Appendix 22A

Air Quality Analysis Methodology

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This appendix discusses the approach and methodology used to assess construction and operational emissions associated with the water conveyance facility. The analysis evaluates maximum daily and yearly emissions to comply with CEQA and NEPA guidelines in the Plan Area (the area covered by the BDCP). Emissions analyzed include criteria pollutants and GHGs (CO_2, CH_4, N_2O, SF_6, and HFCs).

22A.1 Construction

Construction of the water conveyance facilities would generate emissions of ROG, NO_X, CO, PM10, PM2.5, SO_2 and GHGs (CO_2, CH_4, N_2O, SF_6, and HFCs) that would result in short-term impacts on ambient air quality in the Plan area. Emissions would originate from mobile and stationary heavy-duty equipment exhaust, marine vessel exhaust, tunneling locomotive exhaust, employee and haul truck vehicle exhaust, helicopter exhaust, site grading and earth movement, paving, electricity use, and concrete batching. Construction-related emissions vary substantially depending on the level of activity, length of the construction period, specific construction operations, types of equipment, number of personnel, wind and precipitation conditions, and soil moisture content.

DWR and 5RMK Inc. (5RMK) developed construction phasing and scheduling assumptions as part of an economic analysis ("cost estimate") in 2014 for the modified pipeline alignment (MPTO). The cost estimate provides detailed information on equipment and vehicle activity (e.g., operating hours per day), as well as the start date and number of working days for each phase. Construction features analyzed in the cost estimate include the intakes, intermediate and Clifton Court forebays, and tunnel reaches. Schedule and construction activity assumptions for features not evaluated in the cost estimate, including geotechnical explorations, utility development, and tunnel segment hauling, were provided separately by DWR. The construction assumptions developed by 5RMK and DWR were used to estimate emissions, as described further below in Sections 22A.1 through 22A.9.

A similar cost estimate was developed by DWR and 5RMK in 2010 for the pipeline tunnel option (PTO) and east canal. The assumptions and methodology used in the 2010 cost estimate have been superseded by the approach utilized to develop the MPTO cost estimate. Accordingly, emissions associated with the PTO and east canal were analyzed using a combination of the 2010 and 2014 cost estimate assumptions, where appropriate, as well as activity scaling factors, as described further below. Emissions generated by the west canal and separate corridors options (SCO) were analyzed using a similar approach, since cost estimates unique to these alignments were not available at the time of analysis.

Table 22A-1 summarizes the cost estimate files that inform the emissions analysis for each feature, as well as whether any scaling factors were utilized to adjust or update the underlying cost estimate assumptions. The scaling factors were derived based on similarities in construction design among the alternatives. For example, Alternative 4/4A would construct three intakes, whereas Alternatives 1A, 2A, and 6A would construct five, resulting in a scaling factor of 1.67.

Table 22A-1. Cost Estimate Assumptions and Scaling Approach for the Air Quality and Greenhouse Gas Emissions Analysis

		Scaling Factor									
Feature	Assumption Source[a]	Alts 1A, 2A, 6A	Alts 1B, 2B, 6B	Alts 1C, 2C, 6B	Alt 3	Alt 4/4A	Alt 5	Alts 7, 8	Alt 9	Alt 2D	Alt 5A
Intakes	2014 MPTO cost estimate	1.67	1.67	1.67	0.67	None	0.33	None	2.80	1.67	0.33
Intermediate Forebay	2014 MPTO cost estimate	3.33	-	-	3.33	None	3.33	3.33	-	None	None
Tunnels	2014 MPTO cost estimate	0.80	0.04	0.40	0.63	None	0.62	0.70	-	None	None
Clifton Court Forebay	2014 MPTO cost estimate	0.50	0.50	0.50	0.50	None	0.50	0.50	-	None	None
Combined Pumping Plant	2014 MPTO cost estimate	-	-	-	-	None	-	-	-	None	None
Geotechnical Explorations	DWR activity estimate	-	-	-	-	None	-	-	-	None	None
Temporary Utilities 69Kv	DWR activity estimate	0.58	0.29	0.29	0.34	None	0.34	0.40	0.15	None	None
Temporary Utilities 69kV+	DWR activity estimate	-	-	-	-	None	-	-	0.15	None	None
Permeant Utilities	DWR activity estimate	3.29	1.33	2.85	1.33	None	0.68	1.98	-	None	None
Segment Hauling	DWR activity estimate	-	-	-	-	None	-	-	-	None	None
Pumping Plants	2012 MPTO cost estimate[b]	1.67	1.67	1.67	0.67	-	0.33	None	0.67	-	-
Pipelines	2010 PTO cost estimate	None	1.77	1.23	0.56	-	0.27	0.60	-	-	-
Intermediate Pumping Plant	2010 PTO cost estimate	None	0.95	None	0.44	-	0.33	None	0.00	-	-
Canals	2010 East cost estimate	-	None	0.93	-	-	-	-	0.16	-	-
Siphons/Gates/Barriers	2010 East cost estimate	-	4.07	3.82	-	-	-	-	4.40	-	-
Bridges	2014 MPTO cost estimate[c]	-	3.01-5.42[d]	0.00-5.57[d]	-	-	-	-	3.00	-	-
Dredging	2014 MPTO cost estimate[e]	-	-	-	-	-	-	-	1.70	-	-

\- = Feature does not exist.

None = No scaling factor needed; the activity estimates in the assumption file were used without modification.

[a] Representing the underlying source for the activity assumptions (e.g., operating hours, vehicle trips). The assumptions source is also used to define the scaling factor for each alternative. For example, the 2014 MPTO cost estimate is based on the construction of three intakes for Alternative 4. Alternatives 1A, 2A, and 6A would construction five intakes, resulting in a scaling factor of 1.67.

