2.5.1.2.7.1 Travel Time

Patterns of anadromous fish migration are influenced by a number of variables, including flow velocity, direction, volume, and source. When velocities along migratory corridors are reduced, juvenile outmigration takes longer and smolts are more likely to be vulnerable to increased predation risk (Anderson et al. 2005; Muthukumarana et al. 2008; Cavallo et al. 2013). The amount of time outmigrating juvenile salmonids spend traveling through migratory corridors in the Delta is one indicator of predation risk, with longer travel time through the Delta often resulting in higher mortality rates. Table 2-165 provides a summary of the modeling tools used to assess the impacts of travel time changes caused by the PA on juvenile salmonid survival and green sturgeon.

Table 2-165. Models Used to Assess Changes in Velocities and Juvenile Salmonid Outmigration Travel Time Under the PA.

Model	Source	Method	Applicability	Analysis
Channel Velocity Analysis	CWF BA Section 5.4.1.3.1.2.1.1	DSM2 hydrodynamic modeling	Juvenile salmonids and sturgeon migratory patterns	Hydrological changes between PA and NAA at key channels throughout the north, central, and south Delta
NDD bypass flows and smolt entrainment model	Perry et al. (2016)	Historical flow at Freeport (USGS gage 11447905) and Sacramento River downstream of Georgiana Slough (USGS gage 11447650) to predict velocities under NDD proposed bypass rules	Juvenile salmonids and sturgeon migratory patterns	Velocities below NDD intakes due to written bypass rules as compared to NAA (no diversions)
Perry Survival Model (Travel Time component)	Perry 2016	Statistical analysis of travel time over eight distinct reaches based on Delta inflow and a five-year study of the travel time of acoustic tagged Chinook salmon smolts applied to the PA operational scenarios in comparison with the NAA.	Chinook salmon smolts (i.e., >70 mm)	Calsim simulations of scenarios to determine through Delta and route specific travel times based on relationships from acoustic tag studies.

Note: The unlimited pulse protection scenario is not evaluated with these modeling tools specifically relative to travel time

2.5.1.2.7.1.1 Channel Velocity Analysis

The first component of the travel time analysis is an evaluation of channel velocity changes caused by the PA. The BA provides information on the hydrodynamic conditions that an outmigrating fish will experience and the resultant differences between scenarios, PA and NAA. Because flow velocity can affect fish travel time, and therefore the potential risk of exposure to predation, results from these comparative velocity analyses can indicate whether they facilitate successful juvenile migration and in particular, smolt outmigration. The BA provides analysis of key migration routes and channel junctions in the Delta and the effects of PA operations on the hydrodynamics of those routes and junctions (BA Section 5.4.1.3.1.2.1.1 Channel Velocity).

Table 2-166 describes the channels used in the velocity analysis, as well as the hypothesized importance of a particular channel on salmonid migration and survival. The analysis in the BA uses DSM2 modeling to evaluate the NAA and PA for differences in:

1. Magnitude of channel velocities,
2. Magnitude of negative velocities, and
3. Proportion of each day that velocity was negative in the study channels.

Table 2-166. Description of Channels Used in the Velocity Analysis and Their Hypothesized Importance for Fish Migration.

DSM2 Channel	Description	Hypothesized importance
21	San Joaquin River downstream of the head of Old River.	Fish in this region have avoided entering the interior Delta at Head of Old River and are in a potentially higher survival route, where survival may be influenced by river flow (velocity).
45	San Joaquin River near the confluence with the Mokelumne River.	Fish entering the San Joaquin River from the Sacramento River via Georgiana Slough and the DCC experience this area.
94	Old River downstream of the south Delta export facilities.	Fish attempting to move north from the south Delta experience are within the hydrodynamic footprint of the south Delta export facilities and are particularly susceptible to entrainment.
212	Old River upstream of the south Delta export facilities.	Fish moving through Old River experience conditions in this channel as they approach the facilities.
418	Sacramento River downstream of proposed NDD.	Fish moving down the Sacramento River could experience operational effects in this region (flow-survival relationships).
421	Sacramento River upstream of Georgiana Slough.	This region is where fish may enter the interior Delta from the Sacramento River, and there may be flow-survival relationships.
423	Sacramento River downstream of Georgiana Slough.	This region is where fish may enter the interior Delta from the Sacramento River, and river flow (velocity) may affect survival (i.e., there is a significant flow-survival relationship; Perry 2010).
DCC	Delta Cross Channel	Fish from the Sacramento River may enter the interior Delta through this channel.
379	Steamboat Slough	Fish using this route are not exposed to entrainment into Georgiana Slough and the DCC, and river flow (velocity) may affect survival (i.e., there is a significant flow-survival relationship; Perry 2010)
383	Sutter Slough	Fish using this route are not exposed to entrainment into Georgiana Slough and the DCC, and river flow (velocity) may affect survival (i.e., there is a significant flow-survival relationship; Perry 2010)

