nearby reservoirs.

- Fish tissue methylmercury concentrations in the Sites Reservoir under each of the project alternatives are expected be within the range observed at other nearby reservoirs and lakes where median tissue methylmercury normalized to 350 mm largemouth bass concentrations are approximately 0.47 mg/kg and exceed the 0.20 mg/kg ww sport fish objectives (SWRCB 2017a).

6F.3.2   Colusa Basin Drain

Water column mercury and methylmercury concentrations in the Colusa Basin Drain at Knights Landing are presented in Table 6F-4 and Table 6F-6, respectively. The mean total mercury concentration in surface water from Knights Landing prior to 1998 was 8.6 ng/L and from 1999-2007 was 4.5 ng/L. A maximum reported concentration of 75 ng/L total mercury represents a

storm-water sample collected in January 2003 and was the only one of 92 samples collected between 1996 – 2007 that exceeded the lowest CTR criterion of 50 ng/L. Total mercury discharges from the project are not expected to exceed 3.6 ng/L (Table 6F-3) and the project alternatives would not increase long-term average concentrations in the Colusa Basin Drain relative to the No Project Alternative. Moreover, the project would not cause exceedances of the lowest CTR criterion. Mean methylmercury concentrations in the Colusa Basin Drain at Knights Landing were 0.17 ng/L prior to 1998 and 0.13 ng/L from 2000-2007 (Table 6F-6). These concentrations, representing the No Project Alternative, are greater than the long-term average expected methylmercury concentration (0.08 ng/L) and the long-term reasonable worst case methylmercury concentration (0.12 ng/L) estimated for Sites Reservoir. However, the expected short-term and reasonable worst-case short-term methylmercury concentrations that could be released from the Sites Reservoir (0.16 and 0.24 ng/L, respectively) would potentially exceed long-term average concentrations in the Colusa Basin Drain.

Data for the Tehama-Colusa Canal and the Glenn-Colusa Canal were lacking. Nevertheless, it is assumed for the purpose of this assessment, based on similar water sources and canal morphology, that analyses for the Colusa Basin Drain are applicable to the Tehama-Colusa Canal and the Glenn-Colusa Canal.

As described in the conceptual model above, effects of the proposed project alternatives on the Colusa Basin Drain, Tehama-Colusa Canal, and the Glenn-Colusa Canal could potentially be:

1) increased flows due to releases from the Sites Reservoir, and

2) potentially increased mercury or methylmercury concentrations from the Sites Reservoir deliveries.

Greater flows under each of the alternatives, relative to the No Project Alternative, would originate from the reservoir during the release period. Releases from Sites Reservoir to the Sacramento River and Delta could occur at any time but are more likely to occur during May through November during drier water year types. These increased flows could decrease temperatures in the canals, while slightly increasing depth. It is possible that increased flows would also keep sediments suspended, increasing turbidity and decreasing bed sediments. Increased flows would also occur during low-flow periods and would not cause flooding, a condition that would increase methylmercury production. The Colusa Basin Drain is an engineered water transmission channel and with limited natural habitat which would be conducive to mercury methylation and biological uptake. Mercury concentrations in and exported from the Colusa Basin Drain are considered a minor component of mercury budgets of receiving basins. Therefore, none of the changes anticipated from increased flows would be expected to substantially increase methylmercury concentrations or bioaccumulation within the Colusa Basin Drain, and some may even serve to decrease methylation potential within the canal.

If methylmercury concentrations in the Colusa Basin Drain were to increase somewhat from Sites deliveries, it is unlikely that this would lead to substantial long-term increases in bioaccumulation and fish tissue concentrations. This is because releases to Colusa Basin Drain would not be continuous, mostly occurring during drier months of drier years. Temporary increases in water column methylmercury concentrations may translate to short-term increases of mercury in fish tissues. However, there is a lag-time of several months for these increases to be reflected in fish tissues (SWRCB 2017b). This was demonstrated by a temporary spike in water

column methylmercury in the San Joaquin River of 0.75 ng/L in May of 2006, over baseline levels of approximately 0.15 ng/L, that were reflected in Mississippi silverside tissue concentrations in July. The fish tissue concentrations increased to 0.24 mg/kg and then returned to baseline concentrations of 0.05 mg/kg by September (SWRCB 2017b). This 2 to 3 month lag-time for small fish tissue concentrations to reflect water column methylmercury changes will limit the duration over which fish tissue concentration increases would occur. Fish tissue concentrations might increase in response to a sufficiently long period of elevated methylmercury concentrations, but would also return to baseline concentrations after discharges with elevated water concentrations cease.

Existing fish tissue methylmercury concentrations in the Colusa Basin Drain are presented in Table 6F-9. Channel catfish (TL4) and crappie (TL4) had methylmercury concentrations approaching but not exceeding the California sport fish objective (0.2 mg/kg ww). The sport fish objective applies to the highest trophic level fish in the waterbody. Therefore, it was not exceeded in this waterbody even though maximum tissue concentrations for common carp (TL3) and brown bullhead (TL3) fillets were 0.47 and 0.58 mg/kg ww, respectively.

Assessment Summary for the Colusa Basin Drain

- Surface water concentrations of total mercury in the Colusa Basin Drain (also applicable to the Tehama-Colusa Canal and Glenn Colusa Canal) are expected to be reduced by the project alternatives, relative to the No Project Alternative, and will not cause exceedances of the CTR criterion of 50 ng/L.

- In the short-term after initial reservoir inundation (i.e., 1 – 10 years), and under reasonable worst-cast conditions, average methylmercury concentrations may increase in the Colusa Basin Drain from about 0.13 ng/L up to about 0.24 ng/L due to the project alternatives, relative to the No Project Alternative.

- Fish tissue methylmercury concentrations in the Colusa Basin Drain currently approach the California sport fish objective and may increase by a measurable amount under each of the project alternatives, relative to the No Project Alternative, during the release period, at least over the short-term (i.e., <10 years). Therefore, the alternatives could potentially cause exceedances of the sport fish objective that would result in increased risk for adverse effects to humans and wildlife that consume Colusa Basin Drain fish during these years and months.

- The Colusa Basin Drain is included in the Section 303(d) list as impaired by mercury (SWRCB 2017c). The project alternatives may result in further increases in drain water column and fish tissue mercury concentrations when Sites Reservoir releases would be greatest (generally during May through November of drier years),such that impairments to WARM, COLD, and WILD beneficial uses could be made discernably worse.

6F.3.3 Yolo Bypass

Total mercury concentrations in the Yolo Bypass were reported by the Central Valley RWQCB (2010a) to have a mean concentration of 73.2 ng/L, which exceeds the lowest CTR criterion of 50 ng/L. Exports from Sites entering the Yolo Bypass, with a short-term reasonable worst-case total mercury concentration of 3.6 ng/L, would be lower than this average concentration in the Bypass (Table 6F-4). Likewise, exports from the project with a short-term reasonable worst-case methylmercury concentration of 0.24 ng/L would be less than the mean concentration in the

Yolo Bypass of 0.35 ng/L (Table 6F-6). Also note that this assessment is conservative because releases would be diluted in the Sacramento River prior to entering the Yolo Bypass via the Fremont Weir unless conveyed directly into the Yolo Bypass through the Knights Landing Ridgecut.

Reduced flows entering the Yolo Bypass at the Freemont Weir would occur with all project alternatives, relative to the No Project Alternative, due to diversions to the Sites Reservoir in periods of high flow in the Sacramento River. Thus, reduced flooding is expected in the Yolo Bypass with all project alternatives, relative to the No Project Alternative. A lower frequency and/or intensity of flood conditions would decrease methylmercury formation potential in the Bypass, as lower levels of seasonal inundation and floodplain utilization reduces the amount of soils and sediments available for methylmercury formation to occur.

Releases from the Sites Reservoir intended for the south Delta pumping facilities would primarily occur during the transfer window (July through November) when background flows are typically low. These releases would not cause total Yolo Bypass flows to exceed 1,000 cfs. The Bypass is a 73,000 acre floodplain that receives flows of over 30,000 cfs from multiple sources during flood flows; therefore, exports from the Sites Reservoir would be negligible and would not cause substantial changes in water levels that affect wetting and drying of soils in the Bypass and produce measurable increases in methylmercury.

All TL3 species with tissue mercury concentration data from the Yolo Bypass reported in the California Environmental Data Exchange Network (CEDEN; SWRCB 2020) exceeded the Central Valley RWQCB methylmercury TMDL objective of 0.08 mg/kg ww (Table 6F-9). White crappie, the only TL4 species in the Yolo Bypass with measured mercury tissue concentrations, had a maximum concentration of 0.17 mg/kg ww and did not exceed the TL4 objective of 0.24 mg/kg ww.

Assessment Summary for the Yolo Bypass

- Surface water concentrations of total mercury in the Yolo Bypass are not expected to substantially increase due to the project alternatives, relative to the No Project Alternative, and will not cause exceedances of the lowest CTR criterion of 50 ng/L.

- Surface water concentrations of methylmercury are not expected to substantially increase in the Yolo Bypass due to the project alternatives, relative to the No Project Alternative.

- Fish tissue methylmercury concentrations in the Yolo Bypass exceed the Central Valley RWQCB methylmercury TMDL objectives. The project alternatives are not expected to cause measurable increases in fish tissue mercury concentration relative to the No Project Alternative.

- The Yolo Bypass is included in the Section 303(d) list as impaired by mercury (SWRCB 2017c). Mercury water and fish tissue levels within the Bypass are not expected to be further degraded on a long-term basis due to the project alternatives, relative to levels of the No Project Alternative.

6F.3.4   Delta

Mercury concentrations at Freeport represent a conservative (i.e., worst-case) assessment location for the rest of the Delta. This location is a point of entry into the Delta for Sacramento

River water where the maximum percent of Sites Reservoir discharges would occur, relative to other Delta locations. Delta mercury concentrations associated with the project alternatives in the Sacramento River at Freeport would be diluted by source waters from the San Joaquin River, eastside tributaries, agriculture return waters, and bay water intrusion when in the central, south, and western Delta. Modeled concentrations at Freeport are, therefore, protective of the entire Delta if there is no potential for adverse effects due to project alternatives, relative to the No Project Alternative.

The average concentration of total mercury in the Sacramento River at Freeport is 4.5 ng/L (Table 6F-4). A maximum concentration of 89 ng/L, reported on October 15, 1996, was the only value that exceeded the lowest CTR criterion (50 ng/L) in the available data between 1994 and 2015. Sacramento River concentrations of total mercury returned to typical conditions by the time another sample was collected less than two weeks later (i.e., 4.2 ng/L on October 26, 1996). Sites Reservoir releases, with the short-term reasonable worst-case total mercury concentration of 3.6 ng/L, indicate that expected concentrations would be consistent with or below the historical average total mercury concentration entering the Delta from the Sacramento River.