[b] An initial draft of the MPTO cost estimate was prepared in 2012, but was superseded by the 2014 estimate. Since the pumping plants were eliminated from the construction design in 2014, the 2014 estimate did not include pumping plants. Accordingly, the 2012 MPTO cost estimate represents the best available data for construction of the pumping plants.

[c] Construction of a single bridge was excerpted from the 2014 MPTO cost estimate to define the additional bridges needed for the SCO and east and west canals. Please note that construction of bridges at specific features (e.g., intakes) under the MPTO and PTO are incorporated into that features activity assumptions (i.e., there is no standalone bridge "feature" for these alignments).

[d] Separate scaling factors were identified for each anticipated bridge contract, as defined below:

East Canal: Contract 1 = 3.01; Contract 2 = 4.00; Contract 3 = 5.42; Contract 4 = 4.95; Contract 5 = 3.61

West Canal: Contract 1 = 3.09; Contract 2 = 1.82; Contract 3 = 5.57; Contract 4 = 5.46; Contract 5 = 0.00

[e] The dredging only activity at the Clifton Court Forebay was excerpted from the 2014 MPTO cost estimate to define dredging activities under the SCO. Please note that dredging activities at the Clifton Court Forebay under the MPTO are incorporated in the activity assumptions for the Clifton Court Forebay feature (i.e., there is no standalone dredging "feature" for the MPTO).

All equipment operating assumptions from the 2010 and 2014 cost estimates are summarized in Appendix 22B, *Air Quality Assumptions.* This appendix also provides the construction schedule (Table 22B-1), emission factors, and model outputs, as applicable. Please refer to Sections 22A.1.1 through 22A.1.9 for a detailed overview of the equations and approach used to quantify emissions from each source (e.g., heavy-duty equipment).

22A.1.1 Heavy Duty Equipment

Emission factors obtained from the CalEEMod Users Guide and ARB's OFFROAD2007 model were used to calculate exhaust emissions from heavy-duty construction equipment without environmental commitments. Equipment descriptions provided by DWR and 5RMK as part of the cost estimate were frequently model specific (e.g., CAT 963), and were not grouped into generic operating types (e.g., bulldozer). To estimate emissions using CalEEMod emission factors, which are given for generic equipment, individual equipment provided by the cost estimate was assigned a generic type based on the model description, industry resources, and professional experience.

Table 22B-2 in Appendix 22B, *Air Quality Assumptions,* summarizes the heavy-duty equipment assumed in the emissions modeling. Key assumptions include:

- Equipment load factors were based on latest Carl Moyer Program Guidelines[1] (California Air Resources Board 2011:236-237).
- Diesel equipment were evaluated based on emission factors from the CalEEMod Users Guide, whereas gasoline powered equipment were evaluated based on emission factors from the OFFROAD2007 model.
- Accessory equipment (e.g., trailers, clamshell bucket) with no engines or emissions-generating components were excluded from the analysis.
- Tunnel boring machines, tunnel fans, tunnel lights, certain air compressors, and pumps were assumed to be electric and were included in the electricity analysis (see Section 22.1.8).

Criteria pollutant, CO_2, CH_4, and N_2O (gasoline equipment only) emissions for each phase were calculated using the information summarized Table 22B-2 and Equation 22A-1.

Equation 22A -1 $$E_{phase} = \Sigma(Activity \times EF_i \times LF_i \times HP_i) \times Conv$$

Where:

E_{phase} = Total exhaust emissions for the phase, pounds per day

Activity = Equipment activity, hours per day (Table 22B-2)

EF = Engine emissions factor, grams/horsepower-hour (CalEEMod and OFFROAD)

LF = Engine load factor, unitless (Table 22B-2)

HP = Engine horsepower, unitless (Table 22B-2)

Conv = Conversion from grams to pounds, 0.002205

i = Equipment type

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[1] The Carl Moyer Program provides funding to encourage the voluntary purchase of cleaner-than-required engines. Load factors provided in the guidelines account for the most recent engine technologies and regulations.

CalEEMod does not include emission factors for N_2O for off-road diesel equipment. Emissions of N_2O generated by each diesel-powered equipment piece were determined by scaling the CO_2 emissions quantified by Equation 22A-1 by the ratio of N_2O/CO_2 (0.000025) emissions expected per gallon of diesel fuel according to the Climate Registry (2015).

22A.1.2 Marine Vessels (Workboats, Passenger Boats, Tugboats)

Marine vessels used during construction include workboats, passenger boats, and tugboats. Workboats would be needed to support in-water construction of the intakes, Clifton Court Forebay, combined pumping plant, and portions of tunnel reach 6. A passenger speedboat would be required to transport personnel to exploration sites during the geotechnical investigations (MPTO only). Finally, tugboats would be used to transport a portion of the tunnel segments to Bouldin Island and the Clifton Court Forebay (MPTO only). Tunnel segments were assumed to originate from three offsite casting yards, as described further in Section 22A.1.9.

Criteria pollutant emissions from marine vessels without project commitments were quantified using activity data provided by 5RMK and DWR and the ARB's (2012) *Emissions Estimation Methodology for Commercial Harbor Craft Operating in California* (Harbor Craft Methodology). The methodology is based on a zero hour emission rate for the engine model year in the absence of any malfunction or tampering of engine components that can change emissions, plus a deterioration rate. The deterioration rate reflects the fact that base emissions of engines change as the equipment is used due to wear of various engine parts or reduced efficiency of emission control devices.[2] GHG emissions were estimated using the DWR activity data and emission factors obtained from the EPA (2009).