A limitation to this model, as stated in the BA, is that differences in velocity may not directly correspond to biological outcomes in scenarios. Juvenile salmonids may show a selective tidal-stream transport that does not allow simple differences in velocity to translate into biological outcomes (Delaney et al. 2014). The uncertainty in these results limits their use to general trends in differences, such as decreased overall velocity, increased negative velocity, and a greater proportion of negative velocity as indicators of adverse effects to juvenile salmonids, including delayed migration or advection into migration pathways with higher mortality risk.

Though the operations of the PA have the potential to beneficially change channel flows in the Delta, the changes will depend on the extant conditions and specific PA operational conditions. The velocity analysis can indicate whether operations beneficially increase channel flows in ways that would reduce travel time and decrease the likelihood of exposure of juvenile salmonids to less-suitable migration routes.

BA Tables 5.4-9, 5.4-10, and 5.4-11 in Appendix C of this Opinion show the results of the analyses of median channel velocity, median negative channel velocity, and median daily proportion of negative velocity values at the locations specified in Table 2-166. The effects of channel velocities under the PA on travel time of outmigrating salmonid species are described in the exposure and risk subsections below.

Magnitude of change in channel velocities under the PA

Under the PA, water velocities in the north Delta would be lower by at least 5% in all water years and most months with the exception of April (BA Table 5.4-9 in Appendix C of this Opinion). This would increase migratory travel time and potentially increase the risk of predation for juvenile salmonids. In the South Delta, median velocities generally increase under the PA in all water years and most months with the exception of December. The positive change in velocity would decrease migratory travel time and reduce predation risk for juvenile salmonids migrating through the south Delta. In the Central Delta, there is little difference in magnitude of channel velocities between the NAA and PA for any month or water year type at the DCC, except for June when the median velocity under the PA is more negative in all water years but wet.

Magnitude of change in negative velocities (or reverse flows) under the PA

In the North Delta, reverse flows would increase in most water years and months with the exception of December and January under the PA (BA Table 5.4-10 in Appendix C of this Opinion). In the South Delta, reverse flows occur roughly half of the time (BA Table 5.4-11 in Appendix C of this Opinion) under the PA and NAA, and differences between scenarios are only prevalent in the San Joaquin River downstream of the HOR. During January through June, negative velocities are reduced in the San Joaquin River downstream of the HOR under the PA (BA Table 5.4-10 in Appendix C of this Opinion).

Proportion of each day that velocity was negative under the PA

In the North Delta, the PA had a higher proportion of each day with negative velocities (reverse flow) particularly in Steamboat Slough and Sacramento River downstream of Georgiana Slough (BA Table 5.4-11 in Appendix C of this Opinion). In the South Delta, results were similar between scenarios except for the San Joaquin River downstream of the HOR where the PA had less proportion of the day with negative velocities. In the Central Delta, results showed little difference between scenarios with the DCC having more proportion of day with negative velocities under the PA only during the month of June.

Under the PA, the channel reach in the Old River upstream of the south Delta export facilities had less water moving toward the pumps in most months and water years (BA Table 5.4-9 to 11 in Appendix C of this Opinion). This would result in fewer fish exposed to entrainment in the South Delta pumping facilities. The higher probability of reverse flows and daily proportion of reverse flows in this channel under the PA would reduce the frequency of flows into the South Delta pumping facilities and therefore reduce the number of fish potentially entrained in the facilities (BA table 5.4-9 to 11 in Appendix C of this Opinion).