Long-term average methylmercury concentrations in the Sacramento River at Freeport are 0.069 ng/L (Table 6F-6). Sites releases would be substantially diluted by the Sacramento River when they reach the Delta, but there could be slightly increased methylmercury concentrations based on releases from Sites containing methylmercury concentrations of 0.16 to 0.24 ng/L in the short-term, and 0.08 to 0.12 ng/L in the long-term when concentrations stabilize (Table 6F-3). The effects associated with potential increases in methylmercury concentrations entering the Delta are discussed as part of the quantitative analysis below.

Existing Fish Tissue Mercury Concentrations

Existing fish tissue methylmercury concentrations in the Delta at Freeport and River Mile (RM) 44 are presented in Table 6F-9. Several species of bass (TL4) and Sacramento pikeminnow (TL4) at RM44 exceeded the Central Valley RWQCB Methylmercury TMDL objective of 0.24 mg/kg ww. Splittail (TL3), Sacramento sucker (TL3), and sunfishes also exceeded the TL3 objective of 0.08 mg/kg ww.

 Freeport represents a conservative (i.e., worst-case) assessment location for the rest of the Delta. This is because Sacramento River flows at Freeport are combined and thus diluted with source waters from the San Joaquin River, eastside tributaries, agriculture return waters and bay water intrusion when in the central, south, and western Delta. Modeled concentrations are, therefore, protective of the entire Delta if there is no potential for adverse effects at Freeport due to project alternatives, relative to the No Project Alternative.

Modeled Long-term Average Water Column and Fish Tissues

Central Valley TMDL Model results for water column and fish tissue methylmercury concentrations are presented in **Figures 6F-2 and 6F-3**, respectively, and in **Table 6F-12**. The predicted No Project Alternative methylmercury concentration in 350 mm largemouth bass is 0.26 mg/kg ww based on an exposure concentration of 0.069 ng/L, the long-term geometric mean methylmercury concentration at Freeport. Water column methylmercury at Freeport is estimated to increase by no more than 4% (to about 0.072 ng/L) from the alternatives, on a long-

term average basis, relative to the No Project Alternative (
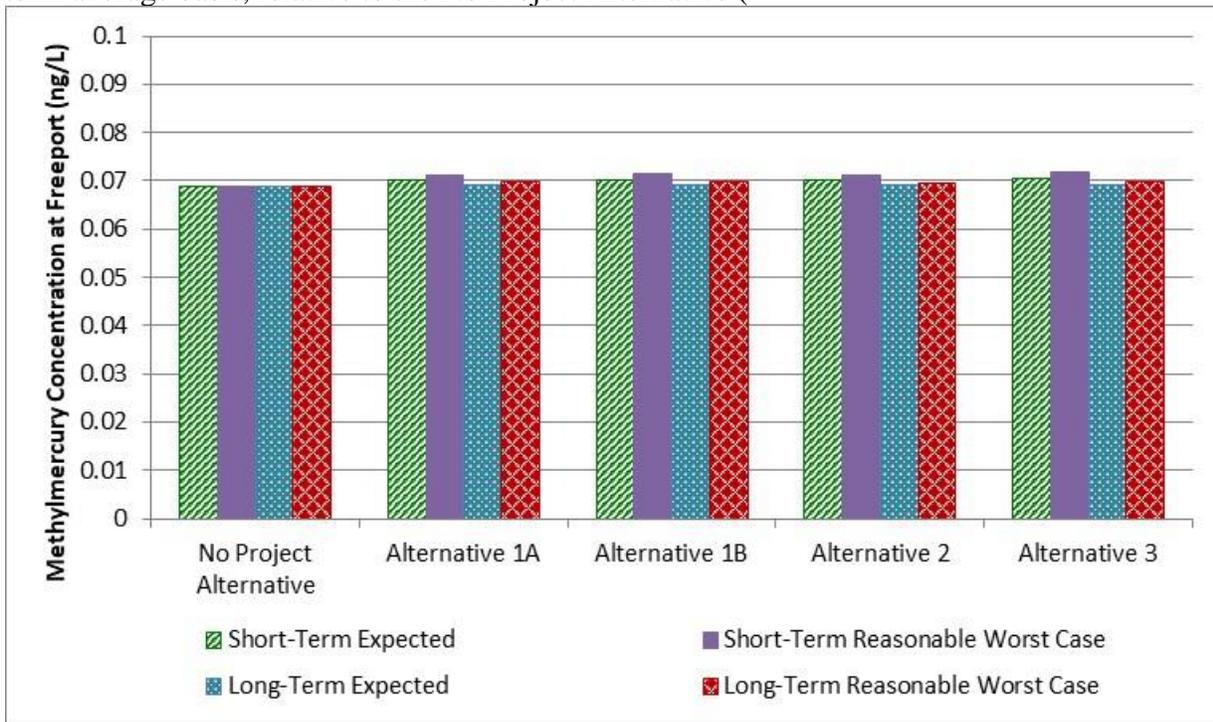
Figure 6F-2). The resulting long-term average fish tissue methylmercury concentrations calculated with the Central Valley RWQCB Model would not increase by more than about 6% (to about 0.27 mg/kg ww) due to the project alternatives, relative to the No Project Alternative (
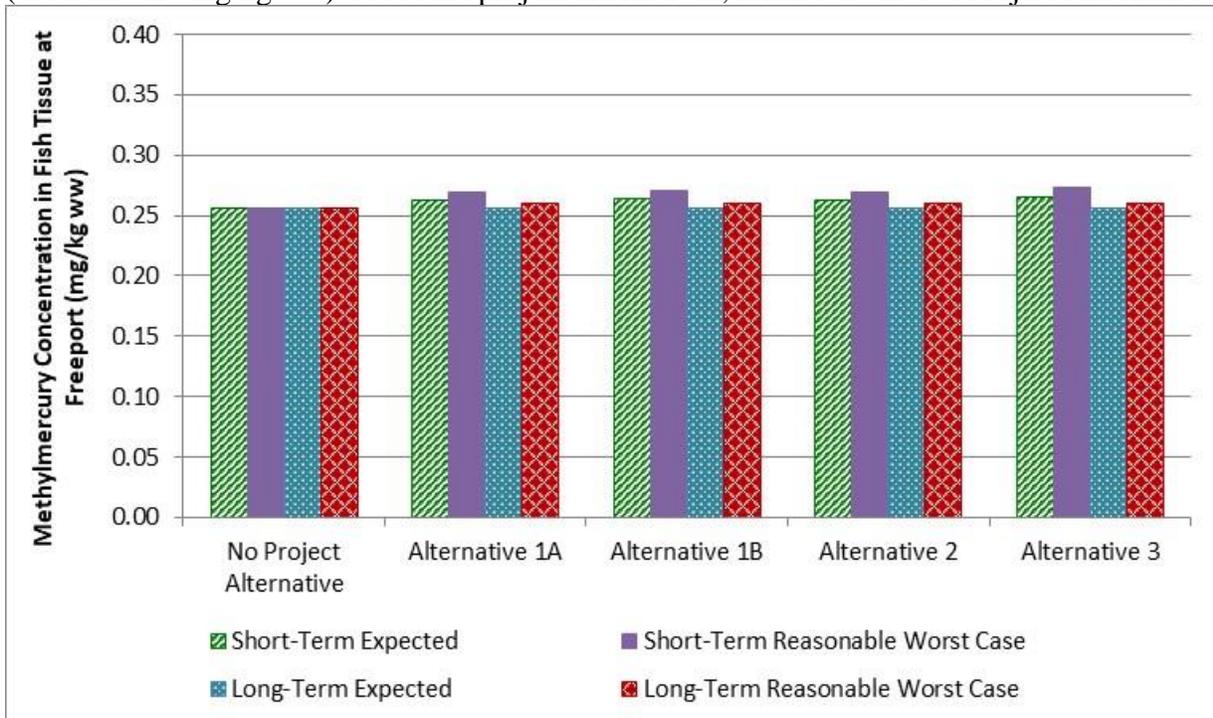
Figure 6F-3). These potential changes associated with project alternatives do not differ substantially from the No Project Alternative. Consequently, the project alternatives are not

expected to result in long-term differences in water column or fish tissue methylmercury concentrations at Freeport, relative to the No Project Alternative, that would be measurable by a typical field monitoring program.

Potential changes in surface water methylmercury concentrations at the Sacramento River at Freeport associated with hypothetical concentrations of mercury in releases from Sites are shown in **Figure 6F-4**. This quantitative sensitivity analysis indicated that Sites discharge would need to have long-term average methylmercury concentrations ranging from about 0.25 to 0.30 ng/L (depending on the alternative) to increase the concentration at Freeport no more than 5% above the historical long-term average, from 0.069 ng/L to about 0.072 ng/L. Such a change in water column concentrations at Freeport would increase in fish tissue methylmercury concentrations by about 7.2% (Table 6F-12 and **Figure 6F-5)**. However, even the reasonable worst-case short-term methylmercury concentration estimated from Sites (i.e., 0.24 ng/L) would not be sufficient to cause this change. Such concentrations would also need to exceed the typical mean water column methylmercury concentrations in reservoirs and lakes in the vicinity of the project (i.e., <0.1 ng/L) to elevate the average concentrations of methylmercury in water at Freeport by 5% over historical average levels (
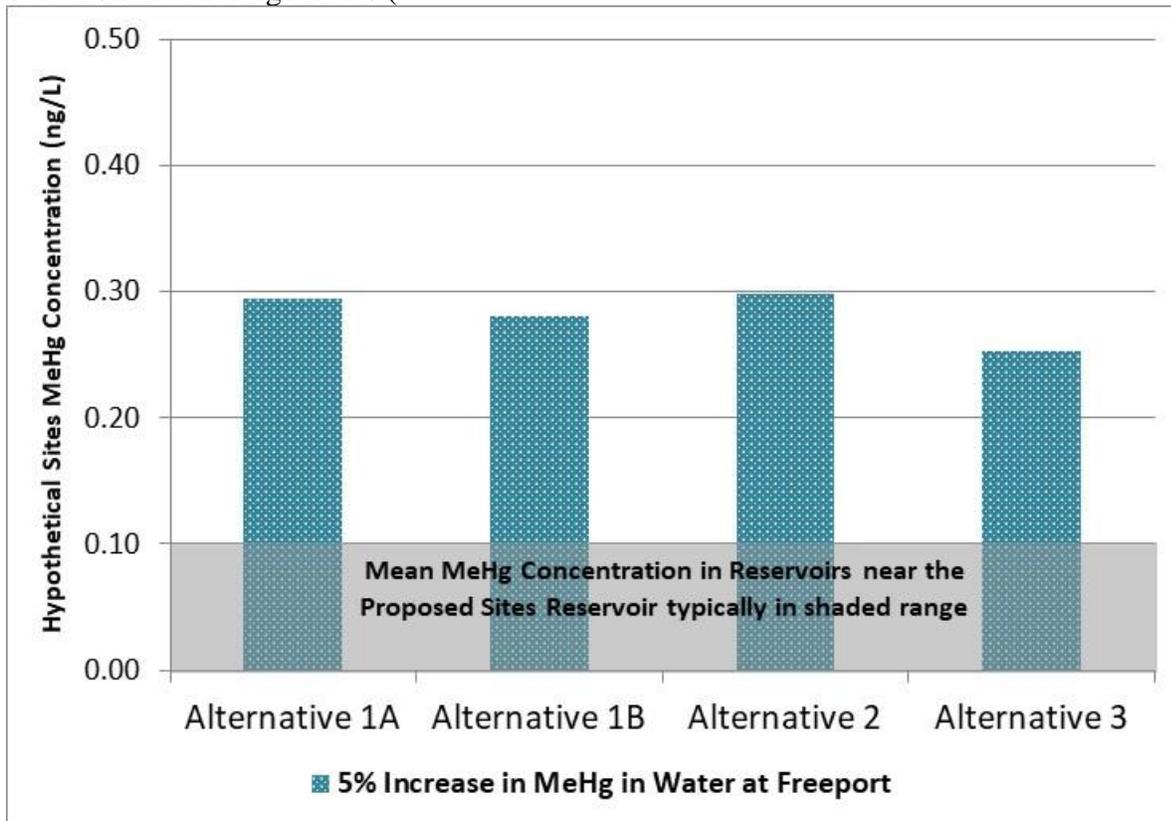
Figure **6F-6**).