Table 22B-3 in Appendix 22B, *Air Quality Assumptions,* summarizes the marine vessels assumed in the emissions modeling. Engine emission factors are summarized in Table 22B-4. Key assumptions include:

- Barges were assumed to be either pushed or pulled by tugboats and workboats; no emissions are generated by the barge.
- All vessels were assumed to utilize model year 2000 or older engines.

Criteria pollutant, CO_2, and CH_4 emissions for each phase were calculated using the information summarized in Tables 22B-3 and 22B-4. N_2O emissions were calculated by scaling the CO_2 emissions quantified by the N_2O/CO_2 ratio identified in Section 22.1.3.1.

Equation 22A -2 $$\mathbf{E_{phase} = \Sigma(Activity_i \times EF_i \times LF_i \times HP_i) \times Conv}$$

Where:

E_{phase} = Total exhaust emissions for the phase, pounds per day

Activity = Boat activity, hours per day (Table 22B-3)

EF = Engine emissions factor, grams/hp-hr (Table 22B-4)

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[2] ARB's deterioration factors, useful life, and zero-hour emission factors were used for all pollutants except SO_X. SO_X emissions were quantified based on brake-specific fuel consumption and a sulfur fuel content of 15 ppm, which is the sulfur content limit for California harbor craft, in accordance with California Diesel Fuel Regulations.

LF = Engine load factor, (Table 22B-3)

HP = Engine horsepower, (Table 22B-3)

Conv = Conversion from grams to pounds, 0. 002205

22A.1.3 Locomotives

Small, mining-type locomotives would be used to convey excavated material and personnel in rail cars through the tunnel alignments. The ARB's (2010) off-road diesel engine standards were used to quantify regulated criteria pollutant emissions (ROG, NO_X, CO, and PM). The SO_X emission factor was calculated assuming a 15 parts per million (ppm) sulfur content, consistent with ARB and EPA requirements. Locomotive engine rating, based on engineering specifications (25-ton), was assumed to be 150 horsepower (Tier 1).

Table 22B-5 in Appendix 22B, *Air Quality Assumptions,* identifies the locomotive operating information assumed in the emissions modeling. Engine emission factors are summarized in Table 22B-6. Criteria pollutant and CO_2 emissions for each phase requiring locomotives were calculated using Equation 22A-3. CH_4 and N_2O emissions were estimated by scaling the CO_2 emissions quantified by the ratio of CH_4/CO_2 (0.000057) and N_2O/CO_2 (0.000025).

Equation 22A -3 $$E_{phase} = \Sigma(Activity \text{ X } EF \text{ X } HP \text{ X } LF) \text{ X } Conv$$

Where:

E_{phas} = Total exhaust emissions for the phase, pounds per day

Activity = Engine activity, hours per day (Table 22B-5)

EF = Engine emissions factor, grams/horsepower-hour (Table 22B-6)

HP = Engine horsepower, 150

LF = Engine load factor, 0.80

Conv = Conversion from grams to pounds, 0. 002205

22A.1.4 On-Road Vehicles

22A.1.4.1 Engine Exhaust

On-road vehicles include vehicles used for material and equipment hauling, tunnel segment hauling, employee commuting, onsite crew and material movement, and as-needed supply and equipment pick-up. Emissions from on-road vehicles without project commitments were estimated using the EMFAC2014 emissions model and activity data provided by DWR and 5RMK. Similar to heavy-duty equipment, generic vehicle types were not provided. To estimate emissions using EMFAC emission factors, individual vehicles provided by DWR and 5RMK was assigned a generic type based on the model description, industry resources, and professional experience. Tables 22B-7 through 22B-10 in Appendix 22B, *Air Quality Assumptions,* summarizes vehicle data assumed in the emissions modeling. Key assumptions include:

- Criteria pollutant, CO_2, and CH_4 emission factors for diesel trucks used for material and equipment hauling are based on weighted average vehicle speeds for EMFAC's T7 Tractor vehicle category. Equipment and materials delivered to the project site will likely originate in the Bay Area, Sacramento, or Stockton. As a reasonable, yet conservative assumption, it was assumed all equipment and material would be delivered from the Port of San Francisco (greatest distance from the project area).

- Criteria pollutant, CO_2, and CH_4 emission factors for diesel trucks used for tunnel segment hauling (MPTO only) are based on weighted average vehicle speeds for EMFAC's T7 Single vehicle category. Tunnel segments were assumed to originate from three offsite casting yards, two of which would be located in the Bay Area and one would be located in Stockton. Trip distances (miles) from each casting yard were quantified using GoogleEarth.
- Criteria pollutant and CO_2 emission factors for employee commute vehicles are based on weighted average vehicle speeds for EMFAC's LDA/LDT vehicle categories. One-way trip lengths were provided by DWR based on a geospatial analysis of labor densities in the Plan area. Each employee would make 2 trips to the project site per day.
- Criteria pollutant and CO_2 emission factors for onsite crew and material movement are based on EMFAC's LDT, T6 Utility, T6 Heavy, T6TS, and T7 Tractor categories for vehicles traveling at 5 miles per hour. Daily mileage assumptions were developed based on data from 5RMK and DWR, as shown in Appendix 22B, *Air Quality Assumptions*.
- Criteria pollutant and CO_2 emission factors for as-needed supply and equipment pick-up are based on weighted average vehicle speeds for EMFAC's LDA/LDT/T7 Tractor vehicle categories. All vehicle trips would be made to hardware or other local supply stores. An average one-way trip distance of 10 miles was assumed, based on information provided by DWR and 5RMK.
- All vehicle emission factors from EMFAC2014 were generated for the counties in which activity would occur, as determined by GIS (see Section 22A.1.6).

Criteria pollutant, CO_2, and CH_4 (diesel vehicles only) emissions for each phase were calculated using the information summarized in Appendix 22B, *Air Quality Assumptions,* and Equation 22A-4.

Equation 22A -4 $$E_{phase} = \Sigma(EF \times Miles) \times Conv$$

Where:

E_{phase} = Total exhaust emissions for the phase, pounds per day

EF = Engine emissions factor, grams/mile (EMFAC2014)

Miles = Trip distance (Tables 22B-7 through 22B-10)

Conv = Conversion from grams to pounds, 0.0002205

Emissions of CH_4, N_2O, and HFCs from gasoline-powered vehicles were determined by dividing the CO_2 emissions quantified by Equation 22A-4 by 0.95. This statistic is based on EPA's assessment that CH_4, N_2O, and HFC emissions account for 1% to 5% of on-road emissions (U.S. Environmental Protection Agency 2014a).

22A.1.4.2 Road Dust

Fugitive re-entrained road dust emissions are based on the EPA's (2006a; 2011) *Compilation of Air Pollutant Emission Factors* (AP-42) methodology, Sections 13.2.1 and 13.2.2. Offsite vehicles, including employee commuting cars and equipment and material delivery trucks, were evaluated based on Section 13.2.1 for paved roads. Onsite vehicles required for general crew and material movement were evaluated based on Section 13.2.2 for unpaved roads. Precipitation data to support the emission factor calculations were obtained from the Western Regional Climate Center (2014). Daily miles traveled for all vehicles were obtained from Equation 22A-4 (see above).

22A.1.5 Helicopters

Helicopters would be used during line stringing activities for the 115-230 kV transmission lines. Based on guidance provided by DWR, two light-duty helicopters were assumed to operate four hours a day to install new poles and lines (see Table 22B-11 in, Appendix 22B, *Air Quality* Assumptions). Helicopter emissions were estimated using emission factors from the Federal Aviation Administration's (FAA) Emissions and Dispersion Modeling System (EDMS), version 5.1.4. EDMS estimates emission factors for standard landing-takeoff cycles (LTO).[3] EDMS does not calculate emission factors for cruising flight or for operations above 3,000 feet altitude.

Since line stringing activities would include operations beyond the standard LTO cycle, the EDMS emission factors were supplemented to account for cruising operations. Key assumptions include:

- Helicopters would fly from base to the jobsite in a cruise mode. The helicopter's cruise speed was assumed to be approximately 138 mph (MD Helicopters 2014). Fuel flow in cruise mode was estimated based on the ratio of cruise to takeoff power levels (MD Helicopters 2014). This ratio is consistent with earlier data from EPA (1985) that have often been used in EIR/EIS analyses of helicopter flight.
- The flight from base to the jobsite was assumed to take 15 minutes, corresponding in a cruise speed and nominal distance from base to jobsite of up to 35 miles. The return flight from the jobsite to base was assumed to be the same as the flight from base to the jobsite.
- Helicopters would fly at low speeds during line stringing and would hover for a significant portion of time. Based on FAA (2012), it was assumed that during line stringing the helicopter would operate at an average of approximately 85% power, and hence approximately 85% of maximum fuel flow rate.

Criteria pollutant and CO_2 emissions were calculated using the information summarized in Appendix 22B, *Air Quality Assumptions,* and Equation 22A-5.

Equation 22A -5 $\mathbf{E_{phase} = \Sigma(EF\ X\ Hours)\ X\ Conv}$

Where:

E_{phase} = Total exhaust emissions for the phase, pounds per day

EF = Helicopter emissions factor, grams/hour (Table 22B-12)

Hours = Helicopter operating hours, hours/day (Table 22B-11)

Conv = Conversion from grams to pounds, 0.0002205

EDMS does not estimate CH_4 and N_2O emissions. CH_4 and N_2O emissions were estimated using data from EPA (2013).

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[3] The LTO cycle consists of the following phases: startup and taxi-Out, takeoff, climb out to the atmospheric mixing height (nominally 3,000 feet altitude), descent from 3,000 feet, landing, and taxi.

22A.1.6 Fugitive Dust from Earth Movement

Fugitive dust emissions from earth movement (i.e., site grading, bulldozing, and truck loading) were quantified using emission factors from EPA's (1998) AP-42 and CalEEMod. Emission factors for site grading and bulldozing were calculated from Section 11.9, *Western Surface Coal Mining,* of AP-42. This approach is consistent with the CalEEMod Users Guide and the resulting emission factors match CalEEMod outputs on a pound per acre and pound per hour basis. Although the CalEEMod Users Guide indicates that Section 13.2.4, *Aggregate Handling and Storage Piles*, of AP-42 is used to quantify emissions from Truck Loading, ICF could not independently derive matching emission factors through CalEEMod model runs. Since the CalEEMod results were slightly higher than the AP-42 calculations, truck loading emissions were quantified based on a pound per cubic yard emission factor obtained from the model output.

The 5RMK cost estimate provided the total acreage, borrow, excavated, and dredged material for each construction phase. The estimate also identified the maximum acreage and material that would be disturbed in any one day. Table 22B-13 in Appendix 22B, *Air Quality Assumptions*, summarizes the total and maximum daily earth movement quantities assumed in the modeling. Bulldozing equipment hours were also obtained from the cost estimate (see Table 22B-2 in Appendix 22B, *Air Quality Assumptions*). Fugitive dust emission factors from AP-42 and CalEEMod are provided in Table 22B-14.