Reasonable Worst-case Water Column and Fish Tissues

The preceding analysis is based upon changes in long-term annual average concentrations in the Sacramento River at Freeport. This reflects long-term trends but does not capture the reasonable worst-case conditions that could occur during drought or extended drought conditions. Sites exports to the Delta, or intended for the south Delta pumping facilities, would be greatest during

the summer and fall months of dry and critical years when Sacramento River flows are relatively low. To account for these reasonable worst-case conditions, the quantitative analyses described above were repeated using the mean monthly flows in the Sacramento River at Freeport and exports from the Sites Reservoir in May through November of dry and critical water years, when Sites Reservoir releases would be relatively high (**Table 6F-13**). This seven-month period is sufficiently long that fish tissue methylmercury concentrations could overcome the lag-effect and be affected by changes in surface water methylmercury concentrations. However, the effect could be transient as fish tissue concentrations would return to lower concentrations when surface water concentrations decrease.

Given the lower Sacramento River flows at Freeport under these conditions, and the greater proportion of these flows would be from Sites, there would be a greater effect on the water column mercury and fish tissue mercury concentrations. This sensitivity analysis for dry and critical years found that a 5% increase in surface water methylmercury at Freeport, corresponding with an 7.2% increase in fish tissue methylmercury concentrations, could potentially occur when Sites releases contain approximately 0.11 ng/L methylmercury. Such concentrations would exceed the expected long-term average methylmercury concentration estimated for Sites Reservoir (0.08 ng/L) but do not exceed estimated concentrations expected in the short-term (0.16 ng/L) and the reasonable worst-case concentrations in the short-term and long-term (0.24 and 0.12 ng/L, respectively).

Results of this second quantitative sensitivity analysis performed for the Sacramento River at Freeport are illustrated in
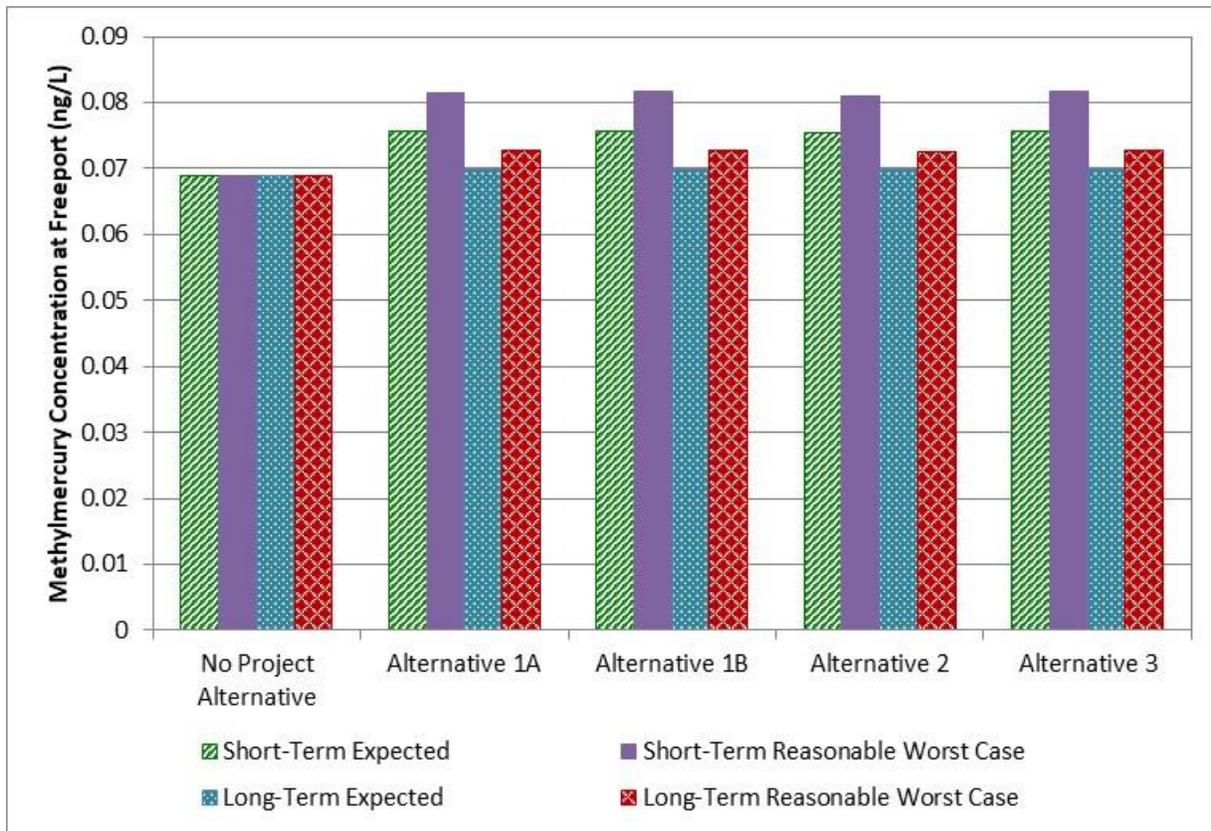
Figure 6F-7 and
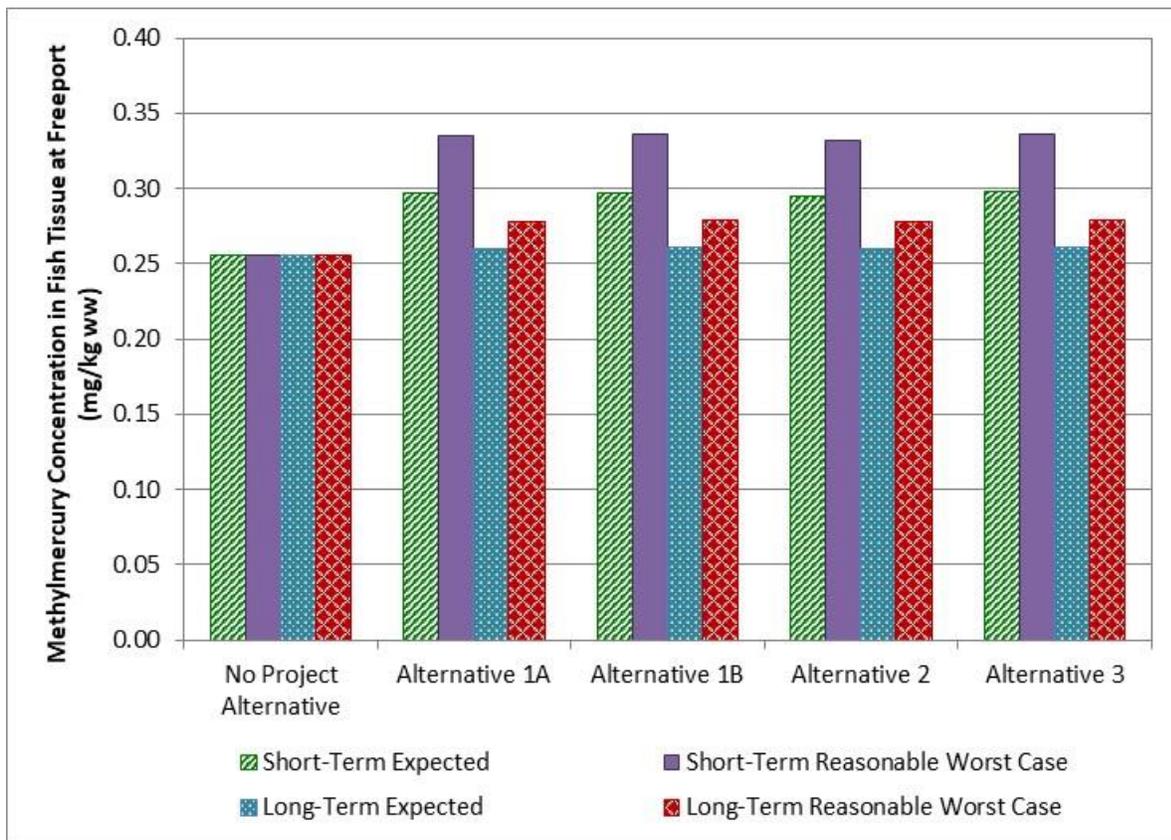
Figure 6F-8 for surface water and fish tissue methylmercury, respectively. All Project alternatives would increase surface water methylmercury concentrations at Freeport to some degree during summer and fall months of dry and critical years. These increases would range from approximately 1% above the No Project Alterative when Sites releases have the long-term expected methylmercury concentration of 0.08 ng/L, to a 18% increase above the No Project Alterative with the short-term reasonable worst-case methylmercury concentration of 0.24 ng/L. Likewise, fish tissue methylmercury concentrations would increase by about 2% above the No Project Alterative when Sites releases have the long-term expected methylmercury concentration of 0.08 ng/L, and up to about 32% above the No Project Alterative when Sites releases have the short-term reasonable worst-case methylmercury concentration of 0.24 ng/L.