22A.1.7 Fugitive ROG from Paving

Fugitive ROG emissions generated during paving activities were calculated using an emissions factor of 2.62 pounds of ROG per acre, as reported in the CalEEMod Users Guide appendix. Table 22B-15 in Appendix 22B, *Air Quality Assumptions*, summarizes the total and maximum daily paving acreages assumed in the modeling.

22A.1.8 Electricity Usage

Construction of the water conveyance facility will require the use of electricity for lighting, tunnel ventilation, boring, and certain types of equipment. Annual electric demand for all alternatives was provided by DWR and 5RMK and is summarized in Table 22B-16 in Appendix 22B, *Air Quality Assumptions*. Generation of this electricity will result in criteria pollutant and GHG emissions at regional power plants.

The EPA (2014b)[4] and University of California, Davis (Delucchi 2006:110) have developed emission factors for the current generation of electricity within California (see Table 22B-15). Emissions associated with the generation of electricity were estimated by multiplying the expected annual electricity usage (Table 22B-17) by the published emission factors. As discussed in Section 22A.1.2, adopted and proposed statewide legislation will increase future energy efficiency and the proportion of renewable energy supplied to the electrical grid. Electricity emissions were therefore also estimated using adjusted factors that account for implementation of the Renewables Portfolio Standard (RPS), as discussed below.

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[4] Power will be supplied to BDCP by multiple utilities. The quantity of power supplied by each utility is currently unknown. Consequently, average statewide emission factors, as opposed to utility-specific factors, were used to quantify emissions associated with electricity consumption.

22A.1.9 Concrete Batching

22A.1.9.1 Particulate Matter

Concrete required to construct the water conveyance facility will be manufactured at batch plants that store, convey, and discharge water, cement, fine aggregate, and coarse aggregate. PM10 and PM2.5 may be emitted through the transfer of aggregate, truck loading, mixer loading, vehicle traffic, and wind erosion. The amount of PM10 and PM2.5 generated during concrete batching depends primarily on the surface moisture content of surface materials, and the extent of fugitive emission controls.

PM10 and PM2.5 emissions from onsite concrete batching were estimated using emission factors provided the EPA's (2006b) AP-42 and concrete data provided by DWR. The total volume of concrete required to construct the major water conveyance features (e.g., Intake, pumping plants) is summarized in Table 22B-18. Daily PM10 and PM2.5 emissions from onsite concrete batching were calculated by multiplying the anticipated volume of concrete produced at each batch plant by the AP-42 dust emission factors (see Table 22B-19). A process rate of 1,100 cubic yards per day was batch plants, based on information from the cost estimate. Annual emissions were quantified based on the daily production rates and the total volume of concrete required to construct the project features.

PM10 and PM2.5 emissions from the thee offsite batch plants were quantified based the volume of concrete associated with the tunnel segments and facility specific permit limits for PM10, as provided by BAAQMD and SJVAPCD through public records requests.

22A.1.9.2 Carbon Dioxide

Cement manufacturing produces CO_2 through fuel combustion and calcination. Emissions generated by on-site fuel combustion account for approximately 40% of total emissions generated by a batching facility, whereas calcination accounts for the reaming 60%. Calcination involves heating raw materials to over 2,500 ˚F, which liberates CO_2 and other trace materials (Portland Cement Association 2011).

Emissions generated by concrete batching were calculated based on the anticipated volume of concrete at various compression strengths. Based on data provided by DWR, structural components would require compression strength between 3,000 and 4,000 pounds per square inch (psi), whereas the tunnel segments would require strength between 6,000 and 8,000 psi. CO_2 emission factors for these strength ratios were obtained from Nisbet, Marceau, and VanGeem (2002) and the Slag Cement Association (2013) (see Table 22B-19).

Studies have calculated the CO_2 absorption rates of hardened concrete. These studies assume a 70 year service life and a 30-year demolition and recycling period for concrete materials. Given these assumptions, up to 57% of the CO_2 emitted during the cement manufacturing calcination may be re-absorbed by concrete over the 100 year life cycle (equivalent to about 7% of total batching emissions) (Haselbach 2009). While reabsorption may occur throughout the project lifetime, GHG impacts from concrete batching were conservatively evaluated assuming no reabsorption would occur.

22A.1.10 State Mandates to Reduce GHG Emissions

Actions undertaken by the state will contribute to project-level GHG reductions. For example, the state requires electric utility companies to increase their procurement of renewable resources by 2020. Renewable resources, such as wind and solar power, produce the same amount of energy as coal and other traditional sources, but do not emit any GHGs. By generating a greater amount of energy through renewable resources, electricity provided to the project will be cleaner and less GHG intensive than if the state hadn't required the renewable standard.

The analysis assumes implementation of Pavley, LCFS, and RPS. Pavley will improve the efficiency of automobiles and light duty trucks, whereas LCFS will reduce the carbon intensity of diesel and gasoline transportation fuels. To account for GHG reductions achieved by Pavley, emissions generated by construction equipment and vehicles were calculated using adjusted emission factors from EMFAC2014.[5]

The RPS will increase the proportion of renewable energy supplied to the electrical grid. The emission factors summarized in Table 22B-17 are based on the statewide renewable energy mix in 2010 (14%). Implementation of the RPS will increase the proportion of renewable energy within the state to 33% by 2020. To account for emissions reductions achieved by increases in renewable energy, annual electricity emission factors were calculated assuming a linear increase in statewide renewables between 2010 and 2020. Because RPS requirements end in 2020, the percentage of renewable energy after 2020 was assumed to remain constant at 33%.

Electricity emissions with implementation of RPS were estimated by multiplying the expected annual electricity usage (Table 22B-17) by the emission factors show in Table 22B-20. Note that implementation of the RPS will affect criteria pollutants, in addition to GHG emissions.

22A.1.11 Environmental Commitments to Reduce Criteria Pollutants, GHGs, and DPM

The lead agency has identified several environmental commitments to reduce construction-related criteria pollutants and GHG emissions, as described in Appendix 3B, *Environmental Commitments.* Emissions were quantified with implementation of the environmental commitments by making the following adjustments to the emissions analysis described in Sections 22A.1.1 through 22A.1.9:

1. **Heavy-Duty Equipment**: CalEEMod and OFFROAD emission factors for heavy-duty equipment greater than 50 horsepower were replaced with model year 2013 emission factors obtained from the Sacramento Metropolitan Air Quality Management District's (SMAQMD) Construction Mitigation Calculator. The 2013 model year emission factors for each equipment piece are built from the zero-hour emissions rates, annual deterioration rates, and assumptions about engine operating hours.

2. **Marine Vessels**: Model year 2000 marine vessel engines were replaced with model year 2010 emission factors (Tier 3 compliance for new engines) obtained from the ARB (2012), as shown in Table 22B-4.

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[5] EMFAC2014 does not include emissions reductions achieved by LCFS.

3. **On-Road Haul Trucks**: Fleet average emission factors for heavy-duty diesel trucks were replaced with average emission factors for model year 2010 or newer vehicles obtained from EMFAC2014.

4. **Locomotives**: Tier 1 emission factors for locomotives were replaced with Tier 4 emission factors obtained from the ARB (2010), as shown in Table 22B-6.

5. **Earth Movement and Road Dust**: Uncontrolled emission factors for onsite soil disturbance and re-entrained road dust were reduced by 61% and 55%, respectively, pursuant to the Western Governors' Association Fugitive Dust Handbook (Countess Environmental 2006).

6. **Concrete Batching**: Uncontrolled emission factors for batching processes and active piles were reduced by 70% and 80%, respectively, pursuant to the SMAQMD's (2011) Concrete Batching Operations Policy Manual.

22A.1.12 Mitigation to Reduce GHG Emissions

Mitigation Measure AQ-21 requires developing and implementing a GHG mitigation program to completely offset (i.e., to net zero) construction-related GHG emissions through implementing emissions-reduction projects. The mitigation measure outlines 13 GHG-reduction strategies that will be used in formulating the GHG mitigation program. Potential GHG reductions associated with the strategies were evaluated to ensure the mitigation could offset GHG emissions from the BDCP alternatives to net zero.

A brief overview of the method and assumptions for each strategy is provided below. The reduction analysis was developed for informational purposes only and in many cases, only a high-level estimate was generated for offset validation. BDCP proponents will develop a mechanism for quantifying, funding, implementing, and verifying emissions reductions associated with the selected strategies and facility-specific technologies. BDCP proponents will also conduct annual reporting to verify and document that selected strategies achieve sufficient emissions reductions to offset construction-related emissions to net zero.

Strategy-1: Renewable Energy Purchase Agreement: Potential GHG reductions were not explicitly quantified; according to the National Renewable Energy Laboratory (2012), California's technical potential for utility-scale photovoltaics exceeds 246,000 gigawatt-hours, which far exceeds the construction energy demands for CM1 (2,132 gigawatt-hours over the entire construction period for Alternative 4). Assuming renewable energy would offset 50% of the construction electric demands yields an emissions reduction of approximately 231,000 metric tons CO_2e for Alternative 4.

Strategy-2: Engine Electrification: GHG reductions achieved by this strategy would depend on the number and type of equipment pieces ultimately electrified. While some electric engines are commercially available, it is currently unknown which specific equipment in the construction inventory may be electrified. Conservatively assuming only 1 to 5% of the equipment fleet would be electrified yields emissions reductions of approximately 8,000 to 41,000 metric tons CO_2e for Alternative 4.

Strategy-3: Low Carbon Concrete: According to Donovan and Pyle (n.d.), cement with supplementary cementitious materials (SCM) has a 29% lower total carbon footprint. As a high-level estimate, it was assumed that CM1 components would be constructed out of concrete with up to 70% replacement of cement with SCM. Potential GHG reductions were therefore quantified by multiplying estimated CO_2 emissions from concrete batching by 70% and then by 29%, resulting in an emissions reduction of approximately 500,000 metric tons CO_2 for Alternative 4.

Strategy-4: Renewable Diesel and/or Bio-diesel: According to the Department of Energy (DOE) (2008), B20 (20% biodiesel/ 80% petroleum diesel) can reduce CO_2 emissions by 15%. It was conservatively assumed that 50% of diesel-powered equipment would utilize B20 during construction. Potential GHG reductions were therefore quantified by multiplying estimated CO_2 emissions from diesel-powered equipment by 50% and then by 15%, resulting in an emissions reduction of approximately 60,000 metric tons CO_2 for Alternative 4.

Strategy-5: Residential Energy Efficiency Improvements: DOE's (2014) Home Energy Saver (HES) estimates that the retrofits outlined in Mitigation Measure AQ-21 would reduce CO_2 emissions by 5,152 pounds per package per year. There are 1.4 million homes (2008 est.) within the socioeconomic Study area (i.e., Delta Study area). As a high-level estimate, it was conservatively assumed that 50,000 of these homes would be retrofit. Potential GHG reductions were therefore quantified by multiplying 50,000 retrofits by 5,152 pounds of CO_2 per retrofit per year, resulting in an emissions reduction of approximately 116,000 metric tons CO_2e per year. Total lifetime GHG reductions could reach 2.1 million metric tons CO_2e, assuming a retrofit lifetime of 18 years (California Energy Commission 2009).