These estimates are based on a simplified model that assumes the fate and transport of methylmercury from Sites is conservative – that is, there is no loss or generation of methylmercury between Sites and Freeport. This is not likely to be the case in reality – methylmercury could become associated with particulates and settle prior to reaching Freeport, be taken up by biota, degraded by light or bacteria, and mercury present in Sites discharge may be subject to methylation in transit. Collectively, these processes will decrease mercury concentrations in surface waters and may increase or decrease water column methylmercury. Therefore, though the modeling is not meant to be taken as predictive, it gives a reasonable indication of the relative magnitude and direction of effects that are expected in the Delta under worst-case conditions.

Assessment Summary for the Delta

- Surface water concentrations of total mercury in the Delta associated with the project alternatives are expected to be consistent with or below Delta total mercury concentrations under the No Project Alternative and the project will not cause exceedances of the lowest CTR criterion of 50 ng/L.

- Surface water and fish tissue concentrations of methylmercury in the Delta associated with project alternatives are not expected to result in measurable differences in the long-term average concentrations, relative to the No Project Alternative.

- Surface water concentrations of methylmercury in the north Delta may increase due to the project alternatives, relative to the No Project Alternative, in dry and critical water years during periods of peak releases. Such increases may result in measurable increases in the body burdens of methylmercury in fish which could potentially increase risks of adverse effects to humans and wildlife that consume Delta fish during these periods.

- Fish tissue methylmercury concentrations in the Delta currently exceed the Central Valley RWQCB methylmercury TMDL objectives. The project alternatives may cause measurable degradation of water quality with respect to methylmercury concentrations in fish, relative to the No Project Alternative in the north Delta, in dry and critical water years during periods of peak releases, potentially causing exceedances of the methylmercury TMDL fish tissue objectives to occur more frequently and/or by greater magnitudes during these periods.

- The Delta is included in the Section 303(d) list as impaired by mercury (SWRCB 2017c). Water quality may be degraded by measurable levels of mercury or methylmercury on a long-term basis in the north Delta due to the project alternatives, relative to the No Project Alternative, such that impairments to WARM, COLD, WILD, and COMM beneficial uses could be made discernably worse.

6F.3.5   Limitations and Applicability

Mathematical models like CALSIM and the RWQCB fish tissue methylmercury model can only approximate processes of physical systems. Models are imperfect; however, both CALSIM and the RWQCB fish tissue methylmercury model are powerful tools that, when used appropriately, provide useful insights into ecosystem processes.

There is reason to expect fish tissue methylmercury concentrations may increase when water column methylmercury concentrations increase, and to that end, the RWQCB model serves as reasonable approximations of very complex processes. Sources of uncertainty in the quantitative analysis approach include: analytical variability in the original measurements; temporal and/or seasonal variability in Delta source water concentrations of methylmercury; interconversion of mercury species (i.e., the non-conservative nature of methylmercury as a modeled constituent); limited sample size (both in number of fish and time span over which the measurements were made). The RWQCB model did not attempt to estimate the errors and propagate them from correlation to correlation in their application of the model for deriving the water column methylmercury goal (Central Valley RWQCB 2010a).

Considering this uncertainty, relatively small increases or decreases in modeled or expected surface water or fish tissue mercury concentrations should be interpreted to be within the uncertainty of the overall approach, and not precisely predictive of actual effects. Larger

magnitude increases can be interpreted as more reliable indicators of potential adverse effects of the project alternatives.

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Table 6F-4. Total Mercury Concentrations in Surface Waters within the Assessment Area.

Location	Station	n	Mean Concentration	Maximum Concentration	75th Percentile	Data Range (years)	Source
Funks Creek	Golden Gate	2	0.35	1.2	0.93	2006-2007	DWR 2020
Stone Coral Creek	-	3	0.85	2.3	1.61	2007	DWR 2020
Colusa Basin Drain	Knights Landing	26	8.6	19.3	10.8	1996-1998	USGS 2000
Colusa Basin Drain	Knights Landing	66	4.5	75	5.9	1999-2007	SWRCB 2020
Sacramento River	Red Bluff	77	1.2	14.4	1.6	1999-2016	SWRCB 2020, DWR 2020
Sacramento River	Hamilton City	73	1.8	54	2.5	1999-2016	SWRCB 2020, DWR 2020
Sacramento River	Freeport	217	4.5	89	8.8	1994-2015	SWRCB 2020
Yolo Bypass	Prospect Slough [a]	28	73.2	696	-	1995-2003	Central Valley RWQCB 2010a
Delta Agriculture	Various	1	6.5	-	-	2008	Central Valley RWQCB 2010a
East Side Tributaries	Mokelumne and Calaveras Rivers [b,c]	25	8.6	26.2	7.5	2000-2004	Central Valley RWQCB 2010a
San Joaquin River	Vernalis	49	7.6	21.7	8.6	2000-2004	Central Valley RWQCB 2010a
Suisun Bay	Martinez, Bulls Head, Mallard Is, Chipps Is.	63	3.3	21.6	10	2008-2013	SWRCB 2020

Notes:

[a] Sampling at Prospect Slough (export location of the Yolo Bypass) occurred when there were net outflows from tributaries to the Yolo Bypass and no net outflow (i.e., the slough's water was dominated by tidal waters from the south). Average concentration presented.

[b] Mokelumne River at I-5

[c] Calaveras River at railroad upstream of West Lane

DWR – California Department of Water Resources

SWRCB – California State Water Resources Control Board

USGS – United States Geological Survey

Concentrations presented in nanograms per liter; non-detects included in summary statistics at ½ the detection limit

Means are geometric means

Table 6F-5. Dissolved Mercury Concentrations in Surface Waters within the Assessment Area.

Location	Station	n	Mean Concentration	Maximum Concentration	75th Percentile	Data Range (years)	Source
Sacramento River	Red Bluff	36	0.4	3.32	0.7	2000-2007	SWRCB 2020
Sacramento River	Hamilton City	36	0.6	6.17	0.9	2000-2007	SWRCB 2020
Sacramento River	Freeport/RM44	351	1.5	14.9	1.8	1994-2010	SWRCB 2020
Colusa Basin Drain	Knights Landing	55	1.1	16.7	0.85	2000-2007	SWRCB 2020
Yolo Bypass	Prospect Slough	1	4.0	4.0	4.0	2005	SWRCB 2020
Yolo Bypass	Prospect Slough	18	1.4	3.5	1.4	2000-2001	Slotton et al. 2004

Notes:

SWRCB – California State Water Resources Control Board

Concentrations presented in nanograms per liter; non-detects included in summary statistics equal the detection limit

Means are geometric means

Table 6F-6. Total Methylmercury Concentrations in Surface Waters within the Assessment Area.

Location	Station	n	Mean Concentration	Maximum Concentration	75th Percentile	Data Range (years)	Source
Sacramento River	Red Bluff	35	0.037	0.22	0.053	2000-2007	SWRCB 2020
Sacramento River	Hamilton City	35	0.061	0.333	0.078	2000-2007	SWRCB 2020
Sacramento River	Freeport	105	0.069	0.318	0.11	2000–2015	SWRCB 2020
Colusa Basin Drain	Knights Landing	25	0.17	0.89	0.26	1996-1998	USGS 2000
Colusa Basin Drain	Knights Landing	55	0.13	0.55	0.22	2000-2007	SWRCB 2020
Yolo Bypass	Prospect Slough [a]	-	0.35	-	-	2000, 2003	Central Valley RWQCB 2010a
Delta Agriculture	Various	-	0.35	-	-	2008	Central Valley RWQCB 2010a
East Side Tributaries	Mokelumne and Calaveras Rivers [b,c]	27	0.22	0.32	0.20	2000–2004	Central Valley RWQCB 2010a
San Joaquin River	Vernalis	35	0.15	0.37	0.18	2000-2017	SWRCB 2020
Suisun Bay	Mallard Island	22	0.077	1.4	0.11	2008-2015	SWRCB 2020

Notes:

[a] Sampling at Prospect Slough (export location of the Yolo Bypass) occurred when there were net outflows from tributaries to the Yolo Bypass and no net outflow (i.e., the slough's water was dominated by tidal waters from the south). Average concentration presented.

[b] Mokelumne River at I-5

[c] Calaveras River at railroad upstream of West Lane

SWRCB – California State Water Resources Control Board

RWQCB – Regional Water Quality Control Board

Concentrations presented in nanograms per liter

Means are geometric means

Table 6F-7. Surface Water Mercury Concentrations in Reservoirs Near the Assessment Area.

Location	Total Mercury (ng/L)						Data Range (years)	Source
	Det	n	Min	Max	Mean	StDev		
Black Butte Recreation Area	16	16	0.22	4.1	1.78	1.08	2006-2008	DWR 2020
Clear Lake	251	251	0.97	400	12.9	50.7	1994-1998	SWRCB 2017b
Englebright Lake	7	7	0.50	3.6	0.94	1.17	2008-2009	SWRCB 2017b
Englebright Lake	19	19	0.31	15.9	1.20	4.52	2012	YCWA 2013
Indian Valley Reservoir [a]	13	13	1.30	149	4.42	40.3	2000-2001	Slotton et al. 2004
Lake Berryessa	0	3	0.03	0.03	0.03	0	2016	SWRCB 2020
New Bullards Bar Reservoir	22	22	0.27	7.93	0.83	2.29	2012	YCWA 2013
Oroville Reservoir	2	2	0.26	0.52	0.37	0.18	2004-2020	SWRCB 2020
Oroville Reservoir	243	250	0.05	23.2	0.54	1.56	2002-2009	SWRCB 2017b
Shasta Lake	28	28	0.19	3.04	0.91	0.66	1998-2003	SWRCB 2020
Stony Gorge Reservoir [b]	0	1	ND	ND	-	-	1979	DWR 2020
Thermalito Afterbay	128	132	0.006	36.6	0.60	3.15	2002-2009	SWRCB 2017b

Notes:

[a] Samples collected from the North Fork of Cache Creek

[b] Sample collected from Stony Creek below Stony Gorge Reservoir. The reporting limit was 1000 ng/L in this single sample.

DWR – California Department of Water Resources

ND – not detected

SWRCB – California State Water Resources Control Board

YCWA – Yuba County Water Agency

Concentrations presented in nanograms per liter unfiltered mercury

Means are geometric means

Non-detects were included in summary statistics at ½ the method detection limit[1] Samples collected from the North Fork of Cache Creek

[2] Sample collected from Stony Creek below Stony Gorge Reservoir. The reporting limit was 1000 ng/L in this single samp

Table 6F-8. Surface Water Methylmercury Concentrations in Reservoirs Near the Assessment Area.