Strategy-6: Commercial Energy Efficiency Improvements: According to the Energy Information Admiration (2008), average commercial floorspace in the Pacific Region is approximately 28,000 square feet per building. As a high-level estimate, it was conservatively assumed that 10,000 commercial buildings in the Plan Area would be retrofitted to achieve a 15% reduction in building wide energy use. Electricity and natural gas reductions achieved by the retrofits were quantified assuming 15 kilowatt-hours and 0.28 therms are consumed per square foot, respectively (California Energy Commission 2006). The electricity and natural gas reductions were translated to GHG savings based on the emission factors presented in Table 22B-20, resulting in an emissions reduction of approximately 198,000 metric tons CO_2e per year. Total lifetime GHG reductions could reach 2.4 million metric tons CO_2e, assuming a retrofit lifetime of 18 years (California Energy Commission 2009).

Strategy-7: Residential Rooftop Solar: National Renewable Energy Laboratory (NERL) System Advisor Model (SAM) was used to calculate the energy potential of a typical residential solar installation in the Sacramento Valley.[6] As a high-level estimate, it was conservatively assumed that 50,000 of homes would receive solar PV. Energy reductions were therefore quantified by multiplying 50,000 systems by the estimated solar output per system (4,617 kWh). The resulting electricity reductions were translated to GHG savings based on the emission factors presented in Table 22B-20, resulting in an emissions reduction of approximately 49,000 metric tons CO_2e per year. Total lifetime GHG reductions could reach 1.2 million metric tons CO_2e assuming a PV lifetime of 25 years (U.S. Department of Energy 2013).

Strategy-8: Commercial Rooftop Solar: NERL's SAM was used to calculate the energy potential of a typical commercial solar installation in the Sacramento Valley. As a high-level estimate, it was conservatively assumed that 2,500 of commercial buildings would receive solar PV. Energy reductions were therefore quantified by multiplying 2,500 systems by the estimated solar output per system (304,152 kWh). The resulting electricity reductions were translated to GHG savings

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[6] See *Final GHG Reduction Measure Analysis for the Sacramento Municipal Utility District* (ICF International 2011).

based on the emission factors presented in Table 22B-20, resulting in an emissions reduction of approximately 164,000 metric tons CO_2e per year. Total lifetime GHG reductions could reach 4.1 million metric tons CO_2e assuming a PV lifetime of 25 years (U.S. Department of Energy 2013).

Strategy-9: Purchase Carbon Offsets: Potential GHG reductions were not explicitly quantified; according to the Legislative Analyst's Office (2012), it is estimated that between 2012 and 2020, 2.5 billion allowances will be made available within the state, which far exceeds estimated construction emissions for all alternatives.

Strategy-10: Development of Biomass Waste Digestion and Conversion Facilities: Based on information provided by the CEC (Mariscal 2012), the technical potential for biomass feedstock production within 200 miles of the CM1 is approximately 122 MW per year. Potential electricity production (MWh) associated with this potential was calculate based on the energy generating potential (MWh/MW/year) of dairy farms (U.S Environmental Potential 2014b). The resulting electricity reductions were translated to GHG savings based on the emission factors presented in Table 22B-20. As a high-level estimate, it was conservatively assumed that only 10% of the technical potential would be captured, resulting in an emissions reduction of approximately 20,000 metric tons CO_2e per year. Total lifetime GHG reductions could reach 200,000 metric tons CO_2e assuming a digester lifetime of 10 years (Biogas Energy Inc. 2008).

Strategy-11: Agriculture Waste Conversion Development: Based on information provided by the CEC (Mariscal 2012), the technical potential for digestible biomass production within 200 miles of the CM1 is approximately 13 million bone-dry tons (BDT) per year. Potential electricity production (kWh) associated with this potential was calculate based on the energy generating potential (kWh/pound) of woody biomass (U.S. Forest Service et al. 2008). The resulting electricity reductions were translated to GHG savings based on the emission factors presented in Table 22B-20. As a high-level estimate, it was conservatively assumed that only 5% of the technical potential would be captured, resulting in an emissions reduction of approximately 196,000 metric tons CO_2e per year. Total lifetime GHG reductions could reach 3.9 million metric tons CO_2e assuming a system lifetime of 20 years (United States Environmental Protection Agency 2008).

Strategy-12: Temporarily Increase Renewable Energy Purchases for Operations: Potential GHG reductions were not explicitly quantified; this strategy would purchase renewable electricity in excess of the quantity needed to meet DWR's GHG emissions reduction goals.

Strategy-13: Tidal Wetland Inundation: Given the variability associated with land use change and GHG flux, maximum emissions reductions associated with this strategy were not quantified.

22A.1.13 Emissions by Air District and Air Basin

The project cross three air basins—SFBAAB, SVAB, and SJVAB—and falls under the jurisdiction of four air districts—YSAQMD, SMAQMD, BAAQMD, and SJVAPCD. GIS was used to identify the location of all construction activities associated with the five conveyance options. Tables 22B-21 through 22B-25 in Appendix 22B, *Air Quality Assumptions,* summarize the air districts and air basins crossed by each major construction component. Several features cross multiple air districts or air basins. The proportion of activity within each air district and basin was based on the number of miles or acres constructed within each air district and basin. For example, 18 miles of tunnel in the modified pipeline/tunnel alignment will be constructed within Reach 4, of which 7 (40%) will be located within the SMAQMD and 11 (60%) will be located within the SJVAPCD (see Table 22B-21).

22A.2 Operation

22A.2.1 Maintenance Activities

22A.2.1.1 Alternatives 1A, 2A, 3, 5, 6A, 7, and 8 (Pipeline/Tunnel Conveyance), Alternative 4 (Modified Pipeline/Tunnel Conveyance), Alternatives 1B, 2B, and 6B (West Alignment), and Alternatives 1C, 2C, and 6C (East Alignment)

Operations and maintenance (O&M) include both routine activities and yearly maintenance. Routine activities would occur on a daily basis throughout the year, whereas yearly maintenance would occur annually or every five years.