Location	Total Methylmercury (ng/L)						Data Range (years)	Source
	Det	n	Min	Max	Mean	StDev		
Clear Lake	411	427	0.096	25	0.24	2.66	1994-2005	SWRCB 2017b
Englebright Lake	30	33	0.0004	0.072	0.013	0.019	2002-2009	SWRCB 2017b
Englebright Lake	9	19	0.025	0.31	0.044	0.091	2012	YCWA 2013
Indian Valley Reservoir	5	5	0.069	0.15	0.093	0.036	2011	SWRCB 2017b
Indian Valley Reservoir	11	11	0.03	0.19	0.06	0.05	2000-2001	Slotton et al. 2004
New Bullards Bar Reservoir	6	22	0.025	0.27	0.042	0.085	2012	YCWA 2013
Oroville Reservoir	43	273	<0.001	0.069	0.011	0.008	2002-2009	SWRCB 2017b
Shasta Lake	5	5	0.008	0.024	0.014	0.006	2011	SWRCB 2017b
Shasta Lake	6	14	0.01	0.305	0.021	0.077	2000-2003	SWRCB 2020
Thermalito Afterbay	32	136	<0.001	1.41	0.014	0.12	2002-2009	SWRCB 2017b

Notes:

Concentrations presented in nanograms per liter unfiltered methylmercury
Means are geometric means
Non-detects were included in summary statistics at ½ the method detection limit
SWRCB – California State Water Resources Control Board
YCWA – Yuba County Water Agency
Concentrations presented in nanograms per liter unfiltered methylmercury
Means are geometric means
Non-detects were included in summary statistics at ½ the method detection limit

Table 6F-9. Fish Tissue Methylmercury Concentrations within the Assessment Area.

Location	Station	Species	Trophic Level	n	Mean Concentration	Maximum Concentration	75th Percentile	Data Range (years)
Sacramento River	Red Bluff	Sacramento Sucker	TL3	8	0.084	0.12	0.11	2000-2011
Sacramento River	Red Bluff	Rainbow Trout	TL3	15	0.039	0.064	0.043	1998-2011
Sacramento River	**Red Bluff**	**Sacramento Pikeminnow**	**TL4**	**4**	**0.29**	**0.52**	**0.41**	**1998-2006**
Sacramento River	Hamilton City	Hardhead	TL3	11	0.29	0.81	0.38	1981-2006
Sacramento River	Hamilton City	Sacramento Sucker	TL3	19	0.06	0.266	0.07	1998-2006
Sacramento River	Hamilton City	Rainbow Trout	TL3	2	0.027	0.039	0.033	2005
Sacramento River	Hamilton City	Steelhead Trout	TL3	1	0.097	0.097	0.097	2005
Sacramento River	**Hamilton City**	**Striped Bass**	**TL4**	**3**	**0.37**	**0.56**	**0.45**	**2006**
Sacramento River	**Hamilton City**	**Sacramento Pikeminnow**	**TL4**	**18**	**0.34**	**1.15**	**0.33**	**1998-2006**
Colusa Basin Drain	Knights Landing	Common Carp	TL3	8	0.23	0.47	0.26	1998-2002
Colusa Basin Drain	Knights Landing	Sacramento Sucker	TL3	1	0.07	0.07	0.07	1981
Colusa Basin Drain	Knights Landing	Channel Catfish	TL4	2	0.16	0.19	0.17	1981-1987
Colusa Basin Drain	Knights Landing	Crappie	TL4	2	0.086	0.093	0.089	2001
Colusa Basin Drain	Abel Road	Brown Bullhead	TL3	2	0.4	0.58	0.5	1980
Colusa Basin Drain	Abel Road	Common Carp	TL3	1	0.1	0.1	0.1	1981
Colusa Basin Drain	Abel Road	Channel Catfish	TL4	3	0.15	0.16	0.16	1981-1988
Sacramento River	RM 44	Chinook Salmon	TL3	8	0.07	0.08	0.07	2002-2005
Sacramento River	**RM 44**	**Splittail**	**TL3**	**2**	**0.40**	**0.43**	**0.41**	**2001**
Sacramento River	**RM 44**	**Sacramento Sucker**	**TL3**	**21**	**0.22**	**0.45**	**0.27**	**2000-2007**
Sacramento River	**RM 44**	**Bluegill Sunfish**	**TL3**	**2**	**0.11**	**0.12**	**0.11**	**1999**
Sacramento River	**RM 44**	**Redear Sunfish**	**TL3**	**11**	**0.091**	**0.21**	**0.11**	**2005-2007**
Sacramento River	RM 44	Steel Trout	TL3	2	0.05	0.06	0.06	2005

Location	Station	Species	Trophic Level	n	Mean Concentration	Maximum Concentration	75th Percentile	Data Range (years)
Sacramento River	**RM 44**	**Largemouth Bass**	**TL4**	**68**	**0.81**	**2.00**	**1.0**	**1998-2007**
Sacramento River	**RM 44**	**Smallmouth Bass**	**TL4**	**6**	**0.8**	**0.323**	**1.1**	**2001-2005**
Sacramento River	**RM 44**	**Spotted Bass**	**TL4**	**24**	**0.51**	**0.99**	**0.60**	**2005-2007**
Sacramento River	**RM 44**	**Striped Bass**	**TL4**	**6**	**0.4**	**0.6**	**0.4**	**2000-2005**
Sacramento River	**RM 44**	**Sacramento Pikeminnow**	**TL4**	**14**	**0.49**	**1.32**	**0.56**	**2001-2007**
Yolo Bypass	**Prospect Slough**	**Threadfin Shad**	**TL2**	**18**	**0.14**	**0.33**	**0.23**	**1998-1999**
Yolo Bypass	**Prospect Slough**	**Shimofuri Goby**	**TL3**	**4**	0.080	**0.13**	**0.095**	**1999**
Yolo Bypass	**Prospect Slough**	**Yellowfin Goby**	**TL3**	**4**	0.065	**0.76**	**0.075**	**1999**
Yolo Bypass	**Prospect Slough**	**Bigscale Logperch**	**TL3**	**4**	**0.2**	**0.41**	**0.4**	**1999**
Yolo Bypass	**Prospect Slough**	**Mosquitofish**	**TL3**	**8**	**0.16**	**0.29**	**0.17**	**1998-1999**
Yolo Bypass	**Prospect Slough**	**Prickly Sculpin**	**TL3**	**2**	**0.44**	**0.47**	**0.45**	**1999**
Yolo Bypass	**Prospect Slough**	**Peppered Shiner**	**TL3**	**4**	**0.11**	**0.15**	**0.13**	**1999**
Yolo Bypass	**Prospect Slough**	**Silverside**	**TL3**	**102**	**0.11**	**0.36**	**0.13**	**1999-2000**
Yolo Bypass	Prospect Slough	White Crappie	TL4	2	0.15	0.17	0.16	1998

Notes:

Bold indicates that the mean or maximum concentration exceeds the applicable criterion/objective (see Table 6F-1)

Concentrations presented in milligrams per kilogram wet weight; non-detects included in summary statistics at ½ the detection limit

Data from SWRCB (2020)

Means are arithmetic means

Bold indicates that the mean or maximum concentration exceeds the applicable criterion/objective (see Table 6F-1)

Table 6F-10. Fish Tissue Methylmercury Concentrations from nearby Lakes and Reservoirs.

Location	303(d) listed for Mercury [1]	Bioaccumulation Factors	Concentration (normalized to 350 mm) Largemouth bass	Data Range (years)	Source
Black Butte Recreation Area	Yes	-	0.58	2008	Davis et al. 2009
Clear Lake	Yes	7	0.45	2008	Davis et al. 2009
East Park Reservoir	Yes	-	0.47	2008	Davis et al. 2009
East Park Reservoir	Yes	-	0.26 [a]	2000-2001	DWR 2007
Englebright Lake	Yes	20	0.47	2008	Davis et al. 2009
Indian Valley Reservoir	Yes	9	0.88	2008	Davis et al. 2009
Indian Valley Reservoir	Yes	-	0.67 [b]	2000-2001	DWR 2007
Lake Berryessa	Yes	-	0.55	2008	Davis et al. 2009
New Bullards Bar Reservoir	Yes	-	0.39	2008	Davis et al. 2009
Oroville Reservoir	Yes	44	0.57	2008	Davis et al. 2009
Oroville Reservoir	Yes	-	0.50	2000-2001	DWR 2007
Shasta Lake	Yes	21	0.29	2008	Davis et al. 2009
Stony Gorge Reservoir	Yes	-	0.32	2008	Davis et al. 2009
Stony Gorge Reservoir	Yes	-	0.227 / 0.448 [c]	2000-2001	DWR 2007
Thermalito Afterbay	Yes	11	0.16	2008	Davis et al. 2009

Notes:

303(d) listed for mercury in the 2014/2016 California list of water quality limited segments being addressed by TMDLs

Concentrations reported as mg/kg wet weight

Mean Concentration (normalized to TL4 150-500 mm) from Davis et al. 2009

Bioaccumulation factor based on standardized fish methylmercury (x 10^6) (L/kg) to water column methylmercury (Davis et al. 2009)

[a] Data represent a single composite fillet sample from three fish with an average length of 385 cm

[b] Data represent a single composite fillet sample from three fish with an average length of 326 cm.

[c] Data represent a single composite fillet sample from three fish with an average length of 300 cm, primary and duplicate analysis are presented

DWR – California Department of Water Resources

303(d) listed for mercury in the 2014/2016 California list of water quality limited segments being addressed by TMDLs

Bioaccumulation factor based on standardized fish methylmercury (x 10^6) (L/kg) to water column methylmercury (Davis et al. 2009)

Concentrations reported as mg/kg wet weight
Mean Concentration (normalized to TL4 150-500 mm) from Davis et al. 2009

Table 6F-11. Physical Characteristics of Reservoirs Near the Assessment Area.

Location	Max Storage (acre-feet)	Mean Depth (ft)	Maximum Depth (ft)	Surface Area (acres)	Watershed Area (mi²)	Fish Present
Black Butte Recreation Area	143,700	135	135	4,560	741	Largemouth bass, smallmouth bass, white crappie, common carp
Clear Lake	378,000	30	59	43,900	458	Largemouth bass, common carp
East Park Reservoir	54,300	86	92	1,698	98	Bluegill, Channel Catfish, Common Carp, Largemouth Bass, Redear Sunfish, Silverside, Goldfish, Black Crappie
Englebright Lake	70,000	260	285	754	1,110	Rainbow trout, Sacramento sucker
Funks / Holthouse Reservoir	2,312	32	36	215	-	-
Indian Valley Reservoir	359,000	138	190	3,469	120	Channel Catfish, Common Carp, Large mouth Bass, Redear Sunfish, Sacramento Sucker, Pumpkinseed, Rainbow trout
Lake Berryessa	1,902,086	230	273	19,083	568	Largemouth bass
New Bullards Bar Reservoir	969,600	617	635	3,864	489	Largemouth bass
Oroville Reservoir	3,540,000	748	748	15,400	3,639	Common Carp, Largemouth Bass, Small mouth Bass, Spotted Bass, Chinook Salmon
Shasta Lake	4,552,000	514	517	27,336	7,502	Channel catfish, spotted bass
Sites Reservoir* (Alternatives 1a, 1b, and 3)	1,800,000	-	300	13,200	n/a	-
Sites Reservoir* (Alternative 2)	1,600,000	-	300	12,000	n/a	-
Stony Gorge Reservoir	58,500	113	131	1,411	301	Bluegill, Channel Catfish, Common Carp, Largemouth Bass, Sacramento Sucker, Goldfish, Black Crappie, Threadfin Shad
Thermalito Afterbay	57,041	32	32	3,863	3,665	Bluegill, Common Carp, Largemouth Bass, Silverside

Notes:

* Reservoir does not yet exist.
Fish presence determined from SWRCB (2020) and Davis et al. (2009)

Maximum depth reported as the hydraulic height of the dam (US Army Core National Inventory of Dams)
Surface area and Watershed area from Davis et al. (2009), US Army Core National Inventory of Dams

Table 6F-12. Modeled Fish Tissue Mercury Concentrations Associated with Water Column Methylmercury in the Sacramento River at Freeport for Average Annual Flows.

Parameter	No Project Alternative	Alternative 1A	Alternative 1B	Alternative 2	Alternative 3	Units	Notes
Sacramento River at Freeport Historical Long-term Average Methylmercury Concentration (CE)	0.069	0.069	0.069	0.069	0.069	ng/L	From Table 6F-6
Sacramento River at Freeport Historical Estimated Fish Tissue Methylmercury Concentration	0.256	0.256	0.256	0.256	0.256	mg/kg	Calculated using Equation 1 (Central Valley RWQCB 2010a)
Long-term Average Modeled Flow Sacramento River at Freeport	21,489	21,467	21,475	21,464	24,496	cfs	From CALSIM Results
Long-term Average Modeled Flow Originating from Sites (QS)	-	285	304	281	352	cfs	From CALSIM Results
Long-term Average Modeled Flow Originating from All Locations Except Sites (QE)	21,489	21,182	21,172	21,183	21,144	cfs	Calculated
Hypothetical Percent Increase in Methylmercury Concentration at Freeport due to Project	0	5.0	5.0	5.0	5.0	%	Set to Calculate Required Sites Concentration
Hypothetical with Project Sacramento River at Freeport Methylmercury Concentration (CP)	0.069	0.072	0.072	0.072	0.072	ng/L	Calculated using Equation 2
Hypothetical with Project Sacramento River at Freeport Estimated Fish Tissue Methylmercury Concentration	0.256	0.274	0.274	0.274	0.274	mg/kg	Calculated using Equation 1 (Central Valley RWQCB 2010a)
Hypothetical Percent Increase in Fish Tissue concentration at Freeport	0	7.2	7.2	7.2	7.2	%	Calculated
Calculated Methylmercury Concentration Required from Sites Discharge to Result in Change (CS)	**-**	**0.30**	**0.28**	**0.30**	**0.25**	ng/L	Calculated using Equation 3

Notes:

mg/kg = milligram per kilogram

ww = wet weight

Table 6F-13. Modeled Fish Tissue Mercury Concentrations Associated with Water Column Methylmercury in the Sacramento River at Freeport for Mean Monthly Flows in May – November of Dry and Critical Water Years.

Parameter	No Project Alternative	Alternative 1A	Alternative 1B	Alternative 2	Alternative 3	Units	Notes
Sacramento River at Freeport Historical Long Term Average Methylmercury Concentration (CE)	0.069	0.069	0.069	0.069	0.069	ng/L	From Table 6F-6
Sacramento River at Freeport Historical Estimated Fish Tissue Methylmercury Concentration	0.256	0.256	0.256	0.256	0.256	mg/kg	Calculated using Equation 1 (Central Valley RWQCB 2010a)
Modeled Flow in the Sacramento River at Freeport	10,478	11,144	11,128	11,107	11,065	cfs	From CALSIM Results
Modeled Flow Originating from Sites (QS)	-	805	820	772	818	cfs	From CALSIM Results
Modeled Flow Originating from All Locations Except Sites (QE)	10,478	10,339	10,308	10,335	10,246	cfs	Calculated
Hypothetical Percent Increase in Methylmercury Concentration at Freeport due to Project	0	5.0	5.0	5.0	5.0	%	Set to Calculate Required Sites Concentration
Hypothetical with Project Sacramento River at Freeport Methylmercury Concentration (CP)	0.069	0.072	0.072	0.072	0.072	ng/L	Calculated using Equation 2
Hypothetical with Project Sacramento River at Freeport Estimated Fish Tissue Methylmercury Concentration	0.256	0.274	0.274	0.274	0.274	mg/kg	Calculated using Equation 1 (Central Valley RWQCB 2010a)
Hypothetical Percent increase in Fish Tissue concentration at Freeport	0	7.2	7.2	7.2	7.2	%	Calculated
Calculated Methylmercury Concentration Required from Sites Discharge to Result in Change (CS)	**-**	**0.11**	**0.11**	**0.11**	**0.11**	ng/L	Calculated using Equation 3

Notes:

mg/kg = milligram per kilogram
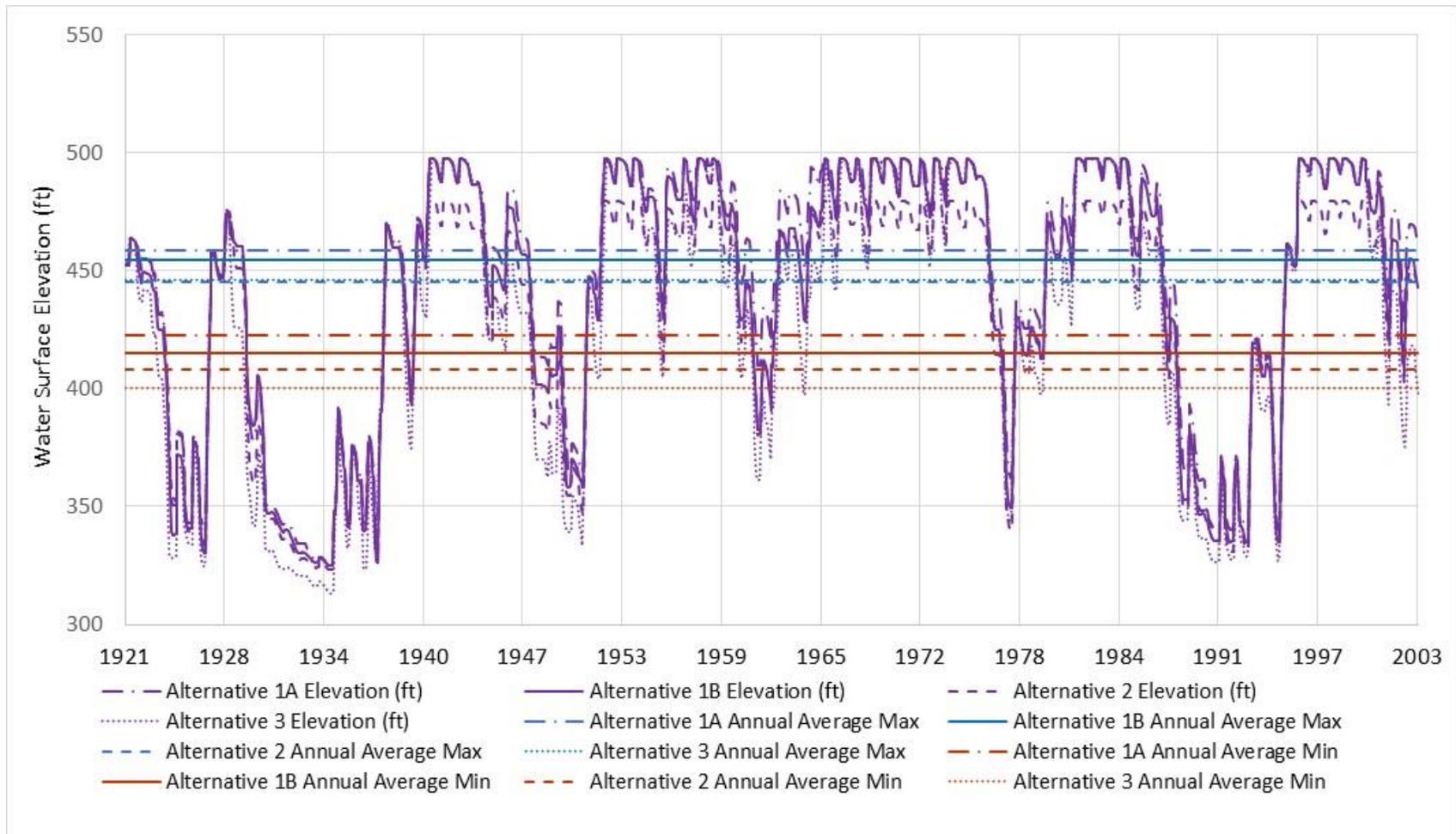
ww = wet weight

Figure 6F-1. CALSIM Modeled Sites Reservoir Surface Water Elevations and Long-Term Average Annual Maximum and Minimum Surface Water Elevations.
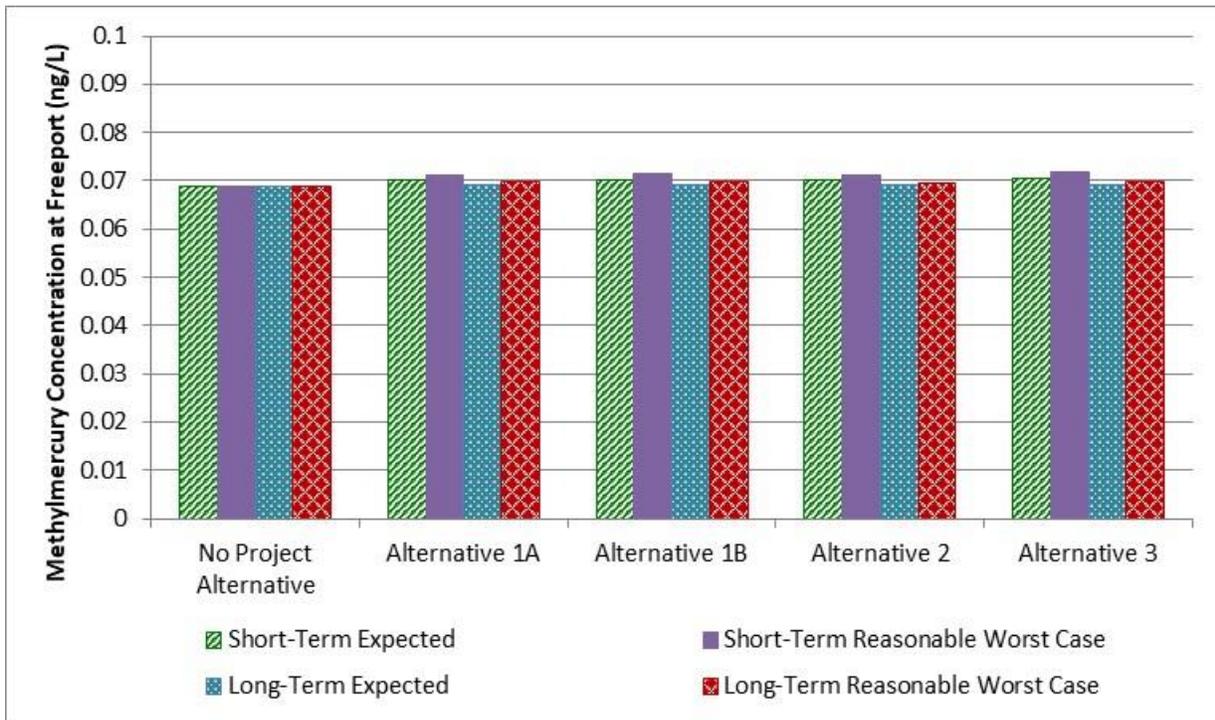
Figure 6F-2. Estimated Surface Water Methylmercury Concentrations at Freeport for Alternatives and the No Project Alternative for Annual Average Flows.
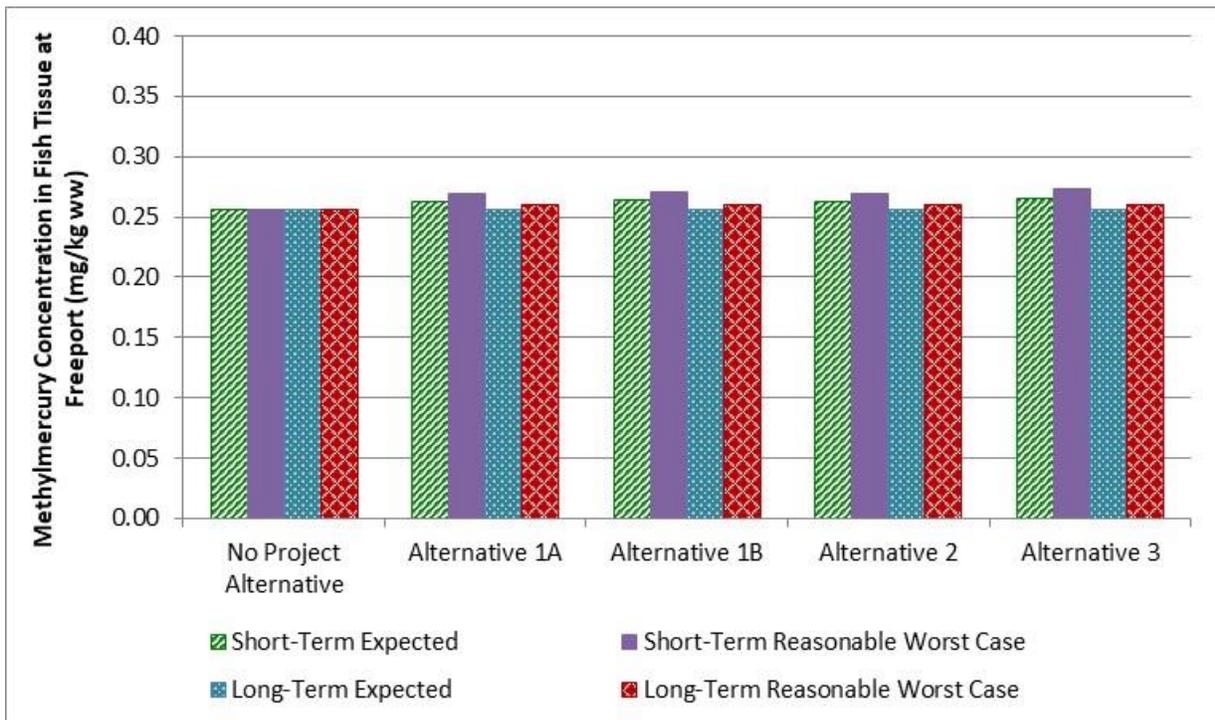
Figure 6F-3. Estimated Fish Tissue Methylmercury Concentrations at Freeport for Alternatives and the No Project Alternative for Annual Average Flows.
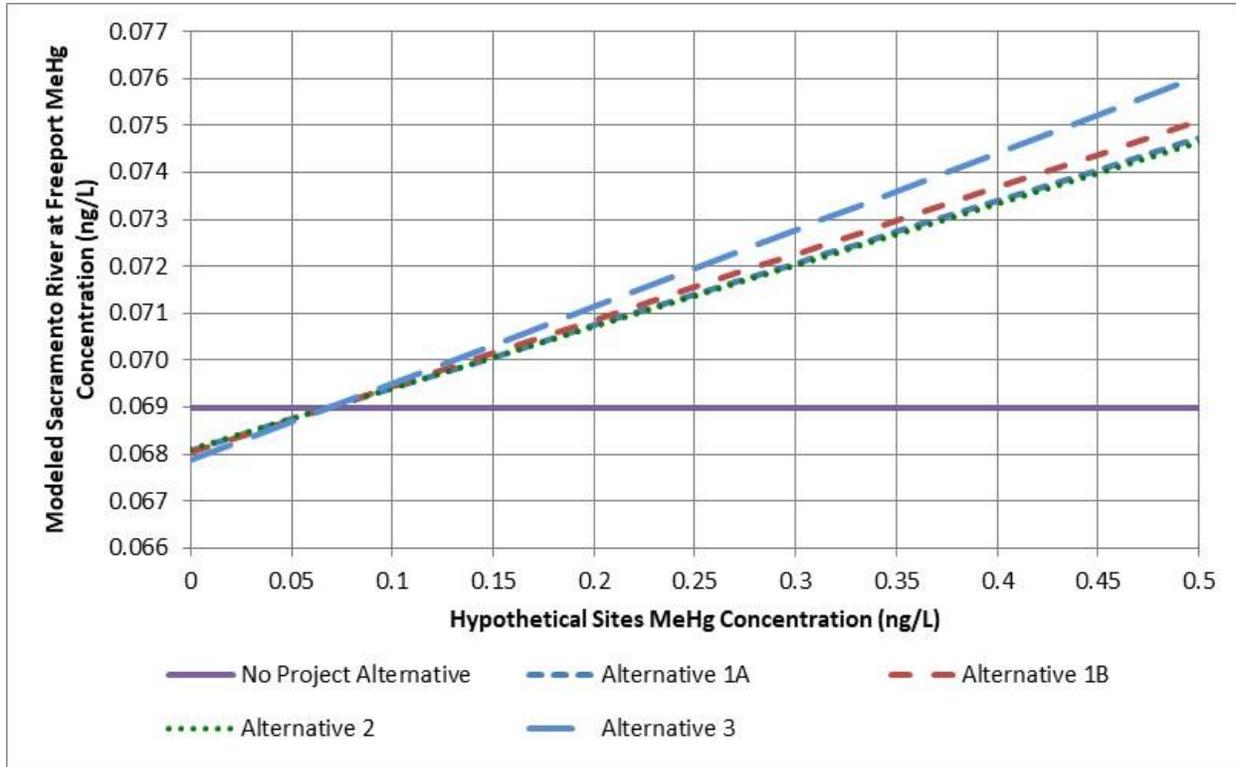

Figure 6F-4. Modeled Surface Water Methylmercury Concentrations in the Sacramento River at Freeport for Hypothetical Sites Reservoir Releases with Annual Average Flows.
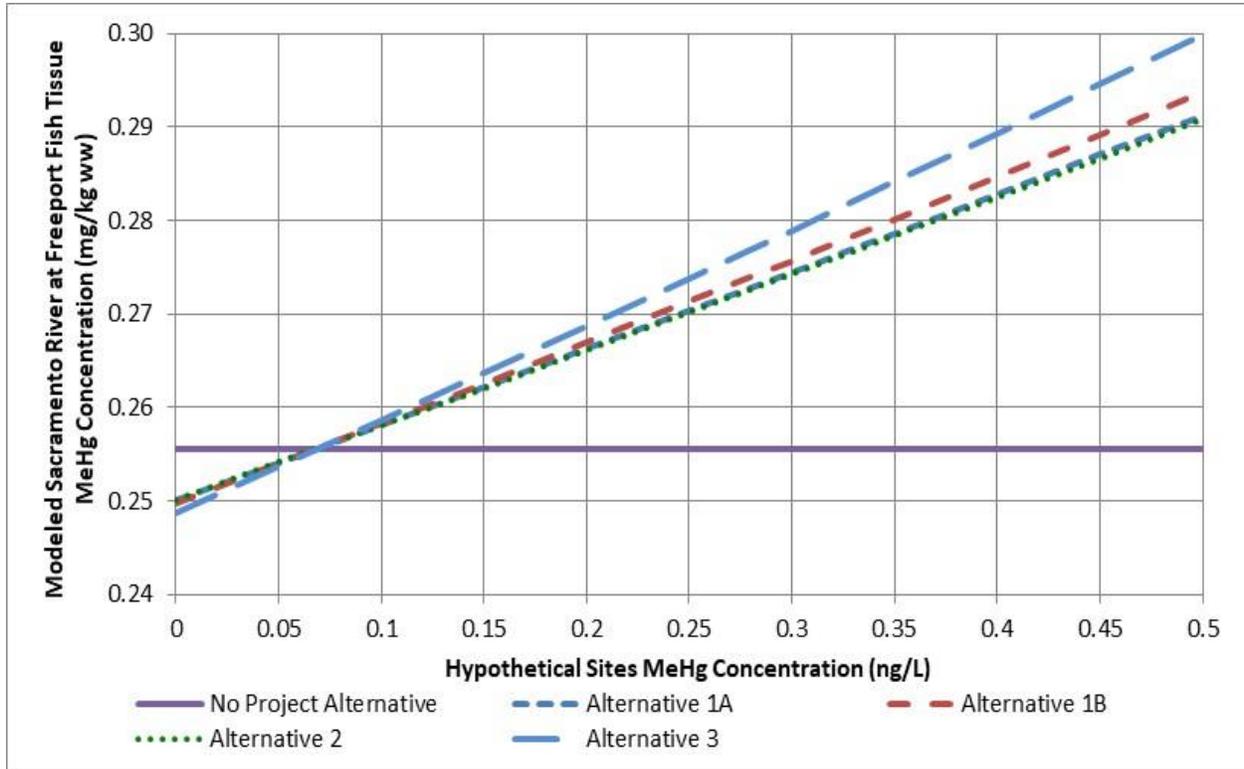
Figure 6F-5. Modeled Fish Tissue Methylmercury Concentrations in the Sacramento River at Freeport for Hypothetical Sites Reservoir Releases with Annual Average Flows.
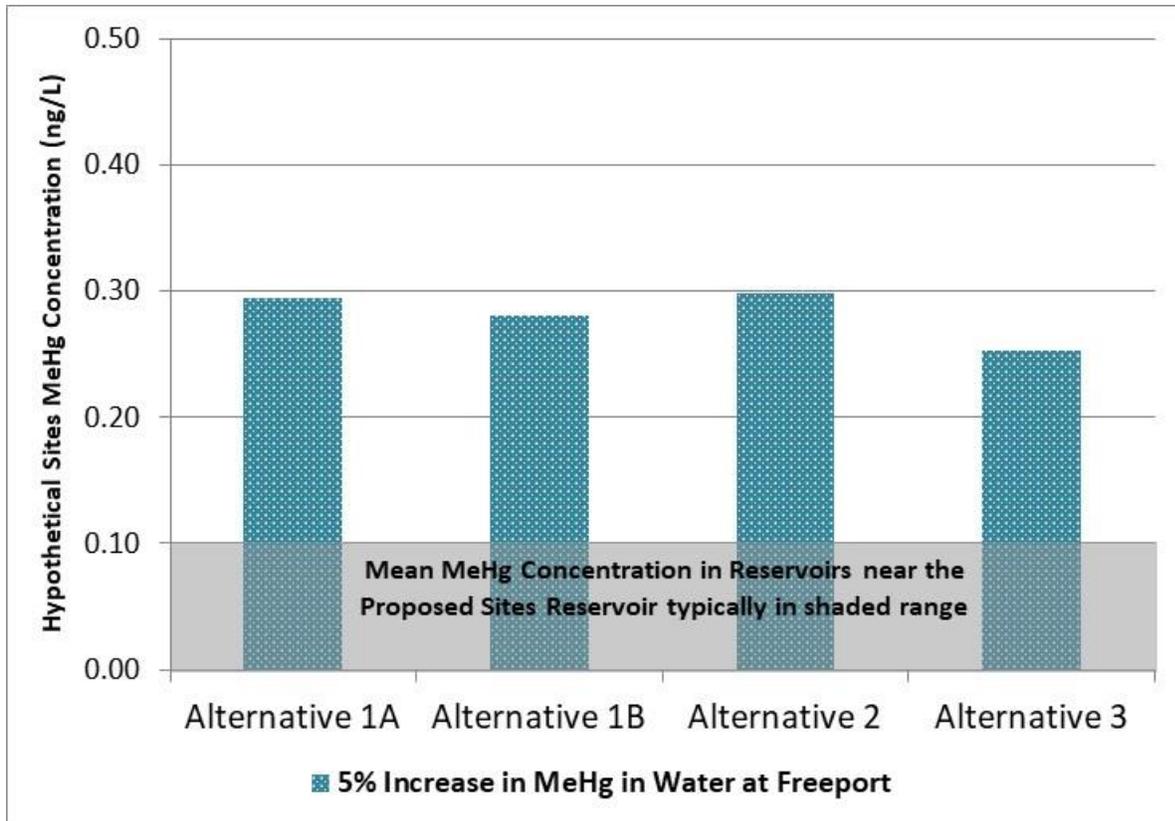
Figure 6F-6. Hypothetical Methylmercury Concentrations in Sites Reservoir Releases Required to Increase Water Column Methylmercury Concentrations in the Sacramento River at Freeport by 5% based on Annual Average Flows.
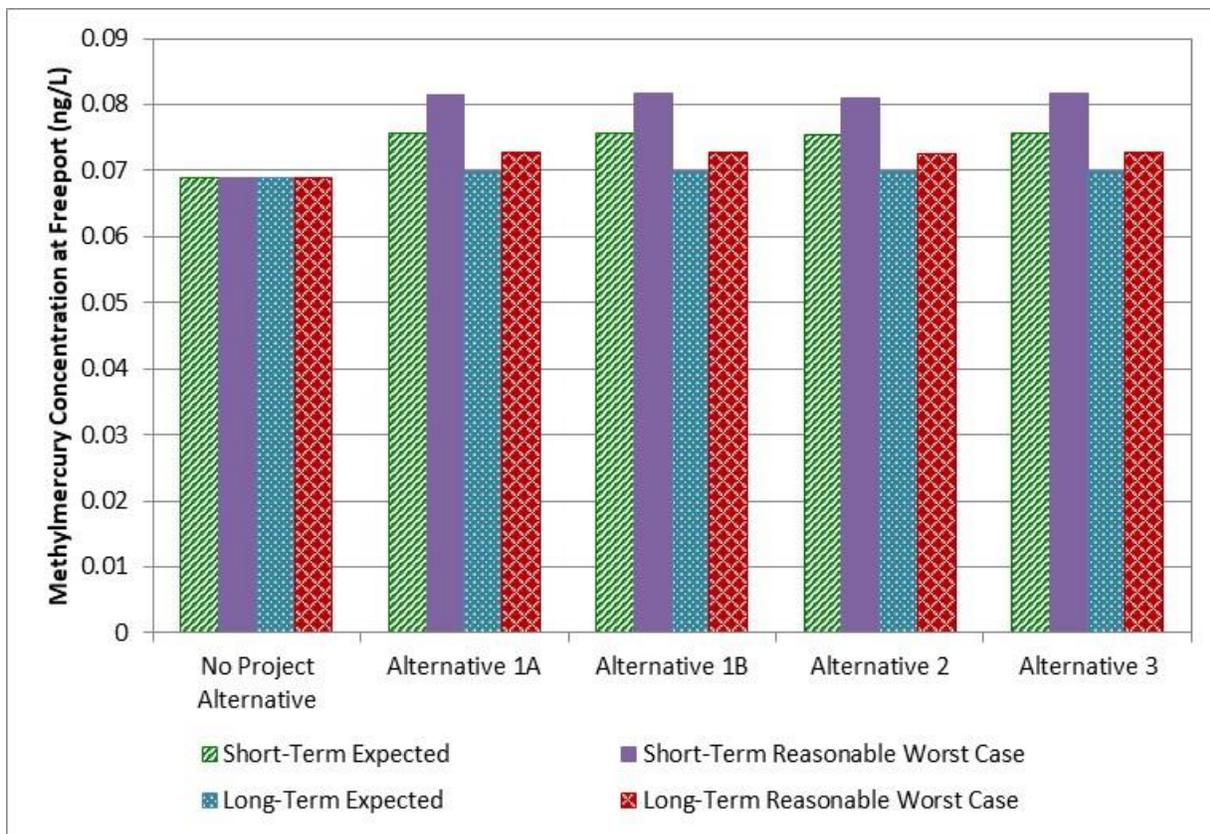
Figure 6F-7. Estimated Surface Water Methylmercury Concentrations at Freeport for Alternatives and the No Project Alternative for Mean Monthly Flows in May – November of Dry and Critical Water Years.
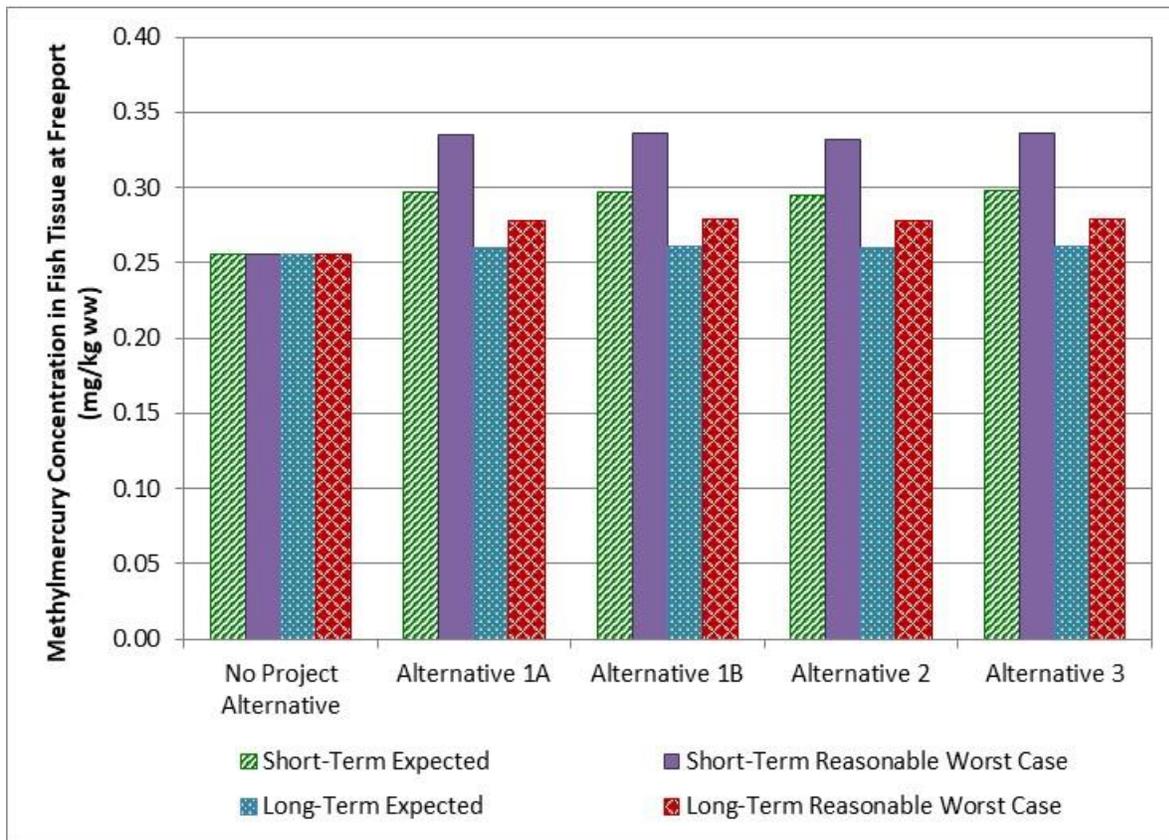
Figure 6F-8. Estimated Fish Tissue Methylmercury Concentrations at Freeport for Alternatives and the No Project Alternative for Mean Monthly Flows in May – November of Dry and Critical Water Years.