Routine Maintenance

DWR provided labor and equipment estimates for maintenance, management, repair, and operating crews. One of each crew type is required to cover daily O&M activities at all pumping plants and intakes. Table 22B-26 in Appendix 22B, *Air Quality Assumptions,* summarizes the number of employees, vehicles, and equipment included in each crew for Alternatives 1A, 1B, 1C, 2A, 2B, 2C, 6A, 6B, and 6C. Assumptions for all other alternatives were scaled based on the number of constructed intakes.[7] Operational emissions associated with vehicle traffic and maintenance equipment were estimated using emission factors from the EMFAC2014 and CalEEMod models, respectively. Emissions were quantified for both the ELT (2025) and LLT (2060) periods. Key assumptions include:

- Employees would make two trips to the project site per day, 250 days per year.
- Employee vehicle roundtrips would be 42.2 miles, based on a geospatial analysis of employment densities and potential drive routes to the intake locations.
- Crew, foreman, and dump trucks would make a maximum of two trips per day.
- Crew, foreman, and dump truck roundtrips would be 30 miles, based on information provided by DWR and the assumption that 1) crew vehicle movement would occur onsite among various facilities and 2) hauled debris would be deposited at local landfill sites.
- All equipment except the welders, backhoes, and offroad trucks were conservatively assumed to operate a maximum of 8 hours per day, 250 days per year; welders, backhoes, and offroad trucks were assumed to occur 4 hours a day.

Yearly Maintenance

Yearly maintenance includes annual inspections, removal of sediment from sedimentation basins and drying lagoons, and half-decadal tunnel dewatering. Annual inspections include work on the fish screens, gate control structures, removal and inspection of pumps and motors, and inspection of tunnels by a remotely operated vehicle (ROV). Tunnel dewatering includes a physical inspection of the tunnel lining and shafts. Table 22B-27 in Appendix 22B, *Air Quality Assumptions,* summarizes the

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[7] Under Alternative 4, one of each crew type is also required for O&M activities at the combined pumping plant. Accordingly, at total of two of each crew type (one set at the intakes [scaled] and one set at the combined pumping plant) will be required.

number of employees, vehicles, and equipment required for annual inspections and tunnel dewatering.

Operational emissions associated with vehicle traffic and maintenance equipment were estimated using emission factors from the EMFAC2011 and CalEEMod models, respectively. Emissions were quantified for both the ELT (2025) and LLT (2060) periods. Key assumptions include:

- Annual inspections would occur over a period of one month for the pipeline/tunnel and modified pipeline/tunnel alignments, two weeks for the west alignment, and one week for the east alignment. Work would occur five days per week.
- Sediment removal from the sedimentation basins and drying lagoons would occur over a period of one to two months for the pipeline/tunnel and modified pipeline/tunnel alignments[8], one month for the west alignment, and two weeks for the east alignment. Work would occur five day days per week.
- Tunnel dewatering inspections would occur over a period of two months for the pipeline/tunnel, modified pipeline/tunnel, and west alignments. Tunnel dewatering requires dewatering the full length of the tunnel and would take 30 days to complete, followed by sediment removal, liner cleaning, and inspection. The east alignment would not require tunnel dewatering maintenance.
- Each employee would make two trips to the project site per day according to the schedules identified above.
- Employee vehicle roundtrip would be 70 miles, based on information provided by DWR and the assumption that specialized crews from the Bay Area or Sacramento would need to travel to the Delta.
- Crew and dump trucks would make a maximum of two trips per day.
- Crew and dump truck roundtrips would be 30 miles, based on information provided by DWR and the assumption that 1) crew vehicle movement would occur onsite among various facilities and 2) hauled sediments would be deposited at local landfill sites.
- All equipment except the cranes and loaders were conservatively assumed to operate a maximum of 8 hours per day; cranes, loaders, man-lifts, and water trucks were assumed to occur 4 hours a day.

22A.2.1.2 Alternative 9 (Separate Corridors)

Specific activity assumptions for Alternative 9 are not available. However, DWR provided a cost estimate for O&M associated with Alternative 9. Total costs for routine O&M were 26% of total costs for routine O&M for Alternative 1A. Zero cost was given for yearly maintenance. Based on this information, O&M emissions associated with Alternative 9 were assumed to be 26% of emissions quantified for Alternative 1A.

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[8] Two months for alternatives with two tunnels; one month for alternatives with one tunnel

22A.2.2 SWP and CVP Pumping

Construction of the water conveyance facility would modify BDCP operations and cause the BDCP alternatives to have slightly different energy requirements within the ELT (2025) and LLT (2060) periods. Increases in annual electricity consumption for all alternatives relative to the No Action Alternative (CVP only) and existing conditions (SWP only) were calculated in Chapter 21, *Energy*, and is summarized in Table 22B-28 in Appendix 22B, *Air Quality Assumptions*. Generation of this additional electricity would result in criteria pollutant and GHG emissions at regional power plants. GHG emissions generated by increased SWP pumping were provided by DWR and are based on actual and forecasted GHG emissions rates for the SWP system. Statewide grid average emission factors (see Table 22B-20) were utilized for SWP criteria pollutant emissions analysis as criteria pollutant emission factors specific to the SWP system were unavailable. Indirect GHG and criteria pollutants generated by increased CVP pumping were also estimated using adjusted statewide grid average emission factors for state renewable energy mandates (see Table 22B-20)

22A.3 References